STRUCTURAL CHANGES AND FINANCIAL FRICTIONS IN THE MONETARY TRANSMISSION MECHANISM

GMM, VAR AND BAYESIAN DSGE APPROACHES

EYOB MULAT-WELDEMESKEL

DEGREE

DOCTOR OF PHILOSOPHY

2016

Structural Changes and Financial Frictions in the Monetary Transmission Mechanism

GMM, VAR and Bayesian DSGE Approaches

Eyob Mulat-Weldemeskel

A Thesis Submitted for the Degree of

DOCTOR of PHILOSOPHY

Department of Economics

Guildhall School of Business & Law

London Metropolitan University

October 2016

ABSTRACT

This thesis focuses on five independent but integrated current topics in macroeconomics and finance. It aims to achieve six objectives: *first*, it evaluates the UK monetary policy rules and determines if monetary policy rule should be different in a financial crisis and recession regimes. *Second*, it investigates the MTM and the dynamics of the channels before and after the GFC. *Third*, it explores the role of credit supply shocks and addresses if the issue of credit supply shocks has a plausible macroeconomic effects in the UK economy. *Fourth*, it addresses the issue of structural changes and determines the degree of significant changes assuming that MSBs exist. Specifically, the study examines the robustness of the Augmented Dickey-Fuller (ADF) and the ZA one break unit root tests to the presence of endogenously determined multiple structural breaks. *Fifth,* it studies credit supply shocks to determine how monetary policy and credit shocks differ during the pre and post-IT regimes. *Sixth*, it explores the role of MP and determines whether financial frictions that accounts for price and financial stability will have more plausible control of the economy than being limited to price stability. The empirical investigation employs a GMM, VAR and estimates Bayesian DSGE models for the UK data from 1955 to 2014.

The GMM simulation analysis confirmed that the UK monetary policy is more of a forward-looking Taylor type and a hybrid Taylor-McCallum MP rules RFs with a mixture of conventional and unconventional policy frameworks in the post-Global Financial Crisis (GFC). The structural break analysis showed that the financial and monetary sectors have more persistent shocks than the macroeconomic sector. Using the MSB approach, the study identified four major structural breaks in the UK economic structure from 1960 to 2014 and showed that the ZA method does not improve the traditional ADF method. The VAR and Bayesian DSGE analyses revealed that the UK MTM has changed in the post-GFC. The empirical analysis, based on the Bayesian likelihood DSGE model, revealed that the traditional view of the interest rate channel has now been replaced by the credit channel. The specified VAR and VEC models identified the bank-lending channel as a major credit channel than the balance sheet channel. The overidentified Augmented SVAR (A-SVAR) model characterised credit supply volatilities as aggregate supply shocks that moves price and output in opposite direction. The study also investigated the prudence of monetary policy alone and monetary policy with a financial component. The DSGE model with financial frictions represented the data well and showed that the role of investment has reduced significantly in the run up to the GFC and gradually replaced by the *Spread shock*. Spread shocks constituted about 14% of output decline as compared with 3.5% decline due to investment shocks. Although economic theory strongly advocates the self-balancing mechanism of the financial sector, the evidence found in this study proved otherwise. The financial and monetary systems are two integral sides of the same coin.

ACKNOWLEDGEMENTS

First, I would like to thank God for giving me the strength and determination to complete this thesis. I would like to express my profound gratitude to my lead supervisor Dr. Ivonia Rebelo, and to my previous supervisors: Professor Joseph Pearlman, Dr. Vlasios Voudouris, Dr. Helen Solomon and Dr. Kefei You, for their advice, guidance and encouragement. I would also like to express my sincere gratitude to Dr. Jalil Ahmed for his continuous support, motivation and practical advice. I am also indebted to him for reading and commenting on my draft thesis. My sincere thanks also goes to the University of Surrey CIMS staff: Professor Paul Levine, Dr. Vasco J. Gabriel, Dr. Cristiano Cantore and Dr. Bo Yang for their advice and organising an introductory and advanced trainings on MatLab and Dynare based DSGE modelling with applications and the follow-up annual conferences that helped me to discuss my research and receive valuable advice and feedback. I also want to take this opportunity to thank the Centre for Microdata Methods and Practice, the Institute for Fiscal Studies and all the organisers of the training and conferences, which have been a cornerstone of my research progress.

This thesis would not have been completed without the understanding and help of the people I mentioned above and my colleagues: Richard Charlesworth, Ann Kennedy and Ken Reid. Miss Kennedy has been a compassionate colleague and a good friend who has provided me a conducive working environment and all the support I needed to progress with my research. I would also like to thank the Post Graduate Research Office and Administrative staff who have been very understanding and supportive throughout the years. I would also like to thank the research staff at the University of London and the London School of Economics for their assistance and cooperation.

Most importantly, my sincere appreciation also goes to my family for their love and patience in every endeavour of the journey I have made in this study. Particularly, I would like to thank my wife for her unreserved encouragement and support at every stage of my study. I also thank my parents, who raised me with love and care to progress with my education, and my brothers and sisters whose admiration and love have always been encouraging me to press on and progress with my study. Finally, I appreciate the financial support I received from the Higher Education Funding Council. The Journey has been far from smooth as expected. However, I am exuberant that, with the guidance and support of my lead supervisor and the people I mentioned above, I have surmounted all the challenges and arrived to where I am now.

DECLARATION STATEMENT

The copyright in this thesis is owned by the author. Any quotation from the thesis or use of any of the information contained in it must acknowledge this thesis as the source of the quotation or information.

DEDICATION

This thesis is dedicated to my parents, Mrs Abeba Tewoldebirhan and Mr Mulat Weldemeskel; to my family: my wife Mrs Caroline and my children Keren and Moses; to my brothers and sisters: Aklilu, Daniel, Abel, Rebka, Martha, Elisabeth, and Nathra.

ABBREVIATIONS

ADF	Augmented Dickey-Fuller
AO	Additive Outlier
AWM	Area-Wide-Models
BDSGE	Bayesian Dynamic Stochastic General Equilibrium
BF	Bayes Factor
BIC	Bayesian Information Criteria
CB	Central Bank
CBB	Central Bank Board
CBI	Central Bank Independence
CED	Consensus Economic Data
DF	Dickey and Fuller
DPAM	Dynamic Programming Algorithm Mathematics
EFP	External Financial Premium
EMH	Efficient Market Hypothesis
EONIA	Euro Overnight Index Average
EURIBOR	Euro Interbank Offered Rate
FAM	Financial Accelerator Mechanism
FCI	Financial Conditions Index
FEVD	Forecast Error Variance Decomposition
FL-GMM	Foreword Looking - GMM
FL-OLS	Foreword Looking- Ordinary Least Square
FPC	Financial Policy Committee
FXR	Fixed Exchange Rate
GFC	Global Financial Crisis
GMM	Generalized Methods of Moments
HMPR	Hybrid Monetary Policy Rules
HP	Hodrick-Prescott
IO	Intervention Outlier
IRFs	Impulse Response Functions (IRFs)
ITR	Inflation Targeting Regime
KPR	Key Policy Rate
LM	Lagrange Multipliers
MDS	Martingale Difference Sequence
MEFT	Macroeconomic and Financial Time
MHA	Metropolis Hastings Algorithm
MLE	Maximum Likelihood Estimation
MODFA	Model with Financial Accelerator
MODNFA	Model with no Financial Accelerator
MP	Monetary Policy
MPTM	Monetary Policy Transmission Mechanism
MSB	Multiple Structural Breaks
MTFS	Medium Term Financial Strategy
MTM	Monetary Transmission Mechanism
NFR	Nominal Fixed Rate
PRA	Prudential Regulation Authority
RBC	Real Business Cycle
RE	Rational Expectations
SB	Structural Break
SBC	Schwartz Bayesian Criterion
SD	Stability Diagnostic
TB	Treasury Bills
TM	Transmission Mechanism
TOR	Turnover Rate
ToTEM	Term of Trade Economic Model

TABLE OF CONTENTS

List of Tables

List of Figures

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

The recent Global Financial Crisis (GFC) has invigorated a fresh interest in monetary economics. It leads us to ask a question: should the objective of monetary policy be extended beyond price stability? The events in the years surrounding the GFC made it clear that price stability may not be sufficient to ensure macroeconomic stability. In the financial meltdown and the recession in the post-GFC, most of the advanced economies, including the UK, experienced severe output contraction particularly in 2008 and 2009, which resulted in a build-up of financial imbalances. The experiences both in the UK and in other advanced economies have given fresh impetus to an old question: in addition to pursuing the objective of price stability, should central banks also respond to financial imbalances, such as those associated with unsustainable credit expansion and asset-price bubbles? (Bailliu et al., 2015). To address this issue, it is important to have clearer understanding of the operational feasibility of the monetary policy across policy regimes, the dynamics of the Monetary Transmission Mechanism (MTM), the nature of persistent and transitory shocks, the characteristics of credit and monetary policy shocks and finally the role of financial market frictions in the real economy.

Studying the role of financial market frictions and the monetary policy in the contemporary macroeconomic environment and a dynamic general equilibrium setting is very important and has become a rapidly growing research area. Monetary economics is closely integrated into the standard short-run macroeconomic theory, as monetary phenomena are predominant in their influence on virtually all major macroeconomic variables in the short-run. National output, employment, exports and imports, exchange rates and the balance of payments are among the variables influenced by the shift in the supply and demand for money. One of the most important questions in macroeconomic analysis is to what extent and how the changes in the money supply, prices and interest rates affect the national output and employment. In the run up to the recent global financial crisis, developments in both theoretical and empirical research in the study of monetary economics evidently led academics, economists and policymakers to claim that the "Great Moderation (GM)" period is known to bring a well-defined "science of monetary policy". Up until August 2007, there was a general consensus about the elements of monetary policy (MP) strategy.

Monetary policy has been perceived as being highly successful in developed economies about their achievement of stable economy in terms of not only low inflation but also low variability in price and output. Governments and central bankers gained confidence, placed too much faith in the monetary policy, and continued to pursue an inflation targeting MP. This strategy brought great success and technology advancement for modernisation so the period from the 1980s to the start of the GFC is widely known as a period of "Great Moderation" (Mishkin, 2011). While countries are enjoying the technology advancement of this period, the systemic risk of the financial sector has been growing since the early 1990s. Central banks and financial regulators have given limited attention to the growing financial risk, particularly in the developed economy. Consequently, the world witnessed what Alan Greenspan, former Chairman of the Fed, described the August 2007 financial crisis as a "once-in-a-century credit tsunami" (Mishkin, 2011:p2). This tsunami not only crippled economic activity, produces severe world-wide economic contraction since the Great Depression, but it also swept away the confidence of private sectors and the ability of central bankers to successfully manage the economy. Although there is a wide spectrum of literature that explores how monetary and macro-prudential policies might be co-ordinated and implemented, there is no consensus yet on whether financial stability measures should be an integral part of monetary policy. Against this backdrop, this thesis addresses these issues by analysing operational feasibilities and comparing the monetary policy performances of a set of policy regimes in the pre-IT, post-IT (before GFC) and post-GFC period. The analysis across the policy regimes provide clearer insight of the interaction between monetary policy and macro-prudential rules; and how the policymakers respond to financial imbalances. In terms of methodological approach, the study employs a Generalized Method of Moments (GMM), Vector Autoregressive Models (VAR/VEC/BVAR), the Zivot and Andrew (1992) one-time structural break, the Bai and Perron (2003a, 2006) MSB dynamic algorithms and the Dynamic Stochastic General Equilibrium (DSGE) models. The Bayesian DSGE model features financial market frictions, fiscal and private sector shocks and standard macroeconomic shocks.

The study is inspired by the open research questions raised in the run up to the GFC and the developments in the post crisis periods. These are the conduct of monetary policy, the changing views of MTM, the role of credit shocks, financial frictions and the presence of persistence and transitory shocks that raised all types of questions to revisit the underpinning theories of macroeconomics. Within the framework of this background, the study aims to make a valid and reliable contribution to the existing and new understanding of the MTM, the channels through which monetary policy impulses pass through, the impact of disturbances due to sudden and gradual changes, the role of structural shocks and financial market frictions in the UK economy. Within this broad theme, the research sought to achieve a number of specific objectives. *First,* it reviews and empirically evaluates the UK monetary policy rules within the existing policy framework and determines if monetary policy rule should be different in a financial crisis and recession regimes.

Second, it investigates the dynamics of the channels before and after the GFC and examines whether the UK MTM has changed because of the recent GFC. *Third*, it constructs a VAR, VEC and SVAR models to explore the role of credit supply shocks and addresses if the issue of credit supply shocks has a plausible macroeconomic effects in the UK economy. *Fourth*, it addresses the issue of structural changes in relation to the UK economy and determines the degree of significant changes assuming that MSBs exist. Specifically, the study examines the robustness of the Augmented Dickey-Fuller (ADF) unit root test to the presence of endogenously determined one to many structural breaks. *Fifth*, it studies credit supply shocks to determine how monetary policy and credit shocks differ during the pre and post-IT regimes. *Sixth*, it explores the role of MP and determines whether financial frictions that accounts for price and financial stability will have more plausible control of the economy than being limited to price stability.

To achieve the research objectives, the study reviews the UK monetary policy structure, theory of time inconsistency and central bank independence. Furthermore, it empirically investigates the MP rules across the three policy regimes using the GMM simulation based on the five MP reaction functions[1]. Using forward and backward looking reaction functions, the study estimates the technical GMM approximations to the internal predictions a central bank is supposed to generate and use when designing its policy. The research contributes to the rapidly growing literature on monetary policy rules analysis to answer the two research questions: (a) should monetary policy be conducted by rules known in advance or by the policymakers' discretion? (b) Should the monetary policy rule be different in a period of financial crisis? In the spirit of McCallum (2000), the estimates provide relevant information on the monetary policy feedback rules and help to assess if the estimated central bank reaction functions are different in terms of the type of instruments and targets. The UK MP structure can be characterised as a forward looking reaction function in the post IT period. In both forward and backward looking reaction functions exchange rate plays active role in determining the UK monetary policy structure. The intuition behind this is that the UK economy is a small open economy that could be impacted by the international economic forces. Further evidence also obtained to suggest that MP should not be conducted solely by rules but also by discretions. The RFs and their estimated coefficients revealed that the post crisis period MP rules combined conventional and unconventional monetary policy strategies.

The research also addresses the general consensus of the role of monetary policy that affects price level in the long-run but the real economy in the short-run. Nevertheless, the recent GFC questions

[1] The Taylor, McCallum and Taylor-McCallum hybrid MP that mix an interest rate instrument with a McCallum nominal income gap target, a MP that mixes a monetary base instrument with a policy target in the spirit of Hall and Mankiw (1994) and a Nominal Feedback Mechanism (NFM) following Dueker and Fischer (1996, 2001).

this assertion on the goals and the tools of monetary policy. It was believed that central banks are not only able to maintain price stability but also minimise the need for “lender-of-last-resort” intervention. This claim has been examined particularly in the post GFC as the TM has failed to function, as it was understood. Thus, the way the monetary policy affects the real economy through the channels received considerable attention and the transmission mechanism (TM) is becoming the focus of attention in monetary economics research. The *first* motivation for the MP study stems from the need to deepen the understating of the complex connections of the transmission channels. The *second* impetus is the need to explore the interaction between monetary and financial stability policies due to a significant weakening of the TM between the short-term central bank rate and its derivatives. There are a number of different but interconnected traditional and non-traditional channels through which monetary policy operates: the *traditional interest rate channel*, the *credit channel,* the *exchange rate channel,* and the *asset price channel*. In practice, the MTM is usually sluggish and incomplete in the short-run. Thus the variance in the policy rate are transmitted to other forms of interest rates with lag. Hence, interest rate differentials exist in the economy. The study also discusses the monetary policy shocks, the dynamics in the interim stages of the TM, the state of shocks with a constant/varied mean and variance, and the new understanding of the MTM in the light of the GFC. To incorporate developments in the current research, the study reviewed the historical understandings of the TM and model the responses of variables to a monetary policy shock based on the optimisation behaviour of economic agents through estimating a Bayesian VAR and a New Keynesian DSGE models.

The standardised and estimated VAR and the Bayesian DSGE model revealed that after 1992, the nominal rigidities became weaker and the coefficient on inflation in the monetary policy rule increased whereas the coefficients on output has declined. The counterfactual analysis indicates that changes in the private sector parameters (non-target variables) are responsible for the stronger reaction of output and inflation to a monetary policy shock and a milder reaction of prices after a cost-push shock in the post 1992 period. The modification of the monetary policy conduct influenced the responses of both output and prices to a technology shock. The drop in macroeconomic volatility in both the pre and post-crisis periods is marginal and is attributable to a more favourable set of shocks in the inflation targeting (IT) policy regime. The changes in monetary policy parameters generally contributed to changes in inflation while the private sector behaviour contributed largely to changes in output.

Macroeconomic models assume that monetary impact is neutral in the long-run, that is, the real effects of an unanticipated and permanent changes tend to disappear as time elapses. On the other hand, the case of structural breaks that challenges the long-run neutrality theory, has limited theoretical support. Regardless of the neutrality assumption, central banks pursue a long-run price stability policy due to the distortionary effect of inflation caused by monetary growth. Identifying the persistent and transitory shocks of the macro, financial and monetary sectors is crucial for policy decisions. On this ground, the study explores the persistent and transitory nature of macroeconomic shocks that are relevant to the traditional long-run monetary neutrality assumption. The issue of unit roots in the long-run macro and financial series has been a matter of controversy ever since Nelson and Plosser (1982) and Perron (1989) seminal works. On one hand, Perron argues that those structural changes are expected phenomena and that most macroeconomic series are not characterised by nonstationarity. On the other hand, Nelson and Plosser argue that structural breaks should not be ignored but should be treated as some expected phenomena. Some macroeconomic research allows one and two structural changes but less attention has been paid to the presence of Multiple Structural Breaks (MSB). The use of the MSB approach in this study is motivated by this gap and addresses the issue of nonstationarity in Macroeconomic and Financial (MEF) time series through conducting tests that allows not only a one time structural shifts in the macroeconomic innovations and financial series, but also endogenously determined multiple breaks.

Although testing mean and variance reversion is not a new approach, the MSB analysis of the UK macroeconomic and financial time series has not been carried out in model specification, particularly in the post-GFC. The contributions of the SB and macroeconomic innovation to the existing literature are: *first*, it highlights the implication of the low power stationarity test on MEFT series using the Zivot and Andrew (ZA) approach and, *second*, it investigates the long-run time-series properties of MEFT series using endogenously determined one-to-many SBs based on BP's dynamic programming algorithm (DPA) approach. The results show that the financial sector has more concentration of significant breaks than the macro and monetary sectors. This result disputes the neutrality assumption of the long-run MEFT series.

Following these findings, the study also investigates the role of MP and disentangles the impact of credit supply shocks from aggregate demand shocks. Assuming parameter instability, the SVAR models quantify the forces that drive the behaviour of macroeconomic, financial and monetary series. It also examines the behaviour of credit supply and monetary policy shocks in the presence of a SBs and compares the behaviour of the two aggregate shocks in the post and pre-IT policy regimes. The approach involves estimating a set of financial, macroeconomic and monetary variables. *First,* each variable is regressed on past movements of itself and the other variables in the system. *Second,* the unexplained component of each variable is then decomposed into the impact of different structural or fundamental shocks. The decomposition is not a straightforward process as each shock is uniquely identified from the other restriction based on economic theories and agents' response to policy decisions. In addition to the regime based SVAR approach, the other novelty of this study is that it attempts to provide unique contemporaneous and sign restrictions for the shocks in order to identify and decompose the movement of each variable into the effects of current and past movements.

The findings show that credit supply shocks generate more volatility in the market than monetary policy shocks. It also establishes that the credit supply shocks account for most of the shocks in the financial market and monetary aggregates particularly during the post 1992 and after the GFC. The impact of monetary policy shock shows some tendencies to disappear after 24 base points, hence a short-run effect. The credit supply shock is found to be more like aggregate supply shocks than aggregate demand shocks. During credit supply shocks, measures taken to reduce price instability are likely to increase output and vice versa. This could be due to two possible reasons: (a) credit supply shocks affect not only actual supply but also potential supply in the economy, or (b) due to its significant effect on exchange rate. The contemporaneous zero and the sign restrictions appear to produce fairly similar results. The research also extended the investigation to identify the conduits of the credit channel using VAR and VEC models based on successive regressions to the policy instruments. The results confirm that the bank-lending channel plays more significant role than the balance sheet channel in the UK MPTM.

Finally, using a Bayesian DSGE model of the real business cycle augmented with a FA mechanism, the study addresses the role of financial frictions. The recent GFC reveals several flaws in both monetary and financial regulations. Contrary to what the theory of monetary policy, price stability is found not to be a sufficient condition for financial stability. At the same time, micro-prudential regulation alone becomes insufficient to ensure the financial stability objective. The financial crisis has stimulated various theoretical and empirical studies on the propagation mechanism underpinning business cycle, particularly on the role of the financial accelerator mechanism. In the presence of weak and fragile banks, addressing this issue is essential. Although, a growing theoretical and empirical literature have shown the relevance of financial frictions and consequently financial intermediaries in propagating monetary policy shocks to the real economy, the role of financial stability has been ignored in the run up to and the onset of the GFC. The 2007 financial crisis provided a growing motivation to conduct further research and examine both the build-up of risks during the "Great Moderation" period as well as the functioning of monetary policy during the crisis and the recovery periods. One of the most important lessons of the recent GFC is that financial and price stability cannot be targeted independently of each other and that MTM very much depends on the state of the banking system that leads to financial stability.

The specification of the DSGE model follows the Smets and Wouters (2003, 2005, and 2007) and Smets (2014) augmented DSGE model with further reflections over the financial accelerator mechanism developed in Bernanke and Gertler (1989), and Bernanke, Gertler and Glichrist (1999, BGG hereafter). The main advantage of using a Bayesian NK DSGE model is that it allows several sources of nominal and real rigidities and various structural shocks to be included in the model structure. Besides, analysing and measuring the stochastic forces that explains its behaviour is a new approach for the UK economy. The findings also highlighted that the estimated external finance premium is not counter-cyclical as theoretically stated in BGG (1999) and empirically confirmed by Queijo von Heideken (2009) for the Euro Area. In the context of the central bank's objective, the first model incorporates only traditional objective, while the second model has an additional financial stability objective. The results clearly show that a more aggregate monetary policy would have more success in improving the response of the economy if the action of central banks was not limited to a single objective, *price stability*, and a single instrument, *the interest rate*. A central bank with price and financial stabilities objectives will have more plausible control of the economy than being limited to price stability objective. The FEVD, CVD and HVD also indicated that many shocks are relevant for the explanation of the variability of the premium.

1.2 Motivation of the Study

Due to the structure of the thesis that comprises standalone but integrated issues, there are numerous factors that motivated this research. The foremost motivational factor is the recent GFC that questions the current macroeconomic and monetary policy understandings. This impetus inspires researchers in the field of macroeconomics and finance. Although various research have been carried out since the 2007/8 financial crisis, there is still no universal consensus on how monetary policy should be conducted and the role of financial market frictions. The study is motivated by the following factors:

First, the unpresidented events that led to the recent GFC embolden macroeconomists and policymakers to invstigate the prominance of a single target monetary policy approach. Given the four major structural changes in the UK, accounting for the reaction function to only a Taylor type MP rule is a narrow view of monetary policy. The long road to price stability monetary policy in the UK laid down a number of policy regimes: monetary targets, shadow exchange rate targets, explicit exchange rate targeting and inflation targeting with and witout operational central bank independence (Chadha and Holly, 2011). The absence of a comprehensive study that investigates the UK monetary policy reaction functions in relation to the GFC and the five MPRs is one of the motivating factors.

Second, the MTM is concerned with the endogenous behaviour of intermediate and final variables in response to exogenous policy impulses. The MTM study has gained considerable importance due to not only structural and economic reforms and subsequent transitions to new policy regimes but also due to the recent GFC. The financial crisis countered the views held prior to the crisis on the goals and instruments of monetary policy and their relationship with financial stability. The conventional view to the end of the "Great Moderation" period was held on the precept that there is no general trade-off between monetary and financial activities. It was believed that a central bank that was able to maintain price stability is able to minimise the need for central banks' intervention. Operationally, central banks not only ease MP to alleviate the distress effect in the financial market but also ease the policy to encourage output and stabilise inflation. In the pre-crisis period, MP have been successful in some developed economies in mitigating inflationary pressures but output growth remained very low in many advanced economies[2]. There are many explanations for the unexpectedly sluggish recovery from the Great Recession including underestimation of the persistently adverse impact of the financial crisis. However, there is a growing debate on the hypothesis[3] that the MTM is impaired due to the unprecedented forces in the run up to the GFC, thereby making monetary policy less effective in stimulating output and inflation compared with non-crisis periods. The study is motivated by the lack of information and the inability of the traditional Philips Curve that has failed to explain the role of macroeconomic agents' objectives subject to constraints.

Third, the controversy over the issue of structural change and nonstationarity of data series and the fact that the structural breaks in the form of persistent macroeconomic innovations have unique properties on the long run dependencies of error and regressors in the MEFT series. An important distinction from the majority of existing literature is that long-run non-neutrality assumption is employed, implying that possible dependence is allowed for explanatory variables and errors in the long-run. In empirical applications, parameters may change dramatically due to important economic forces. There may also be more gradual but fundamental changes in economic structures that may have led to significant changes, such as those related to globalization and technological progress. The common factors may become more (less) important for some of the variables and, therefore, the leading coefficients attached to the common factors are expected to become larger (smaller). Ignoring *Structural Breaks* when estimating the components or assessing the transmission of shocks, to specific variables, could potentially lead to model misspecification[4]. The issue of accounting for structural breaks in empirical analysis is an unresolved issue in macroeconomic time series analysis.

[2] See also Pain et al. (2014).
[3] See also Bouis et al. (2013).
[4] See also Breitung and Eickmeier (2009).

In the presence of considerable number of unexpected macroeconomic shifts, assuming breaks as exogenous phenomena could lead regressions that seem to give a good fit and predict a statistically significant relationship between variables where none actually exists. Despite the presence of multiple structural shifts in the UK economy, the focus of previous studies has been, mostly on one but in some cases two breaks. The existing gap in this area of research has motivated this study to investigate the MEFT series by allowing one and multiple structural breaks rather than employing a restricted break-point assumption.

Fourth, following the nonstationarity structural break analysis that identified the financial system with high concentration of structural shifts, addressing the role of monetary policy and the impact of credit market shocks in an open economy setting is important. Studies show that the role of the credit market shock has changed. Therefore, this study is motivated to investigate the shocks in the credit market within the framework of aggregate supply and demand shocks. Few studies address the role of credit market shocks in the post 1950s policy regimes. The lack of information on the role of the credit market with and without the financial accelerator mechanism has also motivated this study to further explore and quantify the role of the two conduits of the credit channel: the *balance sheet* and *bank lending* channels. To the best of my knowledge, this is the first VAR/VEC/SVAR approach in the pre and post-crisis periods that covers a wide spectrum of the UK business cycle.

Finally, except few attempts, the existing literature in the run up to the GFC, disregards the role of financial sector in the economy. The lack of understanding and the need for policy analysis motivated this study to estimate a Dynamic Stochastic General Equilibrium (DSGE) model to address the issue of how monetary policy should be conducted and the role of financial market frictions. The need to evaluate the performance of a DSGE model with and without the financial accelerator mechanism motivated this study to set up two DSGE models. The setup of the model helps to verify the hypothesis that an inflation targeting monetary policy also brings financial stability. It is also important to understand the dynamic properties of the variables pertaining to those markets, among which the external financial premium. Overall, the most important and the overriding motivational factor is the GFC that necessitates the need to re-evaluate the approaches to monetary policy across advanced economies. This drive led to a number of macroeconomic studies to review the existing approaches and gain deeper understanding of how monetary and alternative policies work and their role in the presence and absence of the financial factor in the real economy settings.

1.3 rganisation of the Thesis

The thesis is divided into seven Chapters. *Chapter 1* provides introductory insight to the thesis. It highlights the background, motivation and the organisation of the thesis. *Chapter 2* discusses the theory of monetary policy rules with respect to Classical and Keynesian views, the role of central bank independence and the theory of time inconsistency. It investigates the monetary policy rules using OLS-BL and GMM-FL models, respectively, in three policy regimes. It explores the empirical features of the alternative policy rules that will condition the estimation and evaluation of the monetary policy reaction functions. By doing so, it profiles the monetary policy developments and provides a reality check for the choice of alternative policy rules. It also provides the MPRF estimation framework, results and salient inferences. Broadly, the UK witnesses two policy regimes: non-inflation and inflation targeting policy regimes. The MP evaluation covers the period from early 1960s to the end of 2014. The findings are able to shed some light not only on the operational feasibility of monetary policy rules but also on the degree of commitment of monetary policy authorities to rules and variations therein.

Chapter 3 presents a comprehensive survey of literature on the monetary policy transmission mechanism and examines the conduct of this pass through mechanism. It discusses the channels of the MTM with respect to the non-New Keynesian and New Keynesian frameworks. The Chapter begins by examining the macroeconomic environment, policy objectives and the TM from the Keynesian and Monetarist perspective. It discusses the channels of MTM, the principal objectives of central banks and the post "Great Moderation" paradigm. It also converses and empirically investigates the evolution of the UK monetary transmission mechanism using a dynamic stochastic general equilibrium (DSGE) models. The results are discussed based on the set priors and estimated posterior parameters.

Chapter 4 reviews the existing literature on unit roots and structural breaks with respect to implications on macroeconomic and financial variables. It highlights the implication of the low power stationarity test on MEFT series using the ZA and BP algorithms. It reviews the methodological aspects of exogenous and endogenous breaks and discusses SB based on the ZA and BP theoretical and computational methodologies. It also examines nonstationarity of MEFT series using one to many endogenously determined SBs based on the BP dynamic programming algorithm (DPA). The analysis identifies the variable(s) with permanent significant structural breaks and categorises the MEFT series homogeneously. The final section summarises and presents concluding remarks. The SBs and corresponding dates that are identified in this Chapter are incorporated in the estimation of the regime based SVAR models.

Chapter 5 presents the SVAR estimation of sixteen specifications allowing parameter variability by way of incorporating structural breaks as an additional identifying power. The *first* section of the Chapter begins with a monetary policy framework and reviews the growing literature on monetary policy and credit supply shocks. It also reviews the general VAR and SVAR modelling approaches and critics, followed by impulse response functions (IRFs) and forecast error variance decompositions (FEVDs). It also discusses the UK SVAR econometric model, the data and the identification problem. Additionally, it examines the property of monetary policy and credit shocks and highlights the main drivers of output, price, money supply, lending and equity prices both historically and during the GFC. The Chapter progresses to robustly verify the identification procedure. The *second* section investigates the UK credit channel using VAR and VEC models. The results obtained in this section highlights the importance of the behaviour of the UK credit shocks. The findings in this Chapter prompted the investigation of the role of financial frictions in the UK economy using the Bayesian DSGE approach.

Chapter 6 investigates the role of financial frictions in the credit sector of the UK economy and in the monetary policy decision. Having identified the prominence of the credit supply shocks in Chapter 5, this Chapter examines to what extent financial transmission channels have accounted for output collapse in the UK during the GFC. For this purpose, the research employs two extended DSGE models in the spirit of Smets and Wouters (2003, 2007, SW hereafter) and BGG (1999). The Chapter begins by reviewing the current developments in the financial frictions literature and specifies the model with the priors and estimates the posterior parameters. It estimates a New Keynesian DSGE models based on the UK quarterly time series data from 1955Q1 to 2014Q4 using Bayesian methods. The Chapter concludes by highlighting the important findings that resembles those predicted by theories of the new paradigm.

Finally, *Chapter 7* presents the overall conclusions of the thesis. It highlights the major theoretical reviews and empirical findings of the monetary policy rules, the MTM, persistent financial and macroeconomic shocks, the structure of credit and monetary policy shocks and the dynamic stochastic general equilibrium model for the parameter estimation of the posterior distribution. This Chapter also draws some policy implications and indicates the limitations of the study to encourage future research.

CHAPTER 2
MONETARY POLICY RULES AND CENTRAL BANK INDEPENDENCE
GMM ESTIMATION AND SIMULATION ANALYSIS

2.1 Introduction

> "...it should be said that proponents of explicit numerical rules for monetary policy do not imagine that any actual central bank would ever turn their determination of instrument settings over to some clerk armed with a simple formula and a hand calculator—or even to a team of PhD economists armed with computers and MatLab simulation programs".
>
> (McCallum, 2002:p1)

Traditionally, macroeconomic performance is defined in terms of both price and output stability (Taylor, 2013). The long-term objectives of monetary policy are full employment, stable economic growth of real output and low inflation. Studies show that Central Bank Independence (CBI) is a precondition to achieve low and stable inflation. However, independent decision-making process without pertinent monetary policy rule may not help to meet the monetary policy goals. This issue has been debated since the 1930s Great Depression. In the early 1970s, Kydland and Prescott (1977) initiated the long-standing debate. They argue that the inflation bias problem that arises from a discretionary monetary policy provides enticements to manipulate inflation in order to achieve other desirable objectives. Additionally, lack of commitment to a monetary policy rule could limit the ability to correct inflation bias. A credible commitment to a monetary policy rule is a means to reduce expected inflation regardless (Clarida, Gali and Gertler, 1999, CGG hereafter). Apart from monetary policy rules, the other possible solution (as in Barro and Gordon, 1983b) could be the delegation of monetary policy to an Independent Central Bank (ICB). Similarly, Rogoff (1985) notes that the inflation bias can be reduced through the delegation of the monetary power to a conservative central banker relatively more averse to inflation than the representative government.

In the post GFC period, the argument over monetary policy rules or discretion; and complete or partial CBI has been re-ignited (Sun et al., 2012). Macroeconomics literature provides numerous reasons why monetary policy should be reviewed. *First,* the literature on time-inconsistency shows that without commitment to a rule, policymakers will be tempted to choose a suboptimal inflation policy that may cause a higher average inflation rate and higher unemployment than if a rule is followed (see Kydland and Prescott 1977; Barro and Gordon, 1983). *Second*, credibility about monetary policy appears to improve its performance and increases the credibility about future policy actions. In addition, policy rules help market participants to forecast future policy decisions and therefore reduce uncertainty particularly in the financial markets (Sun et al., 2012). Policy rules increase accountability and potentially require policymakers to account for the difference between their actions and the rules (Taylor, 1998). Following the non-active constant growth rate rule, supported by Friedman (1959) and Lucas (1980), the well-known simple monetary policy rules are the Taylor and the McCallum rules. According to Shultz (2014:p142):

> "...if you have policy rule, like a Taylor rule, you have a strategy, which is sort of what it amounts to. Milton Friedman was in favour of rules and he liked John's rule. And at least as I have observed from policy decisions over the years in various fields, if you have a strategy, you get somewhere. If you do not have a strategy, you are just a tactician at large and it does not add up. So a strategy is a key element in getting somewhere".

Following the emergence of growing criticism on monetary policy arrangements in the GM and the post-GFC periods, reviewing the MP rules is becoming a common practice. This Chapter reviews the monetary policy rules using theoretical and empirical approaches to address the issue - whether monetary policy should follow rules or discretion and the operational feasibility of the rules. The empirical analysis relies on the approach popularised by CGG (1998, 2000) with solid grounding in New Keynesian macroeconomic theory. It involves estimation of forward and backward looking MP rules incorporating smoothing via the Generalized Method of Moments (GMM) proposed by Hansen (1982) and Ordinary Least Squares (OLS) methods. In this context, the Chapter reviews the theory of CBI, the monetary policy arrangements before and after the GFC and the monetary policy objectives with respect to the Taylor, McCallum and the hybrid monetary policy rules.

The reaction functions are estimated for the benchmark reaction functions based on the *Taylor MPR*, the *McCallum MPR*, the *Taylor-McCallum* hybrid MPR, the *Hall and Mankiw* (1994) (also known as McCallum-Hall-Mankiw) MPR and the *Nominal Feedback* Mechanism following Dueker and Fischer (1999). According to the results obtained from the family of the monetary policy reaction functions, there is enough evidence to suggest that the UK monetary policy operational feasibility varies across the time horizon. The pre-IT, post- IT and post-GFC periods show marked differences in terms of the operational feasibility of the monetary policy rules. Although there are more indications to claim that the UK monetary policy is more of a Taylor rule type, the role of the other reaction functions is not negligible. Particularly, the hybrid Taylor McCallum reaction function illustrates that the monetary policy was operational not only based on specific and recommended rules but also by taking into account variables and their responses to various policy shocks and instruments. The post crisis period phenomena in terms of the operation of the UK monetary policy is markedly different from the pre-crisis period. The post crisis period shows limited role of specific Taylor type monetary policy operation but rather a discretionary or unconventional approaches seem to have dominated the past eight years Bank of England's engagement to the rest of the economy, particularly the financial sector.

The study contributes to the growing literature and attempts to answer questions such as: (a) should monetary policy be conducted by rules known in advance or by the policymakers' discretion? And (b) should a monetary policy rule be different during financial crisis? The strategy of this Chapter involves a review of the operational behaviour of the monetary policy strategies and empirical evaluation of the UK monetary policy rules across three MP regimes. In the spirit of CGG (2000) and McCallum (2000), the estimates will help to understand the MP feedback rules in order to determine - if the estimated central bank reaction functions are different depending on the type of instruments and targets. The UK witnesses two major policy regimes (non-IT, and IT policy regimes). The empirical analysis covers the period from 1962 to 2014. The findings are able to shed some light not only on the operational feasibility of the UK MP rules but also on the degree of commitment of policymakers to rules and variations therein, if any. The outcomes of the MP analysis are introduced into the DSGE model presented in Chapter 3 and 6.

The Chapter is comprised of nine sections. The *second* and *third sections* discuss the theory of time inconsistency, Central Bank Independence and present an overview of monetary policy arrangements before and after the GFC. The *fourth section* profiles the historical developments of monetary policy strategies in the UK over the period of study. *Sections five* and *six* review the theoretical and empirical framework of monetary policy behaviour and rules. *Section seven* describes the data and specifies the MP reaction functions. *Section eight* estimates the family of monetary policy reaction functions and discusses the estimated results in the context of the UK monetary policy and finally, *section nine* offers some concluding remarks.

2.2 Time Inconsistency and Central Bank Independence

2.2.1 Theory of Time-Inconsistency

Kydland and Prescott (1977) exposed inherent flaw of credibility problems in the ability of governments to implement desirable economic policies (Blackburn and Christensen, 1989). This theory was one of the most influential theories of the time put forward as an explanation for the 1970s great inflation. The theory was first introduced by Kydland and Prescott (1977) as "time-inconsistency". According to this theory, governments suffer from an inflationary bias and as a result, inflation becomes sub-optimal. Rogoff (1985) proposes to delegate monetary policy to an independent and 'conservative' central banker to reduce this inflationary bias. Conservative means that the central bank is more averse to inflation than the government, in the sense that central bank places a greater weight on price stability than the government does (Berger et al., 2000). Time inconsistency is a problem in macroeconomics in general and monetary policy in particular. Although technologies, preferences and information could be the same at different times, the policymaker's optimal policy chosen at time t_1 differs from the optimal policy for t_0 chosen at $t_0 < t_1$. The study of time inconsistency is central to assessing the behaviour of policy decision-making process as it not only provides positive theories that help to understand the incentives faced by policymakers, provides the natural starting point to explain the actual behaviour of policymakers and actual policy outcomes, but also requires one to design policy-making institutions. Such a normative task can help one understand how institutional structures affect policy outcomes (Jingyuan and Guoqiang, 2008).

Time-inconsistency describes situations where, with the passing of time, policies that were determined to be optimal yesterday are no longer perceived to be optimal today and are not executed. The key insight that Kydland and Prescott (1977) put forward was that the reason why these policies would not be implemented could also lead to inflationary policies being implemented in their place. In other words, time-inconsistency could generate higher inflation. If one agrees that the theory is a good description of the 1970s inflation, then the relative absence of inflation since the mid-1980s may prove otherwise. This necessitates that time-inconsistency is not a current problem for policymakers so is still valid (Dennis, 2004a). Dennis also argues that time inconsistency describes how policymakers respond to shocks and how resources are allocated through time. As time-inconsistency can affect more than just the average rate of inflation that prevails in the economy, it remains to be a valid theory to study in the post Global Financial Crisis (GFC).

Economic agents question policymakers' credibility. Bain and Howells (2009) show that the credibility of a particular policy statement would depend on: (a) the performance of the policy authorities in the past (their reputation) and, (b) the nature of the policy institutions. Even if the policy authorities were not to be trusted, institutional arrangements might prevent them from attempting to mislead the public. For example, the authorities might be pre-committed to following a particular policy. This might make their policy statements credible in the view of market agents (Dannis, 2004b).

2.2.2 Central Bank Independence and the UK Experience

Central Bank Independence (CBI) refers to the "freedom of monetary policymakers from direct political or governmental influence in the conduct of policy" (Belke and Polleit, 2009:p528). The relationship between the government and central bank is defined in terms of (a) *Institutional Independence* – the legal rank of the central bank statue, prohibition of outside instructions and influence; (b) *Personal Independence* – the role of the government in appointing and dismissing members of the Central Bank Governing Board (CBGB), the voting power (if any) of the government of the board; (c) *Financial Independence* – refers to the degree of budgetary control by the government and the extent to which government expenditure is either directly or indirectly financed via central bank credits; (d) *Policy or Functional Independence* – refers to flexibility given to the central bank in the formulation and execution of the monetary policy (EMI, 1997; European Commission, 1998).

In terms of decision-making process, CBI has two main dimensions: (a) *Political Independence*: is the ability of the central bank to select the final objectives of monetary policy. This dimension is also known as "goal independence" (Debelle and Fischer, 1995). This includes that if the governor and board of directors are appointed without government involvement and for more than five years; there is no mandatory participation of government representatives in the board; no government approval is required in formulating monetary policy; there are requirements in the charter forcing the central bank to pursue monetary stability amongst its primary objectives; and there are legal protections that strengthen the central bank's position in the event of a conflict with the government (Arnone et al., 2006; Grilli et al., 1991); (b) *Economic Independence* – refers to the ability of the central banks to select the monetary instruments necessary to the achievement of the goals (Debelle and Fischer, 1995). This includes limits on lending to government, own determination of monetary policy, control of own budget and salaries and possession of a range of monetary policy instruments (Grilli et al., 1991). There are various indices that are used to measure CBI such as the ones elaborated by Cukierman et al., (1992); Cukierman (2013); the GMT index (Grilli et al., 1991), and the Alesina and Summers (1993) indices, among others[5]. In the post-GFC period, the issue of CBI

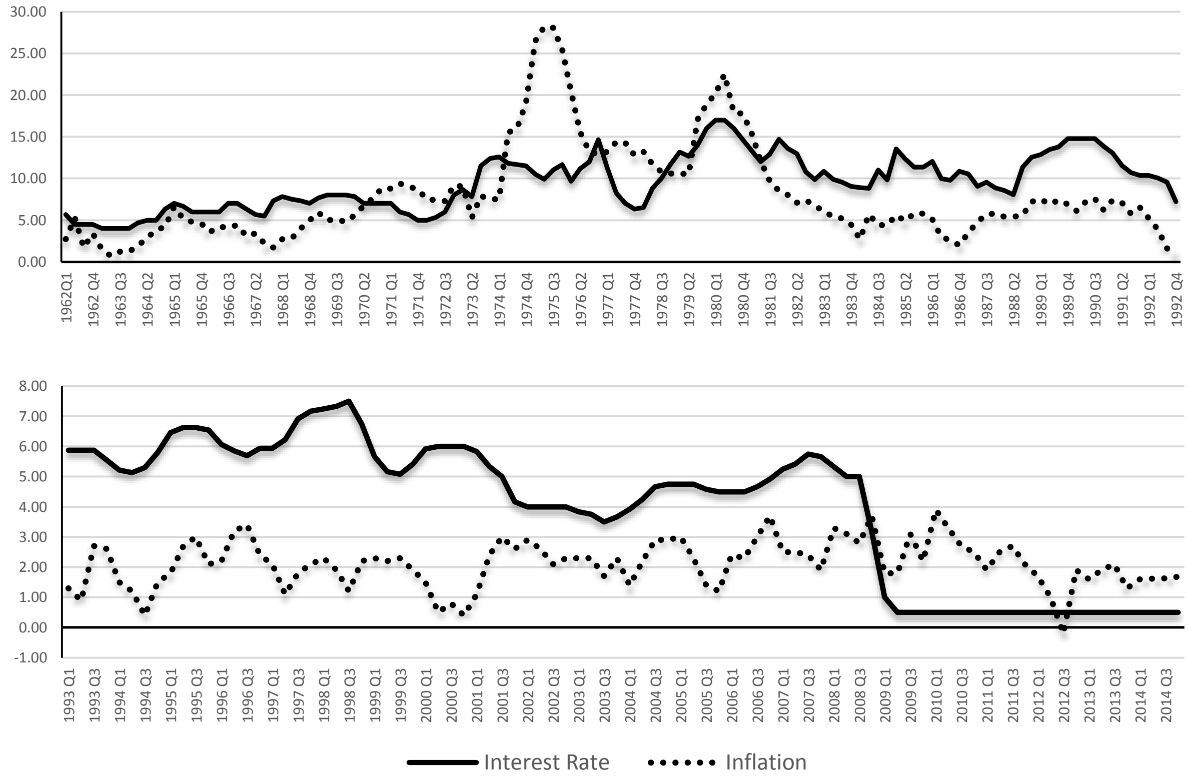
[5] For surveys of indices measuring CBI, see Arnone et al. (2006).

attracts the attention of monetary economists and question its feasibility. Blancheton (2015:p1) notes:

> “...even though there has been no change in the legislation governing the independence of central banks, a new era has indeed dawned since the financial crisis of the late 2000s. Financial upheavals and growth in sovereign debt have prompted central banks to help governments to liquidate debt even if it has meant losing control over the money supply (Goodfriend, 2012; Issing, 2012; Taylor, 2013). What will be the future of central bank independence? As Capie and Wood (2013:379) put it, ‘central bank independence never has survived a crisis and never can”.

In economic research and monetary policymaking, the issue of central bank independence has been widely investigated. Economic theory suggests that countries having an independent central bank can achieve low inflation rates because politicians cannot easily influence monetary policy (Rogoff, 1985; Neumann, 1991; Lohmann, 1992). Studies also show that central banks without independent status from politician’s time inconsistency problem are tempted to expand output beyond its natural level. The pressure to do so is influenced by the desire to be re-elected. On the contrary, independent banks are not restricted by the politician desire (Eijfinger et al., 1998a). When central banks are influenced by politicians, they tend to act in a discretionary manner once private agents have formed their expectations and negotiated nominal wage contracts on the assumption that prices will be kept stable (Sorensen and Whitta-Jacobsen, 2010). The time-inconsistency problem can be mitigated by delegating monetary policy to an independent central bank that is more conservative than the government in the sense that it cares more about inflation, for example, as a monetary policy target. However, the improved credibility that causes the lower rate of inflation comes at the cost of having less flexibility. The other side of the argument states that, since the conservative central bank cares more about a low and stable rate of inflation, it will care less about stabilising output shocks (Eijfinger et al., 1998b).

The indices of economic independence essentially measure how easy it is for the government to finance its deficits by direct access to credit from the central bank. According to Bade and Perkin (1982) CBI index, as extended by Alesina (1988), the prominent 16 countries indices show a maximum of 4 and a minimum of 1, 4 being high level of CBI while 1 is low level of CBI. The study shows that the United Kingdom index of CBI was 2. During this period, the Bank of England was not fully independent. Figure 2.1 shows that inflation was more volatile during the pre-CBI than after the monetary policy shift to inflation targeting in October 1992. The Figures also show that inflation has been stable throughout the inflation targeting policy regime. One could ask, ‘is this because the UK central bank’s correct monetary policy or is this simply due to external influence such as the world economy?’ Although the inflation movement looks stable, it continues to decline to the present period while interest rate is still kept at the lowest rate (0.5%) since 2009.



Source: author's analysis

Figure 2.1 The UK MP Rate and Inflation before and after the CBI

This might indicate that another mechanism is in operation in the monetary transmission mechanism. Apart from the role of CBI, there are many views behind this phenomenon among which consumer confidence and the CBs cautious approach in dealing with price and output gaps have been highlighted in some literature. However, the modern macroeconomic approach is attempting to identify if there is (are) some MP transmission channel(s) playing some role in the interim stages of the transmission. Moreover, many developed countries have continued to have a central bank with a MP that targets inflation and output gaps. About a year after the announcement of the UK inflation targeting MP, Alesina and Summers (1993) employ Index of CBI to study the degree of CBI and show that Switzerland and Germany had the most independent central bank system as compared with Australia, New Zealand, Spain and Italy. On the lower end, Belgium, Canada, Denmark, France, Netherlands, Norway, Sweden and the United Kingdom had lower level of index concerning CBI.

AS (1993) and a recent study by Arnone and Romellib (2013) note that in the early 1970s the UK CB did not have political and economic independent. However, the CB governor was appointed without the involvement of the government and the CB did not participate in primary market for public debt. In the post BoE independence and the recent financial crisis periods, particularly in the 2010s, there was no mandatory participation of the UK government representative in the CBB. As one of its primary objectives, the UK CB is legally obliged to pursue monetary stability and is legally protected when a conflict of interest arises with the government. The BoE gains more economic independence so there was no automatic procedure for the government to obtain direct credit from the BoE but only extended at market interest rate when it is available. The BoE has also gained more independence for setting monetary policy rate with no responsibility to oversee banking sector but shares responsibility with other institutions. These roles and responsibilities are beginning to change since the Global Financial Crisis. Its price stability objective is highly challenged by economists and financial experts. This issue is also becoming an open academic research question in the post GFC that the CB's price stability objective should not be the only approach to achieve stable economy. There are suggestions for the amendment of the CB mandates, which this research has made recommendations. To understand the operational framework of monetary policy and the role of central bankes, it is important to review the past and present MP decision-making procedures. On this background, the following section reviews and discusses the UK monetary policy arrangements before and after the GFC.

2.3 Overview of Monetary Policy Arrangements

2.3.1 Historical Perspectives

The major economic upheaval in the world changes the values of monetary policy arrangements and the role of policymaking institutions. Among other periods, the Great Depression led to deposit insurance, the Great Inflation of the 1970s, which was followed by Volcker's Stabilization, and the ascendency of CBI are remarkable economic events. The GM period encouraged inflation targeting, a Taylor's rule monetary policy approach and the New-Keynesian framework. Nevertheless, the GM period failed to recognise the importance of financial stabilisation as an integral part of price stabilisation policy. The contempt of the financial stabilisation scheme has been highly criticised by the proponents of the New Keynesian macroeconomists. However, the GFC revived this concern and underlined the importance of the central bank's role as an independent institution. It also led to a more intensive use of unconventional monetary policy instruments. The crisis demonstrates that highly expansionary monetary policies do not necessarily raise inflation during financial crisis (Cukierman, 2013).

Historical developments in macroeconomics show that the characteristics of monetary policy arrangements have been influenced by the socio economic events, particularly during the early 20th century. When the great depression of the 1930s struck the Western world, the classical laissez-fair position came under heavy attack. The depression was an "economic earthquake", as Sorensen and Whitta-Jacobsen (2010) put it. Due to the negative shock and macroeconomic policy failures, output in several countries fell by 25% to 30% between 1929 and 1933. This brought devastating consequences for employment (Kedar-Levy, 2016). It was against this ground that John Maynard Keynes and several others challenged the classical view, which stated that resource utilisation at natural rates, is the normal state of affairs. Keynes challenged this tenet on the basis that resources are not always scarce but they are often underutilised due to lack of demand. In such circumstances, the government is able to raise total employment and output through a fiscal and monetary policy, which stimulate aggregate demand. This breakthrough shapes the field of macroeconomics in general, the principles of monetary policy and the arrangements in particular. This historical development also led to the 1950s and 1960s Keynesianism that largely ruled in monetary policy matters.

Fiscal policy could be used to 'fine-tune' the economy and the interest rate used to influence the FX-rate, under the Bretton-Woods fixed exchange rate system. From a monetary point of view, in the 1970s, money supply control was strongly advocated as a means to, simultaneously control domestic inflation and the exchange rate (Cuthbertson et al., 2008). A growing debate in academia centred on a stable demand for money function and the use of intermediate monetary targets, often with some form of monetary base control advocated as the policy instrument. The initial acceptance of this tenet rests on the fact that a contractionary monetary policy might lead to changes in real output in the short-run, but with neutrality in the long-run. Then the New Classical economics with its emphasis on perfectly flexible prices (short-run neutrality) and rational expectations (RE) has come into picture. This emergence reinforced the arguments of 'tough' monetary policy targets, as any output losses would be small or non-existent. The Lucas critique emphasised that the parameters of 'backward looking' macroeconomic models might not be invariant to policy changes, if agents were rational. Hence, policy simulations of such models used by central banks could be misleading. Besides, Kydland and Prescott (1977) argue that such policies are likely to be time-inconsistent as a policymaker has an incentive to deviate from a disinflationary policy (to obtain short-run gains in output). Even if the latter is not the case in practice, enhancing credibility by committing to a rule can improve the inflation output trade-off, if agents are forward looking (King 2002; Cuthbertson et al., 2008). In the 1970's and 1980's UK banks were able to bid for wholesale deposits[6] (e.g. CD's) so the demand for broad money (M2, M3, M4) depended on the 'own rate' as well as the rate on substitutes (e.g. bonds, T-bills) and the demand for broad money became unstable. In the 1980s the emergence of the rational expectations has influenced the analysis of the demand for money, which included as forward looking variables and the idea that money could act as a buffer stock absorbing shocks to output and prices (Laidler, 1984; Cuthbertson, 1988; Cuthbertson and Taylor, 1987). Cuthbertson (1988) discusses that as conditional forecasts depend on current (and past) information, a forward looking model can be re-parameterised to give a purely backward looking (error correction) money demand equation. However, the use of forward looking variables fails to adequately address the instability in money demand. With this insight, the following sections discuss the UK monetary policy arrangements before and after the financial crisis to highlight the variations in monetary policy operations.

2.3.2 The Monetary Policy Arrangements before the GFC

The shock that buffeted the UK economy through the 1970s is a remarkable feature to understand how the economy performed with respect to price and the then monetary policy arrangement. The nature of the shocks that hit the economy through the 1970s was associated, in particular, to the rise in oil prices. But the high and volatile inflation of that period cannot be blamed exclusively on the oil price shocks. Inflation had already risen before the first oil price tremor occurred, averaging more than 7.5% over 1970-1972. It then quickly accelerated to almost 27% annually by the late

[6] In a world where banks did not compete for wholesale deposits, subject to interest rate ceilings, the demand for narrow money (M1) appeared to be reasonably stable (e.g. Artis and Lewis, 1984; Patterson 1987; Boughton, 1993; Hendry and Ericsson, 1991).

1975. This was roughly 6.5 times its average of 4% over the previous two decades. The late 1970s period is known as a relatively lower inflationary period but by mid-1980, inflation was again above 20%. It took another two years, until mid-1982, for inflation to return consistently to single-digit rates (McCafferty, 2013).

McCafferty also notes that in terms of the monetary policy arrangement of that period, there was a case to look through those oil price shocks as one off increase in the price level, much as the MPC did in 2009 as the price of oil climbed to $100pb. Nevertheless, without the credibility of an inflation-targeting regime in place, this simply amounted to letting inflation expectations to rise. As such, it gave rise to dramatic “second-round effects” on wages and in turn prices – the well-known wage-price spiral. It subsequently took substantial losses in employment and output to rein in wage inflation and bring down expectations. The inflation-targeting regime adopted in the early 1990s provides a credible framework for price stability, meaning that the shocks to energy and import prices have not generated second-round effects on wages and other prices.

During the period before the financial crisis (early years of monetary policy) the major role of central banks was to inject liquidity into the financial system when liquidity fades away during financial panics (Cukierman, 2013). Such panics often occurred during short periods immediately preceding the Bank of England (BoE) decision to temporarily relax the gold standard, due to wars or gold drains. In a similar disposition, the Fed was originally created to prevent financial panics and the associated violent spikes in interest rates and banking failures. However, the focus shifted in the aftermath of the Great Depression and the ensuing of Keynesian revolution after WWII. The new focus was to stabilise the real economy. The downward sloping Phillips curve initially estimated by Phillips (1958) represented a stable policy trade-off between inflation and unemployment – and therefore a menu of possible choices confronting monetary and fiscal policymakers (Samuelson and Solow, 1960). The great inflation of the seventies reoriented the focus towards price stability and the Friedman–Lucas (Friedman, 1968; Lucas, 1973) view that money is neutral in the long-run. This led to the conclusion that monetary policy should focus mainly on delivering price stability in the long-run. In parallel, the idea that price stability can be assured via CBI took hold during the eighties, which subsequently led to worldwide upgrades in the autonomy of central banks during the nineties. By making it more difficult to use fixed exchange-rate pegs to deliver price stability, the gradual removal of capital controls reinforced the view that this stability should be maintained by granting autonomy to the central bank and by directing it to focus mainly on price stability. It was after this consensus that the view of CBI emerged.

Developments in both empirical and monetary policy theory in the run up to the GFC led both monetary economists and policymakers to believe that the economic theory and practice had been working based on a well-defined "*science of monetary policy*". Consequently, the then monetary policy was perceived as being highly successful in OECD countries that achieved stable output and prices not only in magnitude but also in terms of variability. The stable developments in inflation and output until August 2007 brought confidence to central banks. As Stark (2011:p11) puts it in a nutshell, "the period from 1999 to the financial crisis, is characterised by a period of globalisation, deregulation, technological and financial innovation, stock and housing market bubble and global current account imbalances". During this period, the European Central Bank (ECB) monetary strategy, through the Governing Council (GC), aims to keep inflation rate below or close to 2% over the medium term.

Except the cyclical downturn in 2000/1, the world economy achieved a period of robust growth since 1999. World trade increased to unprecedented levels and international economic and financial integration deepened significantly during this period. The volatility of the international capital flow drives emerging economies (particularly Asia) to build up foreign exchange reserves, which were driven by the desire to hedge against the volatility endowed with the memory of the currency crisis. The accumulation of the reserve was mainly to maintain large and persistent current account surpluses. The Asian emerging economies were consuming less than they actually produced in each year. Unlike the emerging economies, the advanced economies were doing just the opposite, which is called "living beyond their means". In some of these advanced economies, the strong consumption growth was driven mainly by increasing household indebtedness. Stark (2011: p1-2), in his speech, summarises the phenomena of that period as follows:

> "....this period was characterised by a widespread tendency of deregulation and the emergence of financial innovations…. Securitisation, which was known in the U.S. since the late 1970s, associated to the repackaging of assets that sit on financial institutions' balance sheets into marketable slices, i.e. securities, with the aim of selling these new securities. This sale frees up capital in banks, which can then, in turn, increase their lending. The outstanding amount of the U.S. asset-backed commercial paper,…increased from around USD 500 billion in August 2004 to over USD 1.2 trillion just three years later. Although total issuance of asset-backed securities by banks between January 2005 and August 2007 was more than seven times higher in the U.S. than in the euro area, monthly issuance in the euro area still reached EUR 22 billion, on average. This shows that, although more pervasive in the U.S., excess lending due to insufficiently regulated securitisation activities also affected the Euro area".

Regardless of its substantial downside, the huge benefits of securitisation for growth have been widely recognised during this period. However, the significant increase in sub-prime mortgage lending from 2005 onwards, for instance, was only possible with the help of securitisation (Stark, 2011). During the same period, global financial crisis produced an unexpected change in the economic policy of the United Kingdom (UK). Before the crisis, the UK government, assertively, discourse of price stability, fiscal prudence and light-touch financial regulation. In the wake of the crisis, the government attempted to implement unconventional monetary policies, which led to a surge in public-sector borrowing and the need for a rethink of financial supervision (Hodson and Mabbett, 2009).

2.3.3 The Monetary Policy Arrangements during and after the GFC

The financial crisis has shown the connection of these developments with monetary policy arrangements in advanced economies. Because of the global dynamics, central banks' task of analysing the inflation process become more complicated and potential output may have been overestimated. In other words, some of the strong growth in that period may have been unsustainable in the first place. According to Martin and Milas (2013), deep and rapid reductions in output opened up an output gap of over 5% in developed economies. The shocks to the financial system disrupted the transmission mechanism that links monetary policy to the real economy and created fears for the stability of the system. They also note that the build-up of global imbalances arguably contributed to a distortion in relative asset prices, resulting in a systematic under-pricing of risk in financial markets.

Studies also indicate that insufficient regulation for financial innovations was one of the most important contributing factors to the crisis. This insufficient regulation, led to the creation of whole asset classes, e.g. sub-prime mortgages, whose economic basis was less than sound. This, according to Stark (2011), contributed to the build-up of substantial risks to financial stability, as cash flows in these asset classes would be extremely vulnerable to stagnating or even declining house prices. Taking all this into account, it can probably be argued that central banks around the world have, to some degree of variation, contributed to fuelling asset price bubbles by keeping policy rates at a very low level for a prolonged period of time in an environment of robust economic growth, ample global liquidity, continued low inflation rates and low default risks.

Monetary economists have developed a set of basic scientific principles derived from theory and empirical evidence that now guide almost all central banks and explain much of the success in the OECD nations experiencing double-digit inflation rates over the last three decades. After that, during the so-called GM period, the UK, the U.S. and other industrial countries experienced low inflation and macro-economic stability (Bernanke et al., 2004). During this period, most OECD countries enjoyed stable and low inflation with lower volatility. This was accompanied with lower output volatility (Trifonova, 2012). The improved performance of monetary policy has been associated with advances in the science of monetary policy arrangements with a set of principles that have been developed with rigorous theory and empirical work that guides the thinking of monetary policy practitioners (Mishkin, 2007a). Moreover, Stark (2011) notes that during the last century the monetary policy thinking went through a notable evolutionary process which resulted in stability. It was during this period that the three main monetary policy arrangement principles have emerged. These are the principle of CBI, price stability and successful monetary policymaking.

The UK has been one of the hardest hit European economies by the Global Financial Crisis. The worldwide financial turmoil that began in 2007 triggered the first run on a British bank since 1866 and a near meltdown in the banking system. The severity of the financial crisis in the UK was because the credit crunch has been amplified by the bursting of the decade-old house price bubble. The financial crisis brought policy of co-operation on the international stage (Pauly, 2009) and energised efforts to strengthen financial supervision in the European Union (Begg, 2009). It has also led to a dramatic change of direction in national economic policies in the UK. Some of the changes implemented by the UK government as of 1997 were high-profile institutional reforms, adopting a set of fiscal rules, granting operational control of monetary policy to the Bank of England and creating a single financial regulator, the Financial Services Authority (FSA). The fate of these reforms has been thrown into doubt by the government's response to the financial crisis, which has tolerated unconventional monetary policies, a surge in government borrowing and the introduction of new instruments of financial regulation (Hodson and Mabbett, 2009).

Hodson and Mabbett also note that the UK government's response to the global economic crisis does not constitute a paradigm shift, in terms of Hall's[7] theory of policy changes. They concluded that in the case of monetary policy, the instrument of quantitative easing reflects the limitations of conventional monetary policy but it has not changed the relationship between the government and the bank. The authors also note that the financial crisis has exposed a number of blind spots, including lack of attention to financial instability and concerns over the ability of existing instruments to deliver asset price stability. With this intuition of the monetary policy arrangements before and after the global financial crisis, it is essential to investigate the monetary targeting regimes and instruments based on the UK monetary policy framework.

[7] See Hall (1993) for Hull's theory and the Paradigms, Social Learning and the State.

2.4 The Monetary Targeting Regimes and Instruments

2.4.1 MP Targets and Instruments

There has been a long and constant debate in the theory and practice of central banking as to what optimal monetary policy is. This debate further intensified in the post GFC. Monetary economists and researchers in the field are searching possible answers for questions: is it a rule or discretion? Has MP operational feasibility? As Woodford (2003:p2) puts it "a new consensus in favour of a monetary policy that is disciplined by clear rules intended to ensure a stable standard of value, rather than one that is determined on a purely discretionary basis to serve whatever ends may seem most pressing at any given time". Within the context of the MP control, the instrument problem is the choice of the variable(s) over which the central bank exerts direct control (Friedman, 1997). Since Taylor's essay on ''Discretion versus Policy Rules in Practice'' in 1992, his analysis had considerable influence on the way monetary economists and practitioners think about the policy debate. Taylor (1999) shows that actual MP could be usefully described in terms of a simple rule that appeared promising based on policy evaluation experiments. Most importantly, he described the MP process as a short-term nominal interest rate that was close to the actual decision making process, and described policy directly in terms of the two major operational objectives of MP, stable price and economic growth (Orphanides, 2003).

Monetary policy authorities control directly and being able to determine its value independently of other variables in the system using a policy instrument. The main characteristic of policy instruments is that monetary authorities effectively have direct control over only the very short-term rate of interest at which they make reserves available to the commercial banking system. The longer the term of interest, the less influence the central bank has, and, by contrast, the greater the role played by market forces.[8] Bain and Howells (2009) note that intermediate variables are variables of which the policymaker cannot control directly and that do not have a direct impact on economic welfare but are important determinants of final goals that the policymaker may wish to target. After the failure of the monetary rule experiment, the UK monetary policy target was chosen to be the Deutsche Mark exchange rate. This was mainly due to the then argument that the principal determinant of exchange rates is the rate of inflation in the two countries concerned. If the UK operate, a monetary policy, which kept stable the value of the Pound Sterling against the Deutsche Mark, this would tell the policymakers that foreign exchange markets at least believed that policy in the UK would deliver the same rate of inflation as policy in Germany. It was also believed that,

[8] See Bain and Howells (2009).

since foreign exchange markets were regarded, as notoriously sensitive, any deviation of policy from what was required would be noticed instantly (King, 1997).

2.4.2 Inflation Targeting and the UK Experience

Inflation targeting is a practice of setting an explicit numerical target for the rate of inflation over some future time horizon (Bain and Howells, 2009). The inflation setting process is carried out based on the priority the policymaker gives to achieving that objective. Since the early 1990s, the monetary authorities in a large number of countries have adopted an explicit inflation target. A notable exception is the U.S. Federal Reserve, which makes no formal announcement of a target, was tacitly targeting a rate of 1.5 to 2 percent of target inflation. Inflation-targeting is characterised by 5 criteria, namely (i) public announcement of a medium-term inflation target, (ii) institutional commitment to price stability as the primary goal of monetary policy, (iii) forward looking strategy for inflation forecasts, (iv) enhanced transparency, and (v) greater accountability of central banks in achieving its inflation target[9] (Minea and Topsoba, 2014). There has been a significant increase in the number of countries adopting inflation targeting. Studies show that around 30 central banks use inflation targeting as a monetary policy framework and many others, especially developing countries are moving towards this framework (Minea and Topsoba, 2013). Batini et al. (2006) explore more than 35 developing countries for the possibility of adopting an inflation targeting monetary policy. This increased popularity of inflation targeting stems from its macroeconomic benefits. Studies also show that adopting inflation targeting monetary policy can reduce not only the inflation level but also inflation, output, interest and exchange rates volatilities.[10]

Advocates of the inflation targeting cite many benefits. Inflation targeting solves the dynamic consistency problem that produces high average inflation. It reduces inflation variability, and if "flexible" it can stabilise output as well (Svensson, 1997). Svensson notes that inflation targeting locks in expectations of low inflation, which reduces the inflationary impact of macroeconomic shocks. For those reasons, monetary policy economists advocate inflation targeting for the FR and the ECB due to its macroeconomic benefit, although the advocacy has been challenged [11] particularly in the post GFC. One of these papers studied by Ball and Sheridan (2005) measures the effect of inflation targeting on macroeconomic performance. They examine twenty OECD countries, seven from those that adopted inflation targeting during the 1960s and thirteen that did not. They measure monetary policy performances by the behaviour of inflation, output, or interest

[9]See also Svensson (1997) and Mishkin (2000) for further discussion.

[10]See Batini and Laxton (2007); Rose (2007), and Lin (2010) for further discussion on the advantages of IT monetary policy.

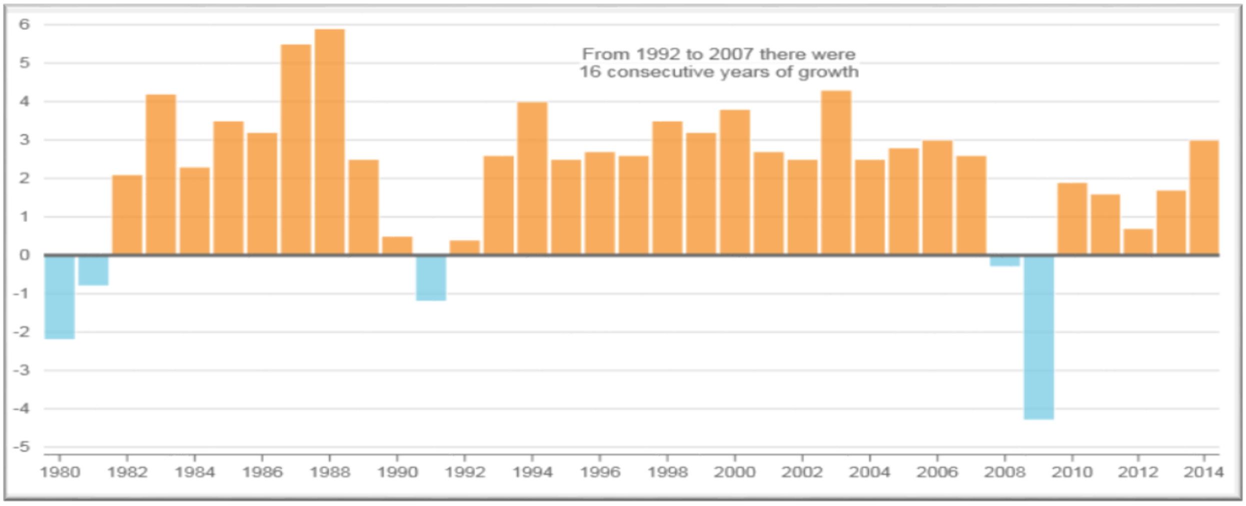
[11] See Ball (2010, 2014); Ball and Sheridan (2005), and Brito and Bystedt (2010).

rate and suggest that, on average, there is no evidence that inflation targeting improves performance. In the context of the UK monetary policy, an inflation targeting approach has been adopted in the autumn of 1992 following the Pound Sterling’s exit from the ERM. Having lost the peg to the Deutsche Mark, some alternative ways were required to express and judge the monetary policy deportment. In its original form, the target was specified as a 2.5 percent per annum increase in the retail prices index (RPI-X) (after excluding mortgage interest payments). The two most important advantages of inflation targeting monetary policy are summarised by Bain and Howells (2009:p255) as follows:

> “(1) The focal point of inflation targeting is on what the policy maker can achieve rather than diverting attention across a number of, possibly conflicting, objectives. This argument is strengthened where the target comes with some clear statement about its overwhelming priority over any other objectives; (2) agents know what to expect and are able to make decisions when inflation targeting is specified. Specific targets are also helpful to reduce the time of adjustment and contribute to the credibility of the policymakers. …Specifying an inflation targets might force the policymaker to adopt a more conservative monetary policy”.

According to King (2002:p2), “inflation in the UK has not only been lower since inflation targeting was introduced, but, as measured by its standard deviation, it has also been more stable than in recent decades. Moreover, inflation has been less persistent in the sense that shocks to inflation die away more quickly under inflation targeting than for most of the past centuries.” Historically, as an achievement of the UK monetary policy to the inflation targeting regime, the average rate of inflation has been 1.4 percent (King, 1997) since the establishment of the Bank of England until the Central Bank’s Independence. However, in the period since the Second World War, inflation has averaged 6 percent followed by no less than 10.3 percent and between 1965 and 1980, it averaged no less than 10.3 percent. Since 1945, prices have risen more than twenty-fold. The creeping inflation in the 1950s and early 1960s led to rapid inflation increase in the 1970s, reaching a peak of 27 percent in August 1975, before a gradual disinflation during the 1980s and 1990s (King, 1997).

The new inflation targeting monetary framework, announced in October 1992, has two components such as: (1) interest rate would be set in order to achieve an explicit target for inflation (was 2.5% or less at that time) some two years or so ahead; (2) a number of institutional changes were made which gave a greater role to the Bank of England in the setting of interest rate, although not yet fully independent in 1992. CPI is a more comparable measure of inflation internationally and represents best international practice and coverage of the CPI was found to be preferable because it is more consistent with national accounts principle of consumer expenditure. The stable growth from early 1980s to 2008 and then after; from early 1990s to late 2007 clearly show that the inflation targeting monetary policy framework contributes to the stable and consistent GDP growth with an exception of the downturn during the 2007/8 crisis (ONS, 2015). As shown in Figure 2.2, real GDP in the UK has typically increased every year with only three downturns since 1980. After the downturn in the early 1990s, the UK economy experienced sixteen consecutive years of growth before output fell in 2008 and 2009. From 2010, output has been growing again and regains pre-downturn level in the third quarter of 2013. Over the period from 1980 to 2014, real GDP growth has averaged 2.2 percent per year (ONS, 2015).

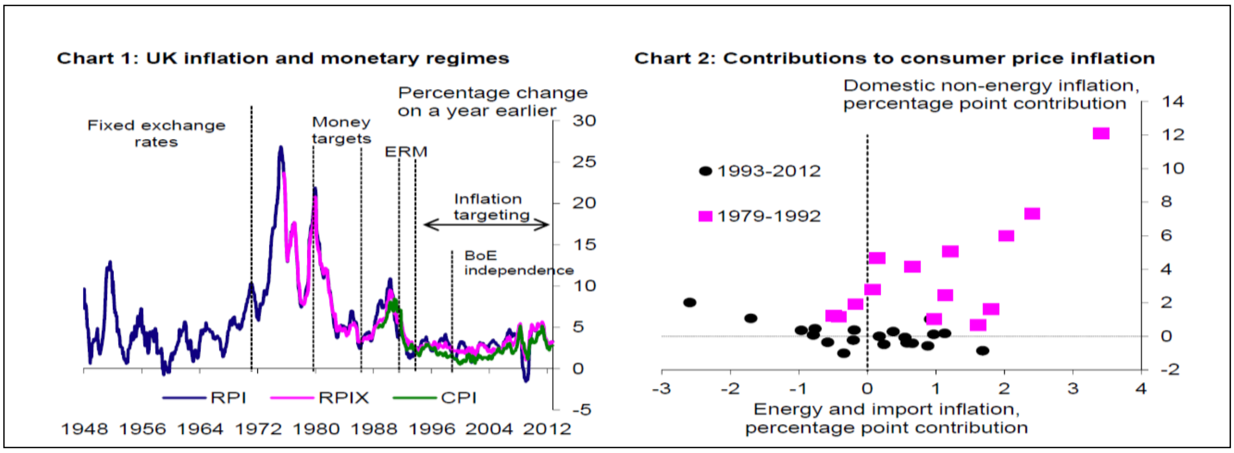


Source: ONS (2015).

Figure 2.2 The UK Real GDP year on year Growth from 1980 to 2014

Further advantages of IT are also discussed by Cecchetti (2011) that focuses on a clearly defined and easily observable numerical inflation statistic, and frequent communication with the public increases policymakers' accountability and helps to establish their credibility. This means that it is not only central bankers know what they are supposed to do, but also everyone else does too. The result is not only just lower and more stable inflation, but also higher and more stable growth. Cecchetti also notes that the adoption of IT frameworks, either explicit or implicit was one of the key factors in the achievement of low and stable inflation rates. In addition to more stable prices, countries with IT MP enjoys higher and more stable growth rates prior to the crisis. However, the GFC casts some doubt on the benefits of Inflation Targeting monetary policy without taking into account the movements of shocks in the financial market, which ultimately determine the financial sector stability.

Institutional commitment and timely and transparent communication are inherent features of price stability to keep inflation expectations stable during good economic condition and at the time of a crisis. This stable inflation expectation reduces the risk of deflation. Inflation expectations have also remained well anchored in the subsequent recovery despite very loose monetary conditions and soaring commodity prices. This was supported by the high accountability and credibility of inflation targeting central banks. Nevertheless, while inflation targeting worked well, there is a need for refinement (Cecchetti, 2011). According to the recent ONS (2015) report, the inflation rate rose to 0.1 percent from -0.1 percent in the previous month of the first quarter of 2015. An annual fall in prices is often referred to as "negative inflation" or "deflation". Based on comparable historic estimates, the last time the UK saw consumer price deflation prior to April 2015 was in the year to March 1960, when prices fell by an estimated 0.6 percent. The inflation rate has exceeded 3 percent during five periods since 2003; the highest rate observed being 5.2 percent in September 2008 and September 2011 (see Figure 2.3). These phenomena questioned the existing economic theory that alludes lower interest rate leads to a higher inflation and periods of lower inflation encourages output growth. On this ground, the conflicting theory, and the contemporary phenomena, particularly in the post crisis period challenges the understanding of the science of economics. To get clearer understanding, further investigation of the historical and current monetary policy reaction functions is essential to uncover the operational feasibility of the monetary policy.



Source: BoE (2013).

Figure 2.3 The UK Inflation and Monetary Regimes and Contributions to CPI

In a recent literature, Cecchetti et al. (2015) argue that existing monetary policy frameworks need to be modified to put additional weight on the risks associated with a build-up of financial imbalances, even when inflation rates remain low and stable. It is imperative for policymakers to monitor general financial conditions, including both the prices and transaction volumes in a broad array of asset markets. The experiences of the past decade have demonstrated that accommodative monetary conditions can lead to substantial increases in asset prices and credit aggregates without triggering movements in consumer price inflation.

2.5 Frameworks of Monetary Policy Behaviour and Rules

For over two decades, central banks' monetary policy decision has been influenced by two major monetary policy rules (MPRs), namely the Taylor's and the McCallum MPR. Monetary economists credit both rules. This is mainly because the two rules contribute to the policy strategy, research, and brought continuous debate in macroeconomics. Before the 1990s, money supply received considerable level of attention as a target variable for monetary policy. However, since the 1990s, industrialised western countries progressively adopt inflation rate as an intermediate target of monetary policy and have played a more imperative role in the conduct of monetary policy. The Taylor rule, proposed by Taylor in 1993, characterises central banks' behaviour through a linear function of interest rate to inflation gap[12] and output gap.[13] After the breakthrough of the 1993 Taylor's monetary policy rule, monetary policy research in CBs, and academia embark on testing the validity of the MPRs using various approaches. Clarida, Galí, and Gertler (1998, 2000, CGG hereafter) apply the forward looking reaction function to test the Taylor rule for two groups of countries: Germany, Japan and U.S. in one group; UK, France and Italy in another group. The test results support the superiority of inflation targeting over fixed exchange rates. Contrary to this outcome, McCallum (2000) tested Taylor's MPR using historical U.S. and UK data from 1962 to 1999 and for Japan from 1972 to 1998. He argues that messages emanated from MPRs are dependent upon the type of instrument used rather than the target variables.

A major advantage of McCallum's MPR over Taylor's MPR is that MMPR does not include unobservable variables such as the real interest rate and the output gap. From the usage point of view, McCallum's rule is much less prominent than Taylor's rule because central banks in industrial countries focus on interest rate instead of monetary base growth rates when designing their policy (McCallum, 2002). The New Keynesian Taylor rule suggested that central bank follows an interest rate target and ignores monetary aggregate (Cochrane, 2007). McCallum's rule is a nominal income target rule with a monetary base policy instrument. Taylor (2000b) claims that a monetary base or some other monetary aggregates can still be a reasonable monetary instrument in emerging economies. Beck and Weiland (2008) support the significance of a monetary base variable in policy-making. In regards to the feasibility of adopting monetary policy rules in emerging economies, Meltzer (1995) and Taylor (2000a) argue that policy rules are applicable both to countries with and without developed financial markets.

Monetary economists have been interested in modelling central bank reserve's reaction function in the past decades. The reaction function is useful to model how central banks adjust monetary policy

[12]The deviation of inflation rate from its target.
[13]The deviation of real output from its potential value.

in response to the developments in the economy. The function provides a foundation for forecasting changes in the policy instrument, such as, short-term interest rates. In addition, within the context of a macro model, the reaction function is an important element in evaluating monetary policy and the effects of other policy actions including fiscal policy or economic shocks such as the 1970s oil price shock. When rational expectations introduced in macro models, the knowledge of the correct reaction becomes an important element in estimating the entire model. For instance, as in forward looking, estimates of a parameter such as the one linking real spending to the policy instrument will likely depend on expected monetary policy and the nature of the monetary policy regime, as in forward looking RFs (Judd and Rudebusch, 1998). Studies explain how monetary policymakers should react to stabilise price and maintain high employment through modelling and estimating reaction functions using autoregressive models (see Bernanke and Blinder 1992). Despite a number of efforts made to represent and model monetary policy rules, previous studies have not been successful to provide a definitive representation of the reaction functions of central bank decision-making behaviour. It appears that, there have not been any great successes in modelling a single and stable reaction function (Judd and Rudebusch, 1998) that can provide a comprehensive and consistent information across policy regimes.

Taylor's MPR stemmed from the fundamental question – "whether commitment to an interest rate rule, incorporating no target path for any monetary aggregate, can serve to determine an equilibrium price level" (Woodford, 2001:pp1-2). Those who disagree with the TMPR, criticised the interest rate rule as undesirable practice as they could lead to indeterminacy of the rational expectations equilibrium price level (Sargent and Wallace, 1975). McCallum (1988), on the other hand, argues that the TMPR analysis assumes a rule that specifies an exogenous path for the short-term nominal interest rate so that determinacy is possible in the case of feedback from an endogenous state variable such as the price level. Various optimising models imply that the Taylor rule incorporates feedback that is adequate to ensure determinacy (Woodford, 2001). The policy rules have been used to explain operational feasibilities in terms of how policy has been set in the past and how policy should be set in the future. The rules serve as benchmarks for policymakers to assess the past performance of MPRs, assessing the current stance of monetary policy and to determine a future policy path.

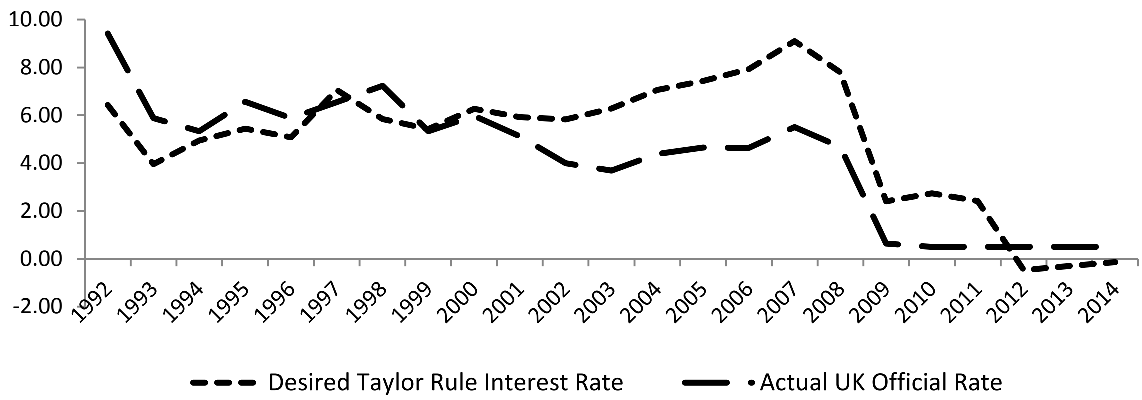
2.6 Theoretical and Empirical Frameworks of MP Rules

This section examines several era of events of the UK monetary policy structure from the perspective of recent research on monetary policy rules. The monetary policy rules are defined as a description expressed algebraically, of how the instruments of policy, such as the monetary base or interest rate, monetary base or national income change in response to economic variables. Thus, a constant growth rate rule for the monetary base is an example of a policy rule, as is a contingency plan for the monetary base. A description of how the interest rate is adjusted in response to inflation or real GDP is another example of a policy rule. A policy rule, in general, can be normative or descriptive. According to this definition, a policy rule can be the outcome of many different institutional arrangements for monetary policy. This section also explores the timing and the political economic reasons for changes in MPRs and examines the effects of these rules on the real economy. Studying the history of these changes is relevant for monetary policy today because it provides information and practical evidence about the effectiveness of different policy rules (Taylor, 1999) in the UK context. Analysing the historical operation of monetary policy is, of course, not the only way to evaluate monetary policy. Another approach is to build structural models of the economy and then simulate the models stochastically with various monetary policy rules.

2.6.1 The Taylor's Monetary Policy Rule (TMPR)

The Taylor (1993) MP rule[14] sets the level of nominal interest (federal funds) rate equal to the rate of inflation[15], plus an "equilibrium" real interest (funds) rate (a "natural" rate that is seen as consistent with full employment), plus an equally weighted average of two gaps. These gaps are, the four-quarter moving average of actual inflation in the GDP deflator less a target rate, and the percent deviation of real GDP from an estimate of its potential level (Judd and Rudebusch, 1998). Given the inflation target and potential output, the monetary policy rule provides adjustment criteria of short-term interest rate to the changes of inflation and real output. The econometric evaluation evidence (as in CGG, 1998, 2000) and its usefulness for understanding of the historical momentum of monetary policy have generated widespread interest in the Taylor rule. The Taylor rule that nests the original specification and allows for interest rate smoothing has been favoured in the empirical literature (Patra and Kapur, 2012). Figure 2.4 depicts the strong positive correlation between the Taylor desired target rate rule and the actual base rate for the UK data.

[14]Taylor rule, proposed by Taylor (1993) based on U.S. real data for the period from 1987 to 1992.
[15] An equation for the ex post real funds rate.



Source: author's analysis – based on Taylor Rule.

Figure 2.4 The UK Actual Base Rate and Taylor-Rule for Desired Target Rate

Figure 2.4 also reveals that, unlike the U.S. FF rate, there has been systematic deviation of monetary policy rates from the Taylor rule desired target rate since early 2000s. Before this period, the central bank policy rates seem to be consistent (to some extent) with the desired rate calculated from Taylor rule until 2000. The Figure also highlights a significant systematic deviation from the desired Taylor Rule rate in the run up to the GFC. There are some indications that policy rules can work well in some periods but may not work in a period of disequilibrium particularly the period from 2000 to 2011. However, the systematic deviation emerged thereafter show that the desired Taylor rule interest rate remains below the UK official rate.

Table 2.1 Statistics of Actual STIR and Estimated Taylor Desired Rate

	ACTUAL STIR	TAYLOR ESTIMATED STIR
Mean	4.2608	4.3766
Median	4.6800	4.8225
Maximum	9.4200	9.1012
Minimum	0.5000	-0.4702
Std. Dev.	2.5540	2.6938
Skewness	-0.2987	-0.7786
Kurtosis	2.2808	2.6777
Jarque-Bera	0.8375	2.4235

Source: author's analysis.

At a description level, as reported in Table 2.1, the average actual short-term interest rate has been in close proximity with the desired rate estimated based on Taylor's monetary policy rule during the inflation targeting period. The period includes the financial crisis and shows to have an approximately equal standard deviation of 2.6 and 2.7, respectively. This indicates that the post IT period may have some elements of similarities with the Taylor rule type monetary policy. In general, there is a fairly strong correlation between the UK actual base rate and the Taylor estimated short-run interest rate. These insights that the UK monetary policy approach targets not only the inflation gap but also the output gap as shown in Taylor's MP rule. The benchmark GMM analysis reported in Table 2.2, based on Taylor's MP rule and the Bank of England's base rate rule, show some interesting outcomes. When Taylor rule is used as an instrument during the IT period (1992 to 2014), the coefficients (approximately 0.51) are statistically significant with high degree of coefficient of determination ($R^2 = 0.87$) but when the instrument changes to the BoE base rate, it shows lower R^2. This may indicate that movements of the actual UK STIR can be explained the desired interest rate when Taylor's rule is used as an instrument. The J-statistics, equal to zero in both cases, also depicts the case that the monetary policy reaction functions, in both cases, are just identified and the case is satisfied. This dictates the number of instrumental variables are equal to the number of explanatory variables, which is true in this case.

Table 2.2 GMM Estimation of Actual UK STIR based on Desired and Actual MP Rate

Dep. Variable	Coefficients	t-stat	Prob.	R^2	J-statistics
<u>Instrument: Taylor Rule</u>					
Actual UK STIR	0.505498	4.114799	0.0005	[0.87371]	0.000
<u>Instrument: BoE Base Rate</u>					
Actual UK STIR	1.274136	2.535460	0.0192	[0.19399]	4.38E-47

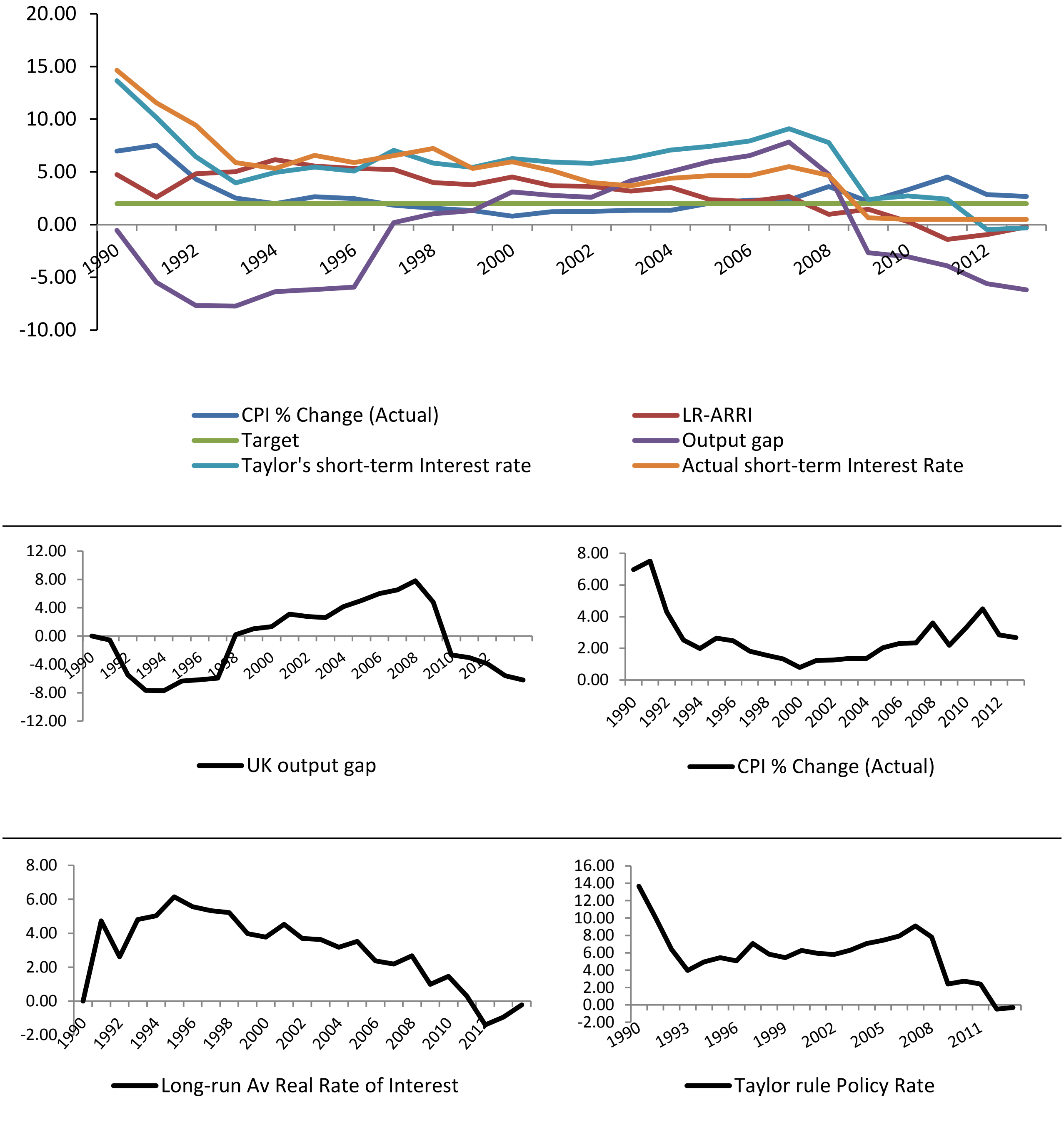
Source: author's analysis.

Furthermore, the results reveal that the official rate remains below the Taylor rule rate during the recession period and up until the recovery in 2011. As revealed in the charts shown in Figure 2.5, the UK official rate remains the same from 2009 when the global economy was in full swing leading to slow recovery. During this period, the gap (see Figure 2.5) starts to open up and the policy rate becomes higher than the rate implied by Taylor rule. With a specific context to the UK economy, the UK inflation targeting can partially be explained using the Taylor rule mechanism. Figure 2.5 also shows that from 1992 to 2004, the UK base rate is fairly correlated ($corr = 0.74$) with the desired Taylor rule STIR. From 2004 to the run up to the GFC, significant deviation from the desired Taylor rule rate has been observed ($corr = 0.54$). Due to the decision made by the BoE to keep the base rate at 0.5%, significant deviation is observed from mid-2008 to 2014. This highlights the significance of searching a possible answer to monetary policy questions[16].

Looking from 2012 onwards, Figure 2.5 shows that the base rate has been closely correlated ($corr = 0.87$) with the Taylor rule desired rate. Although it is too early to make a concluding remark at this stage, there are some evidences suggesting that the UK monetary policy framework can partially be explained by the Taylor rule reaction function for the period between 1992 and the GFC. These periods are considered to hold economic growth (*first phase-1992 to 2004*) and show

[16] (a) Should monetary policy be conducted by rules or by discretion? And (b) should a monetary policy rule be different in the post GFC period? Given the findings based on the Taylor rule linear approach, it is important to ask the questions as the rule may only work during stable economic period.

slow but stable upward output movement starting from the recession period (*second phase- 2012 to 2014*). This is a vital information that helps to set up the monetary policy component of the dynamic stochastic general equilibrium (DSGE) model stated in Chapter 3 and Chapter 6.

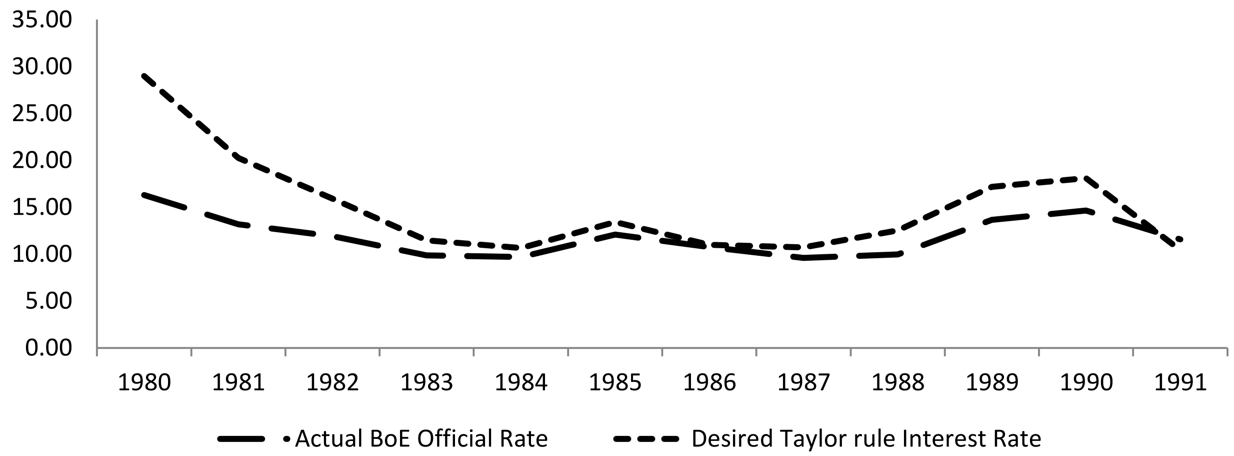


Source: author's analysis based on Taylor's MP Rule.

Figure 2.5 Trends in the UK Inflation, Output Gap, LRARRI, Target and TR IR

Although inflation targeting monetary policy started in October 1992, the period from 1982 to 1991 shows, predominantly, similar pattern with Taylor rule desired rate (see Figure 2.6). The systematic deviation is observed from 1980 to 1982 (according to the sample data). This period is known as a high inflationary period where the UK monetary policy framework was known to have a shadow

Source: author's analysis based on Taylor's MP Rule exchange rate target mechanism. Critics (Mishkin, 2008) against the traditional TR state that in traditional Taylor's rule, the reaction of interest rate to inflation and output gap is contemporary or backward looking. For example, Taylor (1993) considers the deviation of inflation from target over the past four quarters. However, central banks, in principle, do not tend to take the past or actual inflation to adjust the policy instrument but the expected inflation as a forward looking policy framework. In a different setting studies such as Clarida et al. (1998) argue that introducing the expectation to construct, a forward looking version of Taylor rule reaction function allows the central bank to consider a broad array of information to form beliefs about the future condition of the economy.



Source: author's analysis based on desired Taylor Rule rate and Actual UK base rate.

Figure 2.6 UK BoE Base Rate and TR for Desired Target Rate from 1980 to 1991

Methodological issues that arise in the actual estimation of the Taylor rule and its extensions have been extensively surveyed by Patra and Kapur (2012). In theory, a forward looking specification is recommended based on a reasonable assumption that the target variables depend not only on the current policy but also on expectations about future policy. Clarida et al. (2000) and Paez-Farrel (2009) suggest that a general specification with forward looking terms and incorporating the well-documented interest rate smoothing by central banks (inertia in policy response) is preferred in the empirical literature. Furthermore, Taylor's linear feedback rule has subsequently been shown to arise from solving the problem that a policymaker faces in theoretical optimal monetary policy model (Mehrotra and Sanchez-Fung, 2011). The Taylor principle, meaning that the nominal policy interest rate moves more than one-for-one with inflation, is a fundamental aspect leading to stability in theoretical models (e.g. Woodford, 2001; Davig and Leeper, 2007). The general Taylor rule incorporates monetary policy's key objectives. It is expressed as follows:

$$R_t = \hat{r} + \Delta p_t^a + 0.5(\Delta p_t^a - \pi^*) + 0.5\tilde{y}_t. \tag{2.1}$$

where R_t is the short-term nominal interest rate that the central bank in question uses as its instrument or "operating target," i.e., the interest rate over which it exerts control at a daily or weekly frequency. $\hat{r}$ is the long-run average real rate of interest, Δp_t^a is an average of recent inflation rates (or a forecast value), and π^* is the central bank's target inflation rate. Finally, $\tilde{y}_t$ is a measure of the output gap, the percentage difference between actual and capacity output values. In Taylor's original application (Taylor, 1993), the values $\hat{r} = 2$ and $\pi^* = 2$ were specified, expressing the belief that 2 percent per annum is an approximation to the long-run average real rate of interest in the U.S. as it is a reasonable specification for the Federal Reserve's target inflation rate. Also in Taylor (1993), the measure used for Δp_t^a is the average of GDP deflator inflation rates over the past four quarters, while capacity output is represented by a linear trend for the log of real GDP fit to quarterly observations for the year 1962 – 2014. The rule, in this case, suggests that the monetary policy should be tightened (by increasing R_t) when inflation exceeds its target value and/or output exceeds capacity. Subsequent applications of the Taylor rule have modified or extended the equation (see Equation 2.1) in several ways. Some have used proxies for expected future inflation in place of Δp_t^a while others have done something similar for $\tilde{y}_t$ or used $\tilde{y}_{t-1}$instead. A common and major change is to include R_{t-1} on the right-hand side as a determinant of R_t; this adjustment is intended to reflect the practice of interest rate smoothing, which is widely believed to be prevalent in the behaviour of many central banks (McCallum, 2000).

2.6.2 The McCallum Monetary Policy Rule (MMPR)

McCallum's work on monetary policy rules is an example of a nominal feedback mechanism (Mehrotra and Sanchez-Fung, 2011). The policy instrument (monetary base) in the McCallum's rule implicitly sums the effects of pure changes in high-powered money and those induced by changes in reserve requirements. Taking into account the tendency of central banks to systematically offset changes in reserve requirements with open market operations, the explanatory power of the monetary base as a policy instrument is significantly improved by adjusting for the short-run dynamics embodied in discrete changes in reserve requirements (McCallum, 1990; Haslag and Hein, 1995). The rule employs average velocity growth as trends in velocity growth that can shift over time, but not every change in base velocity represents a long-lasting shift in the trend (McCallum and Nelson, 1999). The velocity growth adjustment is intended to reflect long-lasting institutional/technological changes affecting the demand for the monetary base (Patra and Kapur, 2012). The monetary response coefficient that determines the money stock[17] is the key component in McCallum's rule. If the monetary response factor is too large, it can induce an explosive reaction or instability in the economy. On the other hand, a monetary response factor that is too small implies that monetary policy does not affect the economy much. There are ranges of suggested values to represent the monetary response factor (Stark and Croushore, 1996). Among others, Hall (1990)

[17] Refers to how much base money must change when nominal GDP deviates from its target.

and McCallum (1993, 2000) suggest a factor of 0.5 for the US economy to represent the monetary response factor. In contrast, a lower feedback value of 0.25 is needed for Japan (McCallum, 1993). For developing countries, a smaller monetary response factor is found to be appropriate (Sun et al., 2010).

In response to cyclical departures of nominal income from the target path with the coefficient chosen to balance against the danger of instrument instability, McCallum's rule features feedback adjustments in velocity changes. However, McCallum (2000) suggests that the velocity correction term could be omitted without any effect on results. This indicates the non-dependence nature of the McCallum rule on base velocity growth as compared with the Taylor rule. Setting a monetary policy rule free from a model specific problem would work well with different economies as it develops outside the confine and specific representations of a model (McCallum, 2006). Since macroeconomists disagreed about the forces that drive the economy, they are unlikely to come up with an optimal rule for the operation of the monetary policy (Stark and Croushore, 1996). The principle of McCallum's monetary policy rule requires central banks to target the growth rate of nominal GDP using the monetary base as its instrument. When designing a monetary policy, McCallum suggests four principles. These principles are (a) the rule should dictate the behaviour of a variable that the monetary authority can control directly and/or accurately; (b) the rule should not rely on the presumed absence of regulatory changes and technical progress in the financial industries; (c) money stock and nominal interest rate paths are important variables that are relevant only to the extent that they are useful in facilitating good performance in the magnitudes of inflation and output or employment; (d) a well-designed rule should recognise the limits of macroeconomics knowledge. In particular, it should recognise that neither theory nor evidence points convincingly to any of the numerous competing models of the interaction of nominal and real variables.

The above four principles are the fundamental sources of McCallum's policy rule. He specifies a target path for nominal GDP using the monetary base principles as the operational mechanism, a variable that can be accurately set on a daily basis by the central bank with a floating exchange rate. Specifically, the rule "would adjust the base growth rate each month or quarter, increasing the rate if nominal GDP is below its target path and vice versa" (McCallum, 1984:p390). McCallum (1996) revised the rule to use nominal GDP growth rate instead of the nominal GDP as a policy target[18]. In algebraic form, the McCallum's monetary policy rule is formulated as:

$$\Delta\phi_t = \Delta y_t^* - \Delta V\phi_t + \lambda(\Delta y_t^* - \Delta y_{t-1}), \qquad \lambda > 0 \tag{2.2}$$

where all the variables are in logarithms, Δy_t^* is a constant term intended to account for the steady-state nominal output growth, ϕ_t is the monetary base, $\Delta V\phi_t$ is the average base velocity growth

[18] McCallum's work on monetary base rules is an example of a nominal feedback mechanism (Rudebusch, 2002).

rate over the previous years, λ is the monetary response factor which is a feedback coefficient informing on how quickly deviations of output from its target are offset by the central bank. y is the log of nominal GDP. The asterisk (*) denotes the target growth rate, which is the sum of the inflation rate and the long-run average real GDP growth rate. Δ in all cases is the difference operator.

With the velocity growing at a steady-state rate and the nominal GDP growth rate equal to its target, the rule forces the inflation rate to remain at a desired level, assuming that the monetary policy is neutral in the long-run. The last term on the right-hand side of Equation (2.2) is the most important term for stabilisation of output and price level, which suggests, the monetary policy authority to adjust monetary base growth whenever the nominal GDP growth rate differs from its target. Moreover, McCallum's rule considers the monetary aggregate preferences of the policy variables. Sun et al. (2012) discuss three important features of McCallum's policy rules. The *first* feature of the McCallum rule (as monetary authority's principal target variable) prefers nominal GDP to monetary aggregates such as M1 or M2. Under the nominal GDP targeting, the monetary policy would adjust to offset disturbances to aggregate demand. When the nominal GDP growth rate is below its target, the monetary authority should temporarily increase monetary base growth and vice versa (Sun, et al., 2012). The *second* feature of McCallum's rule is the specification of a constant growth target for nominal income, rather than a target rate that varies over the cycle. In this way, it would at least eliminate policy surprises as a source of undesirable fluctuations arising from the central bank's pursuit of an optimal policy decision. The *third* feature of McCallum rule is to utilise monetary base instead of interest rate as a monetary policy instrument. McCallum (1996) argues that if the nominal interest rate is used as an indicator of monetary policy stance, then tightening or easing the policy stance could result in ambiguity. In this regard, the rule is desirably operational, as long as the central bank is capable of controlling the monetary base variable with accuracy.

Advocating the implementation of a nominal output target, McCallum and Nelson (1999) compare the findings of Clarida et al. (2000) for the U.S. using Taylor's rule based on nominal income targets. They consider responses of the policy instrument, the federal funds rate to expected nominal income growth rather than to expected inflation. Their findings show that the U.S. monetary policy since 1979 can be explained by a policy rule that depends on expected nominal income growth. They also argue that the U.S. monetary policy can be interpreted as if it was designed to stabilise nominal income growth. This leads to a new approach in the form of a hybrid variants of the existing monetary policy reaction functions. In the Taylor-McCallum hybrid case, policy interest rate i_t is treated as instrument instead of base money growth $\Delta\phi_t$.

In terms of timing, as in Equation (2.2) for example, both of the variables on the right-hand side are based on variables realised in period $t-1$ or earlier; i.e., current-period values are not utilised. The reason is to make the rule specification realistically operational. It is a common practice to consider a rule with an interest rate instrument and a nominal income growth target. Similarly, it is important to consider a rule with a base growth instrument and a Taylor-style target specification. With $\beta = 1.5$, $\gamma = 0.5$, and a base growth instrument, the baseline Taylor-type specification is represented by a hybrid RF as:

$$i_t^* = \bar{r} + \pi^* + 1.5(\pi_t - \pi^*) + 0.5(y_t - y_t^*) \tag{2.3}$$

where the "hybrid" target variable is defined as $h_t = (\pi_t - \pi^* + \tilde{y}_t)$, where $\tilde{y}_t = y_t - y_t^*$. Thus, rule (2.3) features responses to the same macroeconomic conditions as in Taylor's rule in (2.1) but with a base instrument. Examination of the results involving (2.2) – (2.4) should then permit to determine whether differences in policy advice offered by (2.3) and (2.4) are due primarily to their different instruments or targets. Moreover, McCallum's rule describes the relationship between inflation and the growth in the money supply needed to create that level of inflation. Important inputs in McCallum's rule are the target inflation rate and the long-term average rate of growth in real GDP. The rule proposed by McCallum (1987, 1988, 1993) can also be expressed as follows:

$$\Delta\phi_t = \Delta x^* - \Delta v_t^a + 0.5(\Delta x^* - \Delta x_{t-1}) \tag{2.4}$$

where $\Delta\phi_t$ is the change in the log of the adjusted monetary base, i.e., the growth rate of the base between periods $t-1$ and t. The term Δx^* is a target growth rate for nominal GDP and Δx_t, specified as $\pi^* + \Delta y^*$, is the long-run average rate of growth of real GDP. The second term on the right-hand side of (2.4), Δv_t^a, is the average growth of base velocity over the previous 16 quarters, $v_t = x_t - b_t$ being the log of base velocity. This term is intended to reflect long-lasting changes in the demand for the monetary base that occurs because of technological developments or regulatory changes (presumed to be permanent); it is not intended to reflect cyclical conditions. These conditions are responded to by the final term, which prescribes that base growth is adjusted upward (i.e., policy is loosened) when Δx_{t-1}falls short of Δx^*. In McCallum (1988, 1993), values other than 0.5 are considered for the coefficient attached to $\Delta x^* - \Delta x_{t-1}$, and variants of (2.4) that respond to discrepancies of the level type, rather than the growth rate type. The Taylor and McCallum rule differ concerning both instrument and target variables such as a variable that the policy rule responds to (McCallum, 2000). Apart from the two widely recognised monetary policy rules, there are other forms of combined reaction functions commonly known as hybrid monetary policy rules namely: McCallum-Taylor, McCallum-Hall-Mankiw and the Nominal Feedback rules which is also known as McCallum-Dueker- Fischer rule.

2.6.3 The Hybrid Monetary Policy Rules Reaction Functions (HMPR)

To investigate the combined effects of MP instruments, it is important to assess the forward and backward looking reaction functions of the hybrid MP rules. Studies (such as Taylor, 1993 and McCallum, 2000) show that it is also possible to pair two rules as a hybrid MP rule so they can be paired in some particular combinations to account for instruments and target variables across the policy regimes. This means the forward looking reaction functions are reparametrized to form the backward looking reaction functions. The following section briefly states the three hybrid monetary policy reaction functions.

McCallum-Taylor HMPR

The combination of the Taylor and McCallum rules lead to the consideration of a rule with an interest rate instrument and a nominal income growth target. It is also important to consider a rule with a base growth instrument and a Taylor-style target specification. Therefore, the investigation that follows will also consider, in addition to Equations (2.1) and (2.2), rules of the form:

$$R_t = \hat{r} + \Delta p_t^a + 0.5(\Delta x^* - \Delta x_{t-1}) \tag{2.5}$$

and

$$\Delta\phi_t = \Delta x^* - \Delta v_t^a - 0.5h_t, \tag{2.6}$$

The hybrid target variable $h_t = (\Delta p_t^a - \pi^* + \tilde{y}_t)$[19]. Thus, the rule (2.5) features responses to the same macroeconomic conditions as in Taylor's rule (2.1) but with a base instrument. Examination of the results involving Equation 2.1, 2.2, 2.5 and 2.6 enable policymakers determine whether differences in policy advice offered by Equation (2.1) and (2.2) are due primarily to their different instruments or targets. The hybrid Equation mixes an interest rate instrument with a McCallum nominal income gap target and an exchange rate variable (see Equation 2.22). An important variable in this hybrid rule is the GDP nominal target.

McCallum-Hall-Mankiw HMPR

The McCallum-Hall-Mankiw hybrid monetary policy rule mixes monetary base instrument with a target following Hall and Mankiw (1994). This hybrid target is specified as the deviation of annual inflation from its moving average and an output gap. An increase in McCallum and in Hall-Mankiw targets should lead to a reduction in the monetary base, i.e. a tightening of the monetary policy stance. In this case, the reaction functions with a monetary base instrument, the coefficients of the exchange rate are expected to be negative, if the central bank tightens its policy stance following a depression. The M-H-M rule addresses the issue that the policy rule is set by taking into account the same variables as in the Taylor rule but uses money supply as the policy instrument, which is the dependent variable of the reaction function.

[19] As in McCallum (2000), the term "hybrid" was used for this variable by Hall and Mankiw (1994).

The Nominal MP Feedback Rule (NFR)

Nominal Feedback Rule (NFRs), stated by McCallum (1987), is one form of policy rules that has received considerable attention in developed economies. The primary motive for NFRs is to overcome the shortcomings of Friedman's constant of the money growth rule, which does not take into account the changes in the velocity of money. The NFR is designed in such a way that the monetary authority does not need to rely on a specific model of the economy in order to implement them. The novel feature of the NFR is its feedback mechanism, which specifies precise adjustment in the policy instrument when the nominal target variable deviates from its designed path (Dueker and Fischer, 1999). There are three main features of NFR: (a) it defines a long-run target path for the nominal target variable; (b) it incorporates forecasts for the relationship between the policy instrument and the nominal target variable; and (c) it specifies the speed with which policy will adjust in response to a gap between actual and desired levels of the nominal target variable. As in Dueker and Fischer (1998) and McCallum (1999), the generic feedback rule, with all variables in logs, takes the following form:

$$\Delta y_t = \lambda_0 + \Delta(x - y)_{t|t-1} + \lambda_1 (x^* - x)_{t-1}. \tag{2.7}$$

$$\Delta x^*_{t-1} = \lambda_0 \; for \; all \; t \tag{2.8}$$

Equation (2.7) represents the NFR and consists of four elements: the policy instrument that the monetary authorities can control, y_t; the nominal target variable, x_t; the baseline growth rate for the nominal target variable, λ_0; a forecast of the relationship between the nominal target and the instrument $\Delta(x - y)_{t|t-1}$ and a feedback parameter, λ_1. Equation (2.8) defines the baseline level, x^*_{t-1}. The assumption in NFR is that, the dependent variable in Equation (2.7) is a controllable instrument of the monetary authorities. This assumption narrows their choice of instruments to either the monetary base, the exchange rate, or a short-term interest rate. Empirical studies have focused on either the monetary base or the interest rate as the instrument variable (Dueker and Fischer, 1996). A major advantage of a NFR like (2.7) is that it does not depend on real aggregate economic activity variables. The NFR is also known as a *McCallum-Dueker-Fischer* hybrid MPR.

In the context of the above five monetary policy reaction functions, the study simulates the monetary policy RFs based on the central bank's decision-making behaviour. The simulation exercise and the estimation of the coefficients of the reaction functions for the UK policy regimes covers from early 1960s to late 2014. The estimated reaction functions represent the MP rules implemented by the UK central bank and practiced across the three policy regimes: the pre-IT, the post-IT (excluding post-GFC) and the post-GFC.

2.7 Methodology, Data and Empirical Results

2.7.1 The Reaction Functions in Generalized Method of Moments (GMM)

The forward and backward looking reaction functions are specified based on the aforementioned five monetary policy rules. These are the two independent rules: TMPR, MMPR, and three hybrid MP rules: T-M, M-H-M and NFR rules. The GMM-FL and OLS-BL approaches are used to estimate the forward looking and the parametrised backward looking reaction functions, respectively. The OLS-BL reaction functions follows the standard AR(0) but the GMM approach is specified according to the following empirical framework. Unlike previous studies that focus only on either backward or forward looking reaction functions, this research combines both approaches to generate enough information without pre-assumed approach to show how previous information and future expectations affect the monetary policy making process. This approach claims originality in the sense that it addresses the issue of the UK's historical MP structure of the early 1960s, the rapidly changing approaches of the 1980s to the unconventional MP of the post GFC periods.

Following the methodology developed by Hansen (1982), the forward looking MPRFs are estimated using GMM for the UK data (as reported in Table 2.3). The estimates of the GMM simulation has become one of the most widely used methods of estimation for models in economics, particularly in policy and financial analysis. GMM's ability to estimate without the requirement of a complete knowledge of the distribution of the data makes it unique as compared to the maximum likelihood estimation (MLE) and regression model approaches. The conventional instrumental variable estimator is only efficient in the absence of heteroscedasticity of unknown form. However, when facing this problem (absence of homoscedasticity) of different variabilities that invalidate the significance of statistical test, the usual approach, according to Hansen, is the Generalized Method of Moments (GMM). For Models with more moment conditions than model parameters such as the stated monetary policy reaction functions, GMM estimation provides a forthright way to test the model specification. This is a unique feature of GMM estimation as it makes use of the orthogonality conditions that allows efficient estimation in the absence of homoscedasticity. Similarly, one considers the following general representation of linear regression model:

$$y_t = z_t' \delta_0 + \epsilon_t, \quad t = 1, \dots, n \tag{2.9}$$

where z_t is an $L \times 1$ vector of explanatory variables, δ_0 is a vector of unknown coefficients and ϵ_t is a random error term. The model (Equation 2.9) allows for the possibility that some or all of the elements of z_t may be correlated with the error term ϵ_t, i.e., $E[z_{tk}\epsilon_t] \neq 0$ for some k. If $E[z_{tk}\epsilon_i] \neq 0$ then z_{tk} is called an endogenous variable. If z_t contains endogenous variables then the least squares estimator of δ_0 in Equation (2.9) is biased and inconsistent. Associated with the model (2.9), there exists a $K \times 1$ vector of instrumental variables x_t which may contain some or all of the elements of z_t. To further expound the approach, let w_t represent the vector of unique and non-constant elements of $\{y_t, z_t, x_t\}$, and assuming that $\{w_t\}$ is a stationary and ergodic stochastic process[20], the instrumental variables x_t satisfy the set of K orthogonality conditions:

$$E[G_t(w_t, \delta_0)] = E[x_t \epsilon_t] = E[x_t(y_t - z_t' \delta_0)] = 0 \tag{2.10}$$

where $G_t(w_t, \delta_0) = x_t \epsilon_t = x_t(y_t - z_t' \delta_0)$. Expanding (2.10) gives the relation

$$\Sigma_{xy} = \Sigma_{xz} \delta_0$$

where $\sum_{xy} = E[x_t y_t]$ and $\sum_{xz} = E[x_t z_t']$. For identification of δ_0, it is required that the $K \times L$ matrix $E[x_t, z_t'] = \sum_{xz}$ be of full rank L. This rank condition ensures that δ_0 is the unique solution to (2.10). Note, if $K = L$, then $\sum_{xz} is$ invertible and δ_0 may be determined using:

$$\delta_0 = \Sigma_{xz}^{-1} \Sigma_{xy}$$

A necessary condition for the identification of δ_0 is the order condition

$$K \geq L \tag{2.11}$$

which states that the number of instrumental variables (K) must be greater than or equal to the number of explanatory variables (L) in Equation (2.9) which indicates that there must be at least as many excluded instruments as there are endogenous regressors. Furthermore, if $K = L$ then δ_0 is said to be just identified; if $K > L$ then δ_0 is said to be over-identified[21], where there are more instrumental variables than explanatory variables; if $K < L$ then δ_0 is not identified. In regression model (2.9), the error terms are allowed to be conditionally heteroskedastic as well as serially correlated. For the case in which ϵ_t is conditionally heteroskedastic, it is assumed that $\{g_t\} = \{x_t \epsilon_t\}$ is a stationary and ergodic martingale difference sequence (MDS)[22] satisfying:

$$E[g_t g_t'] = E[x_t x_t' \epsilon_t^2] = S$$

where S is a non-singular $K \times K$ matrix. The matrix S is the asymptotic variance-covariance matrix of the sample moments $\bar{g} = n^{-1} \Sigma_{t=1}^{n} g_t(w_t, \delta_0)$. This follows from the central limit theorem for ergodic stationary martingale difference sequences (Hayashi, 1982). Based on the assertion in model (2.9) and stated monetary policy reaction functions, CGG (2000) estimate a forward looking monetary policy reaction function for the post-war U.S. economy, simulating before and after 1979[23]. Considering a CB's reaction function, its policy rule can be specified by assuming that central banks set their interest rate (the instrument) to react to the contemporaneous output gap[24]

[20] Refers to a stochastic process which exhibits both stationarity and ergodicity. In essence this implies that the random process will not change its statistical properties with time and that its statistical properties (i.e. theoretical mean and variance of the process), can be deduced from a single, sufficiently long sample of the process (Peebles, 2001).

[21] In this case, the number of moment functions is larger than the number of unknown parameters; in the just identified case the number of parameters is equal to the number of moments.

[22] The stochastic process x_t is said to be martingale with respect to an information set $(\sigma - field)$, T_$t-1$, of data realized by time $t-1$ if $E(|x_t|) < \infty; E[x_t | \mathrm{T}_{t-1}] = x_{t-1}$. The process $u_t = x_t - x_{t-1}$ with $E[|u_t|] < \infty$ and $E[u_t | \mathrm{T}_{t-1}] = 0$ for all t is called a martingale difference, MDS. See Eduardo Rossi (2011) for further discussion.

[23] This period refers to Paul Volckers appointment as FED Chairman.

[24] Refers to the difference between current and potential output.

and to the deviation of future expected inflation from its target.[25] CGG takes the relevant time horizon for expected inflation to be about one year (others use 2 years as a short-run period) and proposed a simple baseline forward looking specification for policy reaction function. Accordingly,

$$r_t^* = \bar{r} + \alpha_1 E_t(\pi_{t+12} - \pi^*) + \alpha_2 E_t(y_t - y_t^*), \tag{2.12}$$

$$r_t = (1 - \rho) r_t^* + \rho r_{t-1} + v_t, \tag{2.13}$$

where r_t^* is the target interest rate at time t and $\bar{r}$ is the equilibrium value for r_t^*. The partial adjustment mechanism introduced in Equation (2.13) is justified by the empirical observation of the tendency of central banks to smooth interest rates. Moreover, a constant target rate of inflation is assumed in the estimated version of the rule. The empirical model for the policy rate becomes:

$$r_t = (1 - \rho)[\bar{r} + \alpha_1 E_t(\pi_{t+12} - \pi^*) + \alpha_2 E_t(y_t - y_t^*)] + \rho r_{t-1} + v_t \tag{2.14}$$

from which, by assuming $\alpha_0 = \bar{r} - \alpha_1 \pi^*$ and eliminating the unobserved forecast variables to obtain:

$$r_t = (1 - \rho)\alpha_0 + \alpha_1(1 - \rho)\pi_{t+12} + \alpha_2(1 - \rho)(y_t - y_t^*) + \rho r_{t-1} + \epsilon_t \tag{2.15}$$

where

$$\epsilon_t = v_t - \alpha_1(1 - \rho)(\pi_{t+12} - E_t \pi_{t+12}) - \alpha_2(1 - \rho)(y_t - E_t y_t^*). \tag{2.16}$$

Then, since $E_t[\epsilon_t | u_t] = 0$, where u_t includes all the variables in the central bank's information set at the time interest rates are chosen, the following set of orthogonality conditions can be derived:

$$E_t[f_t | u_t] = 0 \tag{2.17}$$

$$f_t = r_t - (1 - \rho)\alpha_0 - \alpha_1(1 - \rho)(\pi_{t+12} - \alpha_2(1 - \rho)(y_t - y_t^*) - \rho r_{t-1}$$

The parameters of interest $\alpha_0, \alpha_1, \alpha_2$ and ρ are estimated using GMM framework. The J-stat for the validity of over-identifying restrictions can then assess if the specification of the monetary policy rule in Equation (2.17) omits important variables, which enter the central bank rule. Obvious candidates for the role of omitted variables are monetary aggregates, foreign interest rates, long-term interest rates, exchange rate fluctuations and stock markets overvaluation. Moreover, the estimation of parameters of interest allows some relevant consideration on monetary policy. Given Equation (2.12), the equilibrium relation for the real interest rate is:

$$rr_t^* = \overline{rr} + (\alpha_1 - 1)E_t\,(\pi_{t+12} - \pi^*) + \alpha_2 E_t\,(y_t - y_t^*), \tag{2.18}$$

where $\overline{rr}$ is the equilibrium real interest rate, independent from monetary policy. Equation (2.18) illustrates the critical role of parameter α_1. If $\alpha_1 > 1$ the target real interest rate is adjusted to stabilize inflation, while with 0 < $\alpha_1 < 1$, it instead moves to accommodate inflation: the central bank raises the nominal rate in response to an expected rise in inflation but it does not increase it sufficiently to keep the real rate from declining. CGG (2000) also show that $0 < \alpha_1 < 1$ are consistent with the possibility of persistent, self-fulfilling fluctuations in inflation and output.

[25] Future inflation is the relevant variable because the existence of lags between monetary action and their effect on the economy is likely to make reacting to contemporaneous targets useless.

Therefore, the value of one for α_1 is crucial discriminatory criterion to judge central bank's behaviour. In their study, CGG show that in the pre-October 1979 period of the Fed rule features the rule $\alpha_1 < 1$, while the post-October 1979 economic recession period features the rule $\alpha_1 > 1$. Finally, it is possible to use the fitted values for the parameters α_0 and α_1 to recover an estimate of the central banks' constant target inflation rate π^*. The empirical model does not separately identify the equilibrium inflation rate and of the equilibrium real interest rate but it does provide a relation between them conditional upon α_0 and α_1. Given that $\alpha_0 = \bar{r} - \alpha_1\pi^*$ and $\overline{rr} - \pi^*$, then

$$\pi^* = \frac{\overline{rr} - \alpha_0}{\alpha_1 - 1} \tag{2.19}$$

which establishes a relation between the target rate of inflation and the equilibrium real interest rate defined by the parameters α_0 and α_1 in the policy rule. CGG (1998) set the real interest rate to the average in the sample and used Equation (2.19) to recover the implied value for π^*.

2.7.2 Specifications of the FL and BL MP Reaction Functions

This section specifies the rules as backward and forward looking reaction functions. In the spirit of CGG (1999), Taylor (2001), McCallum (2000), Clarida (2001; 2012) and Mehrotra and Sanchez-Fung (2011), the study specifies 10 empirical models for five monetary policy reaction functions for the UK data and estimates the coefficients and other statistics. The MP rules are the Taylor rule, the McCallum rule, the Hybrid of MaCallum-Taylor rule, the Hybrid McCallum-Hall-Mankiw rule and the Nominal Fixed Rate (NFR) – McCallum-Dueker-Fisher rule, also known as a Nominal Feedback Mechanism (NFM). The model specifications represent targets and instruments from the prevalent framework to analyse the UK monetary policy framework. The specifications are:

The Taylor's rule BLRF/FLRF

$$\begin{aligned} R_t &= \alpha_{TR} + \varphi_{TR}R_{t-1} + \beta(\pi_t - \pi^*) + \lambda(y_t - \tilde{y}) + \delta_{TR}\Delta e_t + a_4 i_{t-1} \\ R_t &= a_0 + a_1(E_t\pi_{t+1} - \pi^*) + a_2 * E_t y_{t+i} + a_3\Delta e_{t-1} + a_4 i_{t-1} \end{aligned} \tag{2.20}$$

The McCallum's rule BLRF/FLRF

$$\begin{aligned} \Delta b_t &= \alpha_{MR} + \mu_{MR}\Delta b_{t-1} + \theta(\Delta x_t^* - \Delta x_{t-1}) + \delta_{MT}\Delta e_t \\ \Delta b_t &= b_0 + b_1(\Delta x_t^* - E_t\Delta x_{t+1}) + b_2\Delta e_{t-1} + b_3\delta b_{t-1} \end{aligned} \tag{2.21}$$

The Hybrid McCallum-Taylor rule BLRF/FLRF

$$\begin{aligned} R_t &= \alpha_{MT} + \gamma_{MT}R_{t-1} + \rho(\Delta x_t^* - \Delta x_{t-1}) + \delta_{MT}\Delta e_t \\ R_t &= c_0 + c_1(\Delta x_t^* - E\Delta x_{t+1}) + c_2\Delta e_{t-1} + c_3\Delta i_{t-1} \end{aligned} \tag{2.22}$$

The Hybrid - McCallum-Hall-Mankiw rule BLRF/FLRF

$$\begin{aligned} \Delta b_t &= \alpha_{MHM} + \mu_{HM}\Delta b_{t-1} + \chi((\pi_t - \alpha\overline{p_t} + \overline{y_t})) + \delta_{HM}\Delta e_t \\ \Delta b_t &= d_0 + d_1[(E\pi_{t+1} - \pi^*) + E_t y_{t+1})] + d_2\delta e_{t-1} + d_3\delta b_{t-1} \end{aligned} \tag{2.23}$$

The NFR - McCallum-Dueker-Fisher rule BLRF/FLRF

$$\Delta m_t - \Delta(m-p)_{(t|t-1)} = \alpha_{MDF} + \omega(\Delta m_t - \Delta(m-p)_{(t|t-1)t-1} + \beta_{DF}(\pi_t - \bar{\pi}_t^*) + \delta_{DF}\Delta e_t$$

$$\begin{aligned} &\Delta m_t - \Delta(m-p)_{(t|t+1)} \\ &\quad = \alpha_{MDF} + \omega(\Delta m_t - E\Delta(m-p)_{(t|t+1)t+1} + \beta_{DF}(E\pi_{t+1} - \bar{\pi}_t^*) + \delta_{DF}\Delta e_t \end{aligned} \tag{2.24}$$

The lagged policy instrument is an important feature in Equations (2.20) to (2.24). The specification is intended to account for smoothing by the monetary authorities through the coefficients $\varphi_{TR}, \gamma_{MT}, \mu_{MR}, \mu_{HM}$ and ω (as in English, 2003). All α terms are equation-specific intercepts. Equation (2.20) is the benchmark Taylor-type monetary policy reaction function. As in Taylor (2001), Svensson (2000) and Moron and Winkelried (2005), Equation (2.20) and the other specifications allow for feedback from the exchange rate. The exchange rate variable is the annual depreciation of the exchange rate expressed in percentage points, and an increase in e_t is a depreciation. In the same equation, an increase in the exchange rate is expected to produce an increase in the interest rate ($\delta_{TR} > 0$) if the monetary authorities lean against the wind. The output gap is based on HP filtered GDP data. The coefficient on the output gap is expected to be positive ($\lambda > 0$), indicating that the central bank increases the interest rate if actual output is above the potential output. According to the Taylor's principle, the nominal policy interest should move one for one with average inflation's deviations from target ($\beta > 0$). Using average of observed inflation in the specifications avoids overreacting to temporary movements in the variable. Equation (2.22) is a hybrid rule mixing Taylor's interest rate instrument with a McCallum nominal income gap target and an exchange rate variables. An important variable in the rule is the nominal GDP target. An increase in the nominal income gap[26] should lead to a reduction in the interest rate, that is $\rho < 0$; in Equation (2.22) an increase in the exchange rate should lead the central bank to react by increasing the interest rate ($\delta_{MT} > 0$). Furthermore, the benchmark forward and backward looking models are specified from the Taylor Monetary Policy Rule and McCallum Monetary Policy Rule.

Equation (2.21) is McCallum's benchmark feedback mechanism including an exchange rate variable ($\delta_{MR} < 0$). Equation (2.23) is a hybrid mixing a monetary base instrument with a target following Hall and Mankiw (1994). The hybrid target is specified as the deviation of annual inflation from its moving average and an output gap. In Equations (2.21) and (2.22) an increase in the McCalum and in Hall-Mankiw targets should lead to a reduction in the monetary base, i.e. a tightening of the monetary policy stance; $\theta < 0$ and $\chi < 0$ are expected. In the reaction functions with a monetary base instrument, the coefficients on the exchange rate are expected to be negative ($\delta_{MR} < 0$ and $\delta_{HM} < 0$) if the central bank tightens its policy stance following depreciation.

Equations (2.24 and 2.25) are a nominal feedback rule following Dueker and Fischer's (1996) analysis of monetary policy. The analysis of interest estimates the variable $\Delta(m-p)_{(t|t-1),}$. The estimation amounts to a technical approximation to the internal predictions a central bank is

[26] The nominal income target is computed by applying the HP filter to the real GDP data and taking the growth rates of the resulting trend series, and adding this measure of real trend growth to the inflation target announced by the central bank.

supposed to generate and use a technical approximation when designing its policy. In generating that variable, it estimates a structural time series model from which a data sequence is generated for all the points in the given sample using the Kalman filter. In producing the series, $\Delta(m-p)_{(t|t-1),}$the analysis only uses information available up to the period $t-1$ (Harvery, 1989). In Equation (2.24) the coefficients β_{DF} and δ_{DF} are expected to be negative if the monetary authorities bring the implicit inflation target down following an increase in the inflation gap or a depreciation in the exchange rate. The data description states the items of the monetary policy instruments and identified targets. It also describes the type of data used to fit the reaction functions, the data generating process and the multiple sources used to obtain the data.

2.7.3 Data

As discussed in the above sections, to account for the post Second World War and the high inflation periods together with the frequently changing monetary policy instruments, the early 1960s period is a reasonable starting point for the empirical analysis. The monetary policy reaction functions are estimated over three policy regimes using quarterly data. To allow lags of monetary policy instruments and future expectation for the BL and FL settings, the actual sample series used for estimation are adjusted. The three policy regimes are identified as pre-inflation targeting policy regime (pre-1992), post-announcement/inflation targeting policy regime (1992 to 2007), and post-GFC policy regime (2007 to 2014). The Zivot and Andrew method confirmed that there is a significant structural (at 5%) shift in the stated policy regimes. The reaction functions simulate the policymakers' behaviour based on the assumption that one of the five reaction functions might have been used in the given policy regime. The sample periods are identified based on the UK monetary policy structure and the onset of the GFC.

Following the data description, the empirical analysis allows investigating the UK monetary policy rules based on the Taylor, McCallum and the hybrid rules in three policy regimes using quarterly time series data from 1962 to 2014. The nominal interest rate is used to estimate the benchmark Taylor rule and the hybrid McCallum-Taylor counterpart are the official policy interest rates (controlled by the monetary authority) as shown in Table 2.3. The rate of inflation is the annual change in the consumer price index. The inflation gap is calculated as the difference between moving average of annual inflation and the inflation targets announced by the monetary authorities in IT economies. The exchange rate variable included in the reaction functions is the annual change in the price of domestic currency per U.S. dollar. The output gap is based on the GDP data calculated as a deviation of the log output from its trend using the Hodrick-Prescott (HP) filter. Table 2.3 presents the notation and illustrations of data transformations for the monetary policy instruments and policy targets.

Table 2.3 Variables and Descriptions of the Monetary Policy Rules Reaction Functions

Variables	Description	Units	Sources
	Monetary Policy Instruments		
r_t	Interest rate: controlled by the monetary authorities	Percentage	BoE/OECD
Δb_t	Log deviation of monetary base from its 4PMA (annual rate of change) ($\Delta b_t = b_t - b_{t-4}$).	Percent x 100	BoE/OECD & Author's Computation
$\Delta m_t - \Delta(m - p)_{(t\|t-1)}$	Log of the nominal monetary aggregate (annual change) ($\Delta m_t = m_t - m_{t-4}$) minus the predicted annual change in the real monetary aggregate $\Delta(m - p)$ based on information available in the previous period.	Percent x 100	Author's Computation
	Monetary Policy Targets		
$(\bar{\pi} - \pi^*)$	*Inflation gap*: it is generated as the difference between a moving average of annual inflation, measured as $\pi_t = p_t - p_{t-4,}$ and the inflation target announced by the monetary authorities.	Percent x 100	ONS/BoE/OECD/IFS Author's Computed
$(y_t - \tilde{y})$	*Output gap*: a deviations of log output from trend log output computed using the Hodrick-Prescott (HP) filter	Percent x 100	ONS/BoE/OECD/IFS Author's Computation
$(\delta x_t^* - \delta x_{t-1})$	*McCallum nominal income gap measure*: it is calculated as the difference between the annual change in the target nominal income and the annual change in the previous period's annual nominal income. For inflation targeting economies (the UK), is the sum of real output passed through the HP filter and the inflation target announced by the monetary authorities.	Percent x 100	Author's Computation
$(\pi_t - \delta\overline{p_t} + \overline{y_t})$	*Hybrid model gap measure following Hall and Mankiw*: it is calculated as the deviations of annual inflation from its moving average and a measure of the real output gap	Percent x 100	ONS/BoE/OECD/IFS Author's Computation
δe_t	Annual change in the log of the nominal exchange rate	Percent x 100	BoE/OECD/IFS, Author's Computation

Source: author's data and variable overview in the spirit of MSF (2011).

2.8 Estimating the UK MP Reaction Functions

2.8.1 The Interest Rate MP Reaction Function

The Taylor Rule

The forward looking specifications of the monetary policy rules is estimated using the Generalised Methods of Moments (GMM) based on CGG (1998, 2000). The backward looking (contemporaneous) specification is estimated using the Ordinary Least Square (OLS) approach. The GMM is employed to estimate the unknown parameters in the forward looking monetary policy rules described by Equation (2.20). The forward looking horizon for expected inflation is four quarters. Given that the instruments are correlated with the endogenous variables and uncorrelated with the error term, GMM estimators are strongly consistent and asymptotically normal. Accordingly, the policy targets and instruments used are as follows: lags of monetary policy nominal rate, monetary base rate, inflation gap, the output gap, the exchange rate and the nominal income. The J-statistics tests the validity of the over-identifying restrictions for the GMM estimations. The monetary policy RFs are estimated for three UK policy regimes. Policy regime I represents the monetary and shadow/explicit exchange rate targeting regimes that covers from 1962Q1 to 1992Q4. Following the shift to the inflation-targeting regime in October 1992, policy regime II represents the inflation-targeting regime with RPI and CPI. This regime is presented as policy regime II for the period from 1993Q1 to 2007Q2.

The selection of these sample periods is based on the two major monetary policy frameworks in the UK with respect to its conduct and the time horizon in the regime shift (from a monetary targeting to an exchange rate then towards inflation targeting regimes). This period ends around the start of the GFC, 2007Q2. Policy regime III represents the period known as the GFC followed by recession and recovery (2007Q3 to 2014Q4). The separation of the policy regimes is tested as a break point using the Zivot and Andrews SB algorithm based on T=15% observation trimming and are significant at 5% level. The analysis estimates the Taylor's rule reaction function using OLS-BL, for backward looking and the GMM for forward looking reaction functions. The results, reported in Table 2.4, show that the Taylor type reaction function based on Equation (2.20) had a significant operational feasibility for the non-inflation targeting (PR-I) and the inflation targeting regimes (PR-II and PR-III). The most important common element of policy behaviour in inflation targeting regimes is instrument smoothing with statistically significant coefficients (as in English et al., 2003) of lagged policy rates. Rudebusch and Svensson (1999) argue that gradualism in policy is the characteristic of inflation targeting countries. The statistical significance of the inflation gap coefficient in both backward and forward looking RFs is expected, given the success in disinflationary process in inflation targeting economies. The estimates are in good contrast to simulation estimates of Taylor rules using data from 1962 to 2014. Particularly, the estimates before the GFC are in line with the plausible explanation that highlights a shift in the UK monetary policy reflecting a lesser emphasis on inflation. This is also consistent with the movement in interest rates for a long period of time and the austerity measures from early 2008 to early 2009. This occurs when inflation was above the target 2% level.

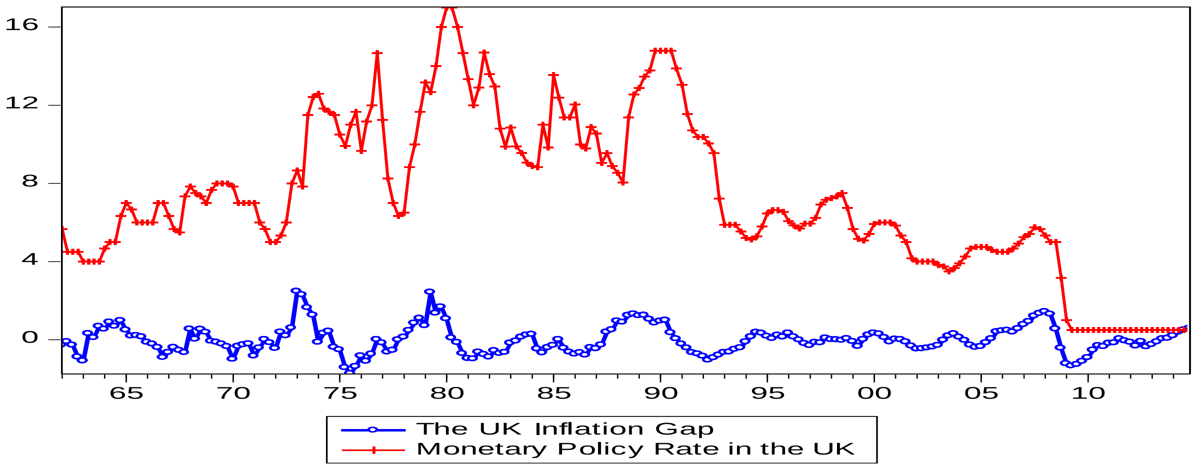
Comparing PR-III with PR-I and PR-II, the response of inflation in PR-II is higher which satisfies the Taylor principle. Turning to output gap, the response is also higher in the inflation pre-2007 period. The annual change in exchange rate is more relevant in the pre-inflation targeting period than the inflation targeting and post-crisis periods. This outcome is consistent with the UK monetary policy structure where exchange rate was a policy target during the pre-inflation targeting period. The significant change in the lagged policy rate is more prominent during the pre-inflation targeting and post 2007 period, unlike Martin and Milas (2013) where their study failed to find significant changes in the equilibrium nominal interest rate or the degree of interest rate smoothing. Additionally, the study by Martin and Milas did not account for the pre-inflation targeting period so its completeness is questionable.

Table 2.4 Estimates of the Taylor Rule Type of the UK Interest Rate RFs

	Policy Regime I		Policy Regime II		Policy Regime III	
	1962Q1-1992Q4		1993Q1-2007Q2		2007Q3– 2014Q4	
	BL-OLS	FL-GMM	BL-OLS	FL-GMM	BL-OLS	FL-GMM
Inflation gap $\tilde{\pi} - \pi_t^*(\%): \beta$	0.013 (0.042)**	-0.012 (0.041)**	0.070 (0.024)**	-0.047 (0.025)**	0.053 (0.066)*	0.028 (0.076)*
Real output gap $y - \tilde{y}(\%): \lambda$	-0.527 (0.0001)***	-1.248 (0.0017)***	-0.113 (0.028)**	0.242 (0.028)**	-0.136 (0.047)**	0.081 (0.056)*
Exchange rate $\Delta e_t(\%): \delta_{TR}$	-0.184651 (0.0001)***	-0.808733 (0.0508)**	-0.12219 (0.0034)**	-0.09252 (0.7391)	0.1471 (0.0030)***	0.004 (0.821)
Lagged policy rate $R_{t-1}(\%): \varphi_T$	0.955 (0.0000)***	1.129 (0.0000)***	0.932 (0.0000)***	0.872 (0.0000)***	1.049 (0.0000)***	5.301 (0.0000)***
R^2	0.895	0.875	0.912	0.875	0.929	0.784
J-statistics		0.228		0.228		0.261

Notes: numbers in parentheses are standard errors. OLS-BL and the GMM-FL, values inside parenthesis refer to level of significance at 10% (*), 5% (**) and 1% (***). The values are determined using autocorrelation consistent standard errors and Jackknife heteroscedasticity, GMM Generalised Method of Moments. The J-statistics tests the validity of the over-identifications for the GMM estimations. All the estimated OLS/GMM models include a constant term. The dependent variable is R_t. The break point given as the p-value of the Zivot-Andrews breakpoint test. The p-value is reported from the maximum LR F-statistic using 0.15 observation trimming, based on Hansen (2001) method. The estimated breakpoint is reported where the test statistic is significant at 0.05. The statistics for the validity of instruments has a χ^2 distribution with 21 degrees of freedom (25 instruments for 4 parameters) and takes the value of 31, 17.4 and 9.6 respectively for each samples, and does not reject the null at $\chi^2_{0.05}(21) = 32.671$.
Source: author's calculations.

The post-crisis period signifies a clear demarcation from the inflation-targeting regime. Table 2.4 also presents the post-crisis OLS-BL and GMM-FL estimates of the Taylor empirical model using quarterly data from 2007 to 2014. Martin and Milas (2013) data includes only from 2007 to 2010 which is marked as a recession period so their data could be misleading as it covers only a short period of time. The response of inflation and output gap in this period is only significant at 10% level of sig. in both the backward and forward looking RFs. Martin and Milas (2013) also find insignificant inflation response to the nominal interest rate. There is a sharp decline in the output gap as compared to PR-I and PR-II. This result is consistent with Martin and Milas (2004, 2013) and Mihailov (2006). The inflation gap coefficients are significant rating from 5% to 10%. $\delta_{TR} > 0$, the coefficient of the exchange rate deviations, implies that the monetary authority leans against the wind. Furthermore, the results in PR-II and III in OLS-BL, with regards to inflation gap and output gap confirm that the UK monetary authority leans against the wind during the inflation targeting and post-crisis periods. The non-inflation targeting regime (PR-I) shows no evidence of this monetary behaviour. The results in Table 2.4 also show that PR-I estimates (coefficients) are statistically significant for exchange rate and lagged policy rate. This implies that the period is known as a non-inflation targeting regime that exchange rates and lagged interest rates were in operation. Although the UK monetary policy did not peg lagged interest rate as a policy target, the outcome suggests that the monetary authorities implicitly tracking lagged interest rate to stabilise the real economic activity and adjust the nominal policy rate.



Source: author's analysis.

Figure 2.7 Monetary Policy Interest Rate and Inflation Gap in the UK

The set of instruments for the GMM estimates of the TRRF include a constant, 1–6th, 9th and 12th lags (as in Hansen, 2001) of the interest rate, the inflation gap, the output gap, and exchange rate gap. The statistics for the validity of instruments has a χ^2 distribution with 21 degrees of freedom (25 instruments for 4 parameters). The reported J statistics are the minimised values of the objective function so it gets the appropriate test statistics, the J stat values are multiplied by the number of observations in each policy regime. The test statistics takes the value of 28.3, 14 and 8.4, respectively for PR-I, II and III, so do not reject the null of validity of instruments ($\chi^2_{0.05}(21) = 32.671$), hence, the over-identifying (OI) restrictions of the set of instruments cannot be rejected for all selected periods and the entire series of the MP rules. Overall, the Taylor rule is rather successful in explaining the UK monetary policy in the pre and post-inflation targeting period.

The GMM estimates presented in Table 2.4, consistently confirm that the coefficient on the inflation gap is statistically significant ($\beta < 0$ FL in PR-I & II; $\beta > 0$ BL for PR-I, II and III; FL for PR-III). It also holds true to the output gap except in PR-I and II. Figure 2.7 displays the actual path of the monetary policy interest rate and the inflation gap, showing a close relationship during the three policy regimes. The negative coefficients represent opposite relationship with the rate of change of the monetary policy rate. This is correctly represented in the inflation gap in PR-I as the inflation is declining while the monetary policy rate increases. The period 1970s and 80s is known as a high inflation period. The sign of point estimates represents in a manner of inflation targeting, although inflation-targeting regime began in October 1992, with a break date identified at 1992Q4, which is a cut-off point for this regime. The monetary authority was implicitly considering the inflation dynamics while base money and exchange rate were known to be the monetary policy targets in the pre-1992 period. The impact of money supply was assumed neutral in the long-run. The exchange rate reaction coefficient (δ_{TR}) is statistically significant in both FL and BL TMRF in PR-I (FL and BL), PR-II (FL) and PR-III (FL). The coefficient carries a negative sign during the non-inflation targeting regime (both BL and FL), PR II (BL) and the expected positive sign in PR-II (BL) and PR-III (both BL and FL). The positive output gap coefficient indicates that the central bank increases the interest rate while actual output is above potential output. A positive inflation gap also indicates the average inflation deviations from target inflation ($\beta > 0$).

There is a strong and statistically significant negative reaction to output gap in TMP RF during PR-I (non-inflation targeting regime). The monetary policy also responded to the exchange rate during policy regime I. It shows significant and strong negative coefficient. The reason for this might be due to the monetary authority's implementation of the exchange rate band regime (targeting regime) until October 1992. The UK monetary policy responded significantly to inflation gap, output gap and exchange rate gap during PR-I. During PR-II, the monetary policy displays significant reaction to inflation gap, output gap and exchange rate gap in the BL and FL reaction functions during PR-II except to the exchange rate gap. The financial crisis and recovery period (PR-III) display weak response to inflation gap both in BL and FL reaction functions, but significantly to output gap (BL), exchange rate gap (BL) and to monetary policy instrument smoothing both in BL and FL functions. The results also show that the UK monetary authority has managed to keep the inflation gap relatively low during the non-IT, and IT periods, except some high inflationary instances. The instrument smoothing (lagged monetary policy rate) is significant in all sample periods for the Taylor-type reaction function.

2.8.2 The Monetary Base Policy Reaction Function

The McCallum Rule

The original McCallum rule is a backward looking reaction function. The study estimates both the contemporaneous and forward looking versions of the monetary policy rules. The monetary base ($\Delta b\%$) is the dependent variable to determine the response as stated by the rule. The income gap term, defined by McCallum as trend growth minus actual growth and defined by Taylor as an actual growth minus trend growth. The term is expected to have a positive coefficient. When actual income growth is declining relative to the trend growth, monetary policy is expected to be accommodative and base money expands. Table 2.5 reports OLS-BL and GMM-FL estimates for the MMPR with monetary base as the central bank's policy variable, in Equation (2.21).

Similarly, the set of instruments for the GMM estimates of the MRRF includes a constant, 1–6th, 9th and 12th lags (as in Hansen, 2001) of the monetary policy base, the nominal income gap, and the exchange rate gap. The statistics for the validity of instruments has a χ^2 distribution with 22 degrees of freedom and takes the value of 31, 17.4 and 10.11, respectively for PR-I, II and III, so the null hypothesis for the validity of instruments is not rejected, ($\chi^2_{0.05}(22) = 33.924$). The over-identifying restrictions of the set of instruments cannot be rejected for all selected periods and the entire series of the MRRF. According to the test statistics, the rule is successful in explaining the UK monetary policy in the pre-inflation targeting period. The estimates of monetary base reaction functions for the UK monetary policy rule, reported in Table 2.5, show that in the non-inflationary targeting period (1962Q1 to 1992Q4) an increase in the nominal income gap is met with a decrease in monetary base, which is expected. The estimated coefficients on the income gap in this period are not close to the value 0.5, employed by McCallum that was estimated for Japan and the U.S. (McCallum, 2003). The period from 1993Q1 to 2007Q4, (inflation targeting to the start of GFC) follows the policy rule whereby an increase in the nominal income gap is met with an increase in monetary base, i.e. the central bank was leaning against the wind. The same is true during PR-III. The nominal income gap coefficient has a positive sign in PR-II (both FL and BL) and PR-III (FL).

In the period 2007Q3 to 2014Q4, which refers to as the GFC and recovery, the McCallum type rule is not able to explain this policy regime and the policy does not seem to be the appropriate reaction function for the UK. The results, both the BL and FL reaction functions' coefficients of the nominal income gap, show that the reaction was not in accordance to the value (0.5) suggested by McCallum. Furthermore, the lower value coefficients of the nominal income gap suggest that the central bank monetary policy target of the nominal income path has not been met with a strong movement in the monetary base (GMM instrument). If the reaction exceeds the McCallum proposed value, the strong movement of the income gap could have been the cause that destabilises the economy. This has not been the case for the UK from 1962Q1 to 2014Q4. The most obvious example of an intermediate target in monetary policy is the rate of growth of the money supply. This was attempted explicitly in the UK during the period known as the "Medium Term Financial Strategy (MTFS)" between 1981 and 1985 (BoE, 2009).

Table 2.5 Estimates of the McCallum Rule Type of the UK Interest Rate RFs

	Policy Regime I		Policy Regime II		Policy Regime III	
	1962Q1-1992Q4		1993Q1-2007Q2		2007Q3– 2014Q4	
	BL-OLS	FL-GMM	BL-OLS	FL-GMM	BL-OLS	FL-GMM
Nominal Income gap $(\Delta x_t^* - \Delta x_{t-1})\theta$	-0.046 (0.279)	-0.179 (0.048)**	0.0067 (0.935)	0.2603 (0.120)	0.1180 (0.7035)	0.0264 (0.9515)
Exchange rate $\Delta e_t(\%)$: δ_{MR}	-0.0149 (0.0521)*	0.0274 (0.819)	0.0086 (0.816)	-0.0136 (0.894)	0.158560 (0.0762)*	0.1604 (0.093)*
Lagged policy instrument $\Delta b_{t-1}(\%)$: μ_{MR}	0.7314 (0.000)***	1.1622 (0.000)***	0.6004 (0.000)***	1.3243 (0.000)***	0.2287 (0.2705)	0.2117 (0.2205)
R^2	0.6554	0.7341	0.5333	0.6478	0.5283	0.48115
J-statistics		0.251		0.289		0.316

Notes: numbers in parentheses are standard errors. OLS-BL and the GMM-FL, values inside parenthesis refer to level of significance at 10% (*), 5% (**) and 1% (***). The values are determined using autocorrelation consistent standard errors and Jackknife heteroscedasticity, GMM - Generalised Method of Moments. The dependent variable is the rate of change of the monetary base $\Delta b(\%)$.The estimated breakpoint is reported where the test statistic is significant at 0.05 level.
Source: author's analysis.

At the outset of the strategy, a declining target range for money growth was published in the hope that this would bring down the rate of inflation. However, the scheme was abandoned in 1985 because the money supply proved impossible to control with sufficient precision and the rate of inflation fell sharply. As an intermediate target, the money supply seemed to tell us nothing useful (Bain and Howells, 2009). Instrument smoothing is significant in the estimates for the UK economy. The reaction of base money to the exchange rate is less important during PR-I and II, both in BL and in FL reaction functions. In the case of the GMM estimates, only PR-III shows a statistically significant reaction to the exchange rate where the accommodative-exchange rate depreciations met with an increase in base money.

2.8.3 The Hybrid MP Reaction Functions

The Interest Rate-Nominal Income Reaction Functions

The set of instruments for the GMM estimates of the MTRF includes a constant, 1st – 6th, 9th and 12th lags of interest rate; nominal income gap and the exchange rate. The statistics for the validity of instruments has a χ^2 distribution with 22 degrees of freedom and the test statistics takes the value of 30.75, 17.16 and 10.4, respectively for PR-I, II and III so does not reject the null of validity of instruments ($\chi^2_{0.05}(22) = 33.924$). The OI restrictions of the set of instruments cannot be rejected for all selected periods and the entire series of the MTRF. The hybrid rule is successful and the overidentifying restrictions are satisfied in explaining the UK monetary policy in the post-IT period.

The study also explores the possibility that the behaviour of the UK inflation targeting monetary policy strategy can be feasibly characterised by a hybrid McCallum-Taylor policy reaction functions. The hybrid reaction function mixes an interest rate instrument with a nominal income target (Equation 2.24). The results presented in Table 2.6 show the OLS-BL and the GMM-FL estimates for the hybrid McCallum-Taylor reaction functions. PR-III shows that there has been a fall in nominal GDP growth with respect to its target. This implies a reduction in policy interest rates, which actually has been the case in the UK. In the GMM estimation, the coefficient is negative and statistically significant in the inflation-targeting regime, the financial crisis and the recovery regimes. The hybrid reaction functions also produce higher or equivalent R square values for the three sample periods. The results provide evidence that, the monetary policy rate responded positively and significantly to the instrument smoothing – the lagged policy rate.

The inflation-targeting regime can be explained by a hybrid McCallum –Taylor rule. To a lesser extent, this has also been the case in the benchmark Taylor-type reaction function. The limited significance of the inflation targeting in the benchmark Taylor rule could reflect the benevolent macroeconomic environment that has allowed for a disinflationary process without a strong stabilising reaction from the monetary authority. However, there is evidence of stabilising monetary policy in the hybrid McCallum-Taylor estimates where the response to the nominal income gap is significant in all of the three cases. The importance of the exchange rate is limited even for inflation targeting regimes. This implies that the UK economy is a small open economy in terms of international trade and reflects the successful consolidation of the inflation targeting regimes.

The Monetary Base-Inflation Gap RF

The set of instruments for the GMM estimates of the MHMRF includes a constant, 1–6th, 9th and 12th lags of the monetary policy base; hybrid Hall-Mankiw target and the exchange rate gap. The statistics for the validity of instruments has a χ^2 distribution with 22 degrees of freedom and takes the value of 23.19, 11.52 and 6.88 respectively for PR-I, II and III, so the null that states the validity of instruments is not rejected ($\chi^2_{0.05}(23) = 33.924$). Similarly, as in the previous reaction functions, the OI restrictions of the set of instruments for the MBRF cannot be rejected for all selected periods and the entire series of the MHMRF. The statistics show that the rule does not seem to be successful in explaining the UK monetary policy in majority of the policy regimes.

The McCallum-Hall-Mankiw hybrid reaction function (see Table 2.6), reveals base money growth reactions with statistically significant positive coefficients to the hybrid gap (χ_h) in the case of PR-III, suggesting that, policy in this period is accommodative. The sign on the hybrid gap coefficient of the GMM estimation is negative with a relatively higher estimated coefficient, indicating a strong stabilising reaction during the financial crisis and recovery period. Instrument smoothing is important in all sample periods except the period from 2008 to 2014. The monetary base reaction to the changes in exchange rate is statistically significant only in the case of PR-III, with a positive exchange rate coefficient. This indicates that an appreciation exchange rate is met with expansionary domestic monetary policy in PR-I and PR-II but depreciation in PR-III both in McCallum and in McCallum-Hall-Mankiw variants. This implies that the UK economy was more open during PR-I and PR-II but less open in PR-III.

Comparing the two reaction functions (McCallum and McCallum-Hall-Mankiw) with base money growth as the policy instrument could reveal that the estimated coefficients on the nominal income gap (Table 2.6) carry opposite signs in PR-I both BL and FL; and PR-III only in the BL reaction function. Furthermore, comparing the two reaction functions, both nominal income gap and hybrid Hall-Mankiw inflation gap react negatively to the monetary base during PR-I but positively during PR-II and PR-III (BL for MR, FL MHM rules). The results so far show that the UK economy was consistently pursuing a policy of leaning against the wind, particularly, during policy regime II and III.

NFR – MP Feedback Mechanisms

Likewise, the set of instruments for the GMM estimates of the NFR includes a constant, 1–6th, 9th and 12th lags of the real money demand, the inflation gap and the exchange rate gap. The statistics for the validity of instruments has a χ^2 distribution with 21 degrees of freedom and takes the value of 30.38, 16.2 and 10.27 respectively for PR I, II and III so does not reject the null of the validity of instruments ($\chi^2_{0.05}(21) = 32.671$). The OI restrictions of the set of instruments cannot be rejected for all selected periods and the entire series of the NFR. The overidentifying restriction is correctly identified.

In addition to the interest rate and monetary base reaction functions, the empirical analysis also investigates the NFR. Following Mehrotra and Sanchez-Fung (2011), the empirical analysis investigates the UK monetary policy rule based on the identified policy regimes using the NFR. The study incorporates an implicit inflation targeting mechanism. As an alternative rule to the McCallum type rule, (see McCallum, 1999), the NFR estimated results are also presented in Table 2.6. The results reveal that the central bank may have pursued accommodative policies where the implicit inflation target increases when inflation is above the trend level. Therefore, the central bank displays a behaviour that leans with the wind[27] in this particular case.

[27] The terms leaning against and leaning into the wind refers to a countercyclical and pro-cyclical, respectively, monetary policy where central banks take action to damp down inflationary booms or to boost growth when the economy is flagging. "The leaning against the wind principle describes a tendency to cautiously raise STIR even beyond the level necessary to maintain price stability over the short to medium term when a potentially detrimental asset price boom is identified. Leaning against the wind has the advantage that it can ameliorate the moral hazard problem of the

Table 2.6 Estimates of the Hybrid MP Rules RFs

	Policy Regime I		Policy Regime II		Policy Regime III	
	1962Q1-1992Q4		1993Q1-2007Q2		2007Q3– 2014Q4	
	BL-OLS	FL-GMM	BL-OLS	FL-GMM	BL-OLS	FL-GMM
(1) Taylor-McCallum						
Nominal Income gap $(\Delta x_t^* - \Delta x_{t-1})\rho$	-0.0807 (0.0465)**	0.0699 (0.0558)*	0.0184 (0.0325)**	-0.5833 (0.0478)**	-0.0425 (0.0497)**	-0.0144 (0.0990)*
Exchange rate $\Delta e_t(\%)$: δ_{MT}	-0.1232 (0.0166)**	-0.2555 (0.2033)	0.1112 (0.0079)***	0.1084 (0.4039)	-0.1473 (0.0022)***	-0.0167 (0.6364)
Lagged policy instrument $R_{t-1}(\%)$: γ_{MT}	0.9355 (0.0000)***	1.1273 (0.000)***	0.9162 (0.000)***	1.1198 (0.000)***	1.0214 (0.000)***	5.2548 (0.0001)***
R^2	0.8804	0.82921	0.9077	0.8647	0.9262	0.9139
J-statistics		0.248		0.286		0.324
(2) McCallum-Hall-Mankiw						
Δ of π_t from MA and y_t $(\pi_t - \Delta\bar{p}_t + \hat{y}(\%)$: χ_h	-0.038 (0.141)	-0.021 (0.672)	0.0481 (0.432)	0.0370 (0.698)	-0.0127 (0.7406)	-0.9409 (0.0403)**
Exchange rate $\Delta e_t(\%)$: δ_{HM}	-0.0134 (0.5636)	-0.1548 (0.2592)	0.0096 (0.7942)	0.0398 (0.6318)	0.1595 (0.1131)	0.6104 (0.0532)*
Lagged policy rate $\Delta b_{t-1}(\%)$: μ_{MH}	0.7345 (0.000)***	0.8521 (0.0000)***	0.0085 (0.6922)	1.1336 (0.0000)***	-0.2147 (0.3512)	-0.3765 (0.3044)
R^2	0.5582	0.5447	0.4308	0.5792	0.4292	0.4740
J-statistics		0.187		0.192		0.215
(3) McCallum-Dueker-Fischer						
Nominal money growth $\Delta m_t - \Delta(m - p)_{(t\|t-1)t-1}(\%)\omega.$	0.7489 (0.000)***	0.9291 (0.000)***	0.5158 (0.000)***	0.6614 (0.0001)***	-0.2101 (0.236)	-0.2532 (0.4276)
Inflation Gap $\pi - \pi_t^*(\%)\beta_{DF}$	0.0199 (0.809)*	0.0615 (0.4410)	-0.0144 (0.0108)***	-0.0250 (0.0047)***	-0.2015 (0.0318)**	-0.1755 (0.0553)*
Exchange rate $\Delta e_t(\%)$: δ_{DF}	0.0153 (0.7207)	0.0815 (0.5228)	-0.0398 (0.2912)	0.0230 (0.7507)	0.1872 (0.0253)**	0.2618 (0.0363)*
R^2	0.781	0.812	0.813	0.5792	0.736	0.647
J-statistics		0.245		0.270		0.321

Notes: (1) Numbers in parentheses are standard errors refer to level of significance at 10% (*), 5% (**) and 1% (***). The values are determined using autocorrelation consistent standard errors and Jackknife hetroscedasticity, GMM. (1) The dependent variable is the rate of change of the monetary policy $R_t(\%)$. The break point given as the p-value of the Zivot-Andrews breakpoint test. The p-value is reported from the maximum LR F-statistic using 0.15 observation trimming, based on Hansen (2001) method. The estimated breakpoint is reported where the test statistic is significant at 0.05. (2) The dependent variable is the rate of change of the monetary base $\Delta b(\%)$. The estimated breakpoint is reported where the test statistics is significant at 0.05. (3) The dependent variable is the implicit monetary target. $\Delta m_t - \Delta(m-p)_{\left(\frac{t}{t-1}\right)}(\%)$.
Source: author's analysis.

Furthermore, the adoption of a formal inflation-targeting regime showed a statistically significant positive impact (in both BL and FL functions in PR-II, and FL function in PR-III) on the implicit inflation target variable and is interpreted as a successful introduction of the new policy regime in the early 1990s. Table 2.6 also reports that the policy has been more successful in policy regime II

purely reactive approach to asset price boom-bust cycles. By reacting more symmetrically – i.e. being tighter in booms as well as looser in busts, the central bank would discourage excessive risk-taking and thereby reduce over-investment already during the boom. This, in turn, would lead to a lower level of indebtedness and less severe consequences of a possible future bust" (ECB, 2010).

than PR-III. The estimates of the NFR OLS-BL and GMM-FL simulation models show that the forecasts over predict the implicit inflation target, which can serve as a measure of the new regime's success in bringing inflation down. The outcome of the empirical exercises for the UK monetary policy is sensible, given the degree of openness and the level of dependence on the monetary policy decision makers' stance. The fact that responses like those of an implicit inflation targeting regimes are not found for the UK consistently, it should be considerable in the light of the rules versus discretion debate (Kydland and Prescott, 1977) and the literature on central bank (non) independence, as in Alesina and Summers (1993). The coefficient on the inflation gap and on the exchange rate depreciation is negative particularly in PR-II and PR-III. The negative coefficients imply that the monetary authorities tighten the policy stance when inflation is above its trend and when the exchange rate is depreciating (as in PR-I). Overall, the results reflect a commitment to improving policy outcomes.

The results of the simulation empirical analysis based on the five alternative MPR reaction functions conveyed that the UK employs a variety of monetary policy rules from early 1960s to the present time. Although there has been specific monetary instruments and policy targets, a combination of policy strategies and discretion, help the UK to achieve and retain lower inflation for a long period. However, the monetary environment is not free from risk. Holding monetary policy rates very low since 2009, could have caused a problem of disequilibrium in the money market. While borrowers might like the consistently low, at 0.5%, monetary base rate, there is little incentive for lenders to provide loans to businesses and consumers at that rate or with a margin of differential interest rates. The supply curve of loans is upward sloping with the interest rate on the horizontal axis and the demand curve is downward sloping and dependent on the interest rate. Firms will not supply more than what the supply curve implies at that ceiling rate, even though consumers would be willing to borrow at lower rates. This resulted in excess demand and lower volume than in the case of an equilibrium interest rate. Lower rates will not automatically create more credit and economic activity but, rather, run the significant risk of discouraging lending and investment the economy needs (see for e.g. Fisher, 2012). There are many other potential negative effects of the low rates and the unconventional policies. Low rates are a drag on consumption for many people whose income is negatively affected by the low rates. This effect may be larger than any offsetting substitution effect, which would encourage consumption by households and investment by business firms. Additionally, the low rates make it possible to roll over rather than write off bad loans at banks, and they reduce fiscal discipline. Recent research on overall macro effects of the change in policy regime includes the economy wide regime-switching model of Baele et al. (2012). They show that monetary policy regime changes are responsible for both the improved economic performance in the "Great Moderation" period and the recent deterioration in performance.

From the CBI point of view, there have been large shifts during the three policy regimes that monetary policy has been rule-based in most of OECD countries including the UK and the U.S. The question still remains – have there been comparably large shifts in the underlying legal basis for Central Bank Independence? There have actually been several notable changes in the operation of the BoE. Monetary policymakers in the UK have been able to engage in varying degree of independence and adherence to rule-based policy. For these reasons, major shifts have been observed in the efficiency of the monetary policy within the same framework of Central Bank Independence. The following tables summarises the GMM and OLS empirical results.

Table 2.7 Summary of Results based on Income, Output and Inflation Gap

MPR Function		UK MP Regimes (1962 - 1992) BL-MPRF	FL-MPRF	(1993 - 2007) BL-MPRF	FL-MPRF	(2007 - 2014) BL-MPRF	FL-MPRF
TMPRF	β/λ	**/***	**/***	**/**	**/**	*/**	*/*
MMPRF	θ	*	NS	NS	NS	*	*
M-T MPRF	ρ	**	*	**	**	**	*
MHMMPRF	χ	NS	NS	NS	NS	NS	**
NFR MPRF	β	*	NS	***	***	**	*

Source: author's analysis.

Table 2.8 Summary of Results based on the Dependent Variables

MPR Function		UK MP Regimes (1962 - 1992) BL-MPRF	FL-MPRF	(1993 - 2007) BL-MPRF	FL-MPRF	(2007 - 2014) BL-MPRF	FL-MPRF
TMPRF	φ	*	***	***	***	***	***
MMPRF	μ	***	***	***	***	NS	NS
M-T MPRF	γ	***	***	***	***	***	***
MHMMPRF	μ	***	***	NS	***	NS	NS
NFR MPRF	ω	***	***	***	***	NS	NS

Source: author's analysis for Lagged Policy Instruments.

Table 2.9 Summary of Results based on Exchange Rate Component of the MPRFs

MPR Function		UK MP Regimes (1962 - 1992) BL-MPRF	FL-MPRF	(1993 - 2007) BL-MPRF	FL-MPRF	(2007 - 2014) BL-MPRF	FL-MPRF
TMPRF	δ_{TR}	***	**	**	NS	***	NS
MMPRF	δ_{MR}	*	NS	NS	NS	*	*
M-T MPRF	δ_{MT}	**	NS	***	NS	***	NS
MHMMPRF	δ_{MHM}	NS	NS	NS	NS	NS	*
NFR MPRF	δ_{NFR}	NS	NS	NS	NS	**	*

Source: author's analysis.

Table 2.10 Summary of Results based on Significant Variables Reactions

MPR Function	UK MP Regimes (1962 - 1992) / (1993 - 2007) / (2007 - 2014): Significant Variables of each MP Reaction Function
TMPRF	SIG. POLICY INST., EXR, INFLATION & OUTPUT GAP REACTION
MMPRF	SIG. POLICY INST. (PR-I & II), & EXR. (PR-I & III) REACTION
M-T MPRF	SIG. POLICY INST., EXR (PR-I,II,III ONLY BL) & INCOME GAP REACTION
MHMMPRF	SIG. POLICY INST. (PR-I, II), INF. GAP (PR-III) & EXR (PR-III) REACTION
NFR MPRF	SIG. POLICY INST. (PR-III), NFR (PR-I,II,III) & EXR. (PR-III) REACTION

Source: author's analysis.

2.9 Conclusions

The monetary policy framework in the UK has shown a considerable change since the early 1960s. The study in this Chapter is the first approach that simulate, empirically recovers and evaluates the MP reaction functions based on a stand-alone and hybrid MP rules to assess the feasibility of the UK monetary policy operations. The study addressed the issue of how monetary policy should be conducted; should it be guided with policy rules or discretions. Motivated by the recent GFC and the unconventional monetary policy rules implemented in the UK, the empirical results of the five well-known policy frameworks shed some light on the conduct of monetary policy rules. The Chapter discussed the economics of monetary policy rules, monetary policy targets, regimes and the problem goes with it. Literature shows that inflation targeting is becoming a common approach in many industrialised countries including Canada, the United Kingdom, New Zealand, Sweden, Australia, Finland, Spain and Israel, among others. Following this policy change, a number of institutional changes gave a greater role to central banks. This led to the independence of the BoE in 1997. However, its achievers have been hampered by sudden and gradual changes in the structure and performance of the economy. The study also discussed institutional commitment based on the theory of time inconsistency for better transparency and accountability to achieve growth and price stability.

The theory of time-inconsistency is the most influential theory since the 1970s. The review highlighted various types of central bank independence indices and the relationship between inflation and central bank independence. It shows that the UK has high economic independence than a political independence. The new legislation by the ECB provides more economic and political independence to France and Italy. Studies also show that high level of central bank independence could reduce a time-inconsistency problem. An independent central bank free from political pressure is expected to behave more predictably to promote economic stability and reduces risk premia.

In terms of the MP arrangements, during the early years, the major role of central banks was to inject liquidity into the financial system. However, this strategy shifted to more profound objectives following the Great Inflation, the period of Moderation and the GFC. During the "Great Moderation" period and in the run up to the GFC, many industrialised countries adopted an inflation targeting strategy and increased their commitment for economic stability, transparency and accountability. Following the theoretical review of monetary policy rules, the study identified five MPRs: The *Taylor rule*, the *McCallum rule*, the *Taylor-McCallum* HR, the *McCallum-Hull-Mankiw* HR and the *McCallum-Dueker-Fischer* or *NFM* HR. The reaction functions for each monetary policy rule are specified as backward looking and forward looking reaction functions. Ten reaction functions are identified and empirically estimated for the UK MP in three policy regimes: the non-inflation targeting, inflation targeting and the post-GFC MP regimes. The econometric approach is theoretically grounded within the New Keynesian model of MP that relied on estimating BL and FL RFs. The models are estimated using the OLS and the New Keynesian GMM approaches on the UK quarterly data from 1962Q1 to 2014Q4. The Taylor-type MPRF, the McCallum-type MPRF and the Taylor-McCallum hybrid MPRF that mixes an interest rate instrument with a McCallum nominal income gap target and an exchange rate variable. It also estimated hybrid reaction functions mixing a monetary base instrument with targets following Hall and Mankiw (1994) and a NFM following Dueker and Fischer (1999). The models estimate the technical approximations to the internal predictions a central bank is supposed to generate and use when designing its policy.

The empirical assessment explored the interest rate, monetary base and the implicit monetary target settings behaviour of monetary policymakers in the UK. The evidence showed that the UK MPA conducts the policy based on set rules in the majority of the time horizon under consideration. Referring back to the research questions, (a) should monetary policy be conducted by rules known in advance or by the policymakers' discretion? (b) Should the monetary policy rule be different in a financial crisis and post-crisis periods? The modelling and estimation exercises discovered that the UK monetary policy has been conducted not only by rules but also by discretion. With specific reference to the Taylor rule, the FL reaction function show an asymmetric MPRF in PR-I that the response to inflation gap (β) was weaker than the response to the output gap (λ). On the contrary, there has been a symmetric response in PR-II, where both inflation gap and output gap responded with the same level of significance (5%). This result is in line with the New Keynesian theory of MP. The analysis outcome sheds some light to characterise the UK inflation targeting monetary policy as a less rigid reaction function. It also revealed that during the period of the BoE political and operational independence, the inflation targeting MP resulted in symmetrical reaction in the period from 1993 to 2007. However, the strength of the output and inflation gap responses diminished in the post-GFC period.

Concerning PR-III, since the GFC, a new approach of monetary policy strategy has witnessed unconventional policy approaches. There is no enough evidence to suggest that the PR-I subsample for monetary policy rule strategy, except the exchange rate, plays a role in anchoring the economic activity. During the second policy regime (PR-II), a hybrid McCallum-Taylor rule that incorporates a nominal income target than the benchmark rules was in play. The results also revealed that during the non-inflationary regime (1962 to 1992) a mixture of monetary and exchange rate targets portrayed differences in the reaction of policy to domestic targets – output gap, inflation gap, or a nominal income target and the exchange rate. Related literature also claims that the dominant stance of the UK monetary policy in the pre-IT policy regime has been different. This was also empirically discovered in this Chapter that the central bank used the monetary base and exchange rate targeting MP rules. Before the granting of the CBI to the BoE and before the IT regime, the period is characterised by episodes of contractionary and expansionary monetary policies.

Overall, there are three major findings: (see the summary in Table 2.7 to 2.10). *First*, the UK interest rate setting behaviour can be described by a mix of MP rules reaction functions in all policy regimes. *Second,* the interest rate setting behaviour in the period from 1993 to 2007 can be described as more of a Taylor-rule type reaction function, where all coefficients of the RFs respond significantly to the policy instrument so it is relevant to the MP theory of the UK case. *Third,* the crisis of the post-2007 period is explained not only by Taylor-rule and McCallum-rule, but also to some extent, by the hybrid reaction functions. There is no clear pattern of responses in each reaction function across the policy regimes. This implies that during the crisis period, specific monetary policy rule is unlikely to make significant impact on price and output. The intuition behind these insights is that a mixture of monetary, financial, income and interest rate rules need to be implemented to achieve stable economic growth. There is also clear evidence that the UK monetary policymakers have abandoned the sole inflation targeting MPR in the post-GFC period. Hence, nominal income and the implicit inflation targeting mechanism have been the focus of the policy in the onset and post-crisis periods. The findings of the MP reaction functions appeared to be consistent with the UK monetary environment of the three policy regimes.

The monetary transmission channels determine the most effective set of monetary policy instruments, the timing of policy changes, and the level of restrictions that central banks face in the decision making process. In this regard, the estimation results raised further questions that the implication of the monetary policy changes in the UK requires a better understanding of how the policy shocks and impulses pass through the transmission channels before hitting their target. In the process of shock transmission, internal and external forces could have changed the dynamics of the UK MTM. To further study the dynamics of the monetary policy transmission mechanism and if it has changed in the course of the GFC, Chapter 3 has investigated the MTM and empirically evaluated the IRFs and HVDs using a Bayesian VAR and a Dynamic Stochastic General Equilibrium (DSGE) models. In the context of the changing MP structure, persistent macroeconomic and financial shocks are believed to be the main cause for structural changes. It is important to address the issue of structural breaks and the monetary policy innovations to understand not only the effects of transitory shocks but also their ability to trigger permanent changes in the economy. This is the subject of Chapter 4.

CHAPTER 3

MONETARY POLICY AND THE TRANSMISSION MECHANISM

3.1 Introduction

> "Though many macroeconomists would profess little uncertainty about it, the profession as a whole has no clear answer to the question of the size and nature of the effects of monetary policy upon aggregate activity."
>
> (Sims, 1992:p975)

This Chapter investigates the monetary policy shock and the channels through which the impulses and responses are transmitted. The MTM is concerned with the endogenous behaviour of intermediate and final variables in response to exogenous policy impulses. Monetary policymakers focus on achieving price stability in the form of low and stable inflation. However, in the advent of the changing economic environment, it is important to understand the dynamics of price inflation, the driving factors and, how the monetary policy fits into this, i.e., how the MTM works. Understanding the monetary policy transmission mechanism is the key to successful conduct of monetary policy.

The study of MTM in industrialised and emerging economies has gained considerable importance due to not only structural and economic reforms and subsequent transitions to new policy regimes but also due to the recent GFC (Aleem, 2010). The influence of monetary policy over a country's economy encourages a dynamic environment depending on the state of the economy, the structure of the financial sector and the size and degree of openness. Theoretical and empirical studies use the MTM to explain the impact of monetary policies on the real economy. These approaches have become the subject of macroeconomic research since the early 1980s. The earliest approach to study the MTM was through the traditional Keynesian approach. However, this approach came under attack by the advocates of the credit view that complements the conventional money channel and the credit channel that amplifies and propagates the standard interest rate effects of monetary policy on real activity. The GFC countered the views held prior to the crisis on the goals and tools of monetary policy and their relationship to financial stability. The interest rate channel was regarded to be orthogonal to financial stability policy tools, such as liquidity and capital adequacy requirements (Barnea et al., 2015). The conventional view up to the end of the "Great Moderation" period was held on the precept that there is no general trade-off between monetary and financial stability (Issing, 2003; Barnea et al., 2015). Long before the current perception, it was also argued that a central bank that was able to maintain price stability is able to minimise the need for lender-of-last-resort intervention (Schwartz, 1998).

For many years, the traditional Philips Curve that posited the standard framework and used to understand inflation dynamics in a reduced form lacks the optimisation behaviour of economic agents. Consequently, the PC approach has proved to be providing a misleading information. This gap in policy analysis led to the development of dynamic models with overt micro-foundations, optimising behaviour, imperfect competition, and 'sticky' prices. Calvo pricing model (based on Calvo, 1983) has been the most popular model, among others. Calvo's pricing perception results in a derived New Keynesian Philips Curve (NKPC). This approach relates current inflation to expected inflation and the variance of real marginal costs. Although the NKPC is a useful framework to understand MTM, it cannot be used to provide quantitative predictions unless it forms part of a general equilibrium model. This approach led to the development of dynamic stochastic general equilibrium (DSGE) model with various estimation techniques based around the NKPC approach. Those authors who employed the Bayesian techniques are Smets and Wouters (2003, 2007), Harrison and Oomen (2010), and Gertler et al. (2008), among others. A Bayesian approach provides a complete description of the data generating process and allows the researcher to test hypotheses within the DSGE models, evaluate their relative performance against each other, and use them to run forecasts.

In the monetary policy transmission mechanism, there are interconnected traditional and non-traditional channels through which monetary policy operates. These are the *traditional interest rate channel*, the *credit channel*, the *exchange rate channel*, and the *asset price channel*. In practice, the transmission mechanism of monetary policy is usually sluggish and incomplete in the short-run. Thus, the variance in the policy rate are transmitted to other forms of interest rates with lag. Consequently, interest rate differentials exist in the economy (Charoenseang and Manakit, 2007). Before the 1990s U.S. credit crunch, many economists believed that monetary policy is neutral in the long-run but does affect real economic activity in the short-run (Eichenbaum, 1997). Evidence (Bernanke and Blinder, 1992) shows that the output effects can last for more than 2 years in some cases. However, disagreements have emerged after the U.S. credit crunch, particularly on how the key policy rate (KPR) transmitted to the real economy. More significantly, the financial crisis has deeply affected money markets and the proper functioning of the interest rate channel (Abbassi and Linzert, 2012). Besides, the credit crunch and the theoretical development in informational imperfection motivated empirical and theoretical studies on MTM. After the GFC, the understanding of the transmission mechanism is beginning to change as the traditional theories and economic models have failed to explain the dynamics of the mechanism and forecast the main reasons for the unprecedented crisis that shakes the foundation of the old and New Keynesian doctrines. In light of these gaps, this Chapter attempts to contribute to the current understanding of the MTM through theoretical and empirical investigations and identify the changes that has occurred due to internal and external forces.

This Chapter discusses the monetary policy transmission mechanism through which monetary policy shocks pass through the various channels to impact the real economy with greater prominence on the interim stages of the mechanism and the state of mean and variability of shocks (persistence or transitory). It also addresses the new understanding of the MTM in light of the recent global financial crisis. There are two motivational factors for this study. The *first* motivation stems from the GFC that revealed the need to deepen the understating of the intricate connections between monetary policy and the rest of the transmission channels with greater emphasis on financial system channels. As echoed by Volcker (2010), there is a prevailing position held by economists and financial regulators that monetary policy disquiets about the structure and condition of banks and the financial system more generally are inseparably intertwined. The *second* motivation is the fact that there is a significant weakening of the pass-through mechanism between the monetary base rate and its derivative banks' rate in many economies[28]. The *third* motivation is the fact that the recent GFC may have brought a paradigm shift not only in MTM but also on the wider perspectives of the strategy and design of macroeconomic policy. Although various attempts have been made to investigate the function of MTM, there is still lack of information on what happens once the MP shocks are released. It is this gap, in the current research development and the need for deeper understanding that motivates this study. The study reviews the fundamentals of MTM, the transmission channels and model the responses of variables to a monetary policy shock. The modelling process employs the optimisation behaviour of economic agents using Bayesian VAR and Dynamic, Stochastic, General Equilibrium (DSGE) model approaches.

The Chapter is organised as follows. *Section one* begins by examining the macroeconomic environment and policy objectives and the MTM based on the Keynesian and Monetarist perspectives. *Section two* reviews the theoretical perspectives based on the old and current views of the MT channels. *Section three* and *four* discuss the principal objectives of central banks, and the evolution of the UK monetary transmission mechanism, respectively. *Section five* analyses the UK MTM using Bayesian VAR and Dynamic Stochastic General Equilibrium models. *Section six* discusses the results and finally, *Section seven* concludes the Chapter.

[28] See also Aristei and Gallo (2014).

3.2 The Monetary Transmission Mechanism

The MTM describes how policy-induced impulses change in the nominal money stock or the short-term nominal interest rate impact real variables, such as aggregate output and employment. Specific channels of monetary transmission operate through the effects that monetary policy has on interest rates, exchange rates, equity and real estate prices, bank lending, and firm balance sheets. Recent research on the transmission mechanism seeks to understand how these channels work in the context of dynamic, stochastic, general equilibrium models. The MTM has attracted much attention in the last two decades but particularly in the post-2007 GFC, from both policymakers and those in the public sector. Despite the fact that every monetary policy impulse has a delayed impact on the economy, it is unclear exactly how monetary policy impulses are transmitted to the price level, or how real variables, such as output, develop in the short and medium-terms (Papadamou et al., 2014).

The transmission mechanism is one of the most studied areas of monetary economics for two reasons: (i) to understand how monetary policy affects the economy and is essential to evaluate the stance of monetary policy at a particular point in time. Even if a central bank's policy objective is low inflation, monetary policy may well be restrictive because of effects that the policy has on other asset prices and quantities, (ii) monetary policymakers must have an accurate assessment of the timing and effect of their policies on the economy to decide on how to set policy instruments. Thus, it is important to understand the mechanisms through which monetary policy influences real economic activity and inflation in order to make accurate assessment essential (Boivin et al., 2010).

Determining the inter-relationships between several macroeconomic variables is a question of interest to policymakers. Traditionally, estimation of the MTM (or features such as impulse responses) was considered as a major goal of macroeconomic research, when analysing the impact of monetary policy changes. However, empirical studies show two important aspects: (i) the transmission mechanism may not be constant over time, (ii) the way the exogenous shocks are generated (and, in particular, their variance) can change over time (see Koop et al., 2009). There are also two phases in MTM. The first phase determines the transfer of changes in the monetary policy practices to the financial market conditions such as market interest rates, asset prices and exchange rates. The second phase refers to how the changes in financial market conditions change the production levels and inflation (Cicek, 2005; Cengiz, 2009). There are also two important contrasting views worth reviewing to comprehend the historical developments in the understanding of the MTM. These are the Keynesian MTM and the Monetarist MTM views.

The Keynesians describe the transmission mechanism based on the IS/LM model. The disequilibrium in the money market, induced by an open market operation, causes an adjustment of interest rates, which in turn affects the level of aggregate demand. The IS/LM implicitly separates the consumption-saving decision from portfolio decisions. The decisions represent part of a single utility maximisation problem for the monetarists (Friedman et al., 1963). The variables that affect consumption implicitly affect portfolio decisions, and vice-versa (Palley, 1993). Subsequently, disequilibrium in the money market can lead directly into the goods and bond markets. Palley also discusses that the monetarist transmission mechanism is broader than the Keynesian transmission mechanism. Expansionary open market operation, initially, creates an excess supply of money balances matched by excess demands for bonds and goods. If firms satisfy the demand for goods, it results in excess demand for inventory, and will have excess money balances because of increased sales.

Meltzer (1995) argues that the movement of asset price plays a central role than the interest rates channel in the transmission mechanism. The monetarist accounts of the traditional Keynesian model question the view that the full thrust of monetary policy actions is summarised by movements in the short-term nominal interest rate. Monetarists argue instead that monetary policy actions impact prices simultaneously across a wide variety of markets for financial assets and durable goods, but especially in the markets for equities and real estate, and that those asset price movements are all capable of generating important wealth effects that impact, through spending, output and employment. According to the Keynesian view, the monetary policy shocks pass to commercial banks' reserve and money supply and impacts the total output through interest rate and investment expenditures (Mishkin, 1997). On the other hand, the monetarist approach claims that the changes in the monetary policy brings changes in the money supply which impacts total output through changes in interest rate.

Given the vast contribution to the body of knowledge and understanding of how the transmission mechanism works, studies suggest that the transmission mechanism may have changed. Karasoy et al. (2005) find evidence of a changed monetary policy rule; Kara and Ogunc (2005) argue that the impact of the exchange rate on the domestic economy has changed, while Basci et al. (2007) argue that the importance of interest rates and domestic credit has changed. Boivin et al. (2010) claim that the advent of the 2007 financial crisis brought significant changes due to new institutional arrangements in credit market and changes in the way expectations are formed. Furthermore, Catik and Martin (2012) affirm that transmission reflects structural macroeconomic relationships as well as the behaviour of policymakers. Changes in the policymaking environment and the structural changes in the credit market may have changed the transmission mechanism. Although there are some indications that the mechanism has changed, the paths and contributing factors in the UK context are not yet studied.

3.2.1 The Key Assumptions of MTM

The components of the monetary base such as currency and bank reserves are central bank liabilities, so central banks control the monetary base in the transmission mechanism. At the very start, monetary policy actions begin when the central bank changes the monetary base through an open market operation, purchasing other securities, such as government bonds to increase the monetary base or selling securities to decrease the monetary base. There are two important assumptions of MTM worth mentioning: (i) if the policy-induced movements in the monetary base are to have any impact beyond their immediate effects on the central bank's balance sheet, other agents must lack the ability to offset them exactly by changing the quantity or composition of their own liabilities. Thus, the theory or models of MTM must assume that there exists no privately-issued securities that substitute perfectly for the components of the monetary base. This assumption holds if, for instance, legal restrictions prevent private agents from issuing liabilities having one or more characteristics of currency and bank reserves. Furthermore, (ii) both currency and bank reserves are nominally denominated, their quantities measured in terms of the economy's unit of account. Hence, if policy-induced movements in the nominal monetary base are to have real effects, nominal prices must not be able to respond immediately to those movements in a way that leaves the real value of the monetary base unchanged. Thus, theory or models of the MTM also assume that some frictions in the economy work to prevent nominal prices from adjusting immediately and proportionally to at least some changes in the monetary base (Ireland, 2006).

Modern-day macroeconomic analysis centres on the transmission mechanism (see for example, Christiano et al., 1999; Boivin et al., 2010). Literature highlights the complexity of the transmission mechanism, which is seen as operating through many distinct channels. Mishkin (1996) distinguishes between interest rate, exchange rate, equity price, bank lending and separate corporate and household balance sheet channels. Boivin et al. (2010) discuss interest rate, wealth, intertemporal substitution, exchange rate, bank-based and balance sheet channels. Other models highlight alternatives such as liquidity and risk-taking channels (Cooley and Quadrini, 2004). Central banks also highlight the diverse ways in which policy rates affect the real economy. Studies have been attempting to unlock the mystery embedded what Bernanke calls the “black box” (Catik and Martin, 2012). Their empirical study on macroeconomic transitions and the transmission mechanism shows that the traditional MTM may have changed due to the forces in the macroeconomic and financial sectors.

3.2.2 The Credit and Money Views of MTM

Traditionally, the monetary policy induced impulses are thought to be transmitted via money or credit channels, hence the *Money* versus *Credit View* of monetary policy. According to the money view, changes in the nominal quantity of money affect spending directly, whereas in the credit view, open market operations induce changes in interest rates that affect spending. The credit view further states that credit rationing and financial accelerator can have additional effects on output and prices (Davoodi et al., 2013). Most models rely on some form of nominal price or wage rigidity to draw the hypothesized links between money, interest rates, and output. These are the views surrounding the debate in the channels of the transmission mechanism. The proponents of the *Money View* assert that monetary policy influences price and rates of return on assets, interest rates and exchange rates. The changes in the rates of return on assets affect the real decisions of households and firms. According to this assertion, banks provide a medium of exchange in terms of issuing deposits and therefore transmit the initial policy change automatically. This theory/view takes money as a special factor but the role of bonds and bank credit are considered to be perfect substitutes that equally play the role of money. The view also places prominence on the changes in the monetary aggregate affecting the output through interest rate channel. The *Money View* has been a standard feature in the traditional Keynesian model. According to this traditional view, banks are considered as inactive entities and their influence in the economy is non-existence (Kashyap and Stein, 1997).

The advocates of the *Credit View*, on the other hand, strongly criticised the money view as it ignores the role of the credit market. The *Credit View* stresses that bonds and credits are imperfect substitutes[29] and is through credit that the impacts of monetary policy changes amplify shocks through the transmission mechanism. The view rejects the notion that all non-monetary assets are perfect substitutes. It also highlights that credit plays an important role in the transmission mechanism (see Bernanke and Gertler, 1995) and bank credit influences the aggregate spending level. The *Credit View* provides a major theoretical underpinning of the effectiveness of monetary policy. Notably, it highlights the fact that information asymmetries between borrowers and lenders in financial markets provide a particular role to banks in reducing information costs and they provide funding to a number of firms and other banks. Financial intermediaries, such as banks, provide the benefit of risk-sharing, liquidity and information services (Bernanke et al., 1998; Wu, 1999).

Literature (e.g. Lensink and Sterken, 2002; Catik and Martin, 2012; Hubbard, 1995; Bernanke, 1995; Ramey, 1993) argues that monetary transmission primarily takes place via changes in interest rates; others point at the importance of balance sheets, bank lending, asset prices and/or exchange rates. It is useful to distinguish the relative importance of the transmission channels and the mechanism through which the pass-through system operates. Understanding the channels through

[29] Blinder and Stiglitz (1983) also argue that monetary policy works through bank credit for there are no close substitutes for it, at least as far as most medium and small firms with relatively high risk are concerned (Wu, 1999).

which monetary policy affects economic variables is a key research topic in macroeconomics and a central element of economic policy analysis. The understanding of the pass-through mechanism also provides significant advantage to the monetary authorities and policymakers. The monetary transmission mechanism works through various channels, affecting different variables at various speeds. The channels determine the most effective set of policy instruments, the timing of policy changes, and hence the main restrictions that central banks face in the decision making process (Yiding and Shuanghong, 2003). There is a consensus among economists that the instruments of monetary policy are able to generate real effects at least in the short-run. However, the exact mechanism is still the subject of controversial debate (Mishkin, 2011).

Research in modern macroeconomics has been intensified in the post-GFC due to a significant paradigm shift in the understanding of macroeconomic phenomena. This is mainly because of the unprecedented force that triggers a financial meltdown, both in developed and developing economies, which consequently, brought a new understanding of monetary policy impulses and the responses of various sectors of the economy through the transmission mechanism. Similarly, the "Great Moderation" framework of the MTM in the pre-GFC has failed to forecast, explain the movements of momentary and persistent shocks and measure their impact on the real economy, particularly, in the run up to the 2007 global financial crisis. To provide a deeper understanding of the mechanism and measure the degree of changes because of the major shifts and fluctuations in the real economy, it is essential to review the Neoclassical and Non-Neoclassical transmission channels.

3.3. The Channels of the MP Transmission Mechanism

3.3.1 The Neoclassical Channels

The Investment-based Channels

The theory of the interest rate channel states that monetary policymakers use their leverage over nominal short-term interest rates. This influences investment through cost of capital and purchases of durable goods. Because capital assets are long-lived and the adjustment of these stocks involve costs, businesses and households take the long view when factoring variation in interest rates into their investment decisions. Consequently, the real interest rate and the expected real appreciation of the capital asset that influence spending, will typically be related to the expected life of the asset, which is often very long. This link is formalised in traditional econometric models through direct inclusion of a long-term interest rate in the user cost formula, rather than a short-term interest rate. In the light of the recent micro-founded model, called Dynamic-Stochastic-General-Equilibrium (DSGE), this link naturally arises through a dynamic intertemporal optimality condition for investment that makes spending depend on the expected sequence of short-term interest rates (Boivin et al., 2010).

The Interest Rate Channels

In the pre-crisis period, the most widely shared view on monetary policy transmission was summarised under the *Money View* and is represented by the traditional interest rate channel. This channel explains the effect of monetary policy on aggregate spending through the changes in interest rates.[30] Originally, Keynes emphasised this channel as operating through businesses' decisions about investment spending. However, investment decisions include consumers' decisions about housing and consumer durable expenditure. An important feature of the interest rate channel is its emphasis on the *real* rather than the nominal interest rate as it affects consumer and business decisions. Moreover, it is often the real long-term interest rate rather than the short-term interest rate that is viewed as having major impact on spending (Boivin et al., 2010). The main question is- how changes in the short-term nominal interest rate induced by a central bank impact a corresponding change in the real interest rate on both short and long-term bonds.[31] (Mishkin, 1996). Taylor (1995) regarded the interest rate channel as the main channel of monetary policy. This channel emphasises the role played by the money market equilibrium in altering interest rates.

[30] The Interest Rate Channel is also known as the first transmission channel and is a primary mechanism in the traditional IS/LM model (Fleming, 1962).
[31] As in Mishkin (1996), the key for this is sticky prices, so that expansionary monetary policy, which lowers the short-term nominal interest rate, also lowers the short-term real interest rate, and this would still be true even in a world with rational expectations.

Given some degree of price stickiness, an increase in nominal interest rate translates into an increase in the real rate of interest and the user cost of capital (see Figure 3.1). These changes in turn lead to a postponement in consumption or a reduction in investment spending. The price and wage rigidities in the short-run real interest rates change the aggregate demand and output.[32]

Ramey (1993) highlights two assumptions on the mechanism of the interest rate channel. The *first* assumption states that central banks can affect the short-term nominal interest rate to influence both the short-term and long-term real interest rates. The concept of "Price stickiness" helps to understand the transmission from nominal to real short-term interest rates. This is because the aggregate price level changes slowly due to factors, such as menu costs and money illusion. An expansionary monetary policy shock lowers not only the nominal but also the real short-term interest rate. The *second* assumption is that investment and consumption expenditures are sensitive to changes in the real interest rate. The more reactive interest rates are the greater is the impact of monetary stimulus. This is plausible for long-term investments, such as business fixed investment, residential housing investment and consumer durable spending. According to the basic IS/LM model (as in Fleming, 1962 and Mundell, 1963), the interest rate channels have been a standard feature in the literature for over fifty years and are the key channels in the MTM. The traditional Keynesian IS/LM view of the expansionary monetary policy can be characterised by the following schematic MTM: $Money\ Suply \uparrow \rightarrow Interest\ Rate \downarrow \rightarrow \ Investment \uparrow \rightarrow \ Output \uparrow$.

Critics of this view argue that the money view provides an incomplete story of how monetary policy works. On the theoretical front, this view largely ignores the potential links between output behaviour and the performance of credit markets. The criticism goes back to Gurley and Shaw (1960) who stressed the importance of the economy's overall financial capacity, which refers to the measure of borrowers' ability to absorb debt, without having to reduce either current spending or future spending commitments.[33] On the empirical ground, the way the monetary policy-induced interest rate changes affect real activities poses some important puzzles (Bernanke and Gertler, 1995). These puzzles are related to the magnitude and timing of the real effect of the monetary policy shocks, and hence difficult to explain solely in terms of the conventional interest rate effects. The magnitude is puzzling because the macroeconomic response to the monetary policy-induced interest rate changes is considerably larger than that implied by the conventional estimates of the interest rate elasticities of consumption and investment. As for the timing puzzle, there is poor

[32] This is the mechanism embodied in conventional specifications of the "IS" as in the "Old Keynesian" model, or the forward looking equations at the heart of the "New Keynesian" macro models (Rotemberg and Woodford, 1997; CGG, 1999).

[33] Thus, financial intermediaries, both banking system and broader credit markets, are relevant to the transmission mechanism as they extend the borrowers' financial capacity. By helping overcome impediments to the flow of funds between savers and investors, these intermediaries make it feasible for certain classes of borrowers.

correspondence in timing between changes in the policy-induced interest rates and movements in some components of spending (Bernanke and Gertler, 1995).

The interest rate channel also works through expectations channel which (see Figure 3.1) plays significant role in stimulating the economy. The fact that it is the real interest rate that impacts on spending rather than the nominal rate, it provides an important mechanism for how monetary policy can stimulate the economy, even if nominal interest rates hit a zero lower bound (ZLB) during an inflationary episode (Mishkin, 1996). With nominal interest rates at ZLB, an expansion in the money supply (MS) can raise the expected price level (P^e) and hence expected inflation (π^e), thereby lowering the real interest rate (ir^r), even when the nominal interest rate is fixed at, and stimulating spending through the interest rate channel. Schematically: $Money\ Supply \uparrow \rightarrow Expected\ Price \uparrow \rightarrow Expected\ Inflation \uparrow \rightarrow Real\ Interst\ Rate \downarrow \rightarrow Investment \uparrow \rightarrow Output \uparrow$.

Bernanke and Gertler (1995) note that empirical studies have had great difficulty in identifying significant effects of interest rates through cost of capital. They see the empirical failure of interest rate MTM as having provided the stimulus for the search of other transmission mechanisms of monetary policy, especially the credit channel. Studies (e.g. Jorgenson, 1963, and Boivin, 2010), also show that the interest rate channel embedded in macroeconomic models involve the impact of the policy rates on the cost of capital and, hence on business and household investment spending. The user cost of capital is a key determinant of the demand for capital, whether it is investment goods, residential housing or consumer durables (Jorgenson, 1963). According to Boivin (2010), the user cost of capital (u_c) function is represented as:

$$u_c = p_c[(1-\tau)i - \pi_c^e + \delta] \tag{3.1}$$

where p_c is the relative price of new capital, i is the nominal interest rate, π_c^e is the expected rate of price appreciation of the capital asset, and δ is the depreciation rate. The user cost formula also allows for the deductibility of the interest rate by adjusting the nominal interest rate by the marginal tax rate τ. Regrouping terms, the user cost of capital can be rewritten, as in Boivin (2010), in terms of after-tax real interest rate, $(1-\tau)i - \pi^e$, and the expected real rate of appreciation of the capital asset, $\pi_c^e - \pi^e$, where π^e , is the expected inflation rate.

$$u_c = p_c[(1-\tau)i - \pi^e\} - \{\pi_c^e - \pi^e\} + \delta] \tag{3.2}$$

In summary, the interest rate channel is resulted from the central bank's response to economic shocks. To achieve price stability, central banks adjust the rate of interest rate paid on domestic bonds (Claus, 2011). There are two essential conditions required for money (interest rate) channel to work. *First,* banks must not be able to perfectly shield transaction balances from changes in reserves and *second*, there must be no close substitutes for money in the conduct of transactions in the economy (Romer and Romer, 1990). The effect of changes in short-term nominal interest rate is transmitted to the long-term interest rate through the mechanism of balancing demand and supply in the money market (Mishkin, 1995).

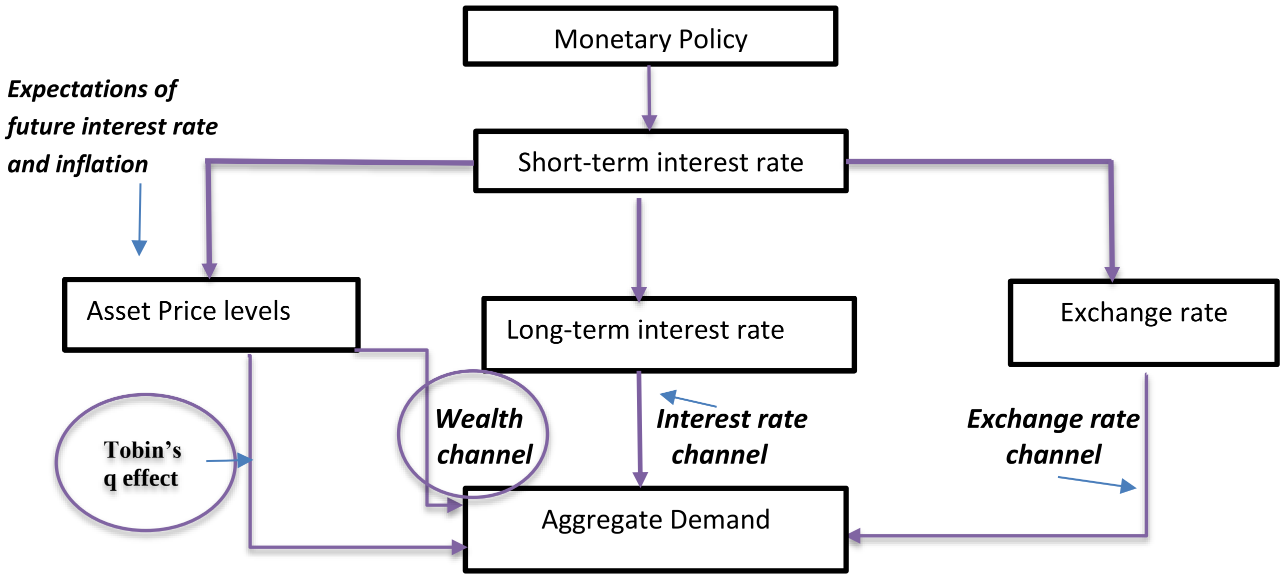
The Consumption Based Channels

The Neoclassical synthesis offered a Keynesian view of the determination of national income through a business cycles arising from changes in aggregate demand because of wage and price stickiness. The Neoclassical principles are known to guide microeconomic analysis (Bernanke and Rotemberg, 1997). Asset market values react to economic news and policy changes, and consumers react to changes in asset market values. The consumption-wealth channel of monetary policy spells out this mechanism: changes in monetary policy affect asset values, which in turn affect consumer spending on nondurable goods and services (Ludvigson et al., 2002).

The Wealth Effect - Equity/Asset Price Channel

The deepness of the macroeconomic impact of the most recent financial crisis has uncovered central banks to research further for better understanding of the linkages between policy instruments, macroeconomic aggregates and wealth composition. In addition, the unconventional measures adopted in many developed countries in the course of the crisis have highlighted the importance of the wealth channel (Castro and Sousa, 2012). Brumberg and Modigliani (1954) first developed the standard applications of the life-cycle hypothesis of saving and consumption and later improved by Ando and Modigliani (1963). Standard lifecycle, wealth effects, operates through asset prices. It specifies that consumption spending is determined by the lifetime resources of consumers, which includes wealth, whether from stock, real estate or other assets. Expansionary monetary policy in the form of lower short-term interest rates will stimulate the demand for assets such as common stocks and housing, thereby driving up their prices. Lower interest rates lower the discount rate applied to the income and service flows associated with stocks, homes, and other assets, driving up their price. The resulting increase in total wealth will then stimulate household consumption and aggregate demand. According to Boivin et al. (2010), a second consumption-based channel reflects intertemporal substitution effects. This channel is central to the models in the DSGE tradition. In this channel, changes in short-term interest rates alter the slope of the consumption profile, so that lower interest rates induce higher consumption today. In DSGE models, this channel arises through the models' use of the standard consumption Euler equation linking the marginal rate of substitution between current and future consumption with the real interest rate.

The importance of monetary-induced changes in equity prices and its impact on consumption and investment spending is highlighted by monetarists (Mishkin, 1995). The asset price channel focuses on the relative prices of a wide range of assets in the transmission of monetary impulses on the financial and real capital markets (Kosfeld, 2002). The asset price channels are also highlighted by Tobin's (1969) *q*-theory of investment (see Figure 3.1). Keynesians and Monetarists agree on how the channel works through the wealth effect and the Tobin's *q*[34] theory of investment. However, they disagree on how the monetary shock affects equity prices. As shown in Figure 3.1, all else equal, a policy-induced increase in the short-term nominal interest rate makes debt instruments such as bonds more attractive than equities; hence, following a monetary tightening, equilibrium across security markets must be re-established in part through a fall in equity prices (Ireland, 2005).



Source: Adapted from Kuttner and Mosser (2002).

Figure 3.1 The Asset Price Channel in the Transmission Mechanism

The Tobin's q Channel

Tobin's q theory provides a mechanism by which monetary policy affects the economy through its effect on the valuation of equities (Tobin, 1969)[35] and the framework consider households' and firms' investment decision in the transmission mechanism. Hayashi (1982) notes that Tobin's q theory is linked to the user cost of capital approach. In addition, the *q*- emphasises the direct link between stock prices and investment spending. Tobin's q centres a channel of monetary

[34] It measures the ratio of the stock market value of a firm to the replacement cost of the physical capital that is owned by that firm. With a lower value of q, firms find it less desirable to issue new shares of stock to finance new investment projects; hence, investment, output, and employment fall. Ando and Modigliani (1963) life-cycle theory of consumption assigns a role to wealth as well as income, as key determinants of consumer spending. This theory also identifies a channel of MT: if stock prices fall after a monetary tightening, household financial wealth declines as well, leading to a fall in consumption, output, and employment (Ireland, 2005).

[35] The transmission in terms of Tobin's q theory of investment works as follows (Poddar et al., 2006:pp6-7): "If q is high, the market price of firms is high relative to the replacement cost of capital, and new plant and equipment capital is cheap relative to the market value of business firms. Companies can then issue equity and get a high price for it relative to the cost of the plant and equipment they are buying. Thus, investment spending will rise because firms can buy many new investment goods with only a small issue of equity. On the other hand, when q is low, firms will not purchase new investment goods because the market value of firms is low relative to the cost of capital. If companies want to acquire capital when q is low, they buy another firm cheaply and acquire old capital instead. Investment spending will then be low".

transmission: when monetary policy is eased and interest rates lowered, the demand for stocks increases and stock prices rise, thereby leading to increased investment spending and aggregate demand. Tobin (1969) develops the q relationship, which is still regarded as an important explanatory approach to the monetary transmission process. The empirical relationship is given by the natural (IRR) and market rates (MR) of interest. The market value (MV) of an enterprise can be calculated as the capitalised earnings value:

$$MV = \sum_{t=1}^{n} (R_t - EX_t) \frac{1}{(1 + MR)^t}, \tag{3.3}$$

where $R_t - EX_t$ is the expected surplus of receipts (R_t) over expenditure (EX_t), MR is the market interest rate. Assuming that replacement cost can be measured by the initial expenditure (EX_0) invested on the project:

$$0 = -EX_0 + \sum_{t=1}^{n} (R_t - EX_t) \frac{1}{(1 + IRR)^t}, \tag{3.4}$$

where IRR represents the internal rate of return. If one regards the internal rate of return as the natural rate of interest, the q relationship can be represented as:

$$q = \frac{MV}{EX_0} = \frac{\sum_{t=1}^{n}(R_t - EX_t)\left[\frac{1}{(1+MR)^t}\right]}{\sum_{t=1}^{n}(R_t - EX_t)\left[\frac{1}{(1+IRR)^t}\right]}, \text{ when } n \to \infty, q = \frac{IRR}{MR} \tag{3.5}$$

The theory illustrates that there is a link between *Tobin's* q and investment spending. However, the question is - how might monetary policy affects equity prices. According to the monetarists' view, when the money supply rises, the public tends to have more money then it tends to reduce the holdings of money by increasing their spending. The Keynesian story comes to a similar conclusion because the fall in interest rates stemming from expansionary monetary policymaking bonds less attractive relative to equities, thereby causing the price of equities to rise. Furthermore, as the market value of an enterprise can be calculated by the share prices, monetary policy can affect the investment of firms by affecting stock markets. When monetary policy is expansionary, the public finds that it has more money and will spend more on stocks, consequently raising the share prices. Higher stock prices will lead to a higher q and thus to higher investment expenditure I (as in Mishkin, 2001): Combining these views with the fact that higher equity prices ($P^e \uparrow$) lead to a higher q ($q \uparrow$) and thus higher investment spending ($I \uparrow$) leads to the following transmission mechanism: $Money\ Supply \uparrow \to\ P^e \uparrow \to\ q \uparrow \to Investment \uparrow \to Output \uparrow$.

An alternative channel for monetary transmission through equity prices occurs through wealth effects on consumption. According to Modigliani (1971) MPS model, consumption spending is determined by the lifetime resources of consumers, which is made up of both human capital, real capital and financial wealth. When stock prices increase, the value of financial wealth increases, thus increasing the lifetime resources of consumers, and consumption is expected to rise. Therefore, expansionary monetary policy can lead to a rise in stock prices $(P^e \uparrow)$ which leads to the alternative monetary transmission mechanism: $MS \uparrow \rightarrow\ P^e \uparrow \rightarrow\ Wealth \uparrow \rightarrow\ Consumption \uparrow \rightarrow\ Y \uparrow$.

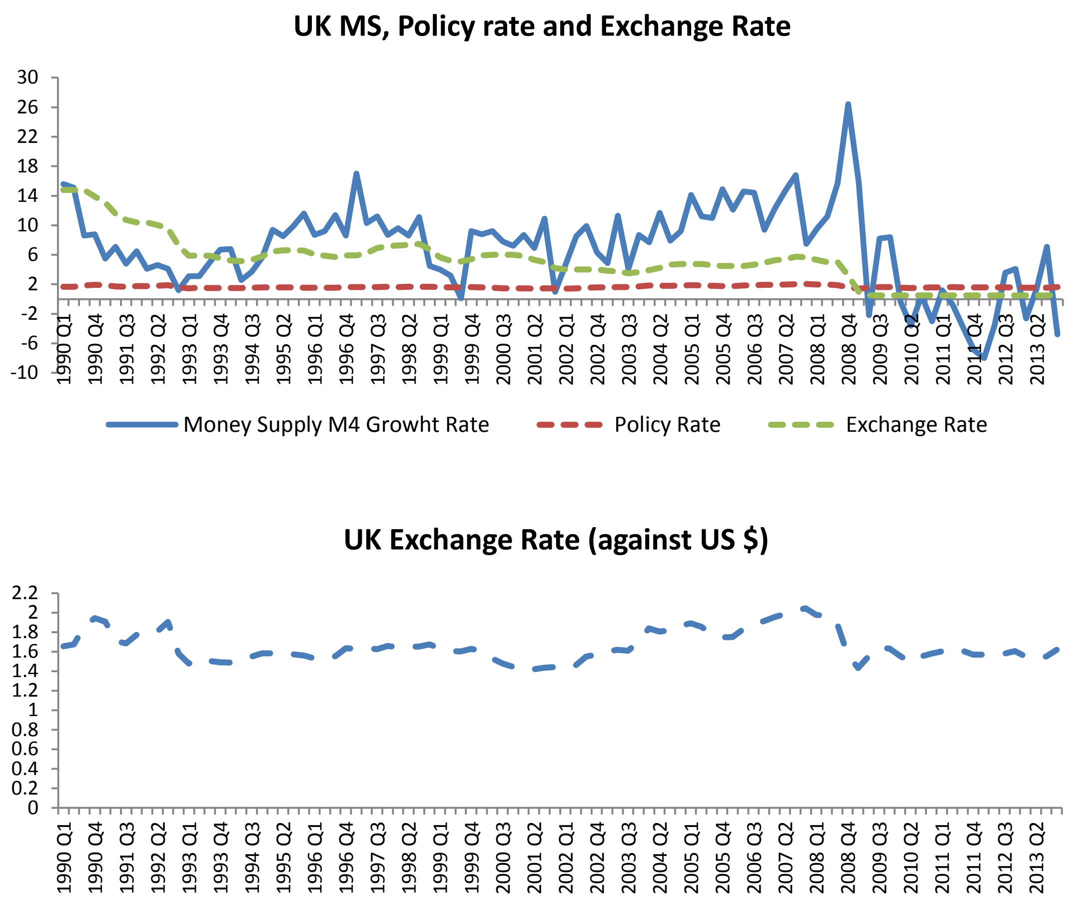
The International-Trade based Channels

When the central bank lowers interest rates, the return on domestic assets falls relative to foreign assets. Consequently, the value of domestic assets relative to other currency assets falls, and the domestic currency depreciates. The lower value of the domestic currency makes domestic goods cheaper than foreign goods, thereby leading to a rise in net exports. The rise in net exports adds directly to aggregate demand. Thus, the exchange rate channel plays an important role in how monetary policy affects the economy. In this regard, two factors are important: *first*, the sensitivity of the exchange rate to interest rate movements; *second*, small open economies tend to see larger effects through this channel (see Bryant et al., 1993; Taylor, 1993, and Smets, 1995).

The Exchange Rate Channel

The exchange rate is also one of the most important channels through which monetary policy affects the real economy. It operates through international trade. An expansionary monetary policy, which decreases the short-term interest rate, makes domestic goods cheaper relative to foreign goods, consequently, increases aggregate demand. Moreover, the exchange rate channel depends on the sensitivity of the exchange rate to changes in the interest rate. The channel, as stated in Claus (2011), operates through net exports. Real exchange rate changes affect the cost of commodity imports, which are an input in firms' production. They also affect the price of exports and the foreign demand for firms' domestic output.

Literature such as Bryant et al. (1993); Taylor (1993); Smets (1995), and Gumata et al. (2013), shows empirical evidence on the importance of the exchange rate channel in small and open economies with flexible exchange rate regimes. The ISLM paradigm that analyses monetary policy effects on the economy focuses on asset price and the interest rate channels (Loayza and Schmidt-Hebbel, 2002). There are two key assets, besides bonds that receive substantial attention in the literature on the transmission mechanism. These are foreign exchange and equities (Mishkin, 1996). With the growing internationalisation of the world economy and the initiation of flexible exchange rates, more attention has been paid to monetary policy transmission operating through exchange rate effects on net exports. This channel also involves interest rate effects because when domestic real interest rates fall (see Figure 3.2), domestic currency deposits become less attractive relative to deposits denominated in foreign currencies. This leads to a fall in the value of the local currency deposits relative to other currency deposits resulting in a depreciation of the domestic currency (denoted by $Ex \downarrow$), thereby causing a rise in net exports ($NX \uparrow$) and hence in aggregate output. The MTM operating through the exchange rate is thus: $Money\ Supply \uparrow \rightarrow\ interest\ rate\ \downarrow \rightarrow$ $Exchange\ rte \downarrow \rightarrow Net\ Export \uparrow \rightarrow Output\ \uparrow$.

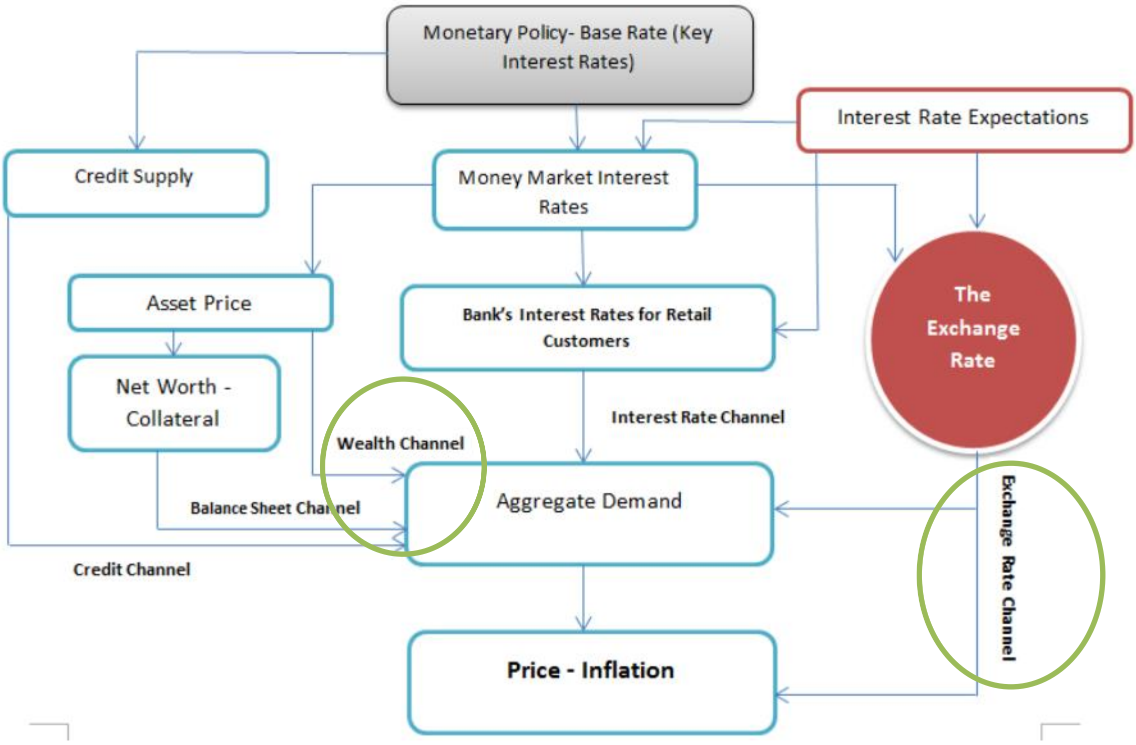


Source: author's analysis.

Figure 3.2 Movements of Exchange Rate and Money Supply Growth in the TM

Similarly, the exchange rate channel works through both aggregate demand and aggregate supply effects. On the demand side, a monetary expansion lowers the domestic real interest rate, which, through the foreign interest parity condition, brings about a real depreciation of the domestic currency. This in turn leads to higher net exports and stronger aggregate demand. On the supply side, the real depreciation that results from a monetary expansion raises the domestic prices of imported goods, raising inflation directly. Moreover, the higher import price contracts aggregate supply, reducing output and increasing inflation (Loayza and Schmidt-Hebbel, 2002). In terms of capital movements, Taylor (1995) indicates that a rise in domestic interest rate causes inflow of capital. In floating exchange rate regime, an appreciation of domestic currency leads to a fall in net export and output. In a fixed exchange rate regime, however, the resultant inflow of capital will be sterilised by an increase in the money supply in an attempt to minimise the fluctuation in the parity.

This may make the initial expansion in money supply redundant and the impact of policy will not be transmitted into exchange rate (Shabbir, 2008). Kuttner and Mosser (2002) also note that this channel is an important element in conventional open-economy macroeconomic models, although it is often neglected in the closed-economy models. The chain of transmission runs from interest rates to the exchange rate via the interest rate parity condition relating interest rate differentials to expected exchange rate movements. Thus, an increase in the domestic interest rate, relative to foreign rates, would lead to a stronger currency and a reduction both in net exports and in the overall level of aggregate demand.



Source: Based on Kuttner and Mosser, (2002).

Figure 3.3 The Exchange Rate and Wealth Channel in the TM

In summary, one can plainly describe the function of this channel in such a way that, when the central bank decreases the policy rate, what follows is adjustments in short-term money market rates. Because of this, businesses' return on domestic investment decline relative to those from foreign investments. This causes outflows of capital, which causes the local currency to depreciate which is benefiting exports, and business expansion, which brings more employment, and finally stimulate consumption. At the same time, depreciation in the local currency causes expensive imports, volume of imports to decline but increases domestic aggregate demand. Subsequently, net exports increase which eventually leads to higher economic growth.

3.3.2 The Non-Neoclassical Channels

The second type of transmission mechanism, which was first proposed by Bernanke and Gertler (1995) as the "credit channel" and is identified as the Non-Neoclassical channel by Boivin et al. (2010). This channel is a result of market imperfections and frictions in credit markets based on the asymmetry of information between lenders and borrowers. Small firms and households that are highly dependent on bank loans are affected by this channel (Gumata et al., 2013). The credit channel also arises either from government interference in markets or through imperfections in private markets, such as market segmentation that leads to barriers to efficient financial markets functioning. Hence, the Non-Neoclassical transmission mechanism involves market imperfections in credit markets and has been given the name - the "*Credit View*". According to Boivin et al. (2010)[36], three basic Non-Neoclassical channels affect credit supply. These are the government credit supply channel, the bank-based channels (through lending and bank capital) and the balance sheet channels (affecting both firms and households).

The Government Credit Supply Channel

Although a free market creed propounds a market free from government intervention, the reality does not conform to the credit market. Governments of DCs and LDCs interfere regularly with the free functioning of credit markets. They do so in order to achieve certain policy objectives such as redistribution, market control, stimulation of capital investment and encouraging household spending and consumption. This interference has been important in the U.S., until the 1980s, where the government intervene in the housing market through mortgage credits. Up until the 1980s, prudent institutions (savings and loan associations) were the primary issuers of residential mortgages.

These institutions primarily made long-term, fixed-rate mortgage loans in their local areas, using funds provided by local time deposits. Government regulation was made through establishing ceilings on the interest rates of deposits under Regulation Q[37] in order to help thrift institutions to attract deposit funding and enabling them to make more mortgage loans. The two pass through effects lead to a decline in credit supply to the mortgage market when the central bank tightens policy. According to Boivin et al. (2010), this process operates as follows: *first*, the contractionary monetary policy effect leads to a decline in credit supply. This works through increasing cost of funds as a result of high interest rate leading to banks' weak balance sheet which results in credit

[36] See also Jorgenson (1963); Tobin (1969); Brumberg and Modigliani (1954); Ando and Modigliani (1963), and Friedman (2008) for further discussion on the NCTM.

[37] Regulation Q is a FRB regulation that prohibited banks from being able to pay interest on deposits within checking accounts (Cook, 1978).

supply contraction; *second*, the effect that leads to a decline in credit supply works through contraction in mortgage credit. This effect exacerbated due to depositors' decision to withdraw their funds due to lower deposit rates. In both first and second effects, the credit supply declines and these negatively affect investment and aggregate demand. To stimulate the credit market and achieve policy objectives, governments intervene by way of injecting money into the credit market.

Extensive government intervention has been a major phenomenon in the recent financial crisis (2007/8) in the U.S. and the European Union. The U.S. government intervene in the credit market in the form of bailout, which amounted to $1.3 trillion, and several European Union member countries (e.g. Spain, Republic of Ireland and Greece) bailed out the credit market amounted to $2.8 trillion. In total, the bailouts by the western nations amounted to $4.1 trillion in commitments (Anderson et al., 2008). Although there has been significant level of intervention in the financial market by government and central banks to bailout failing FIs, developed countries have continued to inject liquid money into their economy to provide financial liquidity to MFIs in the form of QE.

3.3.3 The Bank Based Channels

Theoretical Underpinnings of the Credit Channel

The theory of the credit channel of the MTM states that monetary policy changes impact the amount of credit that banks issue to businesses and individuals, which consequently affect employment and the economy. Unlike the conventional MTM, such as the interest rate channel, the credit channel, in the contemporary macroeconomics understanding, is an indirect amplification mechanism. The credit channel works in tandem with the interest rate channel, which affects the economy by changing the amount of credit available for firms and households. Factors that reduce the availability of credit reduce agents' spending and investment, which leads to a reduction in employment and output. The major difference between the conventional interest rate channel and the credit channel mechanism is on how spending and investment decisions change due to monetary policy shocks (BGG, 1996). This credit channel is synonymous to the "credit view". It arises due to the existence of asymmetric information and costly enforcement of contracts in the financial markets that give rise to an external financial premium charged on top of the market interest rates (Bernanke and Gertler, 1995). Since the external financial premium charge, is unlikely to be equal across the spectrum of capital markets, funds from different segments of capital markets entail different costs and, accordingly, are not perfect substitutes. Bank loans carry less external premium than those intermediated through open financial market (via issuance of stocks or bonds), since the latter involves more costly enforcement of contracts which can only be afforded by large firms, making small and medium firms mainly dependent on bank credits (Fiorentini and Tamborini, 2001).[38] Furthermore, studies by Bernanke and Gertler (1995) and Bernanke (2007) show that the asymmetric information exists between borrowers and lenders. Claus (2011) argues that entrepreneurs, who are borrowers, must obtain external financing from households through financial intermediaries. Because entrepreneurs are subjected to idiosyncratic technology shocks that can only be observed costlessly by entrepreneurs, it leads to agency costs. Therefore, to obtain external financing, entrepreneurs are required to have collateral. Because of this friction, an external finance premium exists; hence, the credit channel arises from the impact of monetary shocks on entrepreneurs' net worth and their ability to borrow.

Bernanke and Gertler (1995) initially disputed the traditional view, which states that the increases in aggregate demand and production volume can only be explained by the interest rate channel. They reason that the direct effects of monetary policy are on short-term interest rates. For this reason, the main effect of monetary policy changes is expected to be on assets, such as inventories and consumer durables. However, the most rapid and powerful effects of monetary policy are on the housing investments which are sensitive to long-term real interest rates. Similarly, the interest rate channel is criticised since the model considers only the two variables, money and bonds, and does not consider the effects of credit on total expenditure. It also ignores the fact that investment decisions of firms are mainly dependent on long-term interest rates, even though the short-term interest rates can be controlled by the central bank (Meltzer, 1995; Bernanke, 1993). The credit channel emphasises the importance of the credit markets. As in Bernanke and Gertler (1995), the interest rate channel is unable to explain the following two observed phenomena: *first*, spending is found to be insensitive to the interest rate. *Second*, why monetary policy has large effect on long-lived assets, which respond to real long-term rates, given the fact that policy must have strongest effects on short-term rates and weakest effect on long-term rates? "While a broad consensus seems to have formed on several aspects of the problem, other areas remain controversial. One area of debate is the relative importance of the money and credit channels in the transmission of monetary policy" (Ramey, 1993: p1-2). Ramey suggests that the effect of some of the leading credit channel variables in the transmission mechanism is negligible. Furthermore, Shabbir (2008) argues that the credit channel is not a separate channel rather it simply amplifies and propagates the monetary policy shocks that pass through the traditional transmission channel.

[38] Financially, large-scale firms are usually less constrained than small and medium firms (SMFs) in terms of their access to external funding. Accordingly, the investment spending by different firms of different financial structure has different sensitivity to financial shocks. Their investment spending depends, to a different degree, on three factors (a) the benchmark market rate, (b) the external premium on the various types of funds, and (c) the extent they are financially constrained.

Kuttner and Mosser (2002) also dispute that the credit channel is not in any sense an alternative to the monetary channel. It is an additional way in which changes in monetary policy affect private spending. The main message is that there are important differences in which the different sectors of the economy react to changes in monetary policy. For example, although the contribution of small firms' sector to total output is still relatively small, its contribution to variability of output is large. The aggregate figures for money and credit may conceal important sector differences between small business and large companies. Bernanke and Blinder (1988) highlight the validity of the credit channel in such a way that unlike the traditional channel, the credit channel takes into account three different assets such as money, securities and bank credits. It is assumed that bank credits and securities do not fully substitute each other. For example, if banks, whose deposit volume decreases due to contractionary monetary policy, they compensate for the decrease in their reserves by reducing the credit supply instead of selling securities. Although Bernanke and Gertler (1995) highlight the importance of the credit channel of the TM long ago, its role is now being recognised with the advancement of the New Keynesian economics and the significant role it has played in the recent global financial crisis, which underlines the prominence of this channel.[39]

A monetary policy shock, which alters interest rates, tends to affect the external finance premium in the same direction. That is, a monetary policy tightening increases market interest rates as well as the external premium. These, the direct effects of monetary policy on interest rate are amplified by changes in the external financial premium (Fiorentini and Tamborini, 2001). There are two possible linkages of the credit channel theory, which can be illustrated within the context of the credit view: the *narrow view* and the *broad view*. The narrow view underlines the *bank lending channel* focusing on the possible effect of monetary policy actions on the supply of loans. The broad view features the *balance sheet channel* emphasising on the impact of the changes in monetary policy on the borrower's balance sheet[40]. Figure 3.6 displays the role of the credit channel, which is typified, based on a rise in policy rate. The credit channel theory offers a well-documented alternative explanation for the real effect of monetary policy. According to this theory, monetary policy can also affect the amount of lending by having an impact on borrowers' balance sheets related to the value of collateral and on lender sensitivity to these balance sheets. This channel of monetary transmission explains the effectiveness of monetary policy by focusing on the borrower side of financial contracts (Aysun and Hepp, 2013). The transmission of monetary policy shocks to

[39] The idea of credit channel is that certain borrowers, typically small businesses and households, are heavily dependent on banks as a source of finance. Hence, the interest rates change on bank loans rather than market rates or rates charged by other financial intermediaries may have a disproportionate effect on spending by this type of borrower. Banks have information about their customers, which is costly for other financial intermediaries to acquire. As a result, bank assets are not perfect substitutes for other types of loan. Decisions made by banks about their Spreads between borrowing and lending rates have an impact on nominal spending (BoE, 2010).

[40] See also Bernanke and Gertler (1995); Lensink and Sterken (2002); Aysun and Hepp, (2013).

the real economy through the lending and balance sheet channels of monetary transmission is explained by asymmetric information costs in credit markets (Bernanke and Gertler, 1995).

3.3.3.1 The NNC Bank Lending Channel (BLC)

The explanation behind the bank lending channel is based on the view that banks play a special role in the financial system because they are well suited to solve asymmetric information problems in credit markets. Because of banks' special role, certain borrowers will not have access to the credit markets unless they borrow from banks. As long as there is no perfect substitutability of retail bank deposits with other sources of funds, the bank lending channel of monetary transmission operates as follows. Expansionary monetary policy can lead to improved bank balance sheets in two ways. *First,* lower short-term interest rates tend to increase net interest margins and so leads to higher bank profits which result in an improvement in bank balance sheets over time. *Second*, expansionary monetary policy can raise asset prices and lead to immediate increases in bank capital. In the bank capital channel, expansionary monetary policy boosts bank capital, lending, and hence aggregate demand by enabling bank-dependent borrowers to spend more (Boivin et al., 2010). Similarly, a strong bank balance sheet increases bank reserves and bank deposits that enhance the quality of bank loans available. Given banks' special role as lenders to classes of bank borrowers, this increase in loans will cause investment and possible consumer spending to rise (Mishkin, 1996). Schematically, the monetary policy effect is represented as follows: $Money\ Supply \uparrow \rightarrow Bank\ Deposits \uparrow \rightarrow\ Bank\ Capital \uparrow \rightarrow\ Bank\ Loans \uparrow \rightarrow\ Investment \uparrow \rightarrow \text{Output} \uparrow$.

The effect of bank lending channel depends on the size of a firm. The channel will have a greater effect on expenditure by smaller firms, which are more dependent on bank loans than it will on large firms, which can also get funds directly through stock and bond markets. This leads to a separate bank channel usually called the *bank capital channel*. In this channel, the state of banks' and other financial intermediaries' balance sheets has an important impact on lending. A fall in asset prices can lead to losses in banks' loan portfolios; alternatively, a decline in credit quality. This is because borrowers are less able or willing to pay back their loans, which may reduce the value of bank assets. The resulting losses in bank assets can result in shrinking of bank capital. The shortage of bank capital can then lead to a cutback in the supply of bank credit, as external financing for banks can be costly, particularly during a period of declining asset prices. This implies that the most cost-effective way for banks to increase their capital to asset ratio is to shrink their asset base by cutting back on lending (Markovic, 2006). This is called "deleveraging", according to Boivin and Giannoni (2006), which means that bank-dependent borrowers are no longer able to get credit and so they will cut back their spending and aggregate demand will fall. Iacoviello and Minetti (2008) show the presence of a bank-lending channel for households in countries where mortgage finance is more bank dependent. At times of GFC, when the financial market is not functioning, i.e. when some banks are unable to access the interbank markets, the interest rate and the bank lending channel can break down. As a result, banks could shut out of the money markets and be forced into asset sales. In these circumstances, the pressure on bank balance sheets can be severe and prevents banks from expanding the supply of credit. The lack of credit in the money market severely affects businesses and lowers aggregate demand and output.

Doubts about the bank lending channel have been raised in the literature (see for example Ramey, 1993, and Meltzer, 1995). Though the bank lending channel has been supported in empirical works by Iacoviello and Minetti (2008); Gertler and Gilchrist (1993, 1994), and Peek and Rosengren (2010), among others, it has raised doubts about its existence and the way it works in the transmission mechanism (see also Romer and Romer, 1989, and Ramey, 1993). Similarly, Bernanke and Gertler (1995) argue that the bank lending channel is not an independent mechanism, but rather a special amplifier of the conventional interest rate channel. They introduce the external finance premium, which is defined as the difference in cost between funds raised externally (by issuing debt or equity) and internally (retained earnings). They state that a change in the monetary policy that raises or lowers open market interest rates usually changes external finance premium in the same direction. The size of this premium reflects the degree of imperfections in credit markets that determines the discrepancy between the expected return received by lenders and the costs faced by potential borrowers. They also note that the impact of monetary policy on borrowing cost and on real activity is amplified due to the additional effect of monetary policy on external finance premium. Thus, they treat bank-lending channel as a connection that explains impact of actions taken by central bank on external finance rather than being a separate channel.

According to Mishkin (1996), the bank lending channel assumes that monetary policy changes will drain bank deposits. Consequently, banks cannot easily replace the shortfall in deposits by issuing other uninsured liabilities, hence imperfect substitution. Bernanke (2007) notes that banks can raise funds through liabilities that pay market interest rates, which then exposes them to an external finance premium as well. Forms of uninsured lending carry some credit risk relative to insured deposits. The cost of raising uninsured funds will reflect that risk, and will be more expensive for banks to purchase. Similar practices have been observed in the UK in terms of secured and unsecured lending. As shown in Figure 3.4 and 3.5, the amount of loan extended by the UK banks exponentially increased between 2003 and 2007 in terms of net total lending with its major share comes from secured lending. This exponential growth takes around 10% share of the UK GDP, which may have contributed to the severity of the impact on UK banks' credit supply shocks during the GFC.

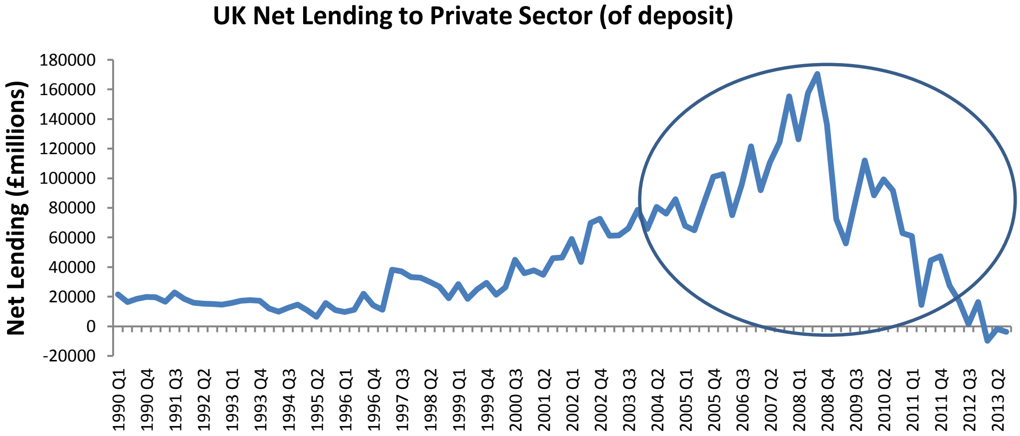
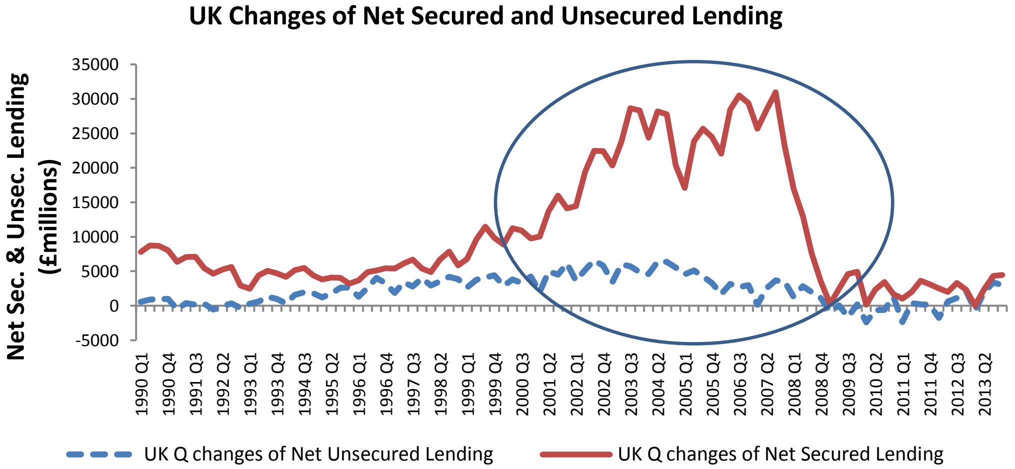


Figure 3.4 The UK Total Net Lending to Private Sector from 1990Q1 to 2014Q4



Source: author's analysis.

Figure 3.5 The UK Changes of NS and NUS Lending from 1990Q1 to 2014Q4

Monetary contraction, on the other hand, raises the reserve requirements and reduces banks' core deposit base and forces banks to raise funds from other (new) sources thus, increasing banks' relative costs of funds and making banks reduce the supply of loans. Consequently, bank dependent borrowers have to bear additional costs to find a new lender and establish credit relationship, which is likely to increase the external finance premium and hence drive real economic activity down.

3.3.3.2 The NNC Balance Sheet Channel (BSC)

According to Townsend (1979) and BGG (1996), the balance sheet channel posits that the size of the external finance premium should be inversely related to the borrower's net worth $\left(EFP = \frac{1}{NW}\right)$.[41] Similarly, the balance sheet channel arises from the presence of asymmetric

[41] Meaning that the greater the net worth, the more likely the borrower may be to use self-financing as a means to fund investment. The higher net worth agents may have more collateral for the funds they need to borrow. A fully collateralised agent faces lower cost of borrowing than a less collateralised agent does. Consequently, lenders assume less risk when lending to highly collateralised agents and agency costs are lower. The cost of raising external funds

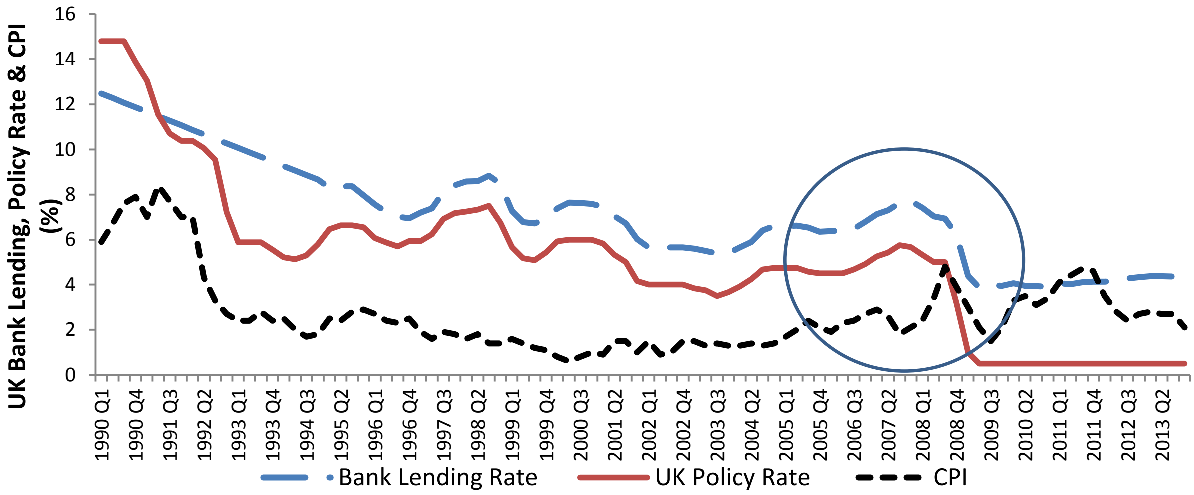
information problems in credit markets. When an agent's net worth falls, adverse selection and moral hazard problems increase in credit markets. Lower net worth means that the agent has less collateral, thereby increasing adverse selection and increasing the incentive to boost risk-taking, thus exacerbating the moral hazard problem. As a result, lenders will be more reluctant to make loans (either by demanding higher risk premia or curtailing the quantity of the loan), leading to a decline in spending and aggregate demand. A particularly convenient and widely adopted model of this type is the financial accelerator framework of BG (1989) and BGG (1999), in which lower net worth increases the problems associated with asymmetric information in debt financing, thereby increasing the external finance premium. The presence of asymmetric information and collateral constraints in the credit market cause financial frictions.

Monetary policy affects firms' balance sheets in several ways. *First*, contractionary monetary policy leads to a decline in asset prices, particularly equity prices, which lowers the net worth of firms and causes adverse selection and moral hazard problems to worsen. *Second*, monetary policy can affect firms' balance sheets through cash flow. Contractionary monetary policy, which raises interest rates, causes firms' interest payments to rise, thereby causing cash flow to fall. With less cash flow, firms have fewer internal funds and must raise funds externally. Therefore, additional reliance on external funds increases the cost of capital, curtailing lending; investment and economic activity (see also Curdia and Woodford, 2009, and Carlstrom et al., 2009). The theory of balance sheet channel also explains how the asymmetric information and moral hazard problems create external financial premium (EFP). A wage between the cost of funds raised externally in such a way that banks issue equities and the opportunity cost of funds raised internally by retaining earnings (Hall, 2008) represent EFP. A tight monetary policy moves the external finance premium in the same direction, thus restricting the firms' ability to obtain funds externally by deteriorating its credit worthiness and net worth.

Therefore, this channel enhances the traditional monetary channel by explaining the firm's inability in raising funds and consequently reducing investment spending in the wake of the interest rate hike (Shabbir, 2008). This approach of the credit channel theory that emphasises the role of narrow and broad monetary aggregates in determining asset, goods, and factor prices has received considerable attention since the influential paper by Bernanke and Gertler (1995). Figure 3.6 shows remarkable patterns of movements of the monetary policy rate in the run up to the GFC that led to bank lending rate and consequently prices. From 1990Q1 to 2007Q3, the monetary target variable shows a fairly similar movement with the policy rate (a sign of positive correlation) then the pattern changes from

should therefore be lower for high net worth agents than the low net worth agents (Townsend, 1979; BG, 1989; BGG, 1996).

2007Q3 onwards. This transmission of instabilities from the base rate to the bank lending rate and other differentials is what the traditional MTM is unable to explain, as it does not recognise the amplifying role of the credit channel. The intuition behind this may lead to the fact that the recent GFC may have highlighted the role of the credit channel through the balance sheet and the bank lending channels. From 2007Q3 onwards, CPI inflation seems to follow the lending rate path rather than the policy rate. One can also argue that the government intervention in terms of holding the base rate at 0.5% and the provision of credit to FI's may have played some roles to increase inflation for some periods. Form the demand side, there is clear evidence to state that the low interest base rate has failed to stimulate aggregate demand and employment in the post-GFC as it was originally thought, despite several efforts made by the monetary policy authority. One can invoke the argument that either the mechanism of the monetary policy transmission has changed or there is another channel, working at the interim stages of the transmission mechanism.



Source: author's analysis.

Figure 3.6 The UK Bank Lending Rate, Policy Rate and Price from 1990Q1 to 2014Q4

The basic notion, as in Bernanke and Gertler, is that monetary policy can have price and output effects through the credit channel rationing from information asymmetries between financial institutions, the firms and consumers to which they lend. This occurs because monetary policy affects the extent of adverse selection and moral hazard that constrains credit provision. It is argued that a monetary expansion alleviates adverse selection and moral hazard by increasing firms' net worth (through higher real interest rates), improving firms cash flow (through lower nominal interest rates), and decreasing the burden of nominal debt contracts (by raising inflation). All these considerations tend to make banks willing to supply more credit. Hall (2008) also explains that contractionary monetary policy causes a decline in equity price or a reduction in cash flow. Therefore, it lowers net worth, in turn leading to a decrease in lending to financing investment and consumption. Shocks to banks' balance sheets from changes in financial regulation or large loan losses, for example, can affect the position of borrowers unable to turn to the capital market.

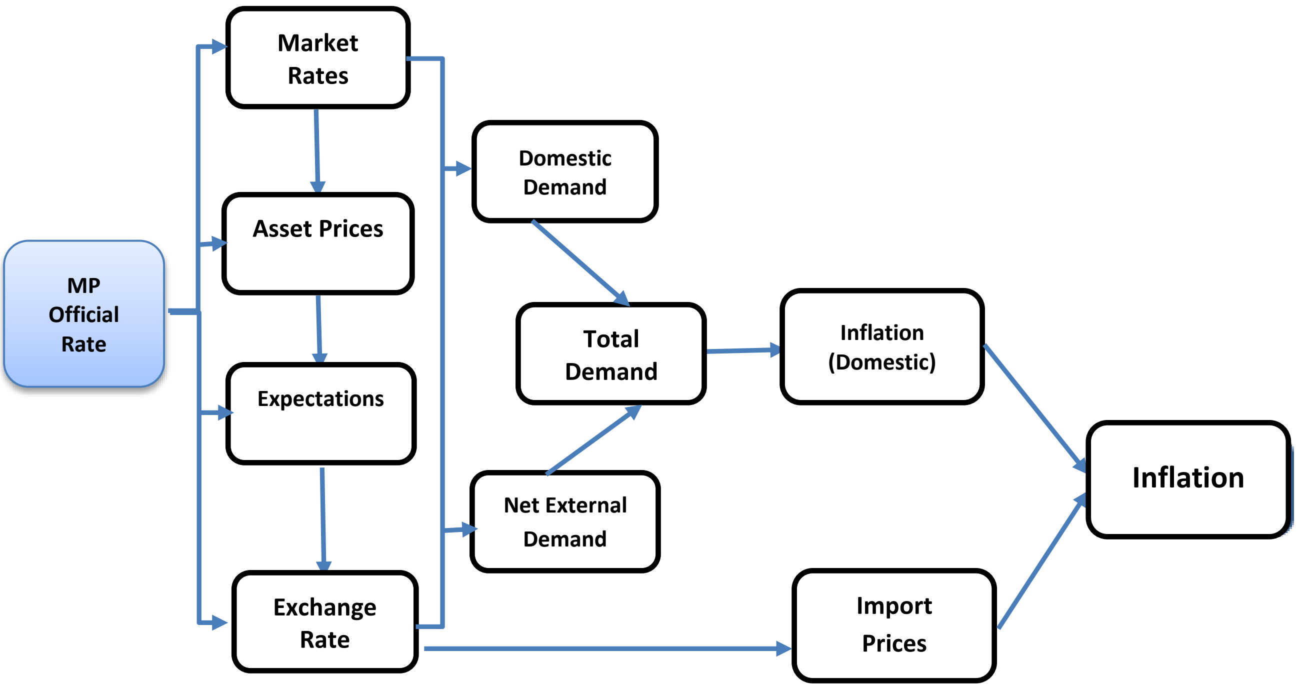
In the context of the MTM, expansionary monetary policy ($MS \uparrow$), which causes a rise in equity prices ($P^e \uparrow$) raises the net worth of firms and so leads to higher investment spending ($I \uparrow$) and aggregate demand ($Y \uparrow$). This is mainly because of the decrease in Adverse Selection (AS) and Moral Hazard (MH) problems. This transmission leads to the following schematic for a balance sheet channel: $MS \uparrow \rightarrow P^e \uparrow \rightarrow AS \downarrow \rightarrow MH \downarrow \rightarrow Lending \uparrow \rightarrow I \uparrow \rightarrow Y \uparrow$. Similarly, expansionary monetary policy, which lowers interest rates, also causes an improvement in firms' balance sheets through raising Cash Flow (CF), thereby reducing adverse selection (AS) and moral hazard (MH) problems: $MS \uparrow \rightarrow Interest\ Rate \downarrow \rightarrow CF \uparrow \rightarrow AS \downarrow \rightarrow MH \downarrow \rightarrow\ Lending \uparrow \rightarrow I \uparrow \rightarrow Y \uparrow$.

The balance sheet channel, introduced by Bernanke and Gertler (1998), is associated with the effects of a policy-induced change in interest rates on the cash flows, hence, the balance sheet positions of non-financial firms that rely heavily on bank loans. A rise in interest rate is also associated with falling asset prices, which indirectly shrink the value of collateral. These effects lead to a reduction of a firm's net worth. Small and medium sized firms, having lower net worth than large firms, are more likely to face a disproportionately larger external finance premium. Therefore, small and medium-sized firms that have relatively poor access to short-term credit markets respond to deteriorated balance sheet positions by drawing down inventories and cutting investment more than large firms (Kim, 1999) do.

3.3.4 The UK MTM and Empirical Evidence

The UK monetary transmission mechanism evolves through numerous regime changes starting from the 1972 Exchange Rate targeting regime to the current inflation targeting policy strategy. Since gaining operational independence, the Bank of England sets the policy rates (repo rate) and is responsible to make sure that low but stable inflation, high but sustainable output growth and low unemployment are achieved. The Bank of England (2010:p3), based on the Monetary Policy Committee's (MPC) view, describes the MT mechanism as "…the MPC sets the short-term interest rate at which the Bank of England deals with the money markets. Decisions about the official interest rate affect economic activity and inflation through several channels".

The key links in that mechanism are illustrated in the Figure below (see Figure 3.7). The impulse of the short-term interest rate pass through various channels to affect other variables in the transmission mechanism in four different ways (BoE, 2010:p4): "(i) official interest rate decisions affect market interest rates such as mortgage, and deposit rates to varying degrees. At the same time, policy actions and announcements affect expectations about the future course of the economy and the confidence…; (ii) these changes in turn affect the spending, saving and investment behaviour of individuals and firms in the economy; (iii) the level of demand relative to domestic supply capacity, in the labour market and elsewhere, is a key influence on domestic inflationary pressure;[42] (iv) exchange rate movements have a direct effect, though often delayed, on the domestic prices of imported goods and services. It has an indirect effect on the prices of those goods and services that compete with imports or use imported inputs, and hence on the component of overall inflation that is imported". According to Griffin and Wall (2004), changes in the rate of interest might not affect all countries equally. In some countries, such as Germany, the UK, the Netherlands, Austria, Belgium and Finland, changes in interest rate might take up to three years before exerting their full impact on the economy, while in others, such as Denmark, France, Italy, Portugal, Spain and Sweden, the effect of changes in interest rates is felt much sooner – within fifteen to eighteen months. This implies that in the Euro area, a tightening of monetary policy would take more time to affect some countries economy than would exert a stronger impact in some other countries.



Source: Bank of England (2010) and author's adaptation.

Figure 3.7 The UK Inflation Targeting Monetary Transmission Mechanism

According to the BIS (2008), in terms of the degree of response to monetary impulses, changes in policy rates are fully and rapidly reflected in changes in market interest rates in the United Kingdom, less so in Germany, and more slowly and incompletely in France. A simple statistical analysis of the past relationships between different interest rates gave a similar result. Therefore, empirical studies show that a country that has experienced more temporary changes to policy rates will

[42] For example, if demand for labour exceeds the supply available, upward pressure on wage tend to increase, which some firms may pass through into higher prices charges to consumers.

probably appear to have a smaller pass-through from policy to market interest rates. In the United Kingdom, France and Germany, monetary policy is set with reference to different targets (inflation, the exchange rate and monetary growth), but in each case monetary policy is implemented primarily through policy rates at the short end of the yield curve. This might lead to the expectation that the economic activity will respond more sensitively to a change in policy rates in a country where there is a higher proportion of lending and borrowing at lower rates.

3.3.5 Empirical Evidence of the MTM Channels

From a quantitative analysis viewpoint, there exists a vast academic literature on empirical evidence on credit channels, based on aggregate time series and micro data. Using Structural VAR Model, Cabrera and Lagos (2000) find weak effects of interest rate on output and inflation. They analyse inflation targeting regimes without taking accounting for the structural break or regime changes in the SVAR model. Keeping other channels outside the state of the model, Betancour et al. (2006) employ reduced form VAR model to examine how "Great Moderation", inflation targeting and target for the structural fiscal surplus have impacted the MTM. Using VAR model Gudmundsson (2007) studies the presence of weak interest rate channel and the overburdening of exchange rate channel. In a similar setting, Catao and Pagan (2010) investigate the effectiveness of the credit channel using expectation-augmented SVAR model. They conclude that the bank credit channel is the most important channel in the transmission mechanism and plays a significant role.

Rigobon and Sack (2003) study the impact on short-term interest rate. They affirm that stock market movements have significant effects on short-term interest rates with a positive co-movement. In an attempt to model the MTM for developing economy, Poddar et al. (2006) study the traditional IRC and conclude that there is little evidence that operating target has an impact on output. Furthermore, Minella et al. (2013) argue that traditional IR channel plays an important role in explaining output dynamics. The Tobin's q representation of the interest rate channel is the baseline model of investment decisions in DSGE models used at central banks (e.g., EDO model of the Federal Reserve Board by Edge et al., 2008; Kiley, 2013), the New Area Wide model of ECB by Christoffel et al. (2008) and ToTEM at the Bank of Canada (Murchison and Rennison, 2006). In these models, investment spending is the bulk of the near-term response to changes in the short-term policy rate. However, the long-term sensitivity of investment to changes in the user cost of capital is still controversial, and the short-term elasticity can be estimated to be quite small in data for the U.S. and other developed economies which led some (e.g. Bernanke and Gertler, 1995) to question the primacy of this channel.

In light of the dynamics of the MTM that has become a debatable issue in the recent financial crisis in the U.S. and the Euro area, some studies attempted to address the role of IR channel within the macro-econometric model. One such study by IMF (2008) reports that the pass through of policy rates to market rates has been disrupted due to the crisis that affected the Euro area, the U.S. and the UK, although differently. According to the IMF study, the interest rate pass through to the STIR has been less affected in the Euro area, while the impact of interest rate passes in the long-term was much more interrupted in both the U.S. and the Euro area. Cihak et al. (2009) study the effectiveness of ECB monetary policy in the context of the financial crisis and show evidence that policy rate changes have still been transmitted to market rates but interest rate transmission has been less efficient. A study by ECB (2009) also pointed out that during the financial crisis, the bank retail interest rate pass through in the Euro area has been responding relatively satisfactorily to the volatility of the Euro Interbank Offered Rate (EURIBOR) and other longer-term market rates, although less well to the volatility of the Euro Overnight Index Average (EONIA) (Boivin, 2010). Wulandari (2012) addresses the role of two MTM channels in managing inflation and contributing to economic growth using a Structural VAR model. Wulandari shows that the interest rate channel plays important role in MTM for maintaining inflation with a limited role in the economic growth but the role of the credit lending channel is greater than the IR channel.

Using a five variable structural VAR model of the UK economy, in a traditional MTM setting, Cover and Mallick (2012) investigate the type of shocks responsible for macroeconomic fluctuations. They examine the FEVD, IRFs and implied long-run (or permanent) effects. They conclude that monetary policy is not responsible for the majority of the output and employment fluctuations. They also identify no price or exchange rate puzzles in response to monetary policy tightening. Without accounting for the credit channel, the study highlights the role of technology and aggregate demand shocks responsible for output and employment fluctuations. Furthermore, they also note that the two shocks explain about 28% of the variation in the bank rate. Given the data range covered in their study (1985 to 2011), excluding the role of credit supply shocks could make the identification process questionable and, possibly, leads to model misspecification. This is mainly because of the fact that, as shown in recent macroeconomic studies, the monetary policy rate is amplified and propagated through the credit channel before hitting the MP targets. There is enough evidence to suggest that the credit channel is working in the TM so it is important to include the credit market series in structural VAR settings to account for the role of credit supply socks.

In a recent study, Ali and Anwar (2013) examine the effectiveness of the interest rate policy in controlling inflation. They argue that, in the presence of a cost channel, it is imperative that the interest rate policy is used with restraint. They also note that ignoring the cost channel of monetary policy can lead to significant under-estimation of the social welfare loss. Using non-nested hypothesis tests, omitted variable tests, and Granger Causality tests, Krainer (2014) compares a traditional demand oriented model of bank lending with specific focus on short-term interest rates in the money market, to a non-traditional capital budgeting model of bank lending based on movements in share valuations for the Euro area. The author rejects the traditional demand oriented model of bank lending but failed to reject the capital budgeting model of bank lending for Monetary Financial Institutions (MFI's) in the Euro area. Furthermore, Krainer (2014) also showed that the stock market in Europe plays a key role in the lending decisions and allocation of resources.

As for the credit channel, Bernanke and Gertler (1995) and Hubbard (1995) state that the credit channel is working in addition to the interest rate channel. They also state that monetary policy affects the level of investment and consumer spending by inducing changes in the cost of capital and yield on savings. Although the credit channel and the interest rate channel diverge in assessing the relevance of financial considerations, they are deemed complementary. This implies that monetary policy can be effective through not only the traditional interest rate channel but also the credit channel simultaneously. Following Bernanke and Blinder (1992), a number of studies examine whether the credit channel is operating alongside the interest rate channel using VAR models on aggregate data. Earlier studies (e.g. Cecchetti, 1995) show that bank loans decline after a monetary policy shock, but these findings are beset by a stark identification problem. It remains unclear whether the drop is driven by loan supply or loan demand effects. Although it is difficult to distinguish, the credit channel is believed to emphasise a shift in loan supply while the interest rate channel underlines a shift in loan demand, which stems from a policy-induced decline in real activity.

In the light of this ambiguity, several studies have explored heterogeneity across agents based on disaggregated data. Gertler and Gilchrist (1993), Gilchrist and Zakrajsek (1995) and Oliner and Rudebusch (1995) use panel data of a large number of U.S. business firms. They argue that firms of different size encounter different financial constraints after a monetary tightening. Using panel data, Kashyap and Stein (2000) investigate the impact of monetary policy changes at the individual bank level. They observe that monetary policy, particularly, affects the lending behaviours of small banks with less liquid balance sheets. Kishan and Opiela (2000) report similar findings by approximating bank lending activities on the basis of bank size and bank capital. Bernanke and Blinder (1992) make use of Vector Autoregression analysis (VAR) and discuss that monetary shock leads to a decrease in the aggregate amount of loan after six months. Rigidity of contracts explains the delay in the response of the credit to a shock. Nevertheless, their findings suffer from identification problem because the fall in the amount of loans could reflect the fall in demand (and not in supply) for loans (Auel and Mendonca, 2011).

Following Bernanke and Blinder (1992), Kashyap et al. (1993) analyse firm's financing mix[43] using a VAR model. Their result suggests that, while changes in both banking loans and commercial papers indicate changes in credit demand, falls in the mix[44] would indicate a decrease in credit supply. They conclude that tight monetary shocks provoke a fall in the volume of banking loans. Furthermore, they study the behaviour of the Spread between commercial paper rates and the American treasury bonds. Their result indicates that there is a significant increase in the Spread after tight monetary shock, which in turn confirms the presence of credit channels. Hallsten (1999) studies the behaviour of the firm's financing mix and the behaviour of the Spread for the Swedish case based on VAR models. They obtain results similar to Kashyap et al. (1993). In short, tight monetary shocks imply a relative decrease in credit supply and an increase in the Spread that affects the output. To address the implication on the scale of firm's loan, Gertler and Gilchrist (1993, 1994) identified the effect of monetary shock on credit flow for small and large borrowers. Using a VAR analysis, they show that a decrease in housing credit and consumer credit is greater than that observed for commercial and industrial credit in response to a tight monetary shock.

On the capital channel, Markovic (2006) argues that the bank capital channel has significant impact on banks' decision on lending. According to Markovic, previous studies highlighted only the bank capital through the deposit-reserve channel. The capital channel comprises shocks to the cost or the value of bank capital that can affect bank lending. Monetary policy actions may lead to a change in the financial position of the banking sector, thus changing the preferences of its shareholders. In the transmission mechanism, a change in the financial position of the banking sector may arise due to changes in the riskiness of banks' assets, an expected change in the value of bank capital, or issues related to the capital regulation of the banking sector (e.g. a change in the bank capital requirement). This change can influence the cost of bank capital, and thus lending, and therefore generate the above effect. Empirical evidence also affirms the importance of bank capital for banking behaviour. Micro-data studies based on individual loan agreements in the U.S. (Lown and Peristiani, 1996; Hubbard et al., 2002) address that low-capitalised banks charge higher loan interest rates than well-capitalised banks in periods of crisis. Markovic (2005), using a micro-data panel approach, finds that well-capitalised banks extend more credit than low-capitalised banks following a monetary tightening in the United Kingdom.

In a follow-up study, using a DSGE model, Markovic (2006) also analyses the macroeconomic consequences of changes in the cost of bank capital, and thus the cost of bank credit. The model includes the interaction between the supply side (banking sector) and the demand side (corporate

[43] Firm's financial mix is defined as the ratio between the volume of banking loans and the sum of volume of banking loans and commercial papers (substitute for banking credit) (Auel and Mendonca, 2011).
[44] The fall in the mix taken as a relative fall of banking loans in regards to commercial papers.

sector) of the credit market. The DSGE model extends the well-known BGG (1998) model of the corporate sector balance sheet channel. Their result shows that monetary policy decisions can have a stronger effect in times when the health of the banking sector deteriorates. Banks may find it costlier to raise the fresh capital required to fulfil regulatory requirements. The study also confirms that the impact of monetary policy can be asymmetric. An increase in interest rates is likely to lead to a fall in the value of bank capital, thus increasing the likelihood of hitting the binding capital constraint. If the latter occurs, banks have either to raise fresh capital or to reduce their loan supply. In contrast, a fall in interest rates does not produce similar effects where the additional capital is in excess of regulatory requirement.

Markovic also argues that the bank capital channels contribute significantly to the MTM, together with the corporate balance sheet channel. However, the author stresses that the importance of the bank capital channel through the bank balance sheet channel can vary over time. The relative importance of bank capital channels is likely to increase in the event of large shocks to the value of bank capital. These shocks might include the writing-off of non-performing loans from banks' balance sheets or a regulatory change that increases capital requirements. In such circumstances, one can expect an interaction between the supply and the demand-side effects, and thus potentially larger shocks to the economy.

In terms of time horizon such as the short-run monetary policy effect, there exists some consensus in the monetary economics literature that monetary policy has a non-negligible short-run effect (for at least 2 years) on the real economy. A large number of empirical studies (Romer and Romer, 1989; Bernanke and Blinder, 1992; Christiano et al., 1996, among others) reach at this conclusion through empirical analysis using Structural VAR models. The standard cost of capital (or interest rate) channel falls short of explaining this short-run effectiveness of monetary policy. Research in the past 20 years has sought alternative explanations. Bernanke and Gertler (1995) produce empirical evidence and show that the effect of monetary policy on the level of financial frictions and thus the amount of bank lending is the most prominent explanation. Further studies analyse banks behaviour to investigate how this channel operates and suggest that the response of total loan supply (an indicator of economic activity) to monetary policy shocks is small and has gradually declined over the past 30 years. The decline in this component of the lending credit channel is mostly explained by the easier access to liquidity that banks, especially larger banks, have gained together with deeper and more developed financial markets (Cetorelli and Goldberg, 2011)[45].

[45] See also Kashyap and Stein (2000); Aysun and Hepp (2013).

The theoretical and empirical literature highlighted that contractionary monetary policy affects small firms more than large size firms. The review also addresses the importance of both the bank lending and balance sheet components of the credit channel in the MTM. The understanding of the traditional interest rate channel has changed in the advent of the recent global financial crisis due to the growing evidence, showing that the credit channel plays significant role in accelerating and spreading the monetary policy impulses in the transmission process. However, the confirmations are limited in scope so there is a need for deeper understanding of the behaviour of monetary policy shocks, credit market shocks and the degree of changes in the UK monetary transmission mechanism. In this framework, the study investigates the behaviour and role of monetary policy, credit market movements and addresses the dynamics of the MTM using a Bayesian VAR and DSGE model approaches. The following section discusses the New Keynesian model and the role of the expectations channel that leads to the development of Bayesian NK DSGE models.

3.3.6 The New Keynesian Model and the Expectations Channel

The New Keynesian Model

Broadly, there are two sections in modern macroeconomics: (i) the Neoclassical view of the real business cycles (e.g., Plosser, 1989, among others) - advocates that the cause of business cycles is to be found in the stochastic character of economic growth itself. They explain cycles and trends with the help of the same model; (ii) the New Keynesian view, on the other hand, addresses the existence of involuntary unemployment, monetary non-neutrality, and sticky wages and prices as the cause for business cycle and the transmission mechanism (Mankiw, 1992). According to Gordon (1990:p21), "...the essential feature of Keynesian macroeconomics is the absence of continuous market clearing. Thus a Keynesian model is by definition a nonmarket-clearing model, one in which prices fail to adjust rapidly enough to clear markets within some relatively short period of time…"

Before the GFC, there has been a growing research in academia and central banks to address the MTM and understand how the traditional Keynesian interest rate channel operates. Previous studies employ VAR, SVAR and the dynamic, stochastic, general equilibrium (DSGE) models. The first wave of New Keynesian models began to appear following the 1970s rational expectations revolution. The New Keynesian approaches, therefore, build on early attempts by Fischer (1977), and Phelps and Taylor (1977) to combine the key theory of nominal price or wage rigidity with the assumption that all agents have rational expectations. This assumption helps to overturn the policy ineffectiveness that McCallum (1979) associates with Lucas (1972), and Sargent and Wallace (1975). The study on MTM builds on those earlier studies by deriving the key behavioural equations of the New Keynesian model from more basic descriptions of the objectives and constraints faced by optimizing households and firms (Ireland, 2005).

According to Woodford (2003), Clarida et al. (1999), and Goodfriend and King (1997), modern monetary macroeconomics is based on the 3 equation New Keynesian model. These are the IS curve, Phillips Curve and interest rate based monetary policy rule $(IS - PC - MR)$. According to the IS equation, also called the first equation labelled as the expectational IS curve by Kerr and King (1996) and McCallum and Nelson (1999) link output today to its expected future value and to the *ex-ante* real interest rate, computed by subtracting the expected rate of inflation from the nominal interest rate:

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \pi_{t+1}), \tag{3.6}$$

where σ is strictly positive. IS model assumes that monetary policy exerted some control over the output gap, y_t. The equation corresponds to a log-linearized version of the *Euler equation* linking an optimizing household's intertemporal marginal rate of substitution to the inflation adjusted return on bonds, that is, to the real interest rate. The IS curve equation presented as deviations of output from equilibrium, $x_t = y_t - y_e$, where y_t is output and y_e is equilibrium output. Thus, the IS equation of $y_t = A_t - ar_{t-1}$, where A_t is exogenous demand and r_{t-i} is the real interest rate, becomes: $x_t = (A_t - y_e) - ar_{t-i}, \;\; i = 0, 1$. The first equation captures the lag from the real interest rate to output (a period is year). Once central bank optimization is introduced, $A_t - y_e$ by $ar_{s,t}$ where $r_{s,t}$ is the so-called 'stabilizing' or Wicksellian (Woodford, 2003) rate of interest such that output is in equilibrium when $r_{s,t} = r_{t-1}$. *The Monetary Rule* is an equation based on an interest rate rule for monetary policy (MR) of the type proposed by Taylor (1993), $i_t = \alpha\pi_t + \psi y_t$ and the *Phillips Curve* takes the form: $\pi_t = \beta E_t \pi_{t+1} + \gamma y_t$ and corresponds to a log-linearized version of the first-order condition describing the optimal behaviour of monopolistically competitive firms that either face explicit costs of nominal price adjustment, as suggested by Rotemberg (1982), or set their nominal prices in randomly staggered fashion, as suggested by Calvo (1983). $E_t\pi_{t+1}$ is the expectation formed in period t of the value of inflation in period $t + 1$. In terms of current and lagged inflation, assuming inflation process as inertia, the Phillips curve equation takes current inflation as a function of lagged inflation and the output gap, i.e.: $\pi_t = \pi_{t-1} + \alpha x_{t-j}$, where, $j = 0, 1$ is the lag from output to inflation. Taking real money supply into account, the implication of the $NKPC$ for monetary policy is better modelled. Inflation, and output, however, requires some specifications of how monetary policy affects output. The output gap: $y_t = m_t - \pi_t$, approach can be justified based on the $IS - LM$ model that, an increase in the real money supply shifts the LM curve upwards leading to a short-run increase in output. This increase is assumed to be offset over time as the higher output leads to higher prices and thus a reduction in the real money supply. Based on this assumption of output, the $NKPC$ model can be re-written as

$p_t - \pi_{t-1} = \beta E_t \pi_{t+1} - \beta \pi_t + \gamma m_t - \gamma \pi_t$ and is re-arranged as a second order difference equation in the price level:

$$\beta E_t \pi_{t+1} - (1 + \beta + \gamma)\pi_t + \pi_{t-1} = -\gamma m_t \tag{3.7}$$

The equations are derived from explicit optimizing behaviour on the part of the monetary authority, price-setters and households in the presence of some nominal imperfections. The three basic New Keynesian models that are crucial in the conventional transmission mechanism involve three variables: output y_t, inflation π_t, and the short-term nominal interest rate i_t.

Critics against the New Keynesian Model

The model features rational expectations, and so is not subject to the criticisms of earlier Phillips curves about *ad hoc* treatment of expectations or to the Lucas critique of econometric accelerationist Phillips curves. The $NKPC$ model has profoundly different implications for the conduct of monetary policy relative to the less formal accelerationist Phillips curve (Le et al., 2012a). Nevertheless, the banking crisis, which flares-up in 2007 and prompted the Great Recession of 2009, has led economists and policymakers to question the standard New Keynesian model because it can neither account for the crisis nor shed any light on banking behaviour (Liu and Minford, 2014). Furthermore, if shifts in the trend of potential output are added to the model, it can give a good account of the overall behaviour since the crisis period includes the permanent effects of such shifts in trend (Le et al., 2012b). The New Keynesian DSGE model answers some of the critics against the NK macroeconomic models by incorporating microeconomic information and systematic data generating process. It also highlights the importance of rational expectations hypothesis as a building block of the dynamic stochastic general equilibrium (DSGE) model. This channel receives considerable attention since the advent of the New Keynesian macroeconomic dynamic models.

The Expectations Channel

One of the most important changes in the practice of monetary policy is the manner in which expectations have become an important tool of monetary authority in the TM. Shifts in the behaviour of the monetary authority can affect the transmission mechanism. These effects come in two forms, which both of them are quantitatively important: (i) expenditures depend directly on the expected path of policy rates through the influence of this path on asset prices. For example, if a rise in the policy rate is expected to be more persistent, the expectations hypothesis of the term structure indicates that the impact on long-term interest rates will be larger than if it is expected to be temporary; (ii) the nature of the policy rule can have important feedback effects through its influence on expected spending and inflation. For example, policy behaviours that responds strongly to deviations of output from potential and deviations of inflation from desired levels will lead to greater stability in expectations for income and inflation, and hence greater stability in actual spending and inflation. Studies show the potential importance of changes in policy behaviours of this type of shifts in the aggregate impact of monetary policy actions (see for e.g., Boivin and Giannoni, 2006).

There is a predominant view that inflation expectations[46] work as a vital part of MTM. However, identifying and assessing the expectations channel are difficult tasks because it usually is entwined with the other transmission channels. Expectations of future inflation are translated into expectations of the driving forces of inflation (which affects unit labour cost, real exchange rate, and output gap). The behaviour of these driving forces can be fully decomposed into non-expectations channels, leaving no role for a separate expectations channel (Minella and Souza-Sobrinho, 2013). The expectations channel is where economic actors make future predictions. This may have a great influence on real economy through inflation, interest rate, and growth. In the expectations channel, the monetary policy shapes the inflation expectations, and this is reflected in inflation by affecting the price and wage policies. In an outward-oriented economy, it provides an information set including the future expectations (Weber et al., 2011).

Theorised by the New Keynesian economics, the expectations channel[47] operates in connection with banks and non-banks expectation of inflation. Market participants, according to Delivorias (2015), do not respond to changes in the supply and demand conditions in the market, but act pre-emptively, drawing on their expectations of future inflation rates, based on past experience. This behaviour presents a challenge, but also an opportunity for central banks, since a credible policy and a solid reputation provide the possibility to 'harness' that effect to help in reaching its objective of price stability. Monetary policymakers can harness this behaviour if they have acquired a reputation for decisively combatting inflation. After all, this would give economic agents no reason to factor higher future inflation rates into returns, prices and wages. One of the most important considerations in the New Keynesian model is the way in which expectations are formed. Official rate changes can influence expectations about the future course of real activity in the economy, and the confidence with which those expectations are held, in addition to the inflation expectations. Such changes in perception will affect participants in financial markets, and they may also affect other sectors of the economy via, for example, changes in expected future labour income, unemployment, sales and profits (Bean, 2001).

[46] See for example Woodford, (2003); Bank of England, (1999).

[47] As Gerke et al. (2012) put it "it is a theoretical concept describing the effect of MP measures on the inflation expectations. For instance, a reduction in the key interest rate will not cause long-term interest rates in the capital market to decline as well if it is thought that the expansionary monetary policy will cause inflation to rise in future".

3.4 Modelling the Monetary Transmission Mechanism

One way to model MTM and to measure the effectiveness of monetary policy on a variable of interest is to regress this variable on the monetary policy instrument and additional control variables in order to estimate coefficients. The policy instrument coefficients are interpreted as the sensitivity of that variable to monetary policy. Changes in the degree of sensitivity imply changes in MPTM but exogenous sources of policy changes are not clearly isolated and causality is not well established. These are not the only potential interpretations. For instance, the estimated coefficients might instead be capturing the response of monetary policy to these variables, rather than the opposite. This variant of a reduced-form approach has been used to examine MTM on disaggregated categories of expenditures. Studies based on reduced-form approach involve either regressions of the expenditure category of interest on the short-term policy rate or on other interest rates, with auxiliary reduced-form equations specified to link the interest rates to the short-term policy rate (see e.g., Friedman, 1989; Mauskopf, 1990, and Dynan et al., 2006).

To establish a causal link and go beyond this reduced form, the main general strategy consists of using an exogenous source of variation in the monetary policy instrument and tracing out its effect on key variables to capture the aggregate behaviour of the economy. This is typically achieved in the context of a system of equations where just enough restrictions are imposed to identify the exogenous source of variations in monetary policy, but that is otherwise left free of a priori assumptions on the structure of the economy. This has the advantage of providing robust estimates of the effect of monetary policy, in the sense that they are consistent with a large class of linear structural models. While these models are useful to document the effect of monetary policy on the economy, their use in determining the cause of the changes is more limited (Boivin et al., 2010).

The empirical models considered in literature can be seen as special cases of a general factor-augmented vector autoregression (FAVAR) model (Bernanke, Boivin and Eliasz, 2005). In its general form, FAVAR has the following state-space representation:

$$\Phi_t = \Upsilon\psi_t + e_t \tag{3.8}$$

$$F_t = A(L)\psi_{t-1} + u_t \tag{3.9}$$

where Φ_t signifies log vector of observed macroeconomic indicators of interest, ψ_t is a vector of potential unobserved variables governing the co-movements of the observable macroeconomic variables, e_t is a variable specific observational error and u_t represent innovation factor that are linear combinations of the structural macroeconomic shocks, one of which is the monetary policy shock. Equation (3.8) states that observable macroeconomic indicators are potentially imperfect measures of the latent macroeconomic forces. Equation (3.9) states the evolution of the comovements among the macroeconomic indicators that is governed by a set of common factors, ψ_t, in a VAR structure. Its consistency with a large class of linear rational expectation structural models make the empirical setup appealing in MTM analysis. The model can accommodate various assumptions about the information set available to the agents and the monetary authority (Boivin and Giannoni, 2006). The system (3.8) collapses to Equation (3.9), which becomes a standard VAR in terms of observable macroeconomic indicators. All the VARs that have been used to investigate the effect of monetary policy can thus be seen as a special case of the system (Equation 3.8 and 3.9). They differ by the macroeconomic indicators they choose to include in ψ_t. Going a step forward, one requires imposing restrictions then identifying a structural shock corresponding to an exogenous change in MP from u_t in order to uncover the MTM (Boivin et al., 2010).

The standard VAR approach assumes that the dynamics of the macro economy can effectively be summarised by a handful of observable macroeconomic indicators. This is unrealistic because the true concepts of interest, such as real activity and inflation, might not be perfectly measured by any observable macroeconomic indicators. Proper estimation would require recognizing the presence of such observational errors and once this is recognised, a potentially large set of macroeconomic indicators could conceivably carry useful information about the true state of the economy. This is why Bernanke, Boivin and Eliasz (2005) propose the more general FAVAR framework characterised by Equations (3.8 and 3.9). While retaining the flavour of the VAR, the general FAVAR framework allows relaxing the assumptions that the relevant theoretical concepts of interest are known and perfectly observed. Instead, it treats observable variables as noisy indicators of the true but unobservable state of the economy. Moreover, by expanding the size of Φ_t, the potentially useful information can be exploited, and the dynamic effect of monetary policy on any of these indicators can be documented.

Turning to the existing approach, a change in the MTM means that some of the parameters of systems (3.8) and (3.9) have changed over time, which from a reduced-form perspective, could manifest itself by a change in the correlation of the policy instrument and the variable of interest. To evaluate the existence and the importance of changes in this transmission mechanism, existing studies have used one of the following three strategies: a) estimate an empirical model over different subsamples; b) estimate an empirical model treating (some subsets of) the parameters as time-varying latent processes (typically assumed to evolve according to random walk); or c) estimate a regime switching version of an empirical model where (some subsets of) the parameters can stochastically switch between different, regime-dependent, values.

3.4.1 The MTM in Specified Structural Models

Studies such as Boivin, Kiley and Mishkin (2010, BKM hereafter) employ a standard New Keynesian DSGE model to study how the transmission process have evolved. Their framework has three key features that permits them to build on FAVAR-based analysis. It allows a discussion of structural features, including monetary policy behaviour. It emphasises the potential role for expectations management in influencing monetary transmission, as highlighted in the New Keynesian literature; and is a framework used widely in research and policy environments. The starting point for BKM's model specification is the model of Smets and Wouters (2007). BKM extend the model along two dimensions: they disaggregate investment spending into consumer durable expenditures, residential investment, and business investment. The disaggregation allows the analysis to bond with the large literature that examines the impact of monetary policy on these spending categories.

The addition of the financial accelerator is inspired by BGG (1999) and Smets and Wouters (2003). This addition allows some consideration of a credit (Non-Neoclassical) channel. Most industrialised countries have experienced sustained structural changes over the last three decades. The changes have seen in the way financial markets operate, liberalisation of products and labour markets, cooperation in trade and a shift of focus on central banks to stabilise prices as their monetary policy objectives (Cecioni and Neri, 2011, CN hereafter). In the United Kingdom, the shift from monetary and exchange rate base to inflation targeting monetary policy structure marked the beginning of the central banks' focus on price stability. Following this period, the BoE independence in 1997, the creation of the EMU in 1999 and the establishment of the ECB with a clear mandate to stabilise inflation might have changed not only the EU but also the UK monetary policy transmission mechanism. There are some grounds to suspect that the MTM might have changed due to the way expectations are formed, with potential effects on consumption and investment decisions by households and firms. It is now over two decades since the announcement of inflation targeting monetary policy in the UK and the restructuring of the financial sector. It is also over 8 years since the recent GFC so the information that can be gathered would allow assessing the periodic change(s) of the UK monetary transmission mechanism. There are various evidences that indicate some changes as the role of monetary policy is beginning to subside, while the role of the credit demand and supply shocks is emerging.

This section provides information on the policy stance and correctly quantifies the macroeconomic effects of policy decisions. By doing so, it disentangles the factors behind the expected changes of the MTM. To pursue this, the study employs two approaches: a Bayesian structural VAR and a dynamic stochastic general equilibrium (DSGE) models. The VAR results are useful to directly compare with those of the literature on this subject. The results of the VAR approach however, according to CN (2011), are (i) not fully informative on the evolution of the MTM as they do not account for the changes in more than one of the structural parameters; (ii) in a VAR approach, it is difficult to interpret results as the factors behind observed changes in the response of output and prices to monetary policy shocks cannot be untangled so is difficult to detect systematic differences.

The VAR approach is complimented with the estimated Bayesian DSGE model over two sample periods. The DSGE approach allows the estimation of a more structural model that helps to untangle the MTM channels and in particular, to understand whether there has been a change in the mechanism of the monetary policy transmission or the parameters that characterise the behaviour of the private sector. To allow direct comparison, the approaches used in this study, closely follow Smets and Wouters (2007), Canova (2007a) and CN (2011), who investigate the U.S. and EU area MTMs. Although their work is informative, it is highly aggregated to a single monetary union, representing a number of countries. The UK is not a member of the monetary union, so addressing this issue to a country with a monetary policy that relies on the independent decision of its central bank is important. Previous studies provide no assessment on the UK MTM of the pre and post-GM period so this research contributes to the existing literature using a Bayesian DSGE model and update the analysis with additional data available since the onset of the GFC.

Several studies investigate the changes in the MTM of the U.S. economy using a complete set of data before and after the GFC.[48] However, there are few theoretical and empirical studies that focus on the evolution of the UK MTM, particularly in the post-GFC. Weber et al. (2011) provide statistical evidence and conclude that MTM in the Euro area has not significantly changed. Boivin et al. (2010) study the MTM of common monetary shocks to a subset of Euro area countries and conclude that this mechanism has, indeed, changed with the creation of the EMU. They also argue that the introduction of the Euro brought about an overall reduction of the effects of MP on output, inflation and the long-term interest rate and an increase in the effects on the exchange rate. Boivin et al. (2006) rationalise these findings in a stylised and calibrated open-economy DSGE model with an increase in the fierceness of monetary policy towards output, inflation and with the disappearance of exchange rate risks (CN, 2011). The following section discusses a structural interpretation of the changes in the MTM through the estimation of a Bayesian VAR and DSGE models that covers the pre and post-IT and GFC periods with a complete set of business cycles. In the spirit of BKM (2010), this study follows a similar approach but characterises the analysis within a Bayesian framework.

[48] See Boivin and Giannoni (2006); Boivin et al. (2010); Cecioni and Neri (2011).

3.4.2 The VAR and SVAR Approaches

Among the methods discussed above, VAR has been a standard approach to study various aspect of the MTM. VAR requires minimal theoretical conditions to characterise vectors of the time series. Since VARs are reduced form models with limited identification restrictions, it does not incorporate economic theory. Therefore, VAR may not be a suitable approach to conduct meaningful policy analysis and out-of-sample forecasting. However, to approximate the Wold representation and for reliable parametrisation, the alternative unrestricted VAR approach is important, although it suffers from insignificant coefficients. Furthermore, the parsimonious time series models, with a limited number of degrees of freedom, estimate a VAR with imprecise coefficient forecasts with large standard errors. To obtain reliable results, it is useful to set up a robust empirical model in the process of combining historical and *a priori* information, both of statistical and of economic nature.

$$y_t = \sum_{l=1}^{p} M(l)y_{t-l} + Cx_t + \varepsilon_t \tag{3.10}$$

where y_t for $t = 1, \ldots, T$ is a $K \times 1$ vector of endogenous variables, x_t is a $Q \times 1$ vector of exogenous or deterministic variables, ε_t is a $K \times 1$ vector of error, p is the number of lags and $M(l)$ and C, with l being the lag operators, $K \times K$ and $K \times Q$ matrix of coefficient ε_t is assumed to be independent and identically normally distributed with mean equal to zero and covariance martrix Σ. To obtain clearer understanding of the MTM and lessen the problem with VAR estimates that are dependent on the data transformation, the estimation process uses data in levels so the results do not depend on the transformation mechanism. Although it is required to isolate the trend from the cyclical movement for DSGE estimation, the VAR estimates do not require this specification. The data are collected for the UK economy at a quarterly frequency. The quarterly data are important to assess the robustness of the results to the frequency of the data and for comparability with those obtained with the estimation of a theoretical model. The quarterly data covers from 1980Q1 to 2014Q4 for the following seven variables:

$$M_0 y_t = \begin{pmatrix} ip_t \\ cp_t \\ p_t \\ y \\ r_t \\ cr_t \\ m_t \\ ex_t \end{pmatrix} = \begin{pmatrix} ln(industrial\ production,) \\ ln(commodity\ prices) \\ ln(consumer\ price\ index) \\ ln(output) \\ (overnight\ rate) \\ ln(credit) \\ ln(monetary\ aggregate) \\ (REexchange\ rate) \end{pmatrix} \begin{pmatrix} \varepsilon^{ip} \\ \varepsilon^{cp} \\ \varepsilon^{\pi} \\ \varepsilon^{y} \\ \varepsilon^{r} \\ \varepsilon^{cr} \\ \varepsilon^{m} \\ \varepsilon^{ex} \end{pmatrix} \tag{3.11}$$

The other problem with unrestricted VAR is that the results are very sensitive to the specification and price puzzle that prices increase following a tightening of monetary policy – to be pervasive across the different periods. The fact that adding more information to the VAR through the inclusion of an expected inflation measure helps to eliminate the price puzzle in the later sample. Additionally, the VAR does not display the puzzle, which leads to believe that it is indeed an anomaly of the simpler VAR specification as opposed to a genuine feature of the economy (BKM, 2010). It also tends to over fit the data when the number of parameters to be estimated are large enough to represent the sample periods under consideration. To reduce this problem, the analysis resorts to a Bayesian method as it combines the information from the *prior* with information obtained from the likelihood function of the data.

Alternative modelling techniques provide different *a priori* information or different relative weights to sample and prior information. *A priori* information is sparsely employed in unrestricted VARs in selecting the lag length of the model and in imposing identification restrictions. Because of this choice, over fitting may happen when the data set is short and when sample information is weak or the number of parameters is large. In-sample over fitting typically translates into poor forecasting performance, both in unconditional and conditional sense. Bayesian methods can solve these problems: they can make in-sample fitting less dramatic and improve out-of-sample performance (Hamilton, 1994; Lutkepohl, 2005; Canova, 2007a). Bayesian VARs (BVARs) were originally designed to improve macroeconomic forecasts. They have evolved dramatically and are now used for a variety of purposes including for the investigation of the MTM. Defining the VARs, $\alpha = [vec(M)vec(C)]'$ a vector of size $(Kp + Q)K$ where coefficients are confined in $M(l)$ and $C(p$ is the number of lags). The estimation process uses a normal prior for the coefficients in α and a diffuse one for variance-covariance matrix of the shocks represented by Σ such that $\alpha \sim N(\bar{\alpha}, \bar{\Sigma}^{\alpha})$ and $p(\Sigma) \sim |\Sigma|^{-(K+1)/2}$, where $\bar{\alpha}$ is the mean of the prior and $\bar{\Sigma}^{\alpha}$ is its variance covariance matrix. Following Litterman (1986), the Minnesota prior are imposed as a restriction on the coefficients in α (also used in Doan et al., 1984). This implies that *a priori* represented in the series included in the VAR as univariate random walks with correlated innovations. All coefficients in $\bar{\alpha}$ are equal to zero except the first own lag of the dependent variance in each equation, which is set to one. Moreover it is assumed that the prior covariance matrix $\bar{\Sigma}^{\alpha}$ is diagonal and that the $\sigma^{\alpha}_{ij,l}$ element, corresponding to lag l of variable j, is equal to:

$$\sigma^{\alpha}_{ij,l} \begin{cases} \dfrac{\phi_0}{h(l)} & if\ i = j, \forall l \\ \phi_0 \dfrac{\phi_1}{h(l)} \left(\dfrac{\sigma_j}{\sigma_i}\right)^2 & if\ i \neq j, \forall l, j\ endogenous \\ \phi_0 \phi_2, & if\ j\ exogenous/deterministic \end{cases}$$

where ϕ_0 is a hyper-parameter representing the tightness of the prior; $\phi_1$is the relative tightness of other variables, ϕ_2 is the relative tightness of the exogenous variables and $h(l)$ is the relative tightness of the variable of lags other than the first one. The relative tightness is assumed, throughout, that $h(l) = l$, representing a linear decay function. Besides, the scaling factor that accounts for the different scale of the variables of the model is represented by the term $\left(\frac{\sigma_j}{\sigma_i}\right)^2$. Following Canova (2007b), the tightness parameters are set to initialize the analysis as shown in Table 3.1 below.

Table 3.1 Canova's Representation of Priors - Tightness of Parameters

Tightness parameters	Parameters	Priors (set values)
Overall tightness	ϕ_0	0.1
Relative tightness (other variables)	ϕ_1	0.5
Relative tightness (exogenous variables	ϕ_2	10^5
Relative tightness of lags	$h(l)$	l

Source: some tightness parameters are taken from Canova (2007a), and Cecioni and Neri (2011).

The VAR in (3.10) is represented in companion form as $Y = MA + u$. The posterior distribution is Normal-Wishart:

$$\alpha \backslash \Sigma, Y \sim N\left(\underline{\alpha}, \left[\underline{\Sigma}^{\alpha}\right)^{-1} + \Sigma^{-1} \otimes M'M\right]^{-1}\right)$$

$$\Sigma^{-1} \backslash \alpha, Y \sim W([(Y - M)'(Y - M') + (M - M)'M'M(M - M')]^{-1}, N) \qquad (3.12)$$

where $\underline{\alpha}$ and $\underline{\Sigma}^{\alpha}$ are the mean and covariance matrix of the posterior distribution and M' is the OLS estimate of the companion matrix M, α and Σ are drawn from the posterior using the Gibbs sampling algorithm.

3.4.3 Identification of Shocks in the UK MTM

One of the difficult task in analysing MTM in the stance of monetary policy framework is isolating exogenous variations, i.e. shocks. It is, however, a crucial step as the results on the MTM may be sensitive to the assumptions for the shock identification. Abstracting for simplicity, from the exogenous variables y_t, the coefficients of the structural equations below can be recovered from the estimated reduced form (3.10) by imposing enough restrictions on the matrix M_0:

$$M_0 y_t = \sum_{l=1}^{p} M(l) y_{t-l} + v_t \qquad (3.13)$$

where v_t are the structural shocks with covariance matrix equal to the identified one. To obtain robust results, the analysis proceeds with three important strategies in order to identify the shocks.

The first identification scheme: is a recursive one (see Christiano et al., 1999). The decomposition process of the variance-covariance matrix of the reduced form residuals follows a Cholesky factorization approach. The ordering of the variables is as follows: (ip), (cp), $(p = \pi)$, (y), (r), (cr), (m) and (ex). The open economy dimension and the foreign inflationary pressure are controlled by the commodity prices (mainly) and the exchange rate, respectively. Both commodity prices and exchange rate variables are treated as exogenous for the recursive identification scheme.

The second identification scheme: is based on the information delay in the transmission mechanism (Sims and Zaha, 1999; Kim, 1999). Hence, monetary policy cannot respond within the month to prices and industrial production. This identification scheme assumes that monetary policy authority observes and reacts to commodity prices, money and the exchange rate. The scheme defines a money demand and money supply equations in such a way that the monetary policy (AD) shock influences output and prices only with a lag, while money and the exchange rate are affected contemporaneously. Money Supply and Credit (MS/CR) depends on prices, output and the nominal interest rate. The innovation to commodity prices affects contemporaneously the nominal effective exchange rate. As an asset price, the nominal exchange rate is assumed to react to all variables in the system. The shocks are exactly identified to allow computing probability error bands for the impulse response and for the determination of the priors[49]. The following matrix represents the identification scheme:

$$\begin{pmatrix} ip/cp \\ \pi \\ y \\ r \\ m/C \\ ex \end{pmatrix}_t M_0 y_t = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & M_{16} \\ M_{21} & 1 & M_{23} & 0 & 0 & 0 \\ 0 & M_{32} & 1 & 0 & 0 & 0 \\ M_{41} & 0 & 0 & 1 & M_{45} & M_{46} \\ 0 & M_{52} & M_{53} & M_{54} & 1 & 0 \\ M_{61} & M_{62} & M_{63} & M_{64} & M_{65} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon^{ip/cp} \\ \varepsilon^{\pi} \\ \varepsilon^{y} \\ \varepsilon^{AD} \\ \varepsilon^{MS/CR} \\ \varepsilon^{ex} \end{pmatrix}_t \tag{3.14}$$

The above matrix summarises the structural identification scheme and allows recovering the structural representation of the VAR (Equation. 3.14) from the reduced form (Equation. 3.11). The (accumulated) impulse response function in the following figures (Figure 3.8, 3.9 and 3.10) show the responses of each variable in the system equation to a positive one standard deviation of each shock. It provides information on the size and dynamics of shocks and how they induce diverse reactions to certain macroeconomic economic impulses. The commodity prices and the exchange rate that are included on the benchmark VAR represent the open economy dimension for the UK case. However, its role in the MTM is not discussed in this Chapter. The non-zero coefficients of

[49] The standard *Monte Carlo* methods and Bootstrapping are used for the impulse response functions to determine the upper and lower confidence limits.

M_{ij} in the identification process states that variable j contemporaneously affects variable i. To achieve a just identified restrictions, the system requires 51 restrictions in both matrices. Together with the diagonal matrix, there are 36 restrictions imposed in both matrices but a further 15 restrictions are required. There are exactly 15 parameters to be recovered and the just identified system $\left[\frac{n(n-1)}{2} = \frac{6(6-1)}{2} = 15\right]$ also requires the same 15 parameters to be recovered from the above identification restrictions. This makes the system to be just identified.

3.4.4 The VAR and SVAR Model Results and Discussions

The Effect of Monetary Policy Shocks

The effects of the monetary policy shock in the TM are characterised in the form of the impulse response to a monetary policy shock estimated from different VARs under the two identification schemes. The main interest of the study is to describe the MTM and determine if the effectiveness of monetary policy transmission mechanism has changed due to the "Great Moderation", the Global Financial Crisis (Beck et al., 2014), government policy and structural changes. To address this, the data is split into two sample periods based on pre and post-GFC. The range of data covers from 1980Q1 to 2014Q4. Previous studies such as SW (2007), CN (2010) and Canova (2011), among others, attempt to address this issue in a slightly different context but their results are not informative due to lack of sufficient data, particularly the post-GFC period. Furthermore, their focus is only on the operation of MTM in the pre and post-adoption of EMU. This study covers the four subsamples based on the three major cases: IT, GM and the GFC.

The cut off point for the two-sample period is therefore determined on the onset of the IT MP and the onset of GFC, where the former is covered in the SVAR and DSGE estimation. The BVAR-IRFs are presented with the number of lags $p = 4$, which is considered to be convenient for a quarterly time series data (see Figure 3.8). The responses of price and the real economic activity to the monetary policy shock are show how opposite of each other across the given sample periods. The responses of price and output in sample period 1 (1992 to 2007) are in line with the stylised facts on MTM (see Figure 3.8). However, the response of price and real economic activity in the sample period 2 (2007 to 2014) is opposite to the stylised facts of the traditional MTM. The intuition behind this outcome leads to a preliminary presumption that the UK MTM may have changed due to internal and external forces. Accordingly, the IRFs show that the economic activity and domestic prices are sensitive to periods of financial crisis as compared to monetary base, interest rate and exchange rates. Turning to the monetary policy impulses, the IRFs in Figure (3.8) also show that, in the pre-GFC period, a contractionary monetary policy in the form of a rise in the short-term interest rate causes a fall in output for about 4 quarters, then responded with persistent increase with a presumed increasing growth rate. The IRFs with opposite responses in the post-GFC, show that output remains above the zero line for about 4 quarters, and then persistently reduces towards the 24th quarter (2 years). In terms of price response, a temporary increase followed by a sluggish but persistent increase of the domestic price level in the pre-GFC, but responses in the post-crisis period show the opposite.

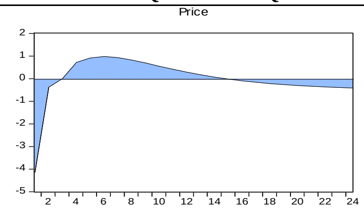
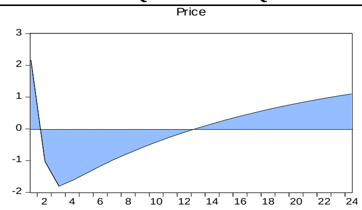
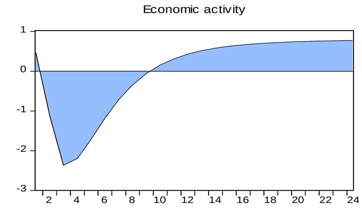
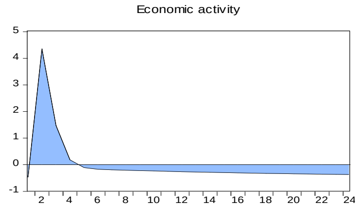
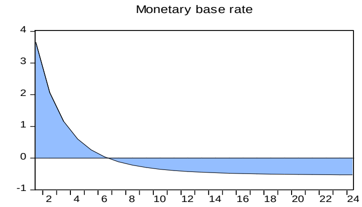
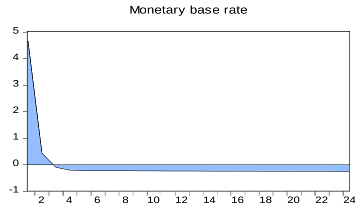
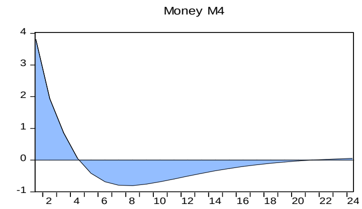
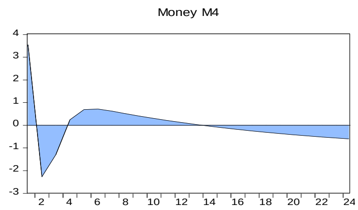
	Bayesian Cholesky Based 1992Q1 to 2007Q3	Bayesian Cholesky Based 2007Q4 to 2014Q4	Description of The IRFs Outcome
Inflation			The IRFs show the price response to a monetary policy shock before and after the GFC. It shows a complete opposite response. The impact of MP shock in the LR moderates but is variable in the post-GFC period. Supply and demand factors are mostly responsible for price movements in the LR rather than MP. However, this does not seem to be the case in the post-2007.
GDP			The economic activity also shows fairly opposite response. In a crisis and recession, consumers and businesses reduce or even stop spending. These declines production, causes unemployment and low investment, which ultimately cause a decline in aggregate demand. The post-GFC IRF confirms this economic implication.
AD			The IRFs, before and after the GFC depict similar patterns of movement. The MP rate responds not only to output and inflation gap (as in Taylor, 1993) but also to its own lag. In addition, the post- GFC response is quicker than the pre-crisis period; there is no marked difference in the long-run.
AS			Theoretically, there is counter-cyclical response of money supply to interest rate movement. The IRFs depict this by immediately reacting to MP shocks. The post-GFC IRF reacted more quickly than the pre-crisis period. Intuitively, this is relevant to economic theory of monetary supply neutrality in the long-run.

Figure 3.8 Normalised Median Response before and after the GFC to MP Shocks

The IRFs are drawn based on 95% confidence internal. For IRFs with the CI, see Appendix 3.

Overall, the IRFs show fairly opposite response to a contractionary monetary policy during the pre and post-crisis periods, except monetary base rate and money supply. In the quarterly VAR with Choleski identification, the negative response of output in the pre-GFC sample reaches to 2.5bps below the zero line for about 3 quarters before it gradually increases throughout the short-run period. The response of domestic price is quantified as -4bps, initially in the pre-crisis period then shows immediate upward movement as compared to a sharp decline from 2bps towards -1.8bps in the pre-crisis period. Notably, the persistent price increase in the post-GFC can be due to the low interest rate regime since 2009. Expansionary monetary policy lowers interest rates, particularly in the short-run. This happens when inflationary effects are not expected. Lower interest rates encourage more consumer and business spending so increases aggregate demand. The economic implication of this opposite movement before and after the GFC implies the changing mechanism of the monetary transmission channels. The traditional mechanism focuses on the interest rate channel as shown in the IRFs. Theoretically, contractionary monetary policy reduces economic activity with lower prices due to lower demand. The opposite effect could be the case in lower interest rate mechanism. However, the persistent decline in economic activity in the post-GFC, an expansionary MP environment, tells a different story. According to the modern macroeconomic theory, this is due to the role of the credit channel in the MTM. A rise in interest rate tends to reduce individuals' and businesses' net worth (*balance sheet channel*). Additionally, a rise in interest rate makes banks less willing to lend (*bank lending channel*). In terms of the *exchange rate channel* reaction to MP shocks, high interest rates lead to currency appreciation as the demand for the currency increases. As a result, exports become more expensive, reduces export volume through the *exchange rate channel* while the currency appreciation attracts more imports, which leads to lower GDP.

Although the information from the BVAR analysis is valuable, the uncertainty around the median estimate is high, as the BVAR approach can easily be affected by the ordering of the variables. The structural VAR, on the other hand, gives a better representation to assess the dynamics of the transmission mechanism during the two sample cases (see Figure 3.9). The results are robust across all identification schemes. The first BVAR case assumes no role of the financial sector and external influences so the two variables (credit and exchange rate) are not included. To measure the role of the response of the financial sector and external impacts, the setting of the structural VAR system alternates between credit and non-credit variable arrangements. The exchange rate variable accounts for the external component in terms of international trade channel. When the credit and exchange rate variables are not in the model (before the crisis), price and economic activity show similar responses except sample period 2 being more volatile. The inclusion of the exchange rate variable highlights the differences in the TM across the two samples (see Figure 3.9). This is also confirmed in Chapter 2 that exchange rate plays significant role in the majority of the standard and hybrid monetary policy reaction functions. The IRFs also display persistent and immediate responses of price and economic activity in sample period 2 than sample period 1. A reverse movement, before and after GFC, is recorded in economic activity and monetary aggregates. However, the aggregate demand (monetary base) remains consistent in both sample periods. According to the median responses of the IRFs in Figure 3.9, there is evidence to suggest that the VAR IRFs have changed when structural restrictions are applied. Noticeably, the decrease in output and price is more visible in sample period 2.

Without Credit and Ex Rate		With Credit and Ex rate	
Structural BVAR	Structural BVAR	Structural BVAR	Structural BVAR
Sample 1: 1992Q1 to 2007Q3	Sample 2: 2007Q4 to 2014Q4	Sample 1: 1992Q1 to 2007Q3	Sample 2: 2007Q4 to 2014Q4

Monetary Policy Shock

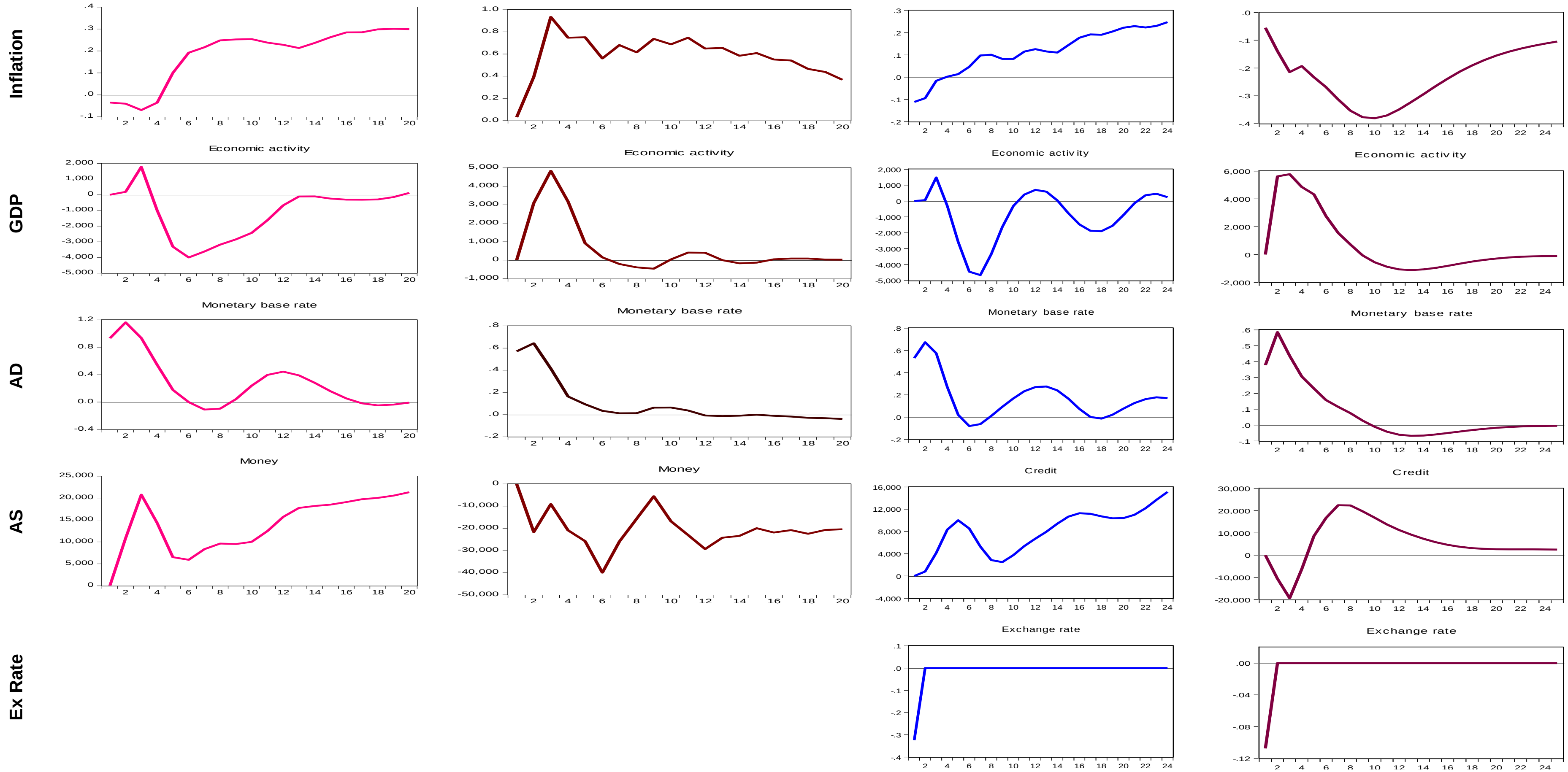


Figure 3.9 Median Response to MP Shock with and without Credit and Exchange Rate

The IRFs are drawn based on 95% confidence internal. For IRFs with the CI, see Appendix 2.

In the absence of credit supply and exchange rate variables, IRFs display no significant shifts in terms of responses except the monetary base. The empirical experiment highlights the role of credit supply and exchange rate shocks on economic activity and domestic prices. The response by the exchange rate shows no marked difference with and without the credit market in the system except during the first 2 quarters. Intuitively, this implies the stable UK currency movements against the U.S. dollar. The currency shows no marked movement before and after the GFC unlike output and prices. The most interesting outcome is the response of price, economic activity and exchange rate to the MP shock. During the post-GFC period, the real economy and price accounted for up to 3.4 percent and 0.23 percent, respectively to the monetary policy shock. For the credit shock, real output and price accounted for 24 percent and 0.4 percent respectively. This implies that the credit channel is more prominent in sample period 2, particularly after the Global Financial Crisis (see Appendix 3 for IRFs and FEVD). This signifies a shift in the perception of the transmission mechanism, which previously taught that the interest rate shock was the only important impulses while other channels, according to the traditional MTM, are functioning as a simple pass-through mechanism.

The FEVD (see Appendix 3) and the IRFs show that the asset price channel works in both sample periods when credit is included in the model. It shows strong response to both credit and monetary policy shocks. This requires further investigation to understand to what extent the asset price channel contributes to overall economy, particularly to output and price. The decline in real activity is more distinct and the price level drops more strongly. In the quarterly VAR with Choleski identification, the peak response of output was 0.51bp and 4.1bps for a short period in the pre and post-crisis samples respectively, and -0.33bp and -0.04bp for the CPI price. To sum up, the IRFs and the FEVDs (see Appendix 3) drown from the Structural Bayesian VAR analyses report that there are minor changes in the effects of monetary policy on output and prices over the the time horizons. However, the VAR evidence is sensitive to changes due to variable ordering, among others, and cannot provide clear and robust information. It is also impossible to separate the responses across sectors, as a modification of the structure from changes in the conduct of monetary policy. Although, the family of VAR models became popular in the forecasting literature pioneered by Litterman (1986) and have been proved to be a reliable tool in terms of data description and forecasting, it is subjected to the Lucas critique (Lucas, 1976).

Furthermore, research shows that structural VAR convincingly show, on one hand, that it is impossible to separate the effects of changes in the policy rule and in the variance of the shocks (Benati and Surico, 2009) and on the other hand, counterfactuals based on SVARs are unreliable and independent of the issue of parameter identification (Benati, 2009). Additionally, the VAR response functions are not able to show the non-linear combinations of structural parameters as it assumes short-term linear interactions. To fill this gap and generate better information about the precise changes (if any) in the traditional MTM, the study employs a Bayesian DSGE model approach, in a New Keynesian setting, to address and quantify the dynamics of the UK MTM based on price and wage rigidity hypothesis. This approach, pioneered by Kydland and Prescott (1982) and Long and Plosser (1989), has become increasingly popular for evaluating the transmission mechanism. The Dynamic Stochastic General Equilibrium (DSGE) models are derived from the first principles. It describes the general equilibrium of a model economy in which agents like consumers, firms, banks, entrepreneurs and the government interact in the economic system to maximise their objectives subject to budget and resource constraints (Del Negro and Schorfheide, 2003). To assess the UK monetary transmission mechanism and disentangle the various channels at work, the estimation of structural DSGE model is believed to provide reliable information and its robustness is highlighted in macroeconomic literature. The following section presents the data, the model economy and the results of the investigation.

3.5 The DSGE Models and the Basic Structure

The VAR results show that it is difficult to interpret the impulse responses and FEVDs estimated from the Choleski and structural approaches. The results are sensitive to small adjustments such as the restriction and the identification schemes. Therefore, the estimation of a more structured and micro-founded model can indicate if there have been offsetting forces that change the MTM as elicited from the VAR model or there could be a possibility that there has been no change at all. To investigate the presence of offsetting forces in the UK MTM, the following section uses an augmented DSGE model for the UK economy. In the past decade, the DSGE models have become the main tools in modern macroeconomics and received a wider recognition among researchers in academia and central banks (Kremer et al., 2006). The term DSGE refers to a class of dynamic stochastic macroeconomic models that feature a sound micro-founded general equilibrium framework. It is mainly characterised by the optimisation objectives of rational agents under the presence of technology, institutional and budget constraints (Smets et al., 2010). The DSGE model is able to fit the structural functions of the demand shocks, supply shocks, monetary policy shocks, productivity shocks, expectations and monetary policy decisions to the data. The disaggregated agents' and policymakers' decision in the presence of permanent and momentary shocks in the monetary transmission mechanism are suitably fit to the data. In this outline, the general DSGE framework can be represented in the following simplified diagrammatic exposition that illustrates the interaction of various shocks such as demand, cost-push, productivity and monetary policy:

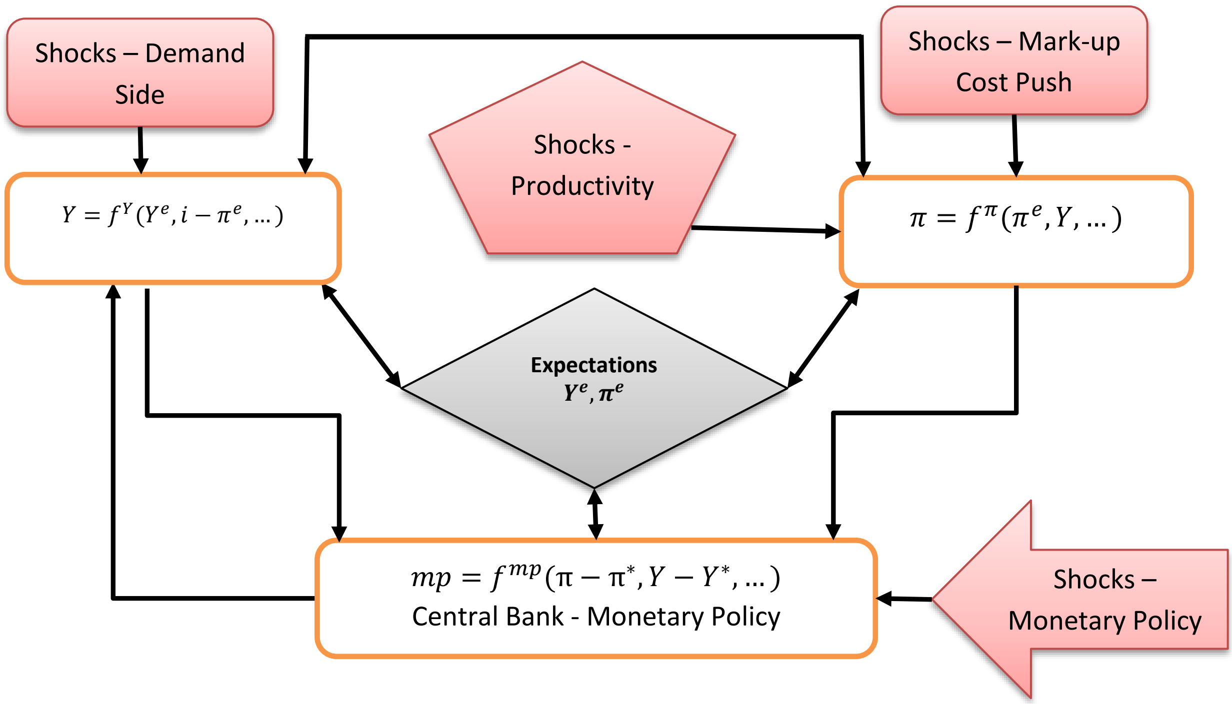


Figure 3.10 A Simplified DSGE Graphical Exposition based on Three Blocks

Unlike the VAR and SVAR specifications, Figure 3.10 demonstrates the interaction among the agents in a basic dynamic stochastic general equilibrium setting.[50] It also insights how the MTM works in the presence of supply and demand shocks and expectations. As shown in the figure, the dynamic model represents the economy by three interrelated blocks: a demand block, a supply block and a monetary policy block. The households' optimal behaviour and their decision making process is characterised by the demand block. It determines the real economic activity (Y) as a function of expected interest rate and future economic activity, which equals the difference between nominal interest rate r and the expected inflation rate π^e. As the rise in the real interest rate increase savings and lowers consumption and investment, it exhibits a negative association, while the functional relationship between real activity and its expected value is assumed to be positive. This positive functional relationship captures the willingness of households to spend more in anticipation of a better economy to come. The supply block represents the firms' optimal decision-making behaviour. It captures a positive relationship between the rate of inflation and the level of real activity, which expresses the weight of factor prices on producer prices, resulted from increased competition for scarce resources. It also accounts for a positive relationship between current inflation and expected inflation (Sbordone et al., 2010). Furthermore, the authors note that the values of real activity and inflation determined by the demand and supply block enter into the monetary policy block. The MP is often described by a central bank that sets the short-term nominal interest rate (base rate). According to the Taylor MP rule, the MPC adjusts the nominal interest rate in response to deviations of current inflation and real activity from their respective target values $(\pi^* \ and \ Y^*)$. The central bank monetary policy reaction function closes the dynamic model to allow complete description of the relationship between output, inflation and the nominal interest rate.

The inclusion of expectations in the DSGE model provides a forward looking dynamic interaction between the three blocks. The stochastic nature of this model originates from exogenous process, which is called shocks. These shocks account for the fluctuations of the model around its deterministic steady state equilibrium, which is also known, as a perfectly predictable path, with neither booms nor busts. In the spirit of the interaction of the three blocks, the MTM is characterised by the transmission arrows that connects the blocks. As shown in the simplified DSGE model diagram (see Figure 3.10), the connecting arrows to and from the blocks of demand, mark-up cost, productivity and monetary policy shocks are impacted by specific driving forces. Using a Bayesian DSGE setting, this study addresses how the movement of these forces altered, if any, the dynamics of the transmission mechanism due to major policy changes, the recent GFC and external forces.

[50] The diagram is the author's adaptation according to Sbordone et al. (2010).

3.5.1 Data, Methodology and Parameter Calibration

The DSGE model that characterises the UK monetary policy is based on Smets and Wouters (2007), CEE (2005) and Milani (2012). Parameter calibration and estimation follows SW (2003, 2007) and is an extension of the model used in CEE (2005) and modified by CN (2011). The calibration is carried out by changing the reaction functions. The reaction function for the UK monetary policy rule is a Taylor rule type to inflation and output gap as stated in Chapter 2. As shown in Figure 3.14, the impulse responses are reasonably good matches for the parameterisation of the model. This implies that the impulse response functions are non-linear combination of structural parameters where differences in those parameters may give rise to almost identical impulse response as estimated from a VAR. The data generating process of the time series includes inflation, output, nominal interest rate, monetary aggregate, investment, consumption, capital, wage and hours worked. The time series of the relevant macroeconomic variables are simulated under a baseline calibration of the model.

The DSGE model components reported from Equations (3.15 to 3.27) are in loglinearized form only to show the role that various shocks in the dynamics of the economy and the MTM. The main building blocks on which the model consists are a basic real business cycle (RBC) model, including investment decisions, capital accumulation, households' labour supply decisions, shocks to total factor productivity, and of a stylised New Keynesian model that allows for imperfect competition, nominal rigidities, such as price and wage stickiness, which assumes an interest rate rule for monetary policy. The model is a successful combination of the two approaches, which is further extended to include features such as capital utilisation, habit formation in consumption, indexation in price and wage settings, and a variety of additional disturbances that help the model to fit the data in the context of the TM with a Taylor rule MP reaction functions.

The Bayesian DSGE model is based on a three-equation basic New Keynesian model in which inflation and output gap depends on a forward looking[51] monetary policy reaction function that the nominal interest rate responds to its lagged value, and to current inflation and output gaps. The model estimating process uses quarterly series ranging from 1980Q1 to 2014Q4[52], and matches the following seven variables: GDP-deflator based inflation, nominal hourly wage inflation, real consumption, real investment, real GDP, employment (matching total hours in the model) and the three-month nominal interest rate. The model is linearly detrended for consumption, investment,

[51] See Chapter 2 for further information on backward and forward looking reaction functions.

[52] As mentioned in the introduction, the DSGE model is simplified in several dimensions; it would not capture adequately the macroeconomic developments of the recent financial crisis. For this reason, the estimates are carried out in a sample period ending in the second quarter of 2007.

GDP, employment and deviations from their respective means for inflation, the interest rate and wage inflation. The linear trends are estimated over the full sample.[53]

The Bayesian method combines information from the prior distribution of the structural parameters that contained in the likelihood function of the model. The resulting posterior distribution of the parameters usually does not belong to any standard family, and therefore the inference must be based on simulation methods. It is a common practice to use the Metropolis Hastings Algorithm (MHA) to generate draws from the posterior distribution. As in SW (2007), CEE (2005) and CN (2011), the estimation process follows two steps. *First*, the log of the posterior density is maximised and followed by computing an approximation of the inverse of the Hessian at the mode. *Second*, 200,000 draws are generated from the posterior distribution of the parameters using a multivariate normal distribution with covariance matrix proportional to the inverse of the Hessian.[54]

3.5.2 The Model Economy

Following SW (2007) and Milani et al. (2012), the model reported below is in loglinearized form mainly to show the role that various shocks and expectations play. The building blocks of the model economy consist of a basic real business cycle (RBC) model, in which investment decisions, capital accumulation, households' labour supply decisions on how many hours to work and shocks to total factor productivity play an important role. The stylised New Keynesian model allows for imperfect competition, nominal rigidities such as price, and wage stickiness and assumes an interest-rate rule for monetary policy. The UK MTM endogenous variables include:

$$\{y_t c_t i_t z_t r_t q_t k_t \mu_t^p l_t k_t^s w_t \mu_t^w \; mpk_t \pi_t \pi_t^w r_t^w\}$$

the exogenous variables are:

$$\{\varepsilon_t^g \varepsilon_t^a \varepsilon_t^b \varepsilon_t^i \varepsilon_t^p \varepsilon_t^w \varepsilon_t^r\}$$

$$y_t = c_y c_t + i_y i_t + u_y u_t + \varepsilon_t^g \tag{3.15}$$

equation (3.15) represents the economy's aggregate resource constraint. Output y_t is absorbed by consumption c_t, by investment i_t, and by the resources used to vary the capacity utilization rate u_t. According to Milani et al. (2012), the government spending is assumed to be exogenous and captured by the disturbance ε_t^g.

$$c_t = c_1 c_{t-1} + (1 - c_1) E_t c_{t+1} + c_2(l_t - E_t l_{t+1}) - c_3(r_t - E_t \pi_{t+1} + \varepsilon_t^b) \tag{3.16}$$

[53] For a description of the data, see Appendix 3A.

[54] The estimation is done with Dynare 4.3.4. The scale factor for the jump distribution has been set in order to obtain acceptance rates around 30 percent.

Equation (3.16) is the Euler equation for consumption, where the contemporaneous value for consumption depends on expectations about future consumption, on lagged consumption, on current and expected hours of work l_t and on the ex-ante real interest rate $(r_t - E_t\pi_{t+1})$. The term ε_t^b indicates a risk-premium shock which is an exogenous shock that affects yields on bonds. It is, sometimes, substituted in the literature by a preference or discount factor shock, which enters in similar ways but with a converted sign in the Euler equation. The investment and capital stocks are formulated as:

$$i_t = i_1 i_{t-1} + (1 - i_1)E_t i_{t+1} + i_2 q_t + \varepsilon_t^i \tag{3.17}$$

$$q_t = q_1 E_t q_{t+1} + (1 - q_1)E_t r_{t+1}^k - (r_t - E_t\pi_{t+1} + \varepsilon_t^b)$$

$$q_t = \frac{R_*^k}{R_*^k + 1 - \delta} E_t\{mpk_{t+1}\} + \frac{1 - \delta}{R_*^k + 1 - \delta} E_t\{q_{t+1}\} - r_t + \varepsilon_t^b \tag{3.18}$$

Equation (3.17) and (3.18) characterise the dynamics of investment. Current investment is influenced by expectations about future investment, by lagged investment and by the value of capital stock q_t. The capital stock is driven by expectations about its future one-period-ahead value, by expectations about the rental rate on capital $E_t r_{t+1}^k$, and by the ex-ante real interest rate. The disturbance terms ε_t^i and ε_t^b affect the behaviour of investment. ε_t^i denotes investment-specific technological charge, while ε_t^b is the same risk-premium shock that also enters the consumption Euler equation which helps in fitting the co-movement of the investment and consumption series.

$$y_t = \Phi_p(\alpha k_t^s + (1 - \alpha)l_t + \varepsilon_t^a \tag{3.19}$$

Equation (3.19) is a Cobb-Douglas production function: output is produced using capital services K_t^s and labour hours l_t. Neutral technological progress enters the expression as the exogenous shock ε_t^a. The coefficient Φ_p captures fixed costs in production. The capital utilisations are expressed in the following equations:

$$k_t^s = k_{t-1} + u_t \tag{3.20}$$

$$u_t = u_1 r_t^k$$

$$z_t = \frac{1 - \psi}{\psi} mpk_t \tag{3.21}$$

$$k_t = \delta i_t + (1 + \delta)k_{t-1} + \delta(1 + \beta)\varphi\varepsilon_t^i \tag{3.22}$$

Equation (3.20) accounts for the possibility to vary the rate of capacity utilization. Capital services are a function of the capital utilization rate u_t and of the lagged capital stock k_{t-1}. The degree of capital utilization itself varies as a function of the rental rate of capital, as evidenced by Equation (3.21). From Equation (3.25), the rental rate of capital is a function of the capital to labour ratio and of the real wage. Capital rate of depreciation is accumulated according to Equation (3.22). The equilibrium in the labour (HHC channel) and goods market takes the following form:

$$\mu_t^p = \alpha(k_t^s - l_t) - w_t + \varepsilon_t^a \tag{3.23}$$

$$\pi_t = \frac{\iota_p}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}E_t\{\pi_{t+1}\} - \frac{1}{1+\beta}\frac{\left(1-\xi_p\right)}{\xi_p}\mu_t^p + \varepsilon_t^p \tag{3.24}$$

$$r_t^k = -(k_t - l_t) + w_t \tag{3.25}$$

Also as:

$$mpk_t = -(k_t^s - l_t) + w_t$$

$$\mu_t^w = w_t - \left(\sigma_l l_t - \frac{1}{1-h/\gamma}(c_t - \frac{h}{\gamma}c_{t-1})\right) \tag{3.26}$$

$$w_t = w_1 w_{t-1} + (1-w_1)\, E_t\{w_{t+1} + \pi_{t+1}\} - w_2\pi_t + w_3\pi_{t-1} - w_4\mu_t^w + \varepsilon_t^w \tag{3.27}$$

Equation (3.23) to Equation (3.27) summarise the equilibrium in the goods and labour markets. Inflation π_t is determined as a function of lagged inflation, expected inflation, and the price mark-up μ_t^p, which is equal to the difference between the marginal product of labour $\alpha(k_t^s - l_t) + \varepsilon_t^a$ and the real wage w_t. The real wage depends on lagged and expected future real wages, on past, current, and expected inflation, and on the wage mark-up μ_t^w, which equals the difference between the real wage and the marginal rate of substitution between consumption and leisure. Inflation and wage dynamics are also affected by the exogenous price and wage mark-up shocks, ε_t^p and ε_t^w, which are obtained by assuming a time-varying elasticity of substitution among differentiated goods.

$$r_t = \rho r_{t-1} + (1-\rho r\,)\left(\chi_\pi \pi_t + \chi_y(y_t - y_t^*)\right) + \chi_{\Delta y}(\Delta y_t - \Delta y_t^*) + \varepsilon_t^r \tag{3.28}$$

$$r_t = r_t^n + E_t\{\pi_{t+1}\} \tag{3.29}$$

Equations (3.28 and 3.29) describe a type of Taylor rule. The monetary authority sets the interest rate r_t in response to changes in inflation and the output gap. The policy rate also responds to the growth in the output gap. The term ε_t^r captures random deviations from the systematic policy rule. The coefficients in the model are composite functions of the "deep" preference and technology parameters, such as the degree of habits in consumption, the elasticities of intertemporal substitution and of labour supply and the *Calvo* price rigidity coefficients, among others (Milani, 2012; SW, 2007).

The model governs the dynamics of 17 endogenous variables, which play in the movement of shocks in the transmission mechanism. The sources of uncertainty are given by Equation (3.21) random shocks: to government spending, risk-premium, investment-specific and neutral technology, price and wage mark-up and monetary policy. All exogenous shocks, often with the exception of the monetary policy shock (assumed *i.i.d.*), are assumed to follow AR(1) or ARMA(1,1,) processes. Seven expectation (expectations channel) terms directly enter the model: expectations about future consumption $E_t C_{t+1}$, hours of work $E_t l_{t+1}$, inflation $E_t \pi_{t+1,}$ investment $E_t i_{t+1}$, value of capital $E_t q_{t+1}$, rental rate of capital $E_t r_{t+1}^k$, and wages $E_t w_{t+1}$. The expectations are typically modelled as being formed according to the REH. The notation E_t in the model denotes model-consistent rational expectations, that is, the mathematical conditional expectation based on time t information set and derived from the above equations.

The model features monopolistic competition in product and labour markets as well as nominal rigidities in prices and wages that allow for backward inflation indexation. In order to match the data various other features such as, habit formation, costs of adjustment in capital accumulation and capacity utilisation, are introduced to the DSGE model. The interest rate channel is assumed to be the main channel that influences the UK MTM with the presence of the credit channel to account for the financial stress. The inclusion of wage and price mark-ups highlights the price and wage rigidities that imply the changes in the nominal interest rate, affecting the real interest rate based on the decisions on the intertemporal allocation of consumption of the agents. As in SW (2007), consumption and leisure are treated separately and the standard Dixit-Stiglitz aggregator are used for prices and wages (as in CN, 2011) instead of the Kimball aggregator of SW (2007). The share of fixed cost in the production function is set to zero, and finally, the study assumes no steady state growth for the UK economy. The Taylor type interest rate rule is modified to fit the model and assumed to be implemented by the central bank:

$$r_t = \rho r_{t-1} + (1-\rho)\left[\rho_\pi \pi_t + \rho_y y_t^{GDP}\right] + \epsilon_t \tag{3.30}$$

where y_t^{GDP} is the weighted sum (with weights equal to the steady state shares) of real consumption, real investment and real government spending that represents real output. As there is sufficient size of the sample used for two periods, the model does not need to be simplified as in CN (2011) and reducing parameter space is not required because the time series is sufficient to respond to the prior parameter restrictions.

3.5.3 Prior and Posterior Distributions

Some of the model parameters are calibrated (see Table 3.2). In line with the historical average for the euro area and as in SW (2007), the households' discount factor is set at 0.995 in order to obtain a steady-state real short-term interest rate of 2 per cent on an annual basis in the process of household intertemporal choices adjusted by a DF. The capital share, the depreciation rate and the share of government spending over output, are set at 0.25, 0.025 and 0.15, respectively, to reflect the standard SW type DSGE model specification. Both shares of government spending and capital are similar to the values used in SW (2007) and CN (2010). As in SW, the share of fixed cost in production is set to zero. Allowing for these costs does not affect the shape and magnitude of the impulse responses. The adjustment cost for capacity utilization is set to 0.1. The parameter measuring the mark-up in wage setting is set at 1.5 as in SW, while the inverse of the labour supply elasticity is calibrated at 1.5, in line with the range of available estimates.

Table 3.2 Calibrated Parameters

Parameter	Value	Descriptions
β	0.995	Discount factor
δ	0.025	Capital depreciation rate
g_y	0.15	Steady state share of gov't spending on output
α	0.25	Capital share in production function
i_y	0.22	Share of investment
ϕ_w	1.5	Steady state mark-up of wage setters
σ_l	1.5	Inverse of the labour supply elasticity
ψ	0.1	Adjustment cost of capital utilisation

Source: standard calibrations as in SW (2007).

The specification and parameterisation of the prior distributions are equal across the subsamples and reported in Table 3.2. All the distributions are fairly loose. The mean of the autoregressive coefficient of the shock processes is set at 0.50. The (β) distribution of the *Calvo* probabilities for prices (ξp) and wages (ξw) have a mean of 0.75, which corresponds to an average duration of one year. The means of the beta distribution of the parameters measuring the indexation of prices (ιp) and wages (ιw) to past inflation are set at 0.50 with a standard deviation of 0.15. The mean of the (β) distribution of the parameter measuring the degree of habit formation in consumption (γ) is set at 0.70, in line with SW (2003, 2007). The parameter measuring the risk aversion (σ_c) has a mean of 1.5, while the cost for adjusting investment (ϕ) has a mean of 5.0, in line with the prior in SW and CN (2011). The prior distribution of the policy parameters is set the mean of the coefficients of the response of past interest rate, current inflation and output equal to 0.75, 1.5 and 0.125, respectively.

3.5.4 The DSGE Model Estimation

Table 3.3 to Table 3.6 report priors and sets of results for parameter estimates. The first set contains the estimated posterior mode of the parameters, which is obtained by directly maximizing the log of the posterior distribution with respect to the parameters, and the second set contains an approximate standard error based on the corresponding Hessian. The posterior distribution of the parameters is obtained through the Metropolis-Hastings sampling algorithm. The results are based on 200,000 draws generated with the random walk version of the Metropolis Hastings Algorithm (MHA). Several results are worth a comment. Most parameters are estimated to be different from zero. The autoregressive parameters are estimated to have persistent shocks that lies between 0.97

(for the technology shocks) and 0.99 (for the government spending shocks) during the pre-IT period; 0.89 and 0.99 respectively, for the post-IT period. The parameter estimates are discussed below.

Table 3.3 Parameter Estimation-1 Pre and Post-IT SPs and Adjustment Costs

Estimated Maximum Prior and Posterior								
					Posterior Distribution MH			
Parameters		Prior			Pre-1993 (IT)		Post-1993 (IT)	
		Distribution	Mean	s.d.	mode	s.d.	mode	s.d.
Structural Parameters: AR and MA Shocks								
Technology	(ρ_a)	β	0.50	0.2	0.972	0.007	0.887	0.028
Preference	(ρ_β)	β	0.50	0.2	0.098	0.059	0.577	0.092
Gov. spending	(ρ_g)	β	0.50	0.2	0.998	0.002	0.996	0.003
Investment	(ρ_i)	β	0.50	0.2	0.091	0.059	0.122	0.077
Interest rate	(ρ_r)	β	0.50	0.2	0.189	0.063	0.029	0.023
Inflation	(ρ_p)	β	0.50	0.2	0.990	0.004	0.287	0.191
Wage	(ρ_w)	β	0.50	0.2	0.926	0.032	0.440	0.203
Price	(μp)	β	0.50	0.2	0.886	0.037	0.483	0.132
Wage	(μw)	β	0.50	0.2	0.878	0.049	0.481	0.167
Structural Parameters: adjustment costs and coefficients								
Investment adjustment costs	(φ)	$N(\mu,\sigma^2)$	5.00	1.50	7.283	1.075	4.572	1.112
Consumption	(σ_c)	$N(\mu,\sigma^2)$	1.50	0.38	1.792	0.259	0.847	0.048
Habit in consumption	(h)	β	0.70	0.10	0.797	0.019	0.949	0.009
Wage Calvo adjustment	(ξw)	β	0.75	0.10	0.950	0.014	0.876	0.021
Labour supply	(σl)	$N(\mu,\sigma^2)$	2.00	0.75	3.057	0.654	2.799	0.671
Price Calvo adjustment	(ξp)	β	0.75	0.10	0.611	0.065	0.421	0.085
Wage indexation	(ιw)	β	0.15	0.15	0.186	0.053	0.165	0.066
Price indexation	(ιp)	β	0.15	0.15	0.169	0.077	0.334	0.136
Steady-state capital utilization rate	(z_k)	β	0.50	0.15	0.081	0.041	0.693	0.130
Fixed cost in production	(ϕ_p)	$N(\mu,\sigma^2)$	1.25	0.13	1.945	0.088	1.455	0.101
T.R. coefficient on inflation	(ρ_π)	$N(\mu,\sigma^2)$	1.50	0.25	1.010	0.003	2.110	0.001
T.R. interest rate smoothing	(ρ_i)	β	0.75	0.10	0.849	0.017	0.500	0.069
T.R. coefficient on output	(ρ_y)	$N(\mu,\sigma^2)$	0.125	0.05	0.011	0.001	0.038	0.017
T.R. coefficient on d(output)	(ρ_{dy})	$N(\mu,\sigma^2)$	0.125	0.05	0.128	0.016	0.265	0.039
Steady-state inflation rate	(π)	γ	0.625	0.20	0.583	0.189	0.669	0.124
Steady-state nominal interest rate	$(100[\beta^{-1}-1)$	γ	0.25	0.10	0.178	0.070	0.165	0.069
Steady-state hours worked	(l)	$N(\mu,\sigma^2)$	0.00	2.00	-0.624	1.506	-1.646	1.309
Trend growth rate	$(trend)$	$N(\mu,\sigma^2)$	0.40	0.10	0.299	0.053	0.269	0.031
Response of gov. spending to prod	(ηga)	$N(\mu,\sigma^2)$	0.50	0.25	1.128	0.152	0.154	0.097
Capital share in production	(a)	$N(\mu,\sigma^2)$	0.30	0.05	0.124	0.017	0.150	0.029
Leverage ratio	(lev)	$N(\mu,\sigma^2)$	1.70	0.20	-	-	1.6302	0.229
Elasticity external risk premium	(w)	$N(\mu,\sigma^2)$	0.05	0.02	-	-	0.0360	0.013

Source: author's analysis.

3.5.5 Results and Discussions

Price and Wage Rigidities

Calvo parameters for nominal wage (ξw) and prices (ξp): focusing on the parameters characterising the degree of price and wage stickiness, the posterior estimates show that the indexation parameters are estimated close to the prior information. According to the posterior estimates, there is a significant reduction in the *Calvo* parameters for nominal wage and prices. The former declines from 0.95 in the pre-IT sample to 0.87 in the post-IT sample while the latter declines from 0.61 to 0.42 (see Table 3.3). Both findings indicate a decrease in the degree of nominal rigidities in the UK economy, showing that the transmission mechanism has not been working the same way before and after the announcement of the inflation targeting monetary policy. The nominal price and wage became more sluggish or resistant in the post-IT period as compared to the pre-IT period. This means that the two parameters were less responsive to macroeconomic shocks as much as it would if they were flexible. The presence of price and wage rigidities explains why markets could fail to reach equilibrium in the short to long-run periods. Keynes (1936) also discussed in his *General Theory of Employment, Interest* and *Money* that nominal wage displays downward rigidity, in the sense that workers are reluctant to accept cuts in nominal wage, which possibly leads to involuntary unemployment as it takes time for the wages to adjust to equilibrium (Knotek, 2009). This seems to have happened in the UK between the post-IT and the start of the GFC and it could possibly be explained due to low inflationary period. Furthermore, the second DSGE model estimation for the pre and post-GFC periods show that the nominal wage *Calvo* adjustment increases from 0.85 to 0.90 and the price *Calvo* adjustment slightly increases from 0.61, pre-GFC to 0.64, post-GFC periods (see Table 3.3). The findings also indicate an increase in the degree of nominal price and wage rigidities in the post-crisis period showing that price and wages have not been responsive to macroeconomic shocks during the post-financial crisis period. This, obviously, is due to the austerity measures taken by the government to balance the books. One of those measures was to freeze wage increases for a certain period of time, which affects household expenditure so price remains to be less responsive to market shocks.

Wage and Price Indexations

Degree of indexation of nominal wage contract (ιw) and price (ιp): the degree of indexation of nominal wage contracts to inflation (ιw) falls in the post-IT sample to 0.15 as compared with 0.19 in the pre-IT period. Concerning the pre and post-crisis periods, a slight increase is documented from 0.22 to 0.24 for wage indexation, and from 0.25 to 0.30 for price indexation, (see Table 3.3, 3.4 and 3.5). This implies that there was more wage and price protection during the post-crisis period than the post-IT period (up to 2007).

Table 3.4 Parameter Estimation-1 Pre and Post-IT Macroeconomic Shocks

Estimated Maximum Prior and Posterior								
					Posterior Distribution MH			
Parameters		Prior			Pre-1993 (IT)		Post-1993 (IT)	
		Distribution	Mean	s.d.	mode	s.d.	mode	s.d.
IG (γ^{-1}) Shock Accounting								
Technology shock	(σ_a)	γ^{-1}	0.100	2	0.831	0.061	1.039	0.093
Financial stress shock	(σ_b)	γ^{-1}	0.100	2	0.709	0.059	0.251	0.053
Preference shock	(σ_β)	γ^{-1}	0.100	2	1.695	0.109	0.875	0.076
Government spending shock	(σ_g)	γ^{-1}	0.100	2	1.638	0.127	1.513	0.159
Investment shock	(σ_i)	γ^{-1}	0.100	2	0.309	0.019	1.030	0.089
Interest rate shock	(σ_r)	γ^{-1}	0.100	2	0.781	0.073	0.646	0.067
Inflation shock	(σ_p)	γ^{-1}	0.100	2	0.313	0.030	0.311	0.039
Wage shock	(σ_w)	γ^{-1}	0.100	2	0.831	0.061	1.039	0.093

Source: author's analysis.

The intuition behind the fall in wage indexation during the post-IT period can be explained by the nature of the UK free and open market, particularly in the post-IT than the pre-IT period. The CBI also plays significant role in reducing government involvement in monetary policy issues. It also shows that the UK government indexed public sector wages to inflation in order to transfer the risk of inflation expectation away from the workers during the pre-IT period. During this period, the government was absorbing the risk of inflation, as inflation was rising rapidly, so the decision to index wages helped to control household expectation of high inflationary period. Therefore, an increase in inflation over a period of time leads to an increase in public sector wages to reduce inflationary expectations. On the contrary, price indexation increases from 0.17, pre-IT to 0.33, post-IT periods (see Table 3.4). In both cases, the estimates of the actual degree of price/wage rigidity and indexation match the degree of rigidity imposed in the priors.

Table 3.5 Parameter Estimation-2 Pre and Post-GFC SPs and Adjustment Costs

Estimated Maximum Prior and Posterior								
					Posterior Distribution MH			
Parameters		Prior			Pre-2007 (Exc. FC)		Post-2000 (Inc. FC)	
		Dist.	Mean	s.d.	mode	s.d.	mode	s.d.
Structural Parameters: AR and MA Shocks								
Technology	(ρ_a)	β	0.500	0.2	0.794	0.043	0.678	0.087
Preference	(ρ_β)	β	0.500	0.2	0.181	0.095	0.773	0.067
Gov. spending	(ρ_g)	β	0.500	0.2	0.994	0.003	0.989	0
Investment	(ρ_i)	β	0.500	0.2	0.301	0.115	0.336	0.136
Interest rate	(ρ_r)	β	0.500	0.2	0.038	0.029	0.275	0.094
Inflation	(ρ_p)	β	0.500	0.2	0.178	0.103	0.156	0.102
Wage	(ρ_w)	β	0.500	0.2	0.378	0.166	0.379	0.123
Price	(μp)	β	0.500	0.2	0.589	0.045	0.581	0.045
Wage	(μw)	β	0.500	0.2	0.523	0.123	0.617	0.054
Structural Parameters: adjustment costs and coefficients								
Investment adjustment costs	(φ)	$N(\mu,\sigma^2)$	4.00	1.50	5.711	1.297	5.489	1.173
Consumption	(σ_c)	$N(\mu,\sigma^2)$	1.50	0.38	1.688	0.245	0.668	0.062
Habit in consumption	(h)	β	0.70	0.10	0.897	0.029	0.883	0.020
Wage Calvo adjustment	(ξw)	β	0.50	0.10	0.858	0.026	0.904	0.015
Labour supply	(σl)	$N(\mu,\sigma^2)$	2.00	0.75	2.677	0.689	1.630	0.405
Price Calvo adjustment	(ξp)	β	0.50	0.10	0.614	0.063	0.637	0.063
Wage indexation	(ιw)	β	0.50	0.15	0.221	0.087	0.244	0.094
Price indexation	(ιp)	β	0.50	0.15	0.248	0.097	0.295	0.110
Steady-state capital utilization rate	(z_k)	β	0.50	0.15	0.473	0.181	0.643	0.139
Fixed cost in production	(ϕ_p)	$N(\mu,\sigma^2)$	1.25	0.13	1.507	0.099	1.497	0.100
T.R. coefficient on inflation	(ρ_π)	$N(\mu,\sigma^2)$	1.50	0.25	1.214	0.099	1.001	0
T.R. interest rate smoothing	(ρ_i)	β	0.75	0.10	0.575	0.078	0.915	0.017
T.R. coefficient on output	(ρ_y)	$N(\mu,\sigma^2)$	0.125	0.05	0.132	0.047	0.035	0.025
T.R. coefficient on d(output)	(ρ_{dy})	$N(\mu,\sigma^2)$	0.125	0.05	0.245	0.051	0.067	0.019
Steady-state inflation rate	(π)	γ	0.625	0.20	0.501	0.145	0.968	0.092
Steady-state nominal interest rate	$(100[\beta^{-1}-1)$	γ	0.25	0.10	0.1734	0.074	0.179	0.076
Steady-state hours worked	(l)	$N(\mu,\sigma^2)$	0.00	2.00	-1.2998	0.977	-1.517	1.051
Trend growth rate	$(trend)$	$N(\mu,\sigma^2)$	0.40	0.10	0.1843	0.021	0.108	0.019
Response of gov. spending to prod	(ηga)	$N(\mu,\sigma^2)$	0.50	0.25	0.3094	0.107	0.122	0.136
Capital share in production	(a)	$N(\mu,\sigma^2)$	0.30	0.05	0.2002	0.035	0.191	0.031
Leverage ratio	(lev)	$N(\mu,\sigma^2)$	1.70	0.2	-	-	1.6302	0.2293
Elasticity external risk premium	(w)	$N(\mu,\sigma^2)$	0.05	0.02	-	-	0.0360	0.0132

Source: author's analysis.

Macroeconomic Shocks

Monetary policy (ρ_i) *, inflation* (ρ_π) *and output* (ρ_y)*:* a significant increase in the response of monetary policy to inflation is documented (ρ_π rises from 1.01 to 2.10) and an increase in the coefficient of output (ρ_y rises from 0.011 to 0.038). Notably, the results suggest that the UK monetary policy is more focused on price stabilisation in the post-IT period than the pre-IT period, which was clearly the aim of the UK monetary policy. This also shows that the model explains the data well. There are also other findings concerning parameter measuring the cost for adjusting investment (φ), which decreases in the post-IT period and the degree of habit formation in consumption (h) increases in the post-IT period from 0.80 to 0.85. With regards to the pre and post-crisis periods, the coefficient of inflation declines from 1.21 to 1.00, response of monetary policy to inflation increases from 0.58 to 0.92. The coefficient of output markedly decreases from 0.13 to 0.04, implying to the recession period (post 2009). The findings, together with the changes in the structural parameters and the policy rule, call for deeper analysis and understanding of the role played by these factors in generating the fall in the volatility of real GDP and inflation (output falls from 0.05 to 0.016 percent and inflation from 0.25 to 0.03). The responses of macroeconomic shocks are plotted to a one percent standard deviation shock to the interest rate Taylor rule after four quarters. The IRFs in Figures 3.11 to 3.13 report the draws of the posterior distribution of the impulse responses of output, inflation and other macroeconomic variables in a two years' time horizon together with a 0 baseline.

Table 3.6 Parameter Estimation-2 Pre and Post-GFC Macroeconomic Shocks

Estimated Maximum Prior and Posterior								
					Posterior Distribution MH			
Parameters		Prior			Pre-2007 Excludes FC		Post-2000 Includes FC	
		Dist.	Mean	s.d.	mode	s.d.	mode	s.d.
IG (γ^{-1}) Shock Accounting								
Technology shock	(σ_a)	γ^{-1}	0.100	2	1.046	0.114	0.964	0.104
Financial stress shock	(σ_b)	γ^{-1}	0.100	2	0.325	0.051	0.549	0.044
Preference shock	(σ_β)	γ^{-1}	0.100	2	0.914	0.089	0.902	0.085
Government spending shock	(σ_g)	γ^{-1}	0.100	2	1.449	0.195	1.109	0.196
Investment shock	(σ_i)	γ^{-1}	0.100	2	1.148	0.116	0.114	0.014
Interest rate shock	(σ_r)	γ^{-1}	0.100	2	0.676	0.072	0.640	0.075
Inflation shock	(σ_p)	γ^{-1}	0.100	2	0.369	0.046	0.419	0.052
Wage shock	(σ_w)	γ^{-1}	0.100	2	1.046	0.114	0.964	0.104

Source: author's analysis.

The Financial and Government Sectors

Financial Stress and Fiscal Shocks: Concerning the sample period that divides the data according to the monetary policy post and pre-IT periods, the DSGE posterior parameter estimation clearly, show that the financial stress reduces from 0.70 in the pre-IT period to 0.25 of the post IT period. The pre-1992 period was known to suffer from not only high inflation but also high level of financial stress. The stress has reduced by over 70 percent because of the move to the IT monetary policy. Turning to the fiscal shocks, documented by the government spending shock, slightly reduces from 1.64 of the pre-IT period to 1.51 of the post-IT period. The period before and after the GFC shows that the financial stress increases from 0.3 (pre-GFC) to 0.6 (post-GFC period), which is almost a 100% increase, while the technology shock has slightly reduced from 1.05 to 0.96. This entails that the role of technology shock becomes less important than the financial stress shock during the post-GFC period. About the government expenditure, the fiscal shock reduces from 1.45, pre-GFC to 1.11, post-GFC period.

3.6 Has the Monetary Transmission Mechanism Changed?

To provide an explanation on the degree of changes in the UK monetary transmission mechanism, this section presents a DSGE counterfactual analysis in terms of output and inflation responses to various shocks. The behaviour of monetary policy is characterised by the parameters $\rho i, \rho\pi$ and ρy and the private sector parameters that includes all other parameters (CN, 2011; Boivin and Giannoni, 2006).

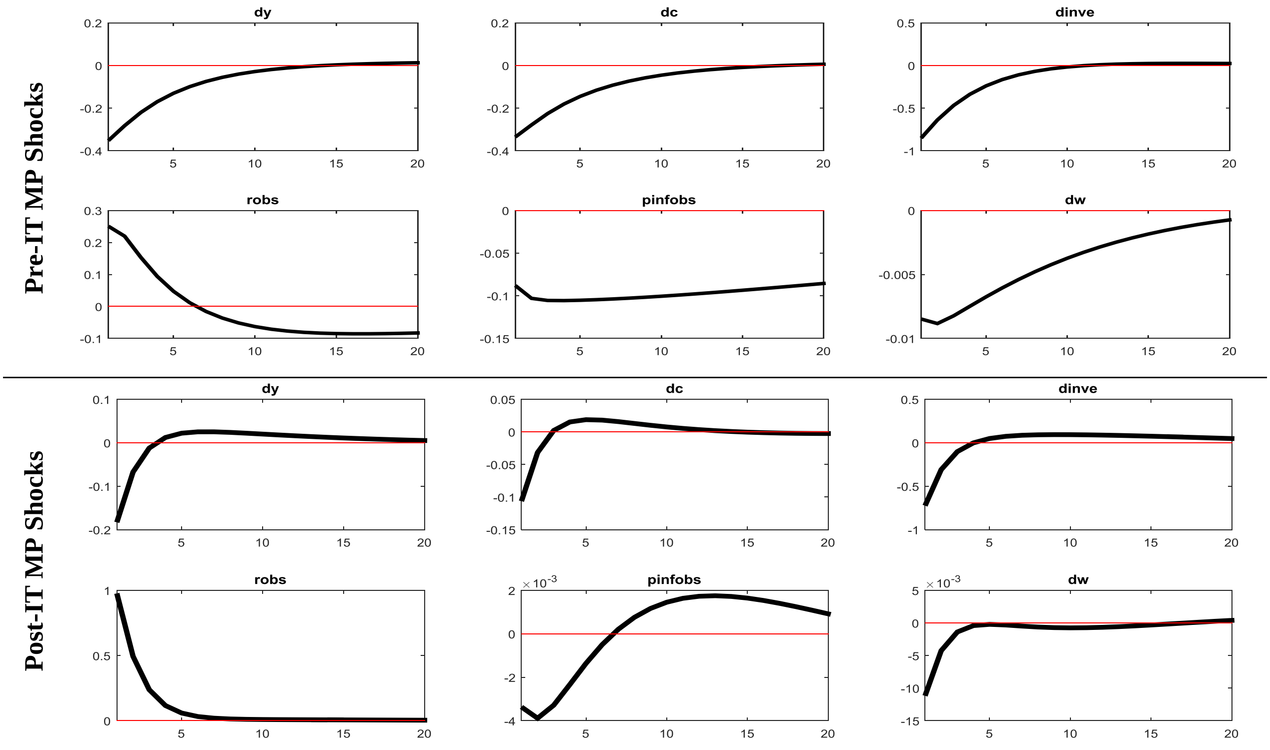


Figure 3.11 Estimated PDs - IRFs of y_t, π_t, r_t and PSP to MP Shocks
Where dy is output, dc is consumption, $dinv$ is investment, $robs$ is monetary policy rate, $pinfobs$ is inflation (price mark-up), and dw is wage (wage mark-up).

The IRFs shown in Figure 3.11 are plotted using the DSGE estimates, based on the macroeconomic shocks as impulse and the response of other shocks. The Figures summarise the information visually by plotting the posterior distribution with the posterior mode as mean and the corresponding Hessian-based estimates as standard error. The Figure plots the impulse responses to a monetary policy shock in the form of raising monetary policy rate by one standard deviation during the pre and post-IT periods for the first sample and during the pre and post-GFC periods for the second sample. Each panel contains the impulse responses of the four possible combinations of monetary policy and private sector parameters. The Figures clearly show that the observed changes in the transmission mechanism can be explained both by a change in the systematic conduct of monetary policy and by the private sector behaviour.

Comparing the black solid lines in both cases of the pre and post-IT periods of Figure 3.11, the changes in the behaviour of monetary policy has increased its effectiveness in stabilising output rather than inflation. The role played by the changes in the structural parameters of the private sector can be gauged by fixing the policy parameters at the median of the posterior of the pre-IT and compute the impulse responses by varying the other parameters. As shown in the IRFs, the changes in the degree of nominal price and wage rigidities have made monetary policy more effective in controlling inflation. Inflation responds more sharply on impact in the post-IT sample as compared with the pre-IT sample. The behaviour of the central bank and the private sector are the main factors that contribute the changing mechanism of the monetary transmission. The effectiveness of the transmission mechanism increases in stabilising inflation around its target.

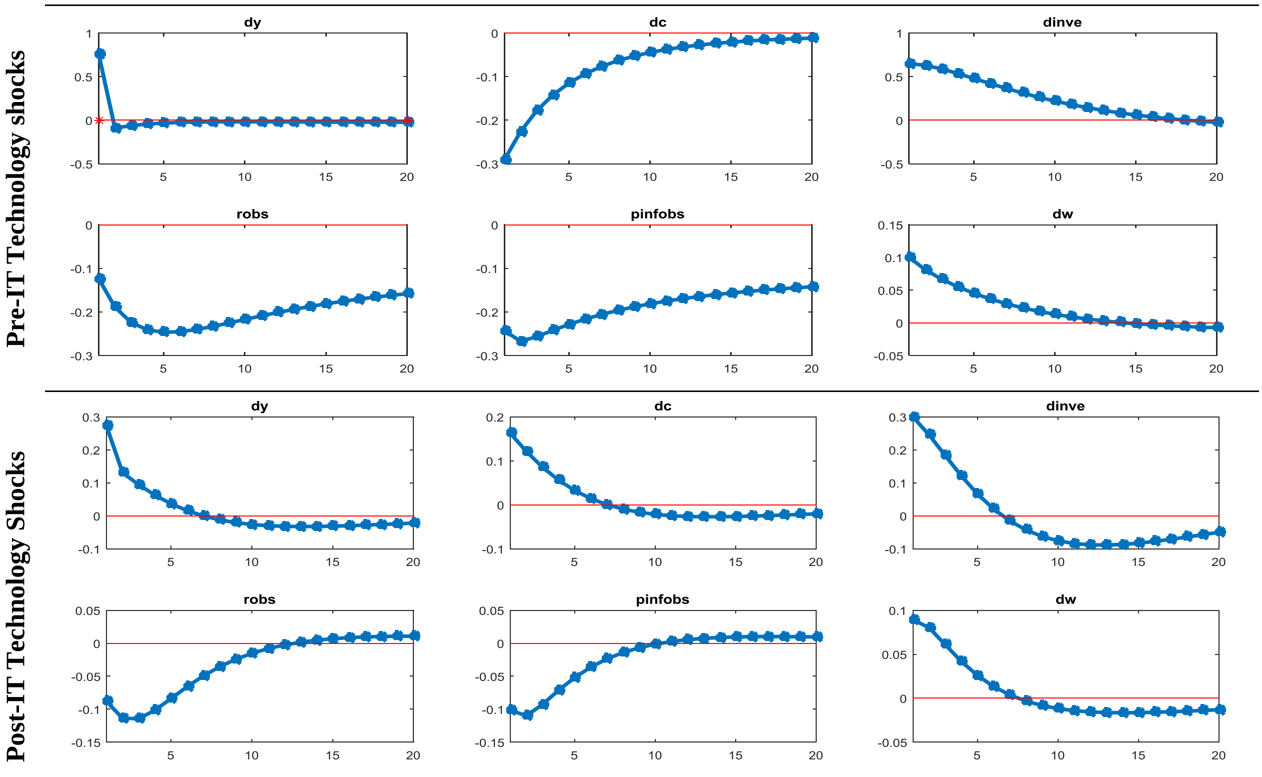


Figure 3.12 Estimated PDs - IRFs of y_t, π_t, r_t and PSP to Technology Shocks
Where dy is output, dc is consumption, $dinv$ is investment, $robs$ is monetary policy rate, $pinfobs$ is inflation (price mark-up), and dw is wage (wage mark-up).

Whether a modification of the monetary policy regime had effect on the transmission mechanism of the UK, economy should emerge not only from the analysis of the responses to an unexpected change of the policy rate, but also from that of the responses to other shocks. In fact, monetary policy influences macroeconomic variables mostly by reacting systematically to all shocks that hit the economy. Therefore, the same counterfactual exercise is performed by analysing the impulse response functions to a transitory technology shock and to a shock in the price mark-up. Output declines to technology shock in the post-IT than the pre-IT period. Inflation shows no marked difference. Its reaction consistently remains below the benchmark until 10 quarters. Likewise, the response of monetary policy to technology shock has been similar in pre and post-IT periods.

Regarding the responses to price mark-up shocks, output responds negatively in the post-IT period as compared with the pre-IT period. Monetary policy on the other hand responds negatively in pre-IT but shows sharp decline with gradual upward movement in the post-IT period.

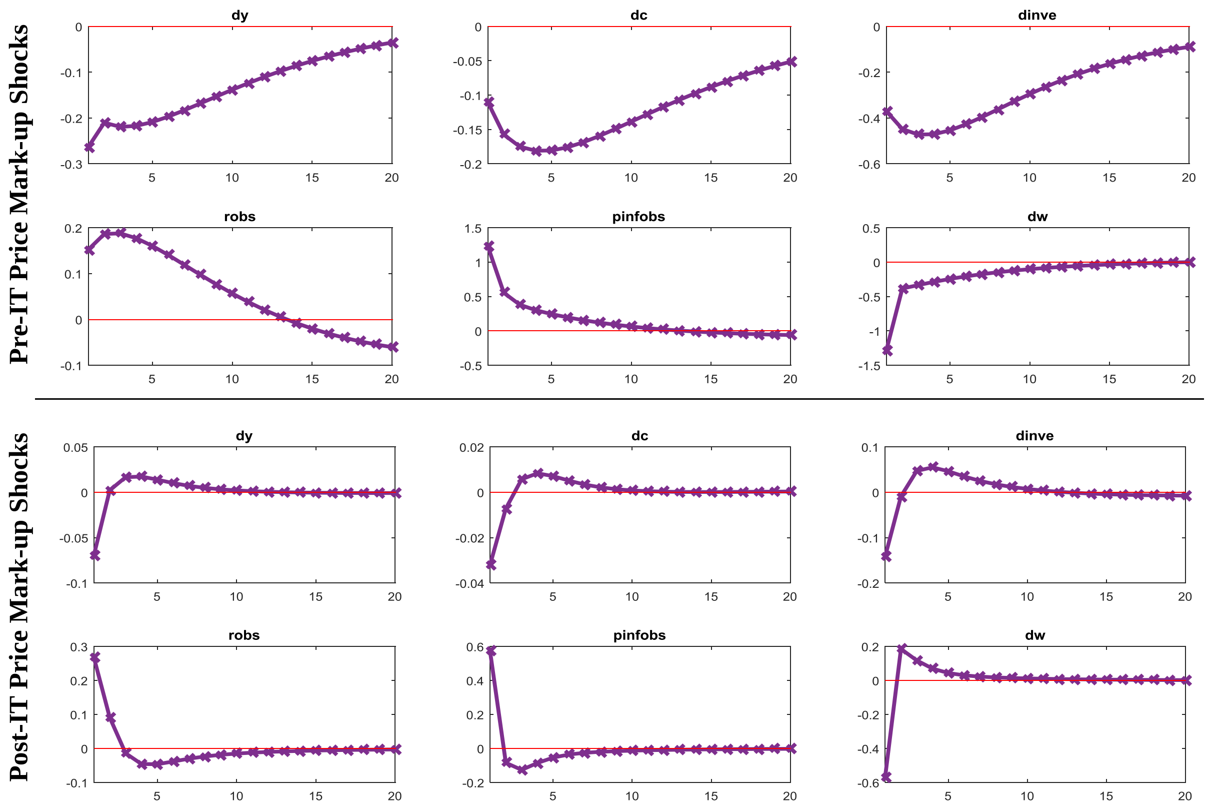


Figure 3.13 Estimated PDs - IRFs of y_t, π_t, r_t and PSP to Price Mark-up

In the first case of Figure 3.13, the responses of output, inflation and prices to the price mark-up shocks are weaker in the post-IT sample, while the responses of the short-term nominal interest rate is stronger in the post-IT sample period. The changes in the responses of output and prices are attributable almost entirely to a change in the systematic conduct of monetary policy. Indeed, maintaining the private sector parameters constant at the pre-IT level, a change in policy from the pre-IT rule to the post-IT explains almost all the changes of the price level and output responses across the two subsamples. In response to a positive shock to the price mark-up (see Figure 3.13), the price level is less responsive in the post-IT sample, while there are no major changes in the real activity. Most of the changes of the price mark-up shock impulse responses across the given periods are due to changes in the private sector parameters.

3.6.1 Implications of Output and Inflation Volatilities

As also stated in Canova et al. (2010) and confirmed by CN (2011) for EU data, this study shows that there is a clear drop in volatility of the main macroeconomic variables after the IT period. The volatility of output declines from 1.18 percent before IT to 0.66 and to 0.41 percent after IT, excluding the crisis period. The volatility of inflation also declines from 1.86 percent to a significantly lower level of 0.61 and to 0.59 percent in the post-IT period, excluding the crisis period. Short-term interest rate also declines from 0.87 to 0.59 and to 0.27, respectively. Looking at the GFC sub sample, output volatility increases from 0.40 to 0.86 percent; inflation increases from 0.59 to 0.64 percent and short-term interest rate slightly increases from 0.34 to 0.42 (see Table 3.7 below). Table 3.7 shows a clear distinction across the sample periods. In the transition from pre-IT to post-IT period, volatility of output, inflation and short-term interest rate has declined.

Table 3.7 MTM in terms of Volatility of Output, Inflation and other Parameters

	<1993b	>1993a	<2007b	>2007a	1993to2007
Con	2.12	0.96	0.87	0.99	0.84
Inv	3.40	2.88	2.89	2.81	2.91
Output	1.18	0.66	0.40	0.86	0.41
Lab	0.53	0.73	0.72	0.86	0.65
Inf	1.53	0.61	0.59	0.64	0.59
Wage	1.86	0.79	0.76	0.78	0.76
Int.	0.87	0.59	0.34	0.42	0.27

Source: author's analysis, a and b refer to before (b) and after (a) the specified period, respectively.

However, unlike Cecioni and Neri (2011) and Canova et al. (2009a, 2010), the UK output, inflation and short-term interest rate volatility show a slight increase in percentage points in the post-crisis period. In terms of the origin of the general decline from pre-IT to post-IT periods, it shows "good policy" or "good luck" as Canova puts it. The conditional moments of the DSGE model also provides valuable information to the origin of the decline in volatility. Turning to the variance decomposition, the following table shows the origin of the volatility in terms of low and high degree of movements for the three non-private sector variables: output, inflation and nominal interest rate.

Table 3.8 Transition of Volatility in the Pre/Post-IT and the Crisis Periods

	output	inflation	Nominal int. rate
Pre-IT	High: ea, eg	High: inf, ea	High: em, ea
Post-IT	Low: $e\beta$, eg	Low: inf, ea	Low: em, eb1
Pre-crisis	Low: eg, eqs	Low: eg, inf	Low: em, eg
Post-crisis	High: eq, eb1	High: inf, eg	High: eb1, em

Note: ea is technology shocks; eg is fiscal stabilisation; $e\beta$ is preference shock; eqs is investment; inf is inflation lag shock; em is monetary policy shocks and $eb1$ is Spread shocks.
Source: author's analysis.

The set of counterfactual experiments show that the major contributor to high volatility during pre-IT period seems to be technology shocks in the form of a productivity shocks followed by inflationary shocks, fiscal stabilisation and monetary policy shocks. On the other hand, the first contributing factor for high volatility in the post-crisis period is mainly consumer preference and fiscal stabilisation shocks, which was actually been the case as households postponed consumption during the crisis period, and also due to the austerity cuts in the major sectors of the economy. The second most important shocks are the inflationary and monetary policy shocks. The results also show that the monetary policy changes resulted in a favourable condition in the post-IT period but not in the post-crisis period. This counterfactual analysis depicts that the traditional monetary policy approach that failed to account for the changes in the structure of the economy do not bring a positive outcome by reducing the volatility of output and prices. The DSGE model also replicates the fact that the volatilities of output, inflation and nominal interest rates are lower in the post-IT period (Table 3.8). A fraction of the decline in the post-IT period is due to more favourable shocks, such as preference, monetary and fiscal stabilisation.

As mentioned above and documented by Canova et al. (2009a), there has been a drop in the volatility of the main macroeconomic variables after 1993 (see Table 3.7). The standard deviation of the real GDP declines from 1.18 to 0.66 percent, the GDP deflator inflation from 1.53 to 0.61 percent and the short-term nominal interest rate from 0.87 to 0.59 percent. This highlights the fall in volatility in the post-IT and post-crisis periods. In the same spirit, as in the analysis of the “Great Moderation” period, the results uncover the origins of the generalized decline in the volatility. According to the first and second moments of the estimated models, the set of counterfactual experiments allow to disentangle the effects on the unconditional moments, due to changes in the volatility of the structural shocks, related to changes in the structure of the economy and in monetary policy (see CN, 2011).

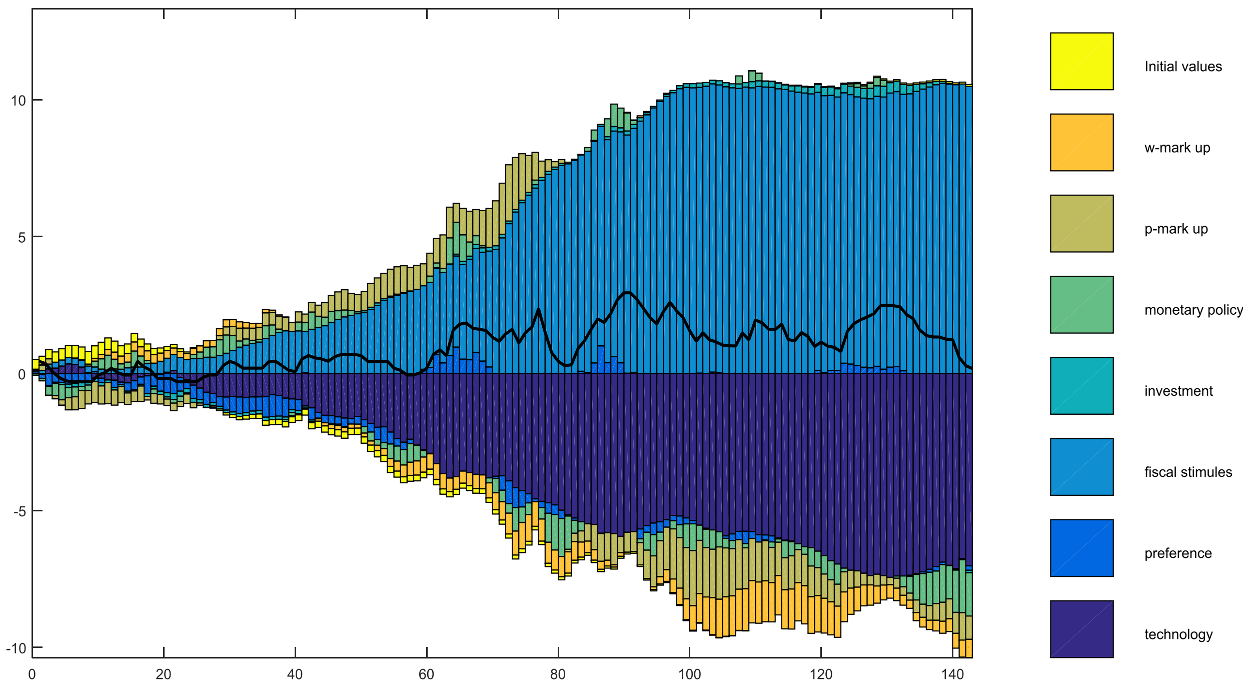
Moreover, the model replicates the fact that volatility of output, inflation and the nominal interest rate is lower in the post-IT and pre-crisis samples. Only a fraction of the decline in these volatilities is due to a more favourable set of shocks. Moreover, the volatility of inflation increases due to the productivity and the price mark-up shocks. Thus, it is plausible to conclude that the changes in the behaviour of monetary policy, inflation and output are due to technology shocks and fiscal stabilisation that leads to the decline of output and prices. When switching from a pre-crisis to the post-crisis period, the financial stress shocks start replacing the investment and government spending shocks. This supports the claim that monetary policy impulses have spread to a credit market shocks in the post-crisis period. Overall, there is enough evidence to claim that the UK MTM has changed and has become more responsive in terms of the credit sector channels rather than the traditional interest rate channel, particularly in the post-crisis period than the transition from pre-IT to post-IT period. The pre and post-IT periods are dominated by a response to technology shocks.

Thus, one can prudently conclude that the changes in the *monetary policy* behaviour has reduced the volatility of output and inflation in the post-IT period, but the traditional monetary policy has not been effective in the post-crisis period. It is vital to note that this outcome implies that the nature of shocks or volatilities in the "Great Moderation" is different from the volatilities in the post-crisis period. Overall, the story that emerges is a more interesting one in such a way that the weaknesses of monetary policy in an environment of financial crisis is highlighted. The traditional belief of the "Great Moderation" period that a self-adjusting mechanism of the financial sector has been challenged. There is, however, no universal consensus on the policy scheme that dictates financial policy to take part in the monetary policy strategy. There are also some indications that the shocks documented in the post crisis period are likely to have a permanent nature that is likely to stay in the long time horizon before they ultimately die out. Thus, this necessitates the need for further investigation to identify the degree and nature of shocks in the UK economy by way of analysing the nonstationarity and nonneutrality behaviour of macro, financial and monetary shocks. This is the subject of Chapter 4.

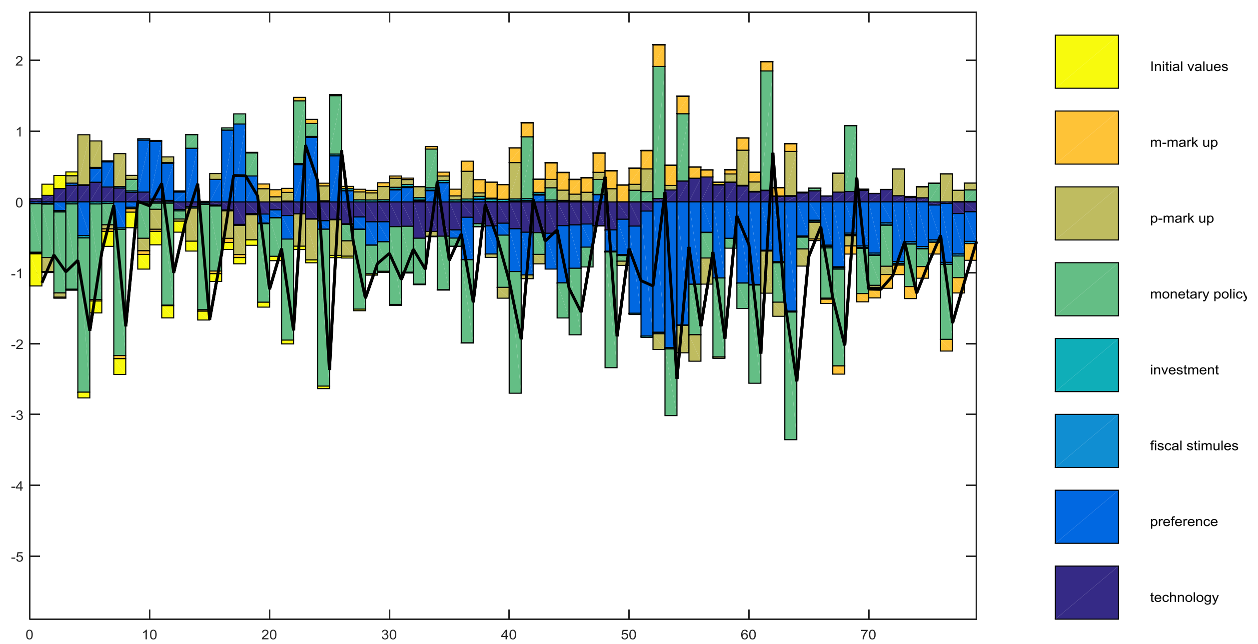
3.6.2 The DSGE Historical Variance Decompositions

The charts for the historical variance decomposition (HVD) analysis report the structural shocks to the forecast error of the endogenous variables at various time horizons: short-run (1 to 2 years), medium-run (2 to 3 years) and long-run (over 3 years)[55]. The HVD charts (see Figure 3.14) display the contribution of shocks to forecast error of the monetary policy at the stated horizon in the pre/post-IT and pre/post-GFC periods. The charts also display a clear transition across the identified periods. The HVD is analysed based on the impact of the contractionary monetary policy impulses. The pre-IT period is known to show a fiscal stimulus in the upward trend. The technology, price and wage mark-ups, contribute to the downward trend. The post-IT period depicts a different story that a wage mark-up dominates the upward trend rather than the fiscal stimulus as in the post-IT period. The downward trend was dominated by the preference and investment shocks. In terms of the dynamics in the pre and post-crisis periods, fiscal stimulus plays significant role to the upward trend but technology, MP and preference shocks marked the downward trend. The downward trend in the post-crisis period, due to technology and investment shocks, has reduced. It was rather dominated by the preference and MP shocks. The upward movement of the shocks was dominated by the wage mark-up and MP shocks. Another form of shocks in the economy slowly replaces the impact (decline) of the technology and investment shocks in the post-crisis period. This outcome motivates further investigation to identify the sector that contributed significantly to the downward movement of output and inflation. This is the subject of Chapter 6.

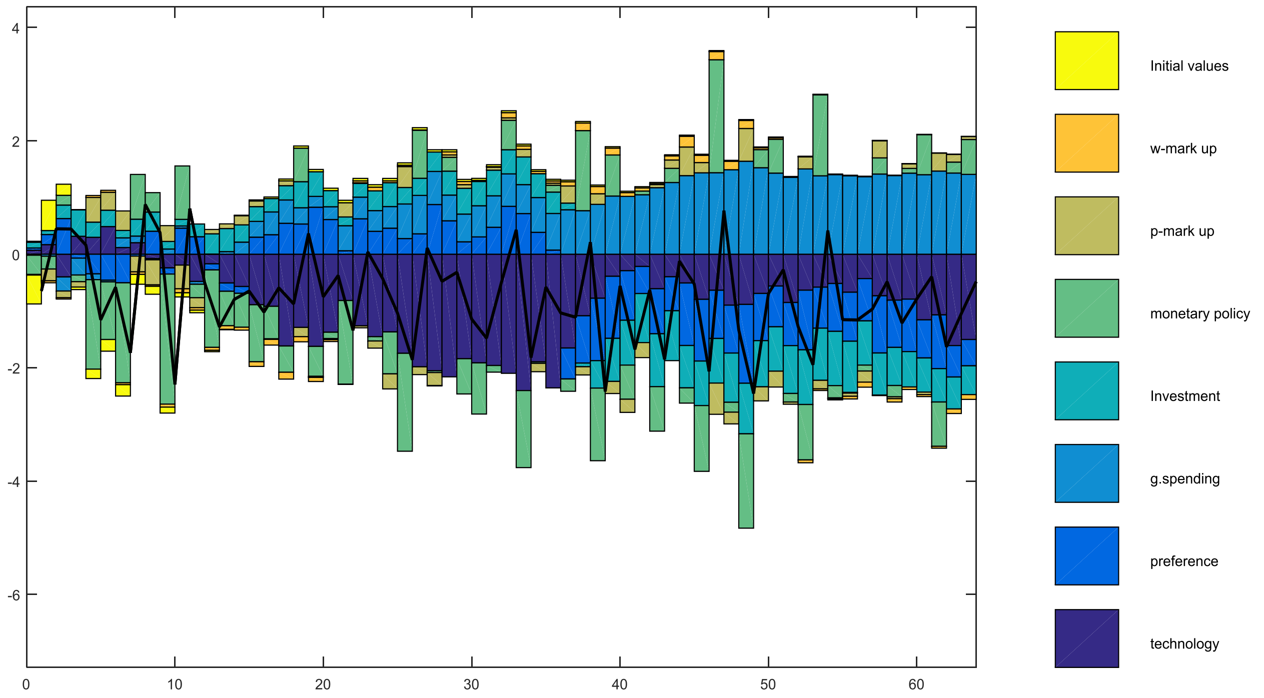
[55] See Appendix 3A



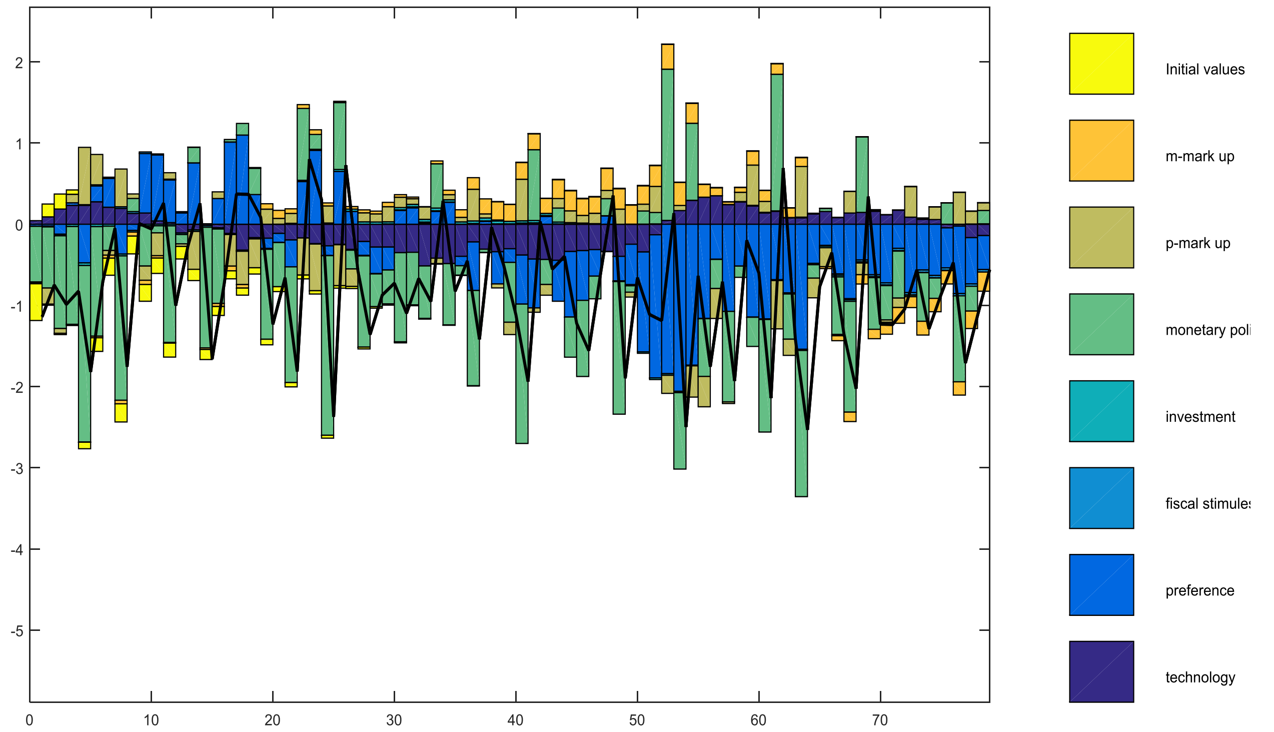
HVD1 – Pre-IT period to Monetary Policy Shock



HVD2 – Post-IT period to Monetary Policy Shock



HVD3 – Pre-GFC period to Monetary Policy Shock



HVD4 – Post-GFC period to Monetary Policy Shock

Figure 3.14 Historical Variance Decompositions of the Pre/Post-IT and GFC Period

3.7 Conclusions

Understanding the mechanism through which the monetary transmission channels operate, gives important advantages to the monetary authorities and policymakers in the choice of policy instruments and achieve policy objectives. Policymakers, who understand the way the mechanism works, are able to identify financial variables affected by monetary policies and allows identifying the right policy. The motivation behind this work is the lack of understanding into the mechanism of MT, particularly, its evolution from pre to post-IT/GFC periods. The Chapter reviewed and discussed the MTM, the transmission channels and investigated how the pass through mechanism works. It also empirically analysed using DSGE simulation and estimation to understand if the mechanism has changed due to internal and external forces across policy regimes. Each channel has a specific role to play and the discussion showed that the shock spawned due to the monetary policy decisions transmitted through different channels. Channels play mixed roles. They are not only transmitting shocks but also accelerate and propagate nominal shocks to the wider economy. The channels are discussed in the context of the Neoclassical and Non-Neoclassical macroeconomic frameworks.

The Chapter also reviewed the Keynesian and Monetarist views of the TM. The proponents of the Keynesians approach advocate that the MTM operates through the interest rates but the Monetarists claim that the changes in other asset prices also play an important role and the money growth only affects nominal variables in the long-run. According to this view, real variables instead are determined by labour mobility, the existence of minimum wages and technological progress, among others. Since real output is not influenced by changes in money growth in the long-run, equilibrium between demand for money and supply of money following an increase in money growth is restored by an increase in prices. On the contrary, Keynesians believe that the change in money growth affect not only the nominal variables but also real variables. The Keynesian view that output is demand determined and that unemployment is due to insufficient aggregate demand has been challenged by the monetarists.

Industrial countries set monetary policy through their central banks in various ways. With greater prominence, the Chapter discussed the critical issue involved in the transmission of monetary policy, the degree and speed at which monetary policy shocks are transmitted to other rates faced by firms and households. Studies also confirm that, in practice, the transmission mechanism is usually sluggish and incomplete in the short-run. Therefore, changes in the policy rate induced by monetary policy are transmitted to other interest rates with lag. Consequently, interest rate differentials exist in the economy. Although, a vast body of knowledge exists on how the MTM works, there is less agreement on the state of the mechanism across the given time horizon and the role of the channels in the interim stages of the transmission. Studies also note that the transmission mechanism may have changed due to exogenous and endogenous forces during periods of policy changes and the GFC. Understanding these changes is important for a macro-prudential policy strategy.

The study showed that the credit channel accelerates and propagates the monetary policy shocks and is considered as the main transmission channel in the UK MTM, unlike the traditional view. Identifying exogenous from endogenous policy impulses is problematic. The research empirically investigates the effectiveness of the MTM. The theoretical and empirical evidences gathered in this study showed that the understanding surrounding the pass-through mechanism is not conclusive. The critical issue involved with the mechanism through which the changes in the official policy rate are transmitted to other rates faced by firms and households required further study. The investigation highlighted the research gap and showed that further understanding is vital to comprehend how the intermediate endogenous variables and the target variables behave in response to exogenous policy impulses.

The creation of the Inflation Targeting framework in the UK with a clear-cut mandate of price stabilisation might have contributed to the changing mechanism of the transmission in the post-IT period. The study provides theoretical and quantitative assessments of the changes in the UK MTM based on BVAR, SVAR and Dynamic Stochastic General Equilibrium (DSGE) models. According to the estimated Structural VAR model, the difference in the response of price and output to monetary policy shocks is not significant across the periods. The main problem with VAR methodology is that it is not very informative to analyse the effective changes MTM brought to the economy. The source of this weakness of a VAR model could be because the estimated responses to monetary impulses cannot always detect variations to the MTM, as different changes in the economy might have counterbalanced to alter the effects of the impulse and responses. A more structural approach such as a DSGE model, based on stronger assumptions, is thus needed to complement the VAR results.

The estimation of a closed-economy, Bayesian DSGE model, for the UK economy revealed that after 1992 the nominal rigidities became weaker while the coefficient on inflation in the monetary policy rule increased and that on output declined. The results also indicated that changes in the private sector parameters (non-target variables) are responsible for the stronger reaction of output and inflation to a monetary policy shock and the milder reaction of prices after a cost-push shock in the post 1992 period. The modification of the monetary policy conduct influenced the responses of both output and prices to a technology shock. The drop in macroeconomic volatility observed in the pre and post-crisis period is only marginally attributable to a more favourable set of shocks in the IT sample; the one on inflation is due to changes in the monetary policy rule parameters, while that on output is due to changes in the private sector behaviour.

The evolution of the UK MTM exhibited a regime specific behaviour. Many studies treat the monetary policy as a single monetary regime regardless of the variations in policy objectives across the short and long time horizons. The distinctive periods from the 1972 to 1997 and the present time marked successive changes of monetary policy strategies that encompasses floating exchange rate regime; monetary policy targeting; Medium Term Financial Strategy and £M3 targeting; informal linkage of the Pound Sterling to Deutsche Mark; the UK's membership of the ERM; inflation targeting and BoE operational independence. This research made particular reference to these regimes from the 1980s MTFS to the current period of "inflation targeting". The study also highlighted that the focus of monetary policy has switched from controlling intermediate variables, such as the money stock or the exchange rate, which was formally thought to be linked to the rate of inflation, to directly targeting the rate of inflation. More importantly, the historical decompositions revealed the dominance of *wage mark-up*, *MP* and *fiscal stimulus shocks* that accounted for the upward movements while *preference*, *investment* and *technology shocks* accounted for the downward movements of the cumulative shocks. The interesting outcome is the declining role of technology and investment shocks in the post-crisis period, which emphasised the need for further search to discover what actually contributed to the significant and permanent shocks in the financial sector. This is the subject of Chapter 6.

Identifying the dynamics of shocks in the MTM is not sufficient. Their degree of presence across the time horizon varies according to the nature and variability of each shock, as some shocks stay longer than expected. The evaluation of the UK transmission mechanism, also underlined the need to further investigate the presence of structural breaks across the UK policy regimes. Structural changes occur due to regime changes and unprecedented periods of high rates, prices and financial crisis. Chapter 4 presents empirical assessment of the UK macroeconomic and financial time series data to determine the presence of permanent and transitory shocks in the framework of structural changes and macroeconomic innovations. It also addressed the impact of structural changes by way of nonstationarity tests. By doing so, the research isolated the impact of distinctive economic events that has changed the course of the economy. Studies showed that the occurrence of regime shifts or structural break(s) is considered as one of the most significant causes of the failure of forecasting models. The next Chapter investigates the transitory and permanent shocks to enlighten the role of the shocks in the financial, monetary and macroeconomic sectors.

CHAPTER 4
STRUCTURAL CHANGES AND THE MACROECONOMIC INNOVATIONS

4.1 Introduction

This study addresses the theoretical and empirical issues of multiple structural changes based on the principle of the Bai and Perron (1998) dynamic programming algorithm. It also addresses the issue of estimating of one and multiple structural changes, and tests the presence of these changes using a Sup Wald type tests for the null hypothesis of no change versus an alternative arbitrary number of changes. Determination of the number of breaks based on single and multiple structural shifts is best viewed as a model selection problem (Maddala and Kim, 2003). The study of structural changes and macroeconomic innovations have considerable prominence in macroeconomic modelling. The presence of structural changes causes difficulty in analysing the effect of macroeconomic innovations. These unprecedented innovations or changes deeply alter the functioning of the economy. Thus, the exogenous change of the structure of macroeconomic models would not account for the effect of the shocks. In this case, models are limited to estimate the amplitude of the effects of innovations without explaining the reasons of this amplitude (see Vilares, 1986). Structural changes can occur for many reasons: political changes, financial and economic crisis, regime changes, government and central bank policy changes, natural disasters and other endogenous and exogenous influences. Most of the assumptions in empirical modelling is parameter consistency in the form of homogeneity and invariance. Principally, macroeconomic models tend to capture these invariant features. However, this assumption is rarely tested in practice and the existing methods of detecting momentary and permanent shifts are not effective (Heracleous et al., 2006).

Economic time series and cross-section data exhibit heterogeneity in the form of non-stationarity. This heterogeneity occurs because internal and external forces are likely to change the course of the economy over time. The modelling practice became popular after Box and Jenkins's (1976, BJ hereafter) proposal to use differencing as a way to address the presence of heterogeneity in econometrics time series. Consequently, the revival of time series modelling in econometrics after BJ's proposal raised a question of appropriateness in the use of differencing as a rule of addressing non-stationarity (Heracleous et al., 2006). This new approach led to the unit root (UR) literature by Dickey and Fuller (1979) and Phillips (1987). Their paper provided partial answer to this question, but gave misleading impressions that unit roots provide some ways to capture the time heterogeneity (Engle and Granger, 1987; Johansen, 1991). The main issue with the UR approach is the fact that the modelling exercise becomes biased towards flawed non-rejection of the hypothesis (Perron, 1997; Leybourne and Newbold, 2003), if structural changes are present in the series. The consequence of failing to account for structural changes implies that any demand shocks, supply shocks or other policy-induced shocks will have long-run effect, which may disturb the accuracy of modelling and forecasting. Several empirical studies demonstrate the prevalence of infrequent parameter variation of time series modelling, as well as the impact of such structural breaks on unit root testing.

Structural changes appear to affect key economic and financial phenomena, such as output growth, inflation, exchange rates, interest rates, bank loans and stock returns. More importantly, it brings technological changes, shifts in economic policy, large macroeconomic shocks, such as oil price shocks of the past decades and changes in interest rates. There are a variety of Classical linear, non-linear and Bayesian approaches to determine the number of significant breaks in macroeconomic time series. The modelling process depends on two viewpoints. The *first* assumes the structural change modelling as a known break point, and the *second* assumes the presence of unknown break point (s). Their diversity is essentially based on the type of breaks such as breaks in mean; breaks in the variance; breaks in relationships; single breaks; two breaks; multiple breaks and continuous breaks (Ferreira et al., 2013). The conventional stability and unit root tests are often associated with the concept of "persistence" of innovations or shocks to the economic system. In this context, the debate has been centred on whether shocks to macroeconomic and financial time series have momentary or permanent effects. Ng and Perron (1982) argue that most macroeconomic time series are best characterised by a unit root process, which implies that disturbances to these series are permanent. Perron (1989, 1990) challenged this and showed empirical evidence that the null hypothesis of a unit root test could be rejected for many macroeconomic series if the test process allows for at least one-time shift in the trend function. Thus, he claimed that macroeconomic time series are characterised by temporary shocks (stationary) around a broken deterministic trend function. In essence, if there is a break in a deterministic trend, then the unit root test (which implicitly assumes the deterministic trend) will incorrectly conclude that there is a unit root, when, in fact, there is not (Ferreira et al., 2013).

A number of prominent studies have developed various methodologies that account for structural breaks and determine break dates. Perron (1989) studies exogenous structural break in the ADF tests, Zivot and Andrews (1992, ZA hereafter) address one endogenously determined structural break, Lumsdaine and Papell (1997, LP hereafter) extended the ZA (1992) model to accommodate two structural breaks based on the claim that a unit root test which identifies two structural breaks is much more robust. Furthermore, Lee and Strazicich (2003, LS hereafter) propose a two break minimum Lagrange Multiplier (LM) unit root test in which the alternative hypothesis implies that the series is trend stationary (Glynn et al., 2007) and finally Bai and Perron (2003, 2006) develop double maximum and sequential algorithms to determine one-to-many structural breaks. Although growing literature on the theoretical underpinnings and empirical application exist for over two decades, few studies address the issue (presence) of multiple structural breaks. The one and two unit root break tests are criticized due to size distortion and the fact that they tend to identify the break dates at a period prior to the true break point. This leads to bias in estimation the persistence parameters and spuriously rejecting the null and alternative hypotheses. However, the BP MSB algorithm does not suffer from size distortions, wrong identification of break points and is able to identify multiple structural breaks.[56]

This study is motivated by the fact that structural breaks in the form of insistent macroeconomic innovations could have impact on long-run dependencies of error and regressors in MEFT series. An important distinction from the majority of existing literature is that the long-run non-neutrality assumption is employed and possible dependence is allowed for explanatory variables and errors in the long-run. Moreover, there is no statement of consensus over the issue of long-term dependency based on unit roots and structural breaks. Although studies show that allowing structural break in the unit root test can improve the power of the test, the methods of determining break points and the corresponding dates are not yet clear. Various methods such as the ZA, LP, and LS algorithms have been used extensively to investigate the power of the test in the presence of one and two structural breaks. In the presence of unexpected macroeconomic shifts, assuming breaks as exogenous phenomena and limiting them to one or two shifts could lead ME models that seem to give a good fit and predict a statistically significant relationship between variables where none actually exist. This necessitates a study to investigate structural changes and the macroeconomic innovations within the framework of one-to-many structural breaks that constitutes not only a single but also multiple structural shifts. Following ZA and BP's one-to-many (multiple structural breaks) approaches, this Chapter empirically investigates: (a) the issue of transitory and persistent shocks in relation to the UK macro, financial and monetary sectors; (b) the robustness of the ADF unit root test in the presence of maximum number of structural breaks, and (c) endogenously determine MSBs and corresponding dates with reference to the UK macroeconomic structure. The study also addresses the validity of the ZA one break approach and its ability to determine the correct break point and the corresponding dates.

The research strategy consists of testing the non-stationarity using a sequence of methods and robustly applying on major UK MEFT series. It analyses three converging views of persistence through the test of mean reversion with and without structural breaks. The research is aimed to

[56] See also, Nunes et.al. (1997); Vogelsang and Perron (1998), and Lee and Strazicich (2001).

reach at robust outcomes regarding the macroeconomic properties of the 25 MEFT series. The analysis is able to identify and categorise the MEFT series in four distinctive homogenous groups based on the order of integration that helps to determine the best strategy for macroeconomic modelling. For MEFT series with persistent shocks, stochastic process is the best alternative. With respect to the dates of the major structural break(s) relevant to the UK economy, the year 1974/78 to 1980/81, according to the ZA approach, and the year 1974/75 to 2008/10, according to the BP multiple structural break approach, have high number of endogenously determined structural breaks. The results also show that the UK macroeconomic series is characterised by four major structural shifts and five regimes from early 1960s to late 2014. The study also determines the timing of the structural breaks for 25 macroeconomic, financial and monetary series composed of 12 monthly and 13 quarterly variables. Based on *Model A* and *Model B* approaches, the results revealed sudden and gradual shifts in a number of variables that coincide with the UK economic and non-economic events from the pre-IT to the post-credit crunch period. Given the evidences found in the SB analysis and the non-stationarity test, the mean shifts in the macro and financial series, and trend breaks in the financial and monetary series bias the conventional tests towards non-rejection of non-stationarity. This denotes that the financial and monetary series contain more persistent and long-run shocks. This study differs from previous literature in three important areas: *First,* it empirically shows the problem with unit root and structural break using time series data that includes major events such as the pre-IT, post-IT, pre-GFC and post-GFC periods. *Second,* it identifies the timing of structural changes and characterise them as persistent and transitory, and sudden and gradual shifts. *Third,* unlike previous studies that restrict the number of breaks to one and two structural shifts, this study employs multiple structural breaks using the sequential and global minimiser algorithms based on Bai and Perron (1998, 2003b).

The rest of the Chapter proceeds as follows. *Section two* reviews existing literature on traditional unit roots, stationarity test with and without endogenously determined structural break. It includes the essence of multiple structural breaks with respect to implications on macroeconomic and financial variables. This section also reviews the methodological approaches of exogenously and endogenously identified breaks in the context of structural changes based on ZA (1998) and the BP (1998, 2003b) theoretical and computational approaches. *Section three* presents the data and selected methodologies. *Section four* estimates the break points based on prior information in $UDMax$ and $WDMax$ global minimisers, followed by the series of programming algorithm approaches to identify the break dates based on sequential hypothesis testing at various trimming points. *Section five* discusses the estimated results in the context of persistent and transitory shocks, and *section six* concludes.

4.2 Review of the Relevant Literature

The theoretical models of macroeconomics state that monetary impact is neutral in the long-run; that is, the real effects of an unanticipated permanent change tend to disappear as time elapses. On the other hand, the case of structural breaks that challenges long-run neutrality has limited theoretical support. As Bullard (1999:p59) puts it "if monetary growth causes inflation, and inflation has distortionary effects, then long-run monetary neutrality should not hold in the data. On the contrary, a permanent shock to the rate of monetary growth should have the same long-run effect on the real economy; why else should we worry about it?" Irrespective of the neutrality assumption, central banks pursue long-run price stability, due to the distortionary effect of inflation, caused by monetary growth (Noriega and Soria, 2002). Analysing structural break in financial time series, among others, has two key prominences: *(i)* the structural breaks can be identified with some unusual events (both domestic and international) which helps to understand the reactions of financial and economic variables to different events; *(ii)* structural breaks allow to derive more detailed information on the behaviour of the reaction function. Naraya (2006) suggests that one avenue for obtaining such information, is by dividing the sample into sub-samples based on the structural breaks. It provides information on whether certain events led to a slowdown in economic activity or vice versa. This information is crucial for policymakers to understand the behaviour of the reaction functions.

The modelling of macroeconomics and financial time series have been an active research in the pre and post-GFC. A number of theoretical and empirical studies focus on the apparent persistent structural breaks manifested by slowly decaying autocorrelation functions, which induces the frequent characterisation of mean, and trend shifts as a long memory process in MEFT series (Chatzikonstanti and Venetis, 2015). Many studies point out that SBs may induce spurious effects in time series (see for e.g. Liu, 2000; Diebold and Inoue, 2001; Granger and Hyung, 2004; Berkes et al., 2006; Qu, 2011; Shao, 2011). From empirical point of view, although the existing literature that examine structural changes is prominent, studies that focus on their impact and interaction in MEFT series are rare but growing steadily. Testing the presence of SBs and determining breakpoints in financial and macroeconomic series is crucial for central banks, for example, to monitor their decision as not only a short-term impact but also as long memory disturbances. While MEFT series typically known to have contain at least one SB but in the post-GFC, one can assume that these series include more than one exogenous variables with breakpoints in their reaction functions that changes from one independent variable to the other (Klose, 2014).

4.2.1 The Traditional Stationarity Tests

In order to test the presence of SBs in MEFT series, the study employs the ADF regression as a benchmark to identify the mean and variance shifts. The Augmented Dickey-Fuller (1979) test constructs a parametric correction for higher-order correlation by assuming that the series follows an $AR(k)$ process and adding lagged difference terms of the dependent variable to the right-hand side of the test regression. The ADF test is based on the auxiliary regressions of the following:

$$\Delta y_t = k + \alpha y_{t-1} + \sum_{\mathrm{j=1}}^{\mathrm{k}} \mathrm{d_j} \Delta \mathrm{y_{t-j}} + \varepsilon_{\mathrm{t}} \tag{4.1}$$

$$\Delta y_t = k + \alpha y_{t-1} + \beta_t + \sum_{j=1}^{k} \mathrm{d_j} \Delta \mathrm{y_{t-j}} + \varepsilon_{\mathrm{t}} \tag{4.2}$$

The auxiliary regression tests for a unit root in y_t, where y refers to the MEFT series, $t = 1, \dots, T$, is an index of time, and Δy_{t-j} is the lagged first difference to accommodate serial correlation in the errors. Equation (4.2) tests the null of a unit root against a trend-stationary alternative[57]. As in Hall (1994), the lag length is selected through the '$t\ sig.$'. This approach involves starting with a predetermined upper bound k_{max} where $k_{max} = 12\left(\frac{T}{100}\right)^{1/4}$ (Narayan and Smyth, 2005). If the last included lag is significant, k_{max} is chosen. However, if k is insignificant, it is reduced by one lag until the last lag becomes significant. If no lags are significant, k is set equal to zero. As shown by Ng and Perron (1995) the '$t\ sig.$' approach produces test statistics, which has better properties in terms of size and power than when lag length is selected with some information-based criteria[58].

As shown in the above equations, a constant or a constant and a trend is included in the ADF test regression. For either case, Elliot et al. (1996) propose a simple modification of the ADF approach to construct DF-GLS test, in which the time series are de-trended so that explanatory variables are "taken out" of the data prior to running the test regression. Phillips and Perron (1988, PP hereafter) propose an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root. The PP method estimates the non-augmented DF test equations (see Equation 4.1 and 4.2) without $\sum_{\mathrm{j=1}}^{\mathrm{k}} \mathrm{d_j} \Delta \mathrm{y_{t-j}}$ term on the rhs, and modifies the t-ratio of the α coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic.

4.2.2 Stationarity Test with a Structural Break

The major downside of unit root tests is that it assumes d_j (Equation 4.1 and 4.2) is correctly specified. Perron (1989, 1990) notes that if there is a break in the deterministic trend d_j, then unit

---

57 In Equation (4.1) and Equation (4.2) the null and alternative hypotheses for a unit root in y_t are H_0: $\alpha = 0$ and H_1: $\alpha < 0$.

58 Akaike Information Criterion (AIC) or the Schwartz Bayesian Criterion (SBC).

root tests lead to a misleading conclusion in favour of a unit root, when in fact there is not. Since Perron’s seminal paper, the debate on the effect of trend breaks on unit root tests and his assumption of known break point attracted a growing criticism. It was argued that if the break point is treated as endogenous, then Perron's conclusions are likely to be reversed (Maddala and Kim, 1998). The issue of endogenous or exogenous treatment of the break point is still inconclusive (Narayan and Popp, 2013). Since the seminal paper of NP (1982), macroeconomists have been interested in unit roots and the source of model misspecification. Using the standard unit root test approach without SBs for a data spanning over 100 years, NP could not reject the null hypothesis of an autoregressive unit root for 13 out of 14 US macro time series. The existence of a unit root was interpreted as having important implications for the theory of business cycles and the persistence of the effect of real shocks to the economy. Cochrane (1991a and 1991b) notes that the evidence on unit roots is empirically ambiguous and irrelevant to the question of persistence of the effect of real shocks.

To overcome the problem with the traditional ADF, Perron (1989) proposes a method that allows for a known or exogenous structural break in the Augmented Dickey-Fuller (ADF) tests. Following this development, many authors including ZA (1992) and Perron (1997), determine the break point endogenously from the data. Lumsdaine and Papell (1997) extend the ZA (1992) one-break approach to two breaks approach. However, these endogenous break point tests are criticised on the grounds of their treatment of breaks under the null hypothesis. Given the breaks are absent under the null hypothesis of unit root, there may be some tendencies for tests to suggest evidence of stationarity with breaks (LS, 2003). LS suggest a two break minimum Lagrange Multiplier (LM) unit root test in which the alternative hypothesis unambiguously implies that the series is trend stationary.

Exogenous and Endogenous Changes

A year after Phillip-Perron (Phillips and Perron, 1988) seminal paper on the unit root test approach, studies have emerged due to the consequence of spurious results and the power problem of ADF and PP tests. In order to accommodate structural changes in the data series, Perron proposes three characterisations of the trend break alternative models: *(i)* a model that allows for a one-time structural break in the intercept of the trend; *(ii)* a model that allows for a one-time structural break in the slope of the trend function, and *(iii)* a model that allows for a one-time structural break in the intercept and slope of the trend function. In his attempt to demonstrate how structural breaks in a series can lead to spurious results, Perron (1989) uses the idea of exogenously determined breaks informed by prior knowledge. Such exogenous assumptions have effects on the timing and properties of the critical values that are used to compare with the test results. ZA (1992), on the other hand, allowed for endogenously determined breaks chosen based on particular statistical criteria in an economically *atheoretical* way. Their critical values are likewise affected by the testing methods and in the original form; the number of breaks permitted is limited. The main differences in the testing procedures, proposed by Perron (1989), and subsequently by ZA (1992) over the original Dickey–Fuller approach, involve the addition of various dummy variables to Equations (4.1 and 4.2). The aim is to capture changes in the intercept and/or trend using the recursive estimation method as shown in Equation (4.3):

$$y_t = \mu + \rho y_{t-1} + \beta t + \gamma DT + \theta DU + \sum_{i=1}^{p} \varphi \Delta y_{t-i} + u_t \tag{4.3}$$

where $DT = 1, if\ t > TB$ and 0 otherwise and $DU = 1, if\ t > TB,$ 0 otherwise. TB refers to the time of the break. DU and DT are included to capture the possibility of 'crashes' *(DU),* trend or gradual changes *(DT)* and joint crashes and trend changes *(DU and DT).* However, Perron's known assumption of the break date was criticised, most notably by Christiano (1992) as simply a process of 'data mining'. Christiano argues that the data based procedures are typically used to determine the most likely location of the break. Since then, several studies have developed using different methodologies to endogenously determine the break date (see also Banerjee et al., 1992; ZA, 1992; Perron and Vogelsang, 1992; Perron 1997; Lumsdaine and Papell, 1997). These studies have shown that bias in the usual unit root tests can be reduced by endogenously determining the time of SBs. If the data-generating process involves more than one break as might be expected in the long time series, the same problem persists as in the original approach. Vogelsang (1997, 2012) shows the loss of power that ensures when using a one-break model in a world of two breaks. Empirically, Ben-David and Papell (1998) present evidence of more than one break and Lumsdaine and Papell (1997) consider a generalisation of the endogenous break point procedure using the ZA (1992) approach.

Regarding the dating of structural breaks, studies show that the potential break is assumed to be known *a priori*. Test statistics are then constructed by adding dummy variables to represent crashes and gradual structural changes. This extends the standard Dickey-Fuller procedure (Perron 1989) to a break date stationarity. However, Christiano (1992) and Bai and Perron (2003a) argue that this approach further invalidates the distribution theory underlying the conventional testing. Following this criticism, a number of studies have developed various methods to determine endogenously determined dates rather than a known *a priori* approach. The latter approach includes ZA (1992), LP (1997), Perron and Vogelsand (1992) and Bai and Perron (2003a). They have shown that the expected bias in the usual mean reversion tests can be reduced by endogenously determining the time of structural breaks and accounting for the breaks in the testing process. However, limiting the number of breaks to either one or two can reduce the power of ADF test so bias still exists.

Econometrics of Structural Breaks

Structural breaks are commonly present in many macroeconomic and financial time series (e.g. Stock and Watson, 1996; Ang and Bekaert, 2002) and are one of the major reasons for misspecification and poor performance of macroeconomic and financial models (Clements and Hendry, 1998a). ZA propose a variant of Perron's original test in which they assume that the exact time of the break point is unknown. Instead, a data dependent algorithm is used to proxy Perron's subjective procedure to determine the break points. Following Perron's characterisation, ZA proceed with three models: (1) *model A,* permits a one-time change in the level of the series; (2) *model B,* allows for a one-time change in the slope of the trend function, and (3) *model C*, combines one-time change in the level and the slope of the trend function of the series. Hence, to test for a unit root against the alternative of a one-time structural break, ZA employ the following regression equations corresponding to the above three models:

$$\text{Model A: } \Delta y_t = c + \alpha y_{t-1} + \beta_t + \gamma DU_t + \sum_{j=1}^{k} d_j \Delta y_{t-1} + \varepsilon_t \tag{4.4}$$

$$\text{Model B: } \Delta y_t = c + \alpha y_{t-1} + \beta_t + \theta DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-1} + \varepsilon_t \tag{4.5}$$

$$\text{Model C: } \Delta y_t = c + \alpha y_{t-1} + \beta_t + \gamma DU_t + \theta DT_t + \sum_{j=1}^{k} d_j \Delta y_{t-1} + \varepsilon_t \tag{4.6}$$

where DU_t is an indicator dummy variable for a mean shift occurring at each possible break-date (TB) while DT_t is the corresponding trend shift variable. Formally,

$$DU_t = \begin{cases} 1 \dots \dots . if\ t > TB, \\ 0 \dots \dots . \dots . . otherwise \end{cases} and$$

$$DT_t = \begin{cases} t - TB \dots \dots if\ t > TB \\ 0 \dots \dots . \dots otherwise \end{cases} and$$

the null hypothesis in all the three models is $\alpha = 0$, which implies that the series {yt} contains a unit root with a drift that excludes any structural break, while the alternative hypothesis $\alpha < 0$ implies that the series is a trend-stationary process with a one-time break occurring at an unknown point in time. The ZA method regards every point as a potential break-date (TB) and runs a regression for every possible break-date sequentially. From amongst all possible break-points (TB), the method selects the date which minimises the one-sided t −statistics for testing $\widehat{\alpha}\ (= \alpha - 1) = 1$ as its choice of break date (TB). According to ZA, the presence of the end points cause the asymptotic distribution of the statistics to diverge towards infinity. Therefore, some region must be chosen so that the end points of the sample are not included. ZA suggest the 'trimming region' to be specified as $(0.15T, 0.85T)$. According to Perron, most economic time series can be adequately modelled using either model A or C. Subsequent literature primarily applied model A and/or model

C. Criticising Perron, Sen (2003) argues that if one uses model A when in fact the break occurs according to model C then there will be a substantial loss of power. However, if break is characterised according to model A, but model C is used then the loss in power is minor. This suggests that model C is superior to model A. As there is no conclusive agreement which method to use in order to investigate structural breaks since Perron's seminal paper, this study employs the three models to identify the single and representative break point(s). In a similar setting, Lumsdaine and Papell (1997) extend the ZA test of Equation (4.4 to 4.6), by adding dummy variables for intercept and slope changes in a single model:

$$y_t = \mu + \rho y_{t-1} + \beta t + \theta DT_1 + \gamma DU_1 + \theta DT_2 + \gamma DU_2 + \sum_{i=1}^{p} \varphi \Delta y_{t-i} + u_t \quad (4.7)$$

as in the ZA single break test algorithm, three types of models can be considered but there are more variations including two breaks in the intercept and two breaks in the slope. Being a variation of a standard unit root test, the $t-statistics$ on ρ is compared to the relevant critical value found in Lumsdaine and Papell (1997). Lee and Strazicich (2001, 2003) employ a similar approach to Lumsdaine and Papell (1997) but their test statistic uses a minimum Lagrange Multiplier (LM) test criteria. This approach is based on the results from Schmidt and Phillips (1992) on the potential for unit root tests to report spurious rejections when the null includes a genuine structural break. The Lee and Strazicich LM-based test assumes that the null hypothesis has permanent structural shift with up to two breaks. In the LS approach, the $t-statistics$ to test the null arises via a LM principle based on scoring methods. This test procedure was also utilised by Greasley et al. (2010) to analyse the empirics of long-run growth. The ability to permit up to and more than two breaks in the null and two breaks in the level or slope of the alternative makes the approach particularly flexible and realistic.

The two important issues stemmed from the above variety of approaches are: (1) the issue raised due to the trade-off between the power of the test and the amount of information incorporated with respect to the choice of break point (Perron 1997:p378); (2) these tests only capture the single most significant break in each series but disregard the presence of more than one or two SBs. The question here is - what if there are multiple breaks in each individual series? (Maddala and Kim, 2003). Studies show that assuming a single endogenously or exogenously determined structural break is insufficient and leads to a loss of information when more than one breaks exist (Lumsdaine and Papell, 1997). Accordingly, LP argue that permanent structural shift tests that account for two significant structural breaks are more powerful than those that allow for a single break. However, limiting structural shifts as one or two break points rather than making an open assumption for the presence of multiple structural breaks is likely to contribute to the loss of information (BP, 2006;

Clemente et al., 1998). One of the reasons why the BP methods are not frequently used could be due to the complex nature of the DGP and the iterative sequential algorithm methods that tests one break against more than one successive breaks. Because of this, there are few attempts made to investigate the presence of MSBs based on the BP dynamic programming algorithm.

Based on Perron and Vogelsang (1992), Clemente et al. (1998) attempt to investigate multiple break points. Ohara (1999) uses a sequential $t - tests$ based on Zivot and Andrew's approach to examine the case on multiple breaks with unknown break dates. Ohara provides evidence and argues that unit root tests with multiple trend breaks are necessary for both asymptotic theory and empirical applications. The next section briefly discusses the development of various approaches since NP's (1982) seminal paper and converses the MSB approach from theoretical, methodological and empirical perspectives.

4.2.3 Multiple Structural Breaks

Since NP's (1982) seminal paper, numerous studies attempted to investigate the potential non-stationarity of important MEF variables. These variables are characterised by a unit root, has important implications for the efficient economic, and market hypothesis, which asserts that returns of a macroeconomic and financial variables are unpredictable from previous changes. If these variables are stationary of $I(0)$ process, any macroeconomic or financial shock effects are temporary. Thus, the shift resulted from the shock that moves parameter values from one level to another will eventually return to its equilibrium level. Therefore, one can assert that forecasting future movements based on past behaviour can be developed as long as the variables are stationary $I(0)$. The intuition behind MEF variables with nonstationary or $I(1)$ process, according to the Efficient Market Hypothesis (EMH), is that the shocks will have a permanent effect. This implies that they will attain a new equilibrium and future returns cannot be predicted based on historical movements (Narayan and Prasad, 2007).

According to Narayan (2008), the movement of nonstationary variables entails, that volatility due to macroeconomic shocks will increase in the long-run without bound. Any economic research that involves MEFT series variables are of considerable concern when conducting empirical studies. Although empirical studies endorse this assertion, critics have steadfastly contended that drawing such a conclusion may be attributed to the lower power of the mean reversion tests employed when compared with near-unit-root but stationary alternatives (Perron, 1982). Furthermore, conventional unit root tests have failed to consider information across regions, thereby yielding less efficient estimations. These shortcomings question many of the earlier findings, which are based on unit root diagnostics and DGP for MEF modelling. The recent development in time series econometrics necessitates that one feasible way to increase power when testing for mean and variance reversions is by allowing multiple structural breaks rather than limiting to one or two breaks (BP, 2006). Studies also show that disregarding the presence of structural breaks can cause inaccurate and misleading conclusions when the univariate unit root diagnostic test is performed. The recent empirical developments in this area highlighted this concern and proposed various correction methods through mean and variance persistence tests with and without SBs (Perron, 1982; Im et al., 2005; Carrion-i-Silvestre et al., 2005; Narayan, 2008).

The MSB approach is famously known as *global minimiser*. BP (2003a) present this approach using a dynamic programming algorithm and argue that the method is very efficient as compared to the approaches used for one and two structural breaks. Although, the process of estimation for MSB is cumbersome, the additional computing time that requires determining MSB for more than two break dates is marginal. Given the sample size T, the total number of possible segments in this approach is at most $T(T+1)/2$ and is therefore of order $O(T^2)$. The method then selects the combination of segments (partition of the sample) that yield a minimal value of the objective function. It also uses a DPA mathematical approach to identify the segments effectively. BP also note that even with large samples, the computing cost to estimate models with MS changes should be considered minimal. The stationary MSB test by Carrion-i-Silvestre et al. (2005) is a modification of Hadri's (2000). It allows for MSBs in the testing procedure through the incorporation of dummy variables in the deterministic specification of the model. Under the null hypothesis, the data-generating process for the variable assumes the following representation:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{m_i} \theta_{i,k,t} + \beta_i t + \sum_{k=1}^{m_i} \gamma_{i,k} DT^*_{i,k,t} + DU_{i,k,t} + \varepsilon_{it} \tag{4.8}$$

with the dummy variable $DT^*_{i,k,t} = t - T^*_{b,k}$ and 0 otherwise; another dummy variable $DU_{i,k,t} = 1$ for $t > T^i_{b,k}$ and 0 otherwise, with $T^i_{b,k}$ denoting the k^{th} data of the break for the i^{th} individual, $k = \{1, \dots, m_i\}$; and $m_i \geq 1$. Equation (4.8) includes individual effects, i.e., individual structural effects if $\gamma_{i,k} \neq 0$ that is, when there are shifts in the individual time trend. This specification is the panel data counterpart of models with breaks proposed in the univariate framework. Thus, when $\beta_i = \gamma_{i,k} = 0$ is the counterpart of the one analysed by Perron and Vogelsang (1992), whereas when $\beta_i \neq \gamma_{i,k} \neq 0$, the specification reverts to the one given by Perron's (1989) model C. Although other specifications could be adopted, e.g. the panel data counterparts of models A and B in Perron (1989), the asymptotic distribution of the test proposed below for those cases cannot be asymptotically distinguished from the one with $\beta_i \neq \gamma_{i,k} \neq 0$. Thus, the models can be rewritten in a way that their representation becomes equivalent and so sharing the limit distribution (see Carrion-i-silvestre et al., 2005). According to Carrion-i-Silvestre et al. (2005), the specification given in Equation (4.8) is general enough to allow for the following characteristics: (a) it permits the individuals to have a different number of structural breaks; (b) the structural breaks may have different effects on each individual time series, with the effects measured by $\theta_{i,k,}$ and $\gamma_{i,k}$, and (c) the structural breaks may be located on different dates. The test of the null hypothesis of the stationary panel follows the one proposed by Hadri (2000):

$$LM(\lambda) = N^{-1} \sum_{i=1}^{N} (\varpi_i^{-2} T^{-2} \sum_{t=1}^{T} S_{i,t}^2), \tag{4.9}$$

where $S_{i,t} = \sum \varepsilon_{i,j}$ denotes the partial sum process that is obtained when using the estimated OLS residuals of Equation (4.9) and where ϖ_i^{-2} is a consistent estimate of the long-run variance of $\varepsilon_{i,t}$. The homogeneity of the long-run variance across the individual time series can also be imposed during the testing process. λ in Equation (4.9) denotes the dependence of the test on the dates of the break. For each individual i, it is defined as the vector $\lambda i = (\lambda i, 1, \dots, \lambda i, mi) = \left(\frac{T_{b,1}^i}{T}, \dots, T_b^i, \frac{m_i}{T}\right)'$, which indicates the relative positions of the break dates in the entire time period, T. Following the BP (2005, 2006) MSB global minimiser approach, *firstly*, the study computes the *global minimisers* of the sum of the squared residuals (*SSR*). The estimates of the break dates are selected based on the argument that it minimises the sequence of individual $SSR\left(T_{b,1}^i, \dots, T_{b,m_i}^i\right)S$ computed from Equation (4.9). Once the dates of all possible $m_i \leq m^{max}, i = \{1, \dots, N\}$ are estimated to obtain the optimal m_i, one selects the most suitable number of structural breaks for each *i*, if there are any. BP (2005, 2006) tackled this issue by using two different procedures. The first procedure makes use of information criteria or more specifically, the Bayesian Information Criterion (BIC) and the modified Schwarz Information Criterion (known as LWZ) of Liu et al. (1997). *Secondly*, to detect the structural break(s), the procedure uses the sequential computation with the application of *pseudo* F-type test statistics. After comparing both procedures, BP (2006) conclude that the second procedure outperforms the first. Thus, they recommend using the global minimisers as detection of the possible number of breaks then the number of structural breaks are estimated using the sequential procedures. The model under the null hypothesis of stationarity does not include trending regressors.

4.2.4 Review of Empirical Evidence of Structural Breaks

The Pioneering paper by Nelson and Plosser (1982, NP hereafter) initiated various follow-up studies. Perron (1989), using the NP's data set that allows for a known single break date (i.e. the 1929 stock market crash) rejects the unit root null for 11 series that NP found them to be nonstationary (Glynn et al., 2007). ZA (1992), testing for a single endogenous break date, found less evidence against the unit root hypothesis than Perron (1989) does. ZA provide evidence and confirm that Nelson and Plosser (1982) findings are mostly in favour of the integrated model. They reject the unit root at the five percent sig. level for only three out of 13 variables using the NP data. The results for nominal GNP, real GNP and industrial production are consistent with Perron's and are rejected even if the breaks are determined endogenously. Similarly, LP (1997) re-examine the NP data for two endogenous breaks. They find more evidence against unit roots than ZA but less than Perron (1989). Using finite-sample critical values, they reject the unit root null for five variables at the five percent level of significance including the 3 series found by ZA plus employment and the per capita real GNP. These endogenous tests have some size problems as the break(s) are considered only under the alternative hypothesis.

LS (2003) employ the two-break minimum LM unit root test based on NP (1982) data and compared it with the two-break LP test. They show evidence for stronger rejections of the null using the LP test than the LM test. At the five percent level of sig., they reject the null for six series with the LP test and four series with the LM test. The unit root null of industrial production and the unemployment rate are rejected by both the LP and LM tests. The LS model permits two endogenously determined breaks both under the null and alternative hypothesis and performs well as compared to other procedures, which are more data dependent (Ahmad and Aworinde, 2016). There are also a number of other studies that test for endogenous determined one-break models in both the intercept and slope. Raj (1992) tests for per capita real GDP for nine countries; Perron (1994) tests for real GDP for 11 countries; and Ben-David and Papell (1995) test for both aggregate and per capita real GDP for 16 countries. They reject the null of unit root for half of the countries. In comparison, Ben-David et al. (2003) apply the LP (1997) approach for two SBs to an international dataset for 16 countries. They reject the unit root hypothesis for three-quarters of the data series (24 out of 32 cases), which is fifty percent more rejections than models that allow a single break. Banerjee et al. (1992), using post-war data for seven OECD countries, found no statistical significance to reject the unit root hypothesis for five countries (France, Germany, Italy, United Kingdom, and the U.S.). However, for Canada and Japan, the unit root is rejected against the alternative of a stationary broken trend. Ghatak (1997) tests the unit root hypothesis under SBs for 12 macroeconomic time series for India from 1900 to 1988. He notes that the conventional ADF tests with no structural breaks cannot reject the unit root hypothesis for any of the series. Allowing for exogenous breaks in the level and rate of growth, Ghatak reports that Perron (1989) test rejects the unit root hypothesis for only three series. The ZA (1992) endogenous break test for India confirms that Perron's test leads to the rejection of the unit root null hypothesis for three more series. Strazicich et al. (2004) apply the endogenous two-break LM unit root test for annual data on per capita GDP for 15 OECD countries for the period 1870-1994 to determine if per capita incomes are stochastically converging. They confirm that null of unit root at the ten percent sig. level is rejected for 10 of the 15 log relative income series. This shows that there is significant support for income convergence among OECD countries. Furthermore, Strazicich et al. (2004) also find stronger support for convergence than previous studies conducted without structural breaks.

From the perspective of macroeconomics, it is well established that different characterisations of the DGP of a MET series have considerably divergent implications for theories and empirics in macroeconomics. For instance, traditional theories of economic fluctuations have claimed that (i) fluctuations are mainly caused by aggregate demand shocks and (ii) demand shocks have only short-term effects, and the economy reverts to the natural rate of output in the long-run. Accordingly, confirmations of unit roots in real output time series compelled many to question the validity of these theories[59]. Similarly, economists have conjectured over the unit root properties of other economic variables such as unemployment rate, price level, inflation rate, consumption expenditure, and stock prices. In each case, the unit root properties of a series have significant implications for economic theories[60]. From an empirical perspective, the order of integration of macroeconomic variables has crucial consequences for appropriate modelling of time series data. These observations have led many economists to explore whether macroeconomic time series could be characterised as containing a unit root.

Statistics and econometrics literature contain a vast amount of work on issues related to structural change. Most of this literature are designed for the case of a single structural change. The problem of multiple structural changes has received considerably less attention (Bai and Perron, 2003a). Some studies relax the assumption of a single break approach for a possibility of considering multiple structural breaks. Hansen (2001) argues that the distinction between a ME series with a unit root and a stationary series with non-constant deterministic component, is less clear when one assumes the presence of more than one break. Following Bai and Perron (1998, 2003) theoretical and practical approaches related to limiting distribution of estimators and test statistics in the linear model with multiple structural changes, few attempts have been made on stationarity test based on multiple structural breaks assumption in linear and non-linear ME series. Carrion-i-silvestre et al. (2005) extend the existing one and two structural break approaches in several ways. They allow for an arbitrary number of changes in both the level and slope of the trend function based on the quasi-GLS detrended method as advocated by Elliott et al. (1996). It permits tests that have local asymptotic power functions close to the local asymptotic Gaussian power envelope, and considered a variety of tests particularly, the class of M-tests induced by Stock (1999) and analysed in Ng and

[59] Statistically, a stationary process fluctuates around a constant long-run mean, i.e. the effects of shocks dissipate over time. Alternatively, if the series features a unit root, then it has no tendency to return to a long-run deterministic path and more importantly, a current shock to the series produces permanent effect on the long-run.

[60] See Gilberto (2005); Christiano and Eichenbaum (1990); Ball (1993); Chaudhuri and Wu (2003).

Perron (2001). Their simulation experiment confirmed that the extended procedure offered an improvement over the commonly used one or two structural break methods. They suggest that the MSB approaches are useful in empirical applications. Pesaran et al. (2006) extend the HMC[61] model by adding a hierarchical structure for all parameters and forecasts time series subject to multiple structural breaks. In order to avoid the restriction imposed by the fixed number of regimes, Pesaran et al. (2006) consider models with different number of regimes and then apply Bayesian model. This is a more reasonable way but not a perfect one since the problem of putting excessive weight near the end of the sample still exists (Koop and Potter, 2007). They suggest that it is essential to develop structural models that explicitly treat the number of structural breaks as unknown. Using Bootstrapped estimates of the breaks, Banergee et al. (1998) address the issue of MSB on GDP and money supply and developed new methods for conducting SB dating and illustrating its use relative to simple DGP. The proposed new methods of detecting and dating multiple breaks in a structural model consisting of a conditional and several marginal processes. They also show how finite sample bootstrapping methods can help to overcome inferential problems arising due to invalidity of standard tests. Recently some papers, among others, attempted to address the issue of multiple structural shifts using various statistical and econometric models in the context of Bayesian and cointegration approaches (see for e.g., Carrion-i-Silvestre et al., 2007; Kejiriwal and Perron 2010; Yamamoto and Perron, 2013, Perron and Yamamoto, 2014; Metin, 2015).

Even though a number of studies attempt to show the long-run properties of univariate macroeconomic time series, majority of the existing literature assume one or two structural breaks in economic model specification process, and thus failed to allow MSBs. Furthermore, studies that investigates the impact of persistent breaks are mainly based on panel data, which leads to the estimation of identical coefficient parameters, particularly for a multi-country study. Therefore, single country approaches are of interest for policymakers as it provides more accurate and consistent information for individual countries. Additionally, because countries experience unexpected shocks in MEF variables, the use of economic methods without structural break is likely to cause forecasting errors (Dogan, 2016). To overcome these shortcomings, this study investigates the presence of not only one or two breaks but also multiple structural breaks in the MEFT series. The investigation of MSBs provide useful information to recognise regime shifts, sources of persistent shocks and allows to obtain more information on the behaviour of macroeconomic, financial and monetary variables. Studies (Lee and Lee, 2009) also show that models that allow for multiple endogenous structural breaks significantly increase the power of the test.

[61] The Hierarchical hidden Markov Chain (HMC) approach assumes that the parameters within each break segment are drawn from some common *meta* distribution. It also assumes that the number of breaks is fixed in the sample (Pesaran et al., 2006).

4.3 Data Overview

In order to undertake a meaningful comparison with previous studies such as NP (1992), Perron (1989), ZA (1992), Narayan (2010), Narayan and Smyth (2008), Narayan and Wong (2009), and Narayan (2008), the univariate structural break analysis includes 25 Macroeconomic and Financial Time (MEFT) series. To account for the impact of data frequencies, the data series is composed of 12 monthly and 13 quarterly series. Additionally, this research includes 12 MEFT data series more than what has been studied previously. The time series variables are obtained from *IFS*, *EUROSTAT*, *OECD*, the *ONS*, and the *BoE* databases. In order to reduce the effect of trends, the series are converted to natural logarithm. The variables are provided in Table 4.1A (see Appendix). Among the MEFT series, 13 of them are similar to the series initially used by NP (1982) for the U.S. and in subsequent studies that examined the time series properties. The 16 MEFT series are similar to what was used by Narayan and Popp (2013) for Australia. The time span was determined by the availability of data. For the majority of the series, it ranges from 1960 to 2014 with a wider coverage of the UK monetary policy regimes and the macroeconomic structural changes.

To describe the basic features of the time series properties, the variables are examined using summary statistics. The order of integration is determined based on the unit root test to ensure univariate stationary process and enable valid inference (El-Shazly, 2016). The univariate time series properties of each MEFT series are presented in Table 4.2A (see Appendix). *First,* based on the mean and standard deviation reported in column two and three, respectively, the coefficient of variance is the highest for *LRINV* (33.26), followed by *LSNLPS, LSNLPS, LRCON, LINV, LIIP* and *LHP*. This probably implies that these series are amongst the most volatile and are expected to have the highest number of significant structural break(s). On the other hand, the least volatile MEFT series are likely to include *LLTIR (0.64), LIBR (1.54), LST90R, LEXR, LSPR* and *LMHE*. *Second,* the statistics on skewness, kurtosis and J-B reveal that the MEFT series are non-normal. Figure 4.1A presents an inspection of the plots that reveals two features worth highlighting as they have implications for the econometric modelling. *First,* it can be noticed that almost all of the MEFT series have a positive trend for most of the period. However, from early 1970s, 2006 and 2008, the trend shows a negative (downward) movement. These changes could be attributed to the oil price crisis and the recent GFC. *Second*, some obvious structural breaks can also be noticed in many of the MEFT series, which motivates further investigation of the time series in order to determine how valid these structural breaks are. The empirical investigation identifies the SBs and test its statistical significance before extracting them to conduct unit root tests so that the power of the test improves (see Perron, 1989; Nelson and Murray, 2000; Narayan, 2008; Narayan and Papp, 2010; Narayan and Wong, 2009; and ZA, 1992, among others).

Assuming structural consistency, it is a standard practice to verify the stationarity property of MEFT series before explaining their properties. Following the data description, the order of integration is determined using the ADF unit root test as a benchmark[62] before allowing structural breaks. The ADF test developed by Dickey and Fuller (1979, 1981) and Said and Dickey (1984) is based on the statistics obtained from applying the Ordinary Least Square (OLS) method. Following the standard ADF test for a unit root in y_{it} for MEFT series (i), at time t, allowing for a drift and a linear deterministic trend is represented as follows:

$$MEFT_{it} = \mu_i + \beta_{it} + \omega_i MEFT_{it-1} + \sum_{j=1}^{k} c_i \Delta MEFT_{it-j} + \varepsilon_{it} \tag{4.10}$$

where $MEFT_{it} =$ natural log of the MEFT series/variable i at time t = time trend:

$$\Delta MEFT_{t-i} = MEFT_{t-i} - MEFT_{t-i-1};$$

$$\varepsilon_{it} \sim i.i.d\ (0, \sigma^2).$$

in Equation (4.10), $MEFT_{it}$ represents the MEFT series i at time t. $\Delta MEFT_{t-1}$ is the lagged first differences of the dependent variable, included to accommodate data for serial correlation in the error term ε_t. The equation examines the null-hypothesis of a unit root against the alternative that the variable is stationary around a constant, a trend, and both constant and trend. ε_{it} is a white noise (serially uncorrelated sequence) disturbance term with variance σ^2, and $t = 1, \dots, T$ is an index of time. Following the standard practice in the real output unit root literature; the study includes a linear deterministic trend in Equation (4.10) (as in Rapach and Wohar, 2004). The $\omega_i MEFT_{it-1}$ term on the right hand side of Equation (4.10) allows for serial correlation and ensures the disturbance term is white noise (Smyth and Inder, 2004). The lag length (k) is selected using the information-based method, the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). The null hypothesis is $\omega_i = 0$, as in Equation (4.10), implying that there is a unit root (a random walk) in $MEFT_{it}$. The alternative hypothesis is that $\omega_i < 0$, which implies that y_{it} is stationary around a linear deterministic trend. When the series is characterised by a unit root, it is considered as strongly dependent or highly persistent because it is highly autocorrelated with its own lags and the contribution of temporary shocks permanently built in it.

The $\tau - statistics$, $\tau = \frac{\omega - 1}{se_\omega}$ is used to test the unit-root null hypothesis. Since τ does not have the usual property of $student - t$ distribution, the test procedure uses the critical values tabulated in Fuller (1976: Table 8.5.2, p373)[63]. The lagged first difference terms are included in the equation to

[62] As in ZA and BP approaches developed based on the traditional ADF test, using ADF as a benchmark allows the analysis to follow the sequential developments in both approaches and permits comparison with previous findings.
[63] Mean of the distribution is equal to zero, the variance is equal to v/(v -2), where v is the degree of freedom and $v \geq 2$, unlike the normal distribution, the variance is always greater than 1, although close to 1 for high degrees of freedom.

take care of possible correlation in the residuals and the number of such lags needs to be an increasing function of the sample size T, at a controlled rate $T^{\frac{1}{3}}$ to whiten the residuals (Said and Dickey, 1984). Since the time lag structure is different for each data series, it is desirable to estimate the optimal time lag by setting the maximum lag k_{MAX} as 2 years (standard short-run period). The optimal lag structure is estimated based on Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC), setting $k_{MAX} = 8$ for quarterly series and $k_{MAX} = 24$ for monthly series.

The ADF test results, reported in Table 4.3A (see Appendix), show that the unit root null is not rejected for all of the MEFT series at all levels of significance, except for manufacturing hourly earnings *(LMHE)* at 10% sig. level. This suggests that a long-run relationship may exist in the univariate time series, which implies that all MEFT series are characterised by the presence of persistent shocks. It is well established in the applied econometrics literature that the failure of the ADF model to reject the unit root null hypothesis is largely due to its inability to cater for structural breaks (BP, 2006). One of the potential problems with time series regression models is that the estimated parameters may change over time. This necessitates testing for structural changes (El-Shazly, 2016). The results are consistent with previous studies. The random walk hypothesis implies that random shocks have permanent effects on the long-run level and fluctuations are highly persistent. This suggests that most of the UK MEFT series are considered as nonstationary stochastic process rather than stationary fluctuations as a drift and around a deterministic trend. When structural breaks are correctly accounted, it becomes a source of power to reject the null hypothesis in unit root testing (Narayan and Liu, 2013). This fact shows that it is necessary for a macroeconomic model to contain a variable that expresses a structural break to obtain stronger evidence of the stationarity property of the series under investigation (Matsuki and Sugimoto, 2013). NP (1982) also obtain similar results for the 14 U.S. macroeconomic variables over the period 1909 to 1970. Their null hypothesis is not rejected for 13 of the 14 series. They conclude that these series behave more like a random walk than like transitory deviations from steadily growing trend.

The following sections investigate the presence of SBs in the MEFT series and identify break points that correspond to known economic events. The research combines the ZA and BP algorithms to the same data series. To accommodate the structural breaks in the MEFT series and for a robustness check, the investigation is carried out based on the ZA one time break, the BP (2003a) double maximum, and the sequential algorithms.

4.4 Estimating the Timing of Structural Changes

4.4.1 The Traditional ADF Unit Root Test

The results reported in Table 4.3A are based on the inherent assumption that the MEFT series do not involve any structural break in the intercept and trend function. The assumption lacks credibility in since a time series data with over 650 observations is likely to be made up of some major events such as financial crisis, oil price shocks, central bank independence, high or low inflation period, MP changes, and political upheavals, which possibly force macroeconomic innovations to remain permanent, which causes structural shifts. It is paramount to say that monetary or/and financial policy that fails to account for permanent and persistent shocks is likely to have inaccurate information to safeguard the economy in the events of sudden and irreversible crashes. Moreover, the misspecification in the modelling process could produce wrong policy advises.

Perron (1989) proposed three types of models. These are: (a) *crash model* or changes in mean, which allows for one-time change in the intercept of the trend function, called Model A; (b) changing *growth model*, which allows for a change in the slope, called Model B*;* and (c) simultaneous *crash and growth model* which allows for a change in both intercept and slope, called Model C. Unlike Perron's approach, a number of different approaches such as Banerjee et al. (1992), Christiano (1992), and ZA (1992) treat the SBs as being endogenously determined. They argue that the break points should be viewed as being correlated with the data. From Perron's point of view, a given series $\{y_t\}_1^T$ has a unit root with drift and that an exogenous structural break occurs at time where $1 < TB < T$ versus the alternative hypothesis that the series is stationary about a deterministic time trend with an exogenous change in the trend function at time TB. To show this empirically, Perron considered three parameterisations of the SB under the null and the alternative hypotheses (see Appendix 4.4A). Perron employed an Adjusted Dickey-Fuller (ADF') type unit-root testing approach (see Dickey and Fuller 1981; Said and Dickey 1984). His test for a unit roots in Model A, B, and C involves the augmented regression equations as shown in Equations (4.4, 4.5 and 4.6).

The empirical analysis begins by examining the validity of the unit-root hypothesis against the alternative hypothesis of drift and trend stationarity. The first investigation allows a one-time endogenous structural break based on the ZA approach. The break determination process takes into account the three models from Perron as a baseline and latter modified by ZA. Including the one break point analysis helps to maintain consistency and allows comparison across the break points in the MEFT series. It is also important to note that combining the ZA approach permits a robustness check with a single break that can be detected using the BP multiple structural breaks dynamic algorithm.

4.4.2 The ZA One-Time Structural Break at Unknown Date

Since the Second World War, the macro series in major European countries is characterised by the presence of several domestic and external shocks, so it is not possible to know exactly when the optimal date of change occurred. Hence, it is appropriate to undertake a test of the unit-root hypothesis allowing endogenously determined one-time structural break. The ZA method provides an estimation procedure for determining the breakpoint in a manner that gives the least favourable weight to the unit-root hypothesis using the test statistics for $\alpha = 1(i = A, B, C),$ where λ is chosen in such a manner that the one-sided t statistics for testing $\alpha = 1$ is minimised. If λ_{inf}^{i} represents such a minimum value for model i, and it follows that

$$t_{\alpha^i}\left[\lambda_{inf}^{i}\right] = \inf_{\lambda \epsilon \Lambda} t_{\alpha^i}(\lambda) \tag{4.11}$$

where λ is a specified closed subset of $(0, 1)$. ZA's method of unit-root test involves estimation of the equations given by Perron. The null hypothesis in this method is specified that it does not require inclusion of the dummy variable $D(TB)_t$, which is included in Perron's Model A, and C. Model B is constructed using the intervention outlier (IO) model instead of the two-step additive outlier (AO) model as in Perron. Following ZA, this study treats the structural break as *endogenous* to determine persistence and transitory innovations in the given series.

The summary results for ZA' Model A^{ZA}, B^{ZA} and C^{ZA} are reported in Table 4.1 and the detailed results in Table 4.4A. The test also finds no evidence of residual serial correlation in the error terms. The endogenous structural break test in ZA approach is a sequential test, which utilises the full sample and uses a different dummy variable for each possible break date (Narayan and Smyth, 2008). The break date is selected where the t-statistic from the ADF test is at a minimum (most negative). Consequently, a break date is chosen where the evidence is least favourable for the unit root null. The critical values in ZA (1992) are different to the critical values in Perron (1989). The differences are because the selection of the time of the break is treated as the outcome of an estimation procedure, rather than predetermined exogenously as in Perron. For each series the coefficients are estimated using the three ZA models with break function $\lambda = \frac{T_B}{T}$, ranging from $j = \frac{2}{T}$ to $j = \frac{(T-1)}{T}$. The t statistics for $\alpha = 1$ reported in the table are the minimum values over all $T - 2$ regressions. The estimated break years $T_B(= \lambda T)$ are the observation corresponding to λ_{inf}^{i} and the minimum value of $t_{\alpha^i}(\lambda)$. It can be seen that the break period that minimises the one-sided t statistics for $\alpha^i = 1$ does not coincide with the breakpoints chosen exogenously from visual inspection of the time plots of the series.

Table 4.1 below summarises the ZA findings of the MEFT series that possess significant break dates at 1%, 5% and 10% level of significance. Unlike previous studies, this research emphasises on MEFT series with significance level (α), a probability threshold below which the null hypothesis will be rejected. Common values are 5% and 1%. However, the MEFT series with 10% obtained from Model A, Model B and Model C are also included to provide further information. If one treats these variables as nonstationary without taking into account the structural breaks, the researcher may use the first or second differences or log differences of the data to achieve stationarity. This leads to loss of long-run cointegrated information as the data are differenced while they are actually break stationary.

Table 4.1 Summary of the MEFT Series with a Break Date Identified by ZA Approach

MEFT series	$Model\ A^{ZA}$ α ≠ 0 ; β = 0	$Model\ B^{ZA}$ α = 0 ; β ≠ 0	$Model\ C^{ZA}$ α ≠ 0 ; β ≠ 0	Significant Break Dates
LCPI (F)	(-4.7142)*[12]		(-5.7586)*** [12]	[1973M09] A
				[1974M01] C
LEXR (F)		(-4.1860)*[3]	(-4.8793)*[3]	[1981M02] B
				[1984M04] C
LLTIR (F)		(-5.893)***[12]	(-5.8939)*** [12]	[1980M07] BC
LIBR (F)	(-8.9404)*** [7]	(-4.6498)** [7]	(-8.0750)*** [7]	[2006M10] B
				[2008M10] AC
LMHE (F)	(-4.6836)* [12]	(-4.3389)* [2]		[1974M03] A
				[1982M04] B
LGNP (ME)			(-5.5860)*** [3]	[1974Q02] C
LGDP (ME)	(-4.5897)* [3]		(-5.7915)*** [3]	[1974Q02] AC

Notes: Figures in parenthesis are t statistics; *, **, and *** denote level of significance of the test of $\alpha^i = 1$ ($i = A, B, C$) at 10%, 5% and 1%, respectively. The ZA critical values are used to reject the false hypothesis. A, B and C refer to Model A, Model B and Model C, respectively. F = Financial; ME = Macroeconomic. See critical values in Appendix 4.
Source: author's analysis.

Following the ZA method, the research allows a one-time structural break around the intercept, slope and simultaneous changes in both intercept and slope. The alternative hypothesis is a trend stationary process that allows for a one-time break in the level, the trend or both. The estimated break points where the unit root null is rejected are ranging from 1973 to 2008. The unit root null is rejected at 5% sig. level for only 5 of the MEFT series (additional 2 series at 10% LS) in favour of the alternative break-point stationary series. These MEFT series show long-term permanent shocks with a non-reverting mean but remains with a non-constant long-run mean, which implies that the series have no tendency to return to a long-run deterministic path. Furthermore, the variance of the series becomes time-dependent. Similarly, ZA reject unit root at the five percent sig. level for only three out of 13 variables (23.08% proportion) using the NP data as compared to 23% proportion of the UK MEFT series that includes all the ZA and NP variables. Re-examining the NP data Lumsdaine and Papell (1997) show more evidence against unit roots than ZA but less than Perron (1989). Using finite-sample critical values, LP reject the unit root null for five series at the 5% level of significance. LS (2003) apply two-break minimum LM unit root test to NP's (1982) and compared it with LP test. At the 5% level of significance, they reject the null for six series with the LP test and four series with the LM test. Only the unit root null of industrial production and the unemployment rate are rejected in both LP and LM tests.

To assess the significance of $t_{\alpha^i}(\lambda_{inf})$, the ZA break dates, the asymptotic estimated break point critical values are reported by ZA (1992, Tables 2, 3 and 4, pp.256 – 257). Allowing a one-time break fraction in the level of the trend function of the crash model and treating the break fraction as the outcome of the estimation procedure defined in Equation (4.4, 4.5 and 4.6), the unit root null is rejected for the total of 7 MEFT series in favour of the one-break alternative. All the series identified as one-point stationary are identified as unit root in the ADF stationarity test. $Model\ A^{ZA}$ tests the unit root null that an MEFT series has a unit root with a structural break in the intercept (also called sudden crash or a mean shift). The unit root null is rejected for *LCPI (at α =90%), LIBR (at $\alpha =$ 99%), LMHE (at α =90%),* and *LGDP (at $\alpha =$ 90%).* At $1 - \alpha$ =10% the structural change is considered to be a weak break point (ZA, 1998) for $LCPI$, $LMHE$ and $LGDP$. This leads to the conclusion that the ZA approach rejects the unit root null for highly significant (1%) MEFT series based on *Model* C^{ZA} than *Model* A^{ZA} and B^{ZA}. These are: $LIBR$ ($Model - A^{ZA}$); $LLTIR$ ($Model\ B^{ZA}$ & C^{ZA}) and $LCPI, LIBR, LTIR, LGDP$ and $LGNP$ ($Model - C^{ZA}$).

The unit root null is rejected for *$LLTIR$ (at α =99%), $LIBR$ (at α =95%), $LEXR$ (at α =90%),* and *$LMHE$ (at α =90%).* $LLTIR$ with a break point in $1980M07$ and $LIBR$ in $2006M10$ have highly significant break points with a level stationary process that allows for a one time break in the trend. The break points are associated with the early 1980s recessions from 1980Q1 to 1981Q1. The main cause for this recession period was the action taken by the monetarist government to reduce inflation. During this period, company earnings have declined by 35%, unemployment has risen by 125% from 5.3% of the working population in August 1979 to 11.9% in 1984. The outcomes characterised by the fact that the long-term interest rate and the *inter-bank rate* categorised by gradual rate of changes during the early 1980s second oil price shock. The case with *LIBR*, the trend break analysis picks up the first signal when the gradual change began after continuous decline since early 1990s. This gradual increase was due to banks reaction to the monetary policy shock, where the Bank of England begins to increase interest rate to stabilise the booming housing prices.

Studies show that $Model\ C^{ZA}$ is more representative than $Model\ A^{ZA}$ and $Model\ B^{ZA}$ in the absence of consistency. This is also shown in the results. When some discrepancies arise while using $Model\ A^{ZA}$ and $Model\ B^{ZA}$, $Model\ C^{ZA}$ is considered to be the most reliable approach. $Model\ C^{ZA}$ tests the presence of the contemporaneous sudden crashes and gradual changes of the financial and macroeconomic series simultaneously. The trend break dates in 1973/74 is associated with the first oil price shock, 1980/81 with the second oil price shocks and the early 1980 recession in the UK. Overall, the results show that all MEFT series have unit root (degree of persistence shocks) both in levels and in trend. The exceptions are the *consumer price index $LCPI$*; the *long-term interest rates $LLTIR$*; the *inter-bank rates $LIBR$*; *gross national product $LGNP$,* and *gross* *domestic product* $LGDP$. The results also show that the weak break point stationary series based on Model C^{ZA} is the *exchange rate* $LEXR$ at α =*90%.* These series have a simultaneous level and trend stationary process that allows a one-time break in both the levels and trend.

The results are consistent with NP (1982), ZA (1992) and Narayan and Smyth (2005). ZA rejects the unit root null for GNP in US data and NS rejects GNP in Australian data. The NS data spans from 1960 to 2004 so size of the sample period could be the main reason that they found no statistical significance to reject more series than the data used in this research. The longer the span of the period, the more MEFT series found to be stationary with, at least, a one-time break. Furthermore, ZAs approach failed to reject the unit root null for 17 out of 22 (77%) of the MEFT series based on $Model\ C^{ZA}$. Generally, the 5 MEFT series that show a significant break-point stationary property also show high cluster of breaks mainly in 1974 ($LGDP$,$LGNP$, and $LCPI$)[64] which corresponds to the world financial crisis that begins after OPEC quadruples the price of oil. The long-term interest rate series shows a break point stationary with a break point in 1980s, which corresponds to the 1980s global credit crunch that prevents many developing countries from paying their debt due to the bond and equity market crashes. Finally yet importantly is the *inter-bank rate (LIBR).* This series has been volatile during the recent global financial crisis and post-crisis periods. It shows a stationary property with a highly significant break in 2008. The period corresponds to the U.S. real estate crisis, which causes the collapse of massive international banks and financial institutions of many industrial countries, including the United Kingdom. This resulted in the collapse of the equity market that led to the perforation of the credit market. Recession in the UK lasted from 2008Q2 until 2009Q3 and gradually extended to 2012, which was the deepest since WW II. Consequently, manufacturing output declined by 7% by the end of 2008 that affected banks and investment firms with many established businesses. These businesses had no other options but to simply declare bankruptcy and ultimately collapsed. Subsequently, the central bank decided to cut the interest rate to historically lowest level of 0.5%. This significant and persistent shock is picked up by the one break ZA analysis for *inter-bank rate (LIBR).* This variable shows both *sudden* and simultaneous *sudden* and *gradual* changes, which combines the properties of additive outliers (AO) and innovation outliers (IO), respectively.

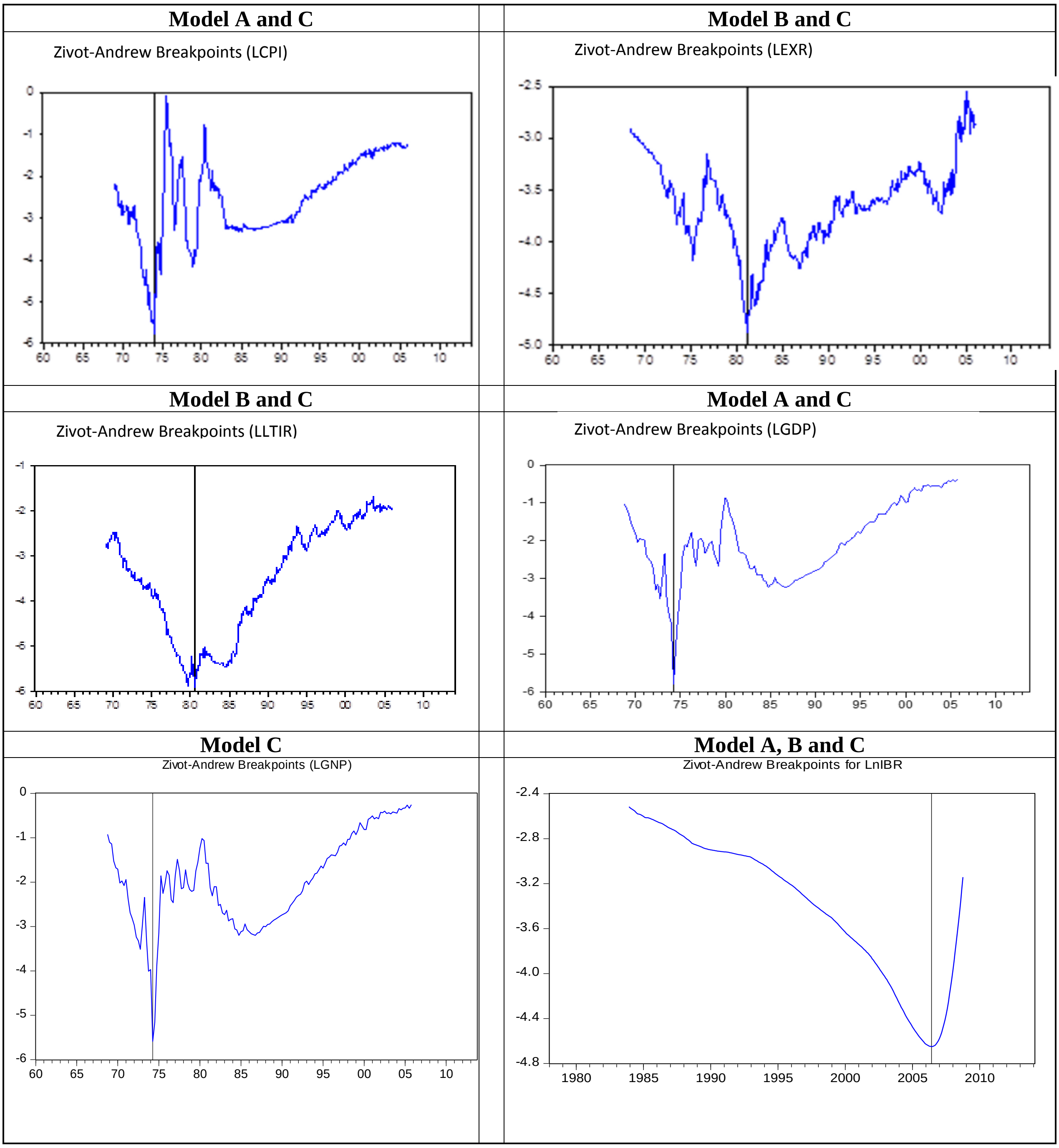
It is also important to note that four of the five significant break point stationary series belongs to the financial sector which tend to be affected by the volatile of oil price shock but the other two variables with significant break point belongs to the ME series. However, for the rest of the other variables, the ADF unit root test remains the same. Accordingly, the ZA one break test approach

[64] The break dates are the combination of mean shift (crash) and changes in slop (growth – gradual change). It is also shown in the above table that some of the breaks were due to simultaneous changes in the form of crash and growth.

seems to support the alternative hypothesis. At this stage, one can partially conclude that macroeconomic variables are more likely to revert to stable growth path with a minimum level of drift than the financial series. Therefore, it is important to make the necessary allowance by adding indicator variables to permit structural movements when specifying economic models.

As stated in the theoretical and empirical discussions, Model C of the ZA approach that signifies the sudden and gradual shifts of the UK MEFT series identifies the breaks better than the two other models (Model A and Model B). The empirical analysis for the one break investigation highlights that the ZA approach is able to identify the endogenously determined significant breaks for each series that correspond to the events in the UK economy. However, the weakness of this approach is its inability to identify more than one structural breaks. The ADF diagnostics reveal that the UK macroeconomic, financial and monetary sectors are characterised by nonstationarity so one can assume the presence of multiple structural breaks in the form of crashes and gradual changes. A well-recognised defect of the ADF and PP stationarity tests is the potential confusion of structural breaks in the series as evidences of nonstationarity. The results of the empirical analysis show that when one structural break is allowed into the ZA unit root test, the null hypothesis of unit root with a structural break is rejected at 1%, and 5% levels of significance for 5 MEFT series. Unlike the ZA one time break approach, all variables found to have a unit root, according to the ADF test, when a structural break is not introduced. Previous researches also show similar outcomes.

The ZA approach identifies only 20% of the data series as one break stationary, which implies that the power of the stationarity test improves by only 20% as compared to the ADF test without structural break. This leads to the assumption that the other 80% of the series contains no break but are nonstationary, implying that the economic time series are described as nonstationary process. The estimation of such variables can lead to spurious regression and their economic interpretation will not be meaningful. When a series contains one unit root, the traditional practice in economics research is to transform the series by differencing or log differencing the variables before including them in the model. This incurs a loss of significant amount of important information. On the other hand, if nonstationarity exists among set of variables, regression involving the levels of the variables can proceed without generating spurious results. On this ground, the ZA one time break approach can be challenged because it is not able to detect more than one breaks in some economic time series. It is also important to note that the critical values of ADF-type endogenous tests are derived without assuming break(s) under the null hypothesis. The following graphical break point expositions show the break point stationarity properties identified by the ZA models (see Figure 4.1). The graphs are drawn in relation to Table 4.1. Except *LMHE*, all the other series show that they have simultaneous sudden and gradual shift differentials.



Source: author's analysis

Figure 4.1 Persistent Shock Plots of Sig. Break Dates based on the ZA one Break Approach

It should be noted that ZA (1992) and Peron (1997) IO and AO approaches only capture one (the most significant) structural break in each MEFT series. The question is -what if there are multiple structural breaks in a series. The argument here is that disregarding the presence of additional shocks could lead to a further loss of information particularly when there is more than one structural break (LP, 1997) in the given series. On this same issue, Ben-David et al. (2003:p304) state,

> "…just as failure to allow one break can cause non-rejection of the unit root null by the Augmented Dickey–Fuller test, failure to allow for two breaks, if they exist, can cause non-rejection of the unit root null by the tests which only incorporate one break…".

However, detailed and convincing the ZA method appears to be, allowing only one break point is not enough to improve the power of the traditional ADF test. It is also possible that more than one structural breaks could exist in MEFT series (BP, 2003a). Furthermore, the Zivot and Andrews test exhibits size distortion in the presence of a break under the null hypothesis. This leads to the rejection of the null ambiguously. When utilizing the ADF and the ZA tests, researchers may conclude that a time series is stationary with break when in fact the serious is nonstationary with break. When the number of breaks increases, the spurious rejections might occur more often. Additionally, the one and two break approaches tend to identify the break point prior to the true break (i.e., at T_{B-t} rather than at T_B). This problem occurs not only in the null but also in the alternative hypothesis (Nunes et.al., 1997; Volgelsang and Perron, 1998; LS, 2001). The BP multiple structural break programming algorithm does not suffer from size distortion and spurious rejection of the hypotheses. It is also able to identify more than one breaks using the global minimiser and sequential algorithms. Therefore, the study proposes the MSB algorithm as an alternative approach utilizing the theoretical and empirical expositions given by BP. Despite its sound empirical approach, there are few studies attempted to investigate MSBs for the UK data using the dynamic programming algorithm of the BP type. Against this backdrop, the following section expands the theoretical and empirical investigation to a multiple structural break.

4.4.3 The BP Multiple Structural Breaks

The added advantage of the BP (2003b) test is that it is flexible enough to accommodate more than one structural breaks in the data series. The contributions of this section are both applied as well as methodological, which is likely to lay the foundation for additional work not only on the application of the testing procedures but also investigating shocks in financial time series. According to Perron and Vogelsang (1992) and Vosseler (2014), the ADF type model with multiple breaks in the deterministic trend function for unit root testing of the MEFT series is reported as follows:

$$MEFT_t = \sum_{i=1}^{m+1} (k_{\{i-1 \le t < ki\}} (\alpha_i + \beta_i . t) + \theta MEFT_{t-1} + \sum_{j=1}^{p-1} \psi_j \,. \Delta MEFT_{t-j} + u_t, \tag{4.12}$$

$$u_t \sim \text{ iid}. N(0, \sigma^2).$$

the coefficient $\theta \equiv \sum_{s=1}^{p} \phi_s$ measures the long-run impact of a shock, where the coefficient $1 \ldots p - 1$, measures transient dynamics. The intercept α and the slope β of the linear time trend are subjected to an unknown number of instantaneous breaks at unknown time, where $k_i < k_1 < \cdots < k_m \le T$ and 1_A denotes an indicator variable that equals 1 if statement A is true and 0 otherwise. Setting $k_0 = 1$ and $k_{m+1} = T + 1$ for the lower and upper margins, respectively, the T observations can be separated into $m + 1$ regimes (Zivot and Wang, 2000). In contrast to the latter author that treat the number of structural breaks, $m = 0 \ldots m_{max}$, and the autoregressive lag order,

$p = 1 \dots p_{\max,}$ as unknown model indicators stacked together in a vector $\gamma \equiv (p, m)'$, which has to be estimated (Vosseler, 2014).

Furthermore, BP (2003a.b) provide a comprehensive analysis of several issues in the context of multiple structural change models and develop tests which preclude the presence of trending regressors. The test endogenously determines the points of break with no prior knowledge. Unlike the ZA one-time break test methods, the MSB method is superior as it allows simultaneous estimation of multiple breaks. It can also be said that the BP approach assumes a maximum number of unknown breaks over the entire sample and intervals between dates sufficiently large to apply asymptotic theory (BP, 1998). The method continuously runs the algorithm starting from the earliest statistically significant break-point, to detect recursively the successive breaks. Let t_1, t_2 and $t_3$be the break dates found in the full sample $t_0 - t_2, t_1 - t_3$ and $t_2 - T.$ The search for the significant break point stops when the dates become stable (Marotta, 2009). Perron and Qu (2006), following the work of BP (2003), search for the optimal partition of all possible segments of data to obtain global minimisers of the sum of squared residuals to identify the location of breaks through minimising their objective function (Eksi, 2009). The method uses DPA and estimates the break dates as global minimisers of the sum of squared residuals from an OLS regression, as in BP.

Before their recent work, BP (1998) explore the theoretical concern related to the limiting distribution of estimators and test statistics in the linear model with multiple structural changes. The asymptotic distributions of the tests depend on a trimming parameter ϵ and critical values are tabulated for $\epsilon = 0.05$[65]. As discussed in BP (2003), larger values of ϵ are needed to achieve tests with correct size in finite samples, when allowing for heterogeneity across segments or serial correlation in the errors. They consider a type of test for the null hypothesis of *no change* versus a pre-specified *number of changes* and versus an alternative of *arbitrary number of changes.* The procedure also tests the *null hypothesis of, say, l change, versus the alternative hypothesis of l+1 changes*. The latter is particularly useful in that it allows a specific to general modelling strategy to determine consistently the appropriate number of structural changes in the data. The tests allow different serial correlation in the error, different distribution for the data, and the error across segments or imposing a common structure. The relevant asymptotic distributions are dependent on a trimming parameter $\epsilon = h/T$ where T is the sample size and h is the minimal permissible length of a segment (BP, 1998, 2003).

[65] According to BP (2006), a trimming as small as 5% of the sample can lead to substantial size distortions, when allowing different variances of the errors across segments, or when serial correlation is permitted. This happens when one is trying to estimate various quantities using very few observations.[65] Similarly, with serial correlation, a heteroscedasticity and autocorrelation consistent covariance matrix estimator needs to be applied to very short samples. The estimates are then highly imprecise and the tests accordingly show size distortions. BP suggest that when allowing different variances across segments or serial correlation, a higher value of ϵ should be used.

Robustness of ZA method based on BP's Approach

Unlike previous studies, this research also tests the robustness of ZA's method using BP's MSB algorithms. According to BP (2006), the method that represents the multiple linear regression for the MEFT series with m breaks in $(m+1)$ regimes is:

$$y_t = x_t' \beta + z_t' \delta_j + u_t, \qquad t = T_{j-1} + 1, \dots, T_j, \tag{4.13}$$

for $j = 1, \dots, m+1$. y_t is the observed MEFT series at time t; x_t' $(p \times 1)$ and z_t' $(q \times 1)$ are vectors of covariates of β and $\delta_j (j = 1, \dots, m+1)$. The parameter vector β is not subjected to shift so it represents a partial structural change model and is estimated using the entire sample. When $p = 0$, one obtains a pure structural change model where all the coefficients are subjected to change. The variance of u_t need not to be constant. The MLR system in its matrix form is:

$$Y = X\beta + Z\delta + U$$

where $Y = (y_1, \dots, y_T)'$, $X = (x_1, \dots, x_T)'$, $U = (u_1, \dots, u_T)'$, $\delta = (\delta_1, , \dots, \delta_{m+1})'$ and Z is the matrix, which diagonally partitions Z at $(T_1, \dots, T_m)$, i.e. $Z = diag(Z_1, \dots, Z_{m+1})$ with $Z_i = (ZT_{i-1} + 1, \dots, ZT_i)'$. The purpose is to estimate the unknown regression coefficient together with the break points when T observations on (y_t, x_t, z_t) are available. The method of estimation is based on the least-squares principle. For each $m - partition$ $(T_1, \dots, T_m)$, the associated least square estimates of β and δ_j are obtained by minimising the sum of square residuals of:

$$(Y - X\beta - Z\delta)'(Y - X\beta - Z\delta) = \sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} [y_t - x_t\beta - z_t\delta_i]^2 \tag{4.14}$$

according to the BP (2005, 2006), each break date must be asymptotically distinct and bounded from the boundaries of the sample. The asymptotic analysis requires an imposition of some restriction on the possible values of the break dates. To this effect, let $\lambda_i = \frac{T_i}{T} (i = 1, \dots, m)$ and define the following set for some arbitrary positive number ϵ, a trimming parameter that imposes a minimal length h for a segment, i.e. $\epsilon = \frac{h}{T}$, .

$$\Lambda_\epsilon = \{(\lambda_1, \dots, \lambda_m); |\lambda_{i+1} - \lambda_i| \geq \epsilon, \lambda_m \geq \epsilon, \lambda_m \leq 1 - \epsilon\} \tag{4.15}$$

Let $\beta(\{T_j\})$ and $\delta(\{T_j\})$ denote the estimates based on the given $m - partition$ $(T_1, \dots, T_m)$, denoted as $\{T_j\}$. Substituting these in the objective function and denoting the resulting sum of square residuals as S_T $(T_1, \dots, T_m)$, the estimated break points $(T_1, \dots, T_m)$ are:

$$(T_1, \dots, T_m) = argmin_{(\lambda 1, \dots, \lambda m) \epsilon \Lambda_\epsilon} S_T(T_1, \dots, T_m) \tag{4.16}$$

with the minimisation taken over all partitions $(T_1, \dots, T_m)$ such that $T_i - T_{i-1} \geq h = T_\epsilon$. The regression parameter estimates are the estimates associated with the $m - partition$ $\{T_j\}$, i.e. $\beta =$

$\beta(\{T_j\})$ and $\delta = \delta(\{T_j\})$. BP also show that, an efficient algorithm based on the principle of dynamic programming, which allows global minimisers to be obtained using a number of sums of squared residuals, is of order OT^2 for any $m \geq 2$. The underlying assumptions[66] state the statistical property in terms of diagonal partitions, minimum eigenvalues bounded away from zero and the martingale difference sequences (MSD)[67] relative to the test procedures (see assumptions in Appendix 4.6A).

4.4.4 Empirical Investigation of the MSBs

Test Statistics and Stability Diagnostics

According to the extensive simulation by BP (2003), pertaining to size and power of the test recommended, a MSBs test strategy is carried out as follows. *First*, it is important to look at whether a significant break point exists based on the algorithms $UDmax$ and $WDmax$ tests. The two algorithm programming approaches confirm if at least one significant structural break is present in the series (see propositions in Appendix 4.6A). *Second*, if the algorithms indicate the presence of at least one break, the number of breaks can be identified based on a sequential examination of the $supF(l + 1 \mid l)$ statistics constructed using global minimisers for the break dates. This is carried out using $SubF(1|0)$ that tests the robustness of the initial algorithm and select m such that the test $supF(l + 1 \mid l)$ are significant for $(l \geq m)$. This method, according to BP, leads to the best results and is recommended for DGP of empirical applications[68]. The stability diagnostic (SD) test in MSBs can be classified into three groups as, SD-1 that tests for structural stability versus single known structural change; SD-2 tests for structural stability versus two structural changes; and SD-3[69] tests for MSBs and determines TB in a sequential approach.

Stability Diagnostics-1

A tests structural of stability (no break) against a fixed number of known breaks/changes: the study, as in BP, first considers $SupF$ test of H_0: structural stability $(m = 0)$ against H_1: the alternative hypothesis that there is a known number of breaks $(m = k)$. Let $(T_1, \dots, T_k)$ be a partition such that $T_i = [T\lambda_i](i = 1, \dots, k)$. Rejecting the null hypothesis highlights the structural

[66] See Assumptions A1 to A5 in Appendix 4.

[67] A MSD is a form of stochastic series. Y is said to be a MDS if its expectation with respect to the past is zero.

[68] With respect to testing, the following recommendations are made: *First*, ensure that the specifications are such that the size of the test is adequate under the hypothesis of no break. If serial correlation and/or heterogeneity in the data or errors across segments are not allowed in the estimated system equation model (and not present in the DGP), using any value of the trimming ϵ will lead to tests with adequate sizes. However, if such features are allowed, a higher trimming is needed. With a sample of $T = 120$, $\epsilon = 0.15$ should be enough for heterogeneity in the errors or the data. If serial correlation is allowed, $\epsilon = 0.20$ may be needed. These could be reduced if larger sample sizes are available (BP, 2006).

[69] SD-3 refers to Sequential Break Point Specification based on $SupF(l + 1/l)$.

instability with respect to the MEFT series under consideration (see Appendix 4.6A for propositions).

Stability Diagnostics-2

A test of structural stability (no break) versus an unknown number of breaks/changes: after intense criticism on the exogenously determined or known break approach, BP (1998, 2006) consider tests of no structural change against an unknown number of breaks, given some upper bound M for m. This new class of tests is called $Double\ Maximum\ Tests$. To investigate a non pre-specified number of breaks to make inference, the BP approach follows two tests of the null hypothesis of *no structural break* against an *unknown number of breaks* given some upper bound M. The first test is an equally weighted version defined by:

$$UDmax\ F_T^*(M,q) = \max_{1\le m\le M} \sup_{(\lambda_1,\dots,\lambda_m)\epsilon\Lambda_\epsilon} F_T^*(\lambda_1,\dots,\lambda_m;q),\ F_T \tag{4.17}$$

the asymptotically equivalent version is presented as

$$UDmax\ F_T(M,q) = \max_{1\le m\le M} F_T(\lambda_1,\dots,\lambda_m;q), \tag{4.18}$$

where $\lambda_j = \frac{T_j}{T}(j = 1,\dots,m)$ are the estimates of the break points obtained using the global minimisation of the sum of squared residuals assuming segments of minimal length $h = \epsilon T$. The limiting distribution of this test is given by:

$$\max_{1\le m\le M} \sup_{(\lambda 1,\dots,\lambda_m)\epsilon\Lambda_\epsilon} F\ (\lambda_1,\dots,\lambda_m;q) \tag{4.19}$$

given the rate of convergence, the derivation of the limiting distribution is possible by strengthening the assumption of second order stationarity to strict stationarity (see assumptions in Appendix 4.6A). The assumption[70] of a continuous distribution for X_t ensures the uniqueness of the global minimum for the process $W^1(l,\lambda_1)$, so that $argumin_l\ W^1(l,\lambda_1)$ is well defined. The proof of this proposition is provided in Bai (1997). The BP second class of test applies weights to the individual test such that the marginal $p - values$ are equal across values of m and is denoted as $WDmax\ F_T(M,q)$. This implies weights that depend on q and the significance level of the test, say α. Let $c(q,\alpha,m)$ be the asymptotic critical value of the test $\sup(\lambda_1,\dots,\lambda_m)\,\epsilon\Lambda, F_T(\lambda_1,\dots,\lambda_m;q)$. For a significance level α. The weights are then defined as $a_1 = 1$ and for $m > 1$ as:

$$a_m = \frac{c(q,\alpha,1)}{c(q,\alpha,m)}.$$

this form is symbolised as

$$WDmaxF_T(M,q) \quad = \max_{1\le m\le M} \frac{c(q,\alpha,1)}{c(q,\alpha,m)} \sup_{(\lambda 1,\dots,\lambda m)\epsilon\Lambda_\epsilon} F_T(\lambda_1,\dots,\lambda_m;q) \tag{4.20}$$

as in BP, the asymptotically equivalent version is

---

[70] See assumptions and propositions in Appendix 4.6A.

$$WDmaxF_T(M,q) \quad = \max_{1\le m\le M} \frac{c(q,\alpha,1)}{c(q,\alpha,m)} F_T(\lambda_1,\dots,\lambda_m;q) \tag{4.21}$$

note that, unlike the $UDmax\ F_T(M,q)$ test, the value of the $WDmaxF_T(M,q)$ test depends on the significance level chosen, since the weights themselves depend on α. Critical values are provided in BP (1998, 2003); for $M = 5$ $(\epsilon = 0.15)$, $M = 3$ $(\epsilon = 0.20)$, and $M = 2$ $(\epsilon = 0.25)$, simulated with q ranging from 1 to 10. Assuming fixed weight, it is defined as:

$$\begin{aligned} UDmaxF_T(M,q,a_1,\dots,a_m) &= \max_{(1\le m\le M)} \quad Sup\ \ F_T(\lambda_1,\dots,\lambda_m\colon q) \\ &= \max_{(1\le m\le M)} am\ F_T(\lambda_1',\dots,\lambda_M'\colon q) \end{aligned} \tag{4.22}$$

the weight $\{\mathrm{a}_1,\dots,\mathrm{a}_\mathrm{m}\}$ reflects the imposition of some *priors* on the likelihood of various numbers of structural breaks. They set all weights equal to unity, i.e. $a_m = 1$ and label this version of the test as $UDmaxFT(M,q)$. Then they consider a set of weights that the marginal $p - values$ are equal across values of m. The weights are then defined as $\mathrm{a}_1 = 1$ and $am = \frac{\mathrm{c(q,\alpha,1)}}{\mathrm{c(q,\alpha,m)}}$, for $\mathrm{m} > 1$, where α is the significance level of the test and $c(q,\alpha,m)$ is the asymptotic critical value of the test $Sup\ F_T(\lambda_1,\dots,\lambda_m\colon q)$. To robustly identify and determine the persistence and transitory behaviour of the MEFT series, the structural breaks are determined based on BPs multiple structural break approaches. According to SD-2, the double maximum tests of $UDmax$ and $WDmax$ statistics that the null hypothesis - no structural breaks in the MEFT series is tested against the alternative hypothesis of endogenously determined unknown number of breaks. Following BP's recommendation, the two algorithms determine if at least one structural break is present in each MEFT series.

The MSB analysis results for the non-pre-specified, endogenously determined number of breaks based on $UDmaxF_T(M,q)$ and $WDmaxF_T(M,q)$ are presented in Table 4.2 and Table 4.3. As suggested by BP, the test is conducted to investigate the presence or absence of endogenously determined structural break(s) based on the null hypothesis of no structural break against an unknown number of breaks based on the upper bound $M = 3$, trimming at $\epsilon = 0.20$. Both algorithms of the global minimisers confirmed that the null hypothesis of no structural break is rejected in favour of unknown number of breaks for all MEFT series. According to the results, one can claim, with high level of certainty that there exists at least one endogenously determined structural break in each MEFT series which some of them are identified as break point trend stationary. Specifically, 13 MEFT series are identified with a minimum of 2 structural breaks as a *drift* and *trend* stationary break points. The BP (1998, 2003, 2006) tests are recent that enable characterisation of MSBs in the long-term relationship, where the number of breaks, as well as the dates at which they appear, is known. Unlike the ZA single break point approach, the two global algorithm tests show that all MEFT series possess at least one structural break. This outcome disputes the ZA one break approach. The ZA algorithm identifies only one break, disregarding the presence of more than one breaks in the given time series property. The successive MSB test approach, according to BP, is recommended as it allows multiple shifts in the time series and is able to identify these breaks.

Table 4.2 UDmax and WDmax Non pre-Specified Breaks (3 SB)

Variables	Statistics [UDmax]	[WDmax]	Variables	Statistics [UDmax]	[WDmax]	Variables	Statistics [UDmax]	[WDmax]
LCPI	150.85*	[2][2]	LHPM	108.16*	[3][3]	LGDP	806.57*	[3][3]
LMSE_M	36.31*	[3][3]	LIBR	506.04*	[3][3]	LINV	68.38*	[2][3]
LEXR(T)	33.18*	[3][3]	LM1	32.20*	[2][2]	LRGDP	134.83*	[2][2]
LIIP	41.04*	[2][2]	LMHE	37.54*	[2][2]	LST90R	143.53*	[2][2]
LM4	276.24*	[2][2]	LNLPS	48.42*	[2][2]	LRCON	17.09*	[2][3]
LSPR	47.27*	[3][3]	LUKUE	22.95*	[2][2]	LRGNP	16.11*	[3][3]
LSTIR	70.49*	[2][2]	LGNP	98.26*	[3][3]	LRINV	75.73*	[ ][2]
LLTIR	264.40*	[1][1]	LNCON	177.90*	[3][3]			

Note: '*' represents significant stability test at 1% level, according to the Bai-Perron (2003) critical value, available in Econometric Journal. Values in the bracket represent the estimated number of breaks of the macroeconomic and financial variables obtained using the global minimisation of the sum of squared residuals assuming segments of minimal length $h = \epsilon T$. The statistics refers to *UDmax* and *WDmax* are presented in the Appendix 4. The first break refers to the equally weighted *UDmax* and the second break refers to weighted *WDmax* test structure. The test procedure is based on structural stability (no break) versus an unknown number of breaks with a maximum $bound\ of\ m\ =\ 3, trimming\ at\ \epsilon = 0.20$[71].
Source: author's analysis based on the BP global minimiser algorithm.

The ZA one break point and LP two break point approaches are not robust enough to identify the presence of high frequency persistent multiple mean or/and trend changes. The empirical evidence shows that BP has the advantage over ZA and LP due to its flexibility and the ability to determine MSBs. To investigate the presence of more than 3 MSBs, the next analysis is conducted based on unknown number of breaks with a maximum bound of $m\ =\ 5,$ trimming $at\ \epsilon = 0.15$. The following approach identifies the MEFT series with more than two statistically significant break points[72]. Among the MEFT series, the variables that show an apparently three or more structural breaks are *LMSE, LSPR, LHPM, LGNP, LHPQ, LCON, LGDP* and *LRGNP*.

Unlike the ADF and the ZA approaches, the results in Table 4.2 and 4.3 showed that none of the macroeconomic and financial series is invariant over time. The presence of a break in the series indicated that the constant/trend varies according to the different regimes. This test assumes that each MEFT series equal to 0.20 (maximum break at $m = 3$) that signifies the average distance between two break dates is at least 0.20*T "time steps", where T represents the $SupF$ test (no break

[71]Test statistics employed - Break test options: Trimming 0.20, Max, breaks 3, Sig. level at 0.01. The test statistics employ HAC covariance (Pre-whitening with lags=1, Quadratic-Spectral Kernel, Andrews Bandwidth). The test also allows heterogeneous error distributions across breaks

[72] This is the novelty and the second empirical contribution of this study to the existing knowledge.

versus m breaks) and the SEQ. The first interest $(at\ m = 3)$ is to determine the number of structural breaks. Thus, the $SupF$ test, whose null hypothesis corresponds to the non-existence of a break as opposed to m ruptures, is significant, at a risk of 5%, for m ranging from 1 to 3. Thus, it is important to consider one or more breaks rather than no break at all as the time series property may show more than one breaks. The results, presented in Table 4.2 and 4.3, established that at least one significant break exists. The sequential procedure of the test for l breaks against $l + 1$ breaks showed that $SEQT(3/2)$ is significant at 1% to 5% in all MEFT series. Thus, the maximum number of endogenously determined breaks is 3 based on the global minimiser weighted and unweighted SB testing approach.

Table 4.3 UDmax and WDmax Non pre-Specified Breaks (5 SB)

Variables	Statistics UDmax][WDmax]		Variables	Statistics [Dmax][WDmax]		Variables	Statistics [Dmax][WDmax]	
LMES_M(T)	418.60	[2][4]	LSTIR(T)	68.18*	[2][4]	LNINV	110.93*	[5][5]
LMSE_Q	36.18*	[3][3]	LHPM(T)	771.27*	[4][5]	LNRGDP	311.74*	[4][4]
LSPR	181.53*	[5][5]	LM1	1053.40*	[5][5]	LRCON	130.51*	[5][5]
LHPM	81.80*	[3][5]	LMHE	2010.85*	[5][5]	LRGNP	119.91*	[2][4]
LGNP(T)	14.78*	[2][3]	LNLPS	1579.57*	[4][4]	LRINV	125.71*	[5][5]
LCON (T)	11.54*	[3][3]	LUKUE	553.77*	[5][5]			
LGDP (T)	12.16*	[2][3]	LCON	1057.68*	[5][5]			
LRGNP(T)	57.05*	[4][4]	LGDP	5134.15*	[4][5]			

Note: same as above. The first break refers to the equally weighted *UDmax* and the second break refers to the weighted *WDmax* test structure. The test procedure is based on structural stability (no break) versus an unknown number of breaks with a maximum $bound\ of\ m = 5, trimming\ at\ \epsilon = 0.15$.
Source: author's analysis based on the BP global minimiser algorithm.

When the maximum bound extended to $m = 5$ at $\epsilon = 0.15$ trimming point, the algorithms are able to identify more breaks in each $0.15T$ segment. This allows the global minimiser algorithms to detect more breaks than the $m = 3$ bound, at 0.20 trimming level. As shown in Table 4.3, the maximum number of significant structural breaks for some of the MEFT series has increased from three to five. The MSBs of $m = 5$ results show that all MEFT series except *LMSE_Q*, *LGNP*, *LCON*, *LGNP*, and *LNGDP*, have more than three structural breaks at 5% sig. level. Among the MEFT series, only one financial time series *(LUSNL)* is found to have less than 4 (based on $UDmax$) structural breaks. Ten of the MEFT series showed, potentially 5 significant breaks detected based on the two global minimisers algorithms. These are *LSPR*, *LHPM*, *LGDP*, *LM1*, *LMHE*, *LUKUE*, *LCON*, *LNINV*, *LRCON*, and *LRINV*, of which the majority of them belong to the financial sector, followed by macroeconomic sector. Theories show that changes in central bank's interest rate is directly proportional to the changes in output and price, although the impulses are amplified in the credit channel of the MTM. BGG (1996) first highlighted the importance of financial market frictions in amplifying macroeconomic shocks in the transmission mechanism. The results shed some light that there are shocks that are more permanent in the financial sector, which accelerate and amplify the monetary policy innovations in the transmission mechanism. In general, based on the maximum break point bound ($m = 5$), the BP approach identifies 17 of the MEFT series with more than 3 significant structural breaks, of which, majority of them are from the financial and monetary sectors.

The second part of the BP analysis focuses on determining the dates of the structural breaks. Following the BP sequential structural break test, the study identifies significant break points and the timing of the structural changes. The majority of the breaks are concentrated between early 1970s, associated with the oil price shock, and around the 2007/8 GFC.

Stability Diagnostics-3 [Break Point Specification]

A tests of l against $l + 1$ structural breaks, $SEQ(l\ vs\ l + 1)$: this sequential test determines the break date and identifies the precise location of the break for each MEFT series. The subsequent steps begin from the $SupFT\ (0\ |l)$, which is a series of Wald tests for hypothesis of 0 breaks $vs.\ l$ number of breaks, i.e. $l + 1$ breaks. Following BP's recommendation of sequential test procedure, this study allows the maximum 3 to 5 breaks with trimming level of $\epsilon = 0.20$, and $\epsilon = 0.15$, respectively. Furthermore, the test corresponds to each segment, having at least 20 and 15 (percentile) observations, respectively.

Table 4.4 The BP Sequential Series of Wald Tests for 0 vs. 1 Break $SEQ(0\ vs\ l)$

Variables	Break dates	$SupFT(0\|1)$	Variables	Break dates	$SupFT(0\|1)$
	TB1	Break Dates		TB1	Break Dates
LCPI	1978M12	85.50***	LUKUE	1973M06(T)	43.77***
LMSE_M	1983M07	29.43***	LGNP	1989Q4(T)	30.52***
LEXR	1982m10(T)	28.81***	LHPQ	1991Q3 (T)	60.82***
LIIP	1985M03	23.28***	LCON	1991Q2 (T)	21.05***
LM4	1991M09 (T)	55.76***	LGDP	1990Q1(T)	19.84***
LSPR	1984M11 (T)	15.24***	LINV	1987Q4	19.24***
LSTIR	1990M05 (T)	26.38***	LRGDP	2003Q2(T)	94.65***
LLTIR	1980m9(T)	74.72***	LST90R	2003Q2(T)	80.09***
LHPM	2001M12	12.91**	LRCON	1987Q1	5.60
LIBR	2007M01	9.91**	LRGNP	2003Q3(T)	64.36***
LM1	2000M01	21.50***	LRINV	1970Q4(T)	36.49***
LMHE	1980M05	28.00***	LNLPS	1991M10(T)	59.48***

Note: "*" , "**" and "***" represent significant stability test at 10%, 5% and 1% level, respectively according to the Bai-Perron (2003) critical value (see Appendix), available in Econometric Journal, 2003. The Scaled F-statistics are compared with the critical values according to Bai-Perron's criteria. The break dates are identified as years, months/quarters. (T) signifies that the series has significant break found on Trend (growth model, as in Perron and ZA), based on the Bai Perron sequential stability test.
Source: author's analysis based on the BP global minimiser algorithm.

As in BP (2003) and Narayan and Smyth (2008), macroeconomic variables contain at least one significant structural break. The results also show that, except real consumption, all MEFT series contain at least one statistically significant break point (see Table 4.4). The break dates are determined by the $SupF(l\ vs\ l + 1)$. If the test is significant at the 5% level, $l + 1$ breaks are chosen. The sequential test is carried out based on the BP tests of $l + 1$ vs l sequentially determined break with a break selection of trimming 0.20 ($m = 3$) and 0.15 ($m = 5$), with maximum number of breaks of 3 and 5 at sig. level of 5%, respectively. For statistical robustness, the HAC standard errors and covariance tests are applied.

Although, the $UDmax$ and $WDmax$ tests confirm that there is at least one structural break in all MEFT series at 5% level of sig., the sequential test identifies series *LRCON*, having no significant break dates that represents the structural change (at 5% to 10% sig. level). This benchmark test is useful as a robustness test to confirm the results of the two algorithms. For the $SupFT(0|1)$, the study follows the Bai-Perron sequential fixed number of breaks verses no breaks employing the HAC covariance; Pre-whitening with fixed lag, *lags=1*, Quadratic-Spectral Kernel and Andrew Automatic Bandwidth, allowing heterogeneous error distribution across breaks. The sequential test results reported in Table 4.4 show that 23 of the MEFT series have a statistically significant single break at 1% sig. level and 2 MEFT series (*LHP* and *LIBR*) at 5% sig. level. In terms of gradual and sudden structural shifts, 9 (37%) of the overall series show significant sudden crashes, while 15 (63%) of the series show significant gradual changes in the form of growth. The findings of the successive break point sequential tests implying that the majority of the MEFT series are characterised by gradual structural changes (as in ZA) of a trend stationary type rather than sudden crashes. Unlike ZA's approach, the second sequential diagnostic test detects the presence of at least two structural breaks in the MEFT series.

Table 4.5 The BP Sequential Series of Wald Tests for 2 vs. 1 Break $SEQ(l + 1\ vs\ l)$

Variables	Break dates	$SupFT(2\|1)$	Variables	Break dates	$SupFT(2\|1)$
	TB2	Break Dates		TB2	Break Dates
LCPI			LUKUE	1967M09(T)	45.64***
LMSE_M	1972M10	14.29**	LGNP	1975Q1(T)	42.91***
LEXR	2002M03(T)	16.82***	LHPQ	1972Q2(T)	552.95***
LIIP	1960M12	2.06	LCON	1974Q4(T)	62.14***
LM4	1960M12(T)	5.86	LGDP	1975Q1(T)	37.93***
LSPR	1974M01(T)	12.91**	LINV	1998Q3	10.94**
LSTIR	2003M05(T)	31.53***	LRGDP	1980Q2(T)	49.38***
LLTIR	1960M12(T)	0.98	LST90R	1979Q3(T)	96.36***
LHPM	1982M12	3.65	LRCON		
LIBR	1977M11	58.31***	LRGNP	1980Q2(T)	41.55***
LM1	2008M01	31.67***	LRINV	1983Q4(T)	21.74***
LMHE	1962M12	6.88			
LNLPS	2008M06	179.356***			

Note: same as above.
Source: author's analysis.

In the 2 vs 1 break sequential test, the results in Table 4.5 confirm that the MEFT series for *LIIP*, *LM4*, *LLTIR*, *LHPM*, and *LMHE*, show no statistical significance to reject the null hypothesis of only 1 break exists so they do not contain more than 1 significant break points. The shocks to these MEFT series are actually momentary (also called transitory). The mean for the above four series reverts to equilibrium and their variance is expected to remain constant after a brief structural shifts.

Except the 5 series, there are two significant (at 1% and 5% sig. level) structural breaks in the form of sudden and gradual shifts. Six of the series show sudden crashes, while the other 12 series gradually shift to a new trend. The mean and variance of the 17 MEFT series have shown long-run relationship, which requires further attention in model specification. These macroeconomic innovations are permanent and remain in the transmission mechanism to a long-run period causing cointegration. In general, the majority (70%) of the MEFT series show the presence of at least two statistically sig. breaks. Eight of the 12 series (67%) that showed gradual changes are from the financial sector. The results highlighted the presence of more significant structural shifts (persistent shocks) caused by financial intermediaries with high concentration of structural breaks in the form of gradual trend shifts rather than sudden changes or crashes.

Table 4.6 The BP Sequential Series of Wald Tests for 3 vs. 2 Breaks $SEQ(l + 1\ vs\ l)$

Variables	Break dates TB3	$SupFT(3\|2)$ Break Dates	Variables	Break dates TB3	$SupFT(3\|2)$ Break Dates
LCPI	1959M12	1.272	LGNP	2006Q1(T)	270.16***
LMSE_Q	2003Q4	5.06	LCON	2003Q2(T)	29.64***
LEXR	1959M12	3.49	LGDP	1998Q1(T)	12.64**
LSTIR	1959M12(T)	6.65	LINV	1959Q4	0.025
LHPM	1978M11(T)	12.70**	LRGDP	1959Q4(T)	7.44
LIBR	1986M06	16.82***	LST90R	1959Q4(T)	2.06
LM1	1986M08	3.36	LRGNP	1972Q2(T)	21.96***
LNLPS	1982M06	2.49	LRINV	1997Q4(T)	5.22
LUKUE	1962M12	1.49			

Note: same as above; where *l*=2.
Source: author's analysis.

The third sequential diagnostic stage tests the presence of three versus two breaks. Results reported in Table 4.6 show that the hypothesis of only two structural breaks is rejected in favour of three significant breaks for 6 MEFT series: *LHPM*, *LIBR*, *LGNP*, *LCON*, *LRGNP* and *LGDP*. Only one series (*LIBR*) shows a sudden crash but the other 5 series display a gradual structural changes. The third stage is the final stage with $m = 3$ bound and 0.20 trimming point. Given the large sample size (650 observations) of the 25 series, there is a possibility that additional breaks up to a maximum of 5 may exist in the MEFT series. The fourth and fifth sequential tests of $SupFT(l + 1\ vs\ l)$, where $l = 3$ and 4, are carried out based on $m = 5$ bound with 0.15 trimming levels.

Table 4.7 The BP Sequential Series of Wald Tests for 4 vs. 2 Breaks $SEQ(l + 1\ vs\ l)$

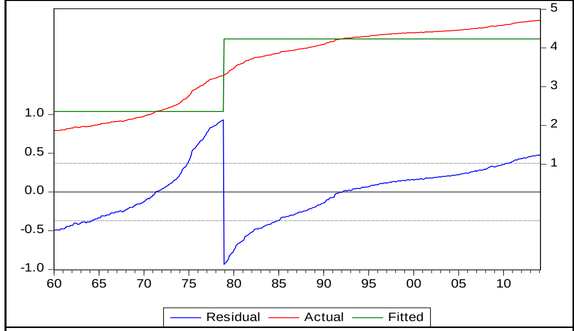
Variables	Break dates TB4	$SupFT(4\|3)$ Break Dates
LMSE_M(T) [F]	2008M09	33.87***
LSTIR (T) [F]	1982M04	48.82***
LHPM(T) [F]	1998M11	82.90***
LM1 [F]	1993M12	33.69***
LMHE [F/M]	2001M12	33.84***

Note: same as above, where *l*=3 and 4.
Source: author's analysis.

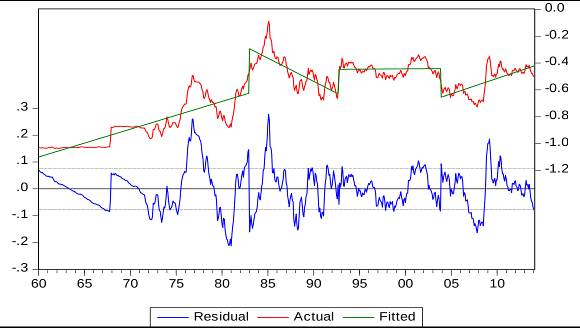
The results presented in Table 4.7 confirm that only *LMSE*, *LSTIR*, *LHPM*, *LM1* and *LMHE* contain the additional (fourth) significant structural break at 1% level of significance. The MEFT series with four structural breaks are manufacturing sector employment, short-term interest rate, monthly housing prices, narrow money, and manufacturing hourly earnings. Three of the series (*LMSE, LSTIR* and *LHPM*) show gradual changes in the form of growth with two series (*LM1* and *LMHE*), showing sudden changes in the form of crash. It is also important to note that none of the MEFT series shows more than three structural breaks. This implies that the UK MEFT series can be characterised by five major regimes and four significant structural changes during the period that covers from early 1960s to the end of 2014. Almost all of the MEFT series that contains more than three significant structural breaks are from the financial sector. Similarly, the outcome of the $SEQ(l+1\ vs\ l)$ sequential test confirms that the financial sector is characterised by more concentration of persistent shocks in the form of gradual changes. This implies that the nonstationarity characteristics of the financial series with more permanent shocks that accumulates gradually than the other sectors. Contrary to the findings, there has been a strong conviction and belief by the central banks and financial control authorities in the run up to the GFC that the financial sector shocks have a self-adjusting mechanism without a trade-off due to monetary policy impulses. On this note, one can make a preliminary deduction that the financial sector contains persistent shocks that impacts the real economy not only in the short-run but also in the long time horizons. It also implies that the financial sector variables are the most volatile as compared with the monetary and macroeconomic sectors. The cointegrating property of the financial sector is also highlighted in the global and sequential tests.

In terms of policy implications, several inferences can be made from the above empirical findings. *First*, the majority of the MEFT series show trend stationarity characteristics, and many of the series with a gradual growth movement are from the financial sector. *Second*, in some of the series, the shocks are found to be transitory with a strong possibility that the series are likely to revert to their gradual long-run growth path within a short period. Therefore, macroeconomic and financial stabilisation policies should be implemented cautiously to avoid overimplementation of these measures while none is required. *Third*, there is enough evidence to suggest that the trend stationary break point process is the main characteristics of the UK MEFT series. Incorporating these characteristics is likely to make the policy action more prudent and the outcomes can be monitored accordingly. The following plots show the MEFT series with a maximum of four breaks identified by the BP MSCs approach. The plots clearly identified the sudden and gradual shifts in the form of significant structural breaks simulating a random walk, a random walk with drift and trend stationarity.

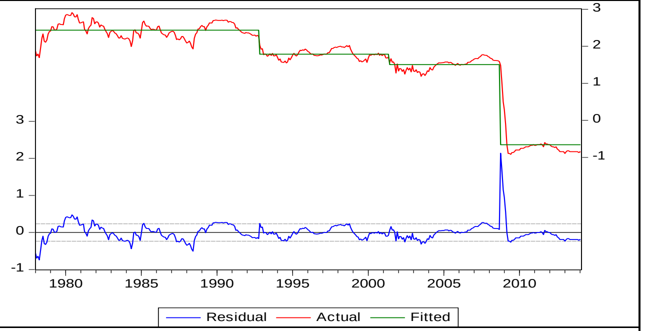
Consumer price index [1]



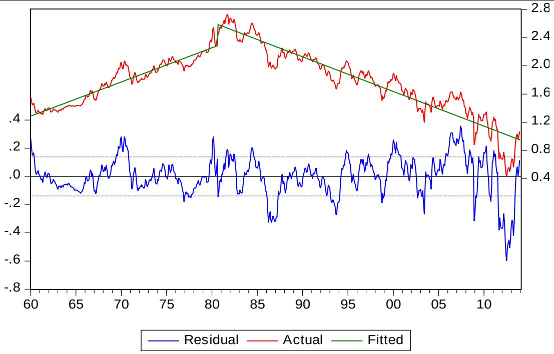
Exchange rate-T [3]



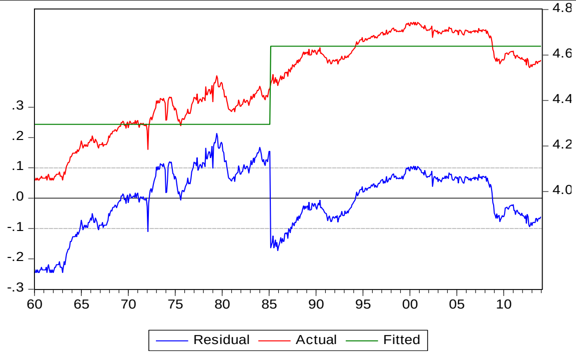
Inter-bank rate [3



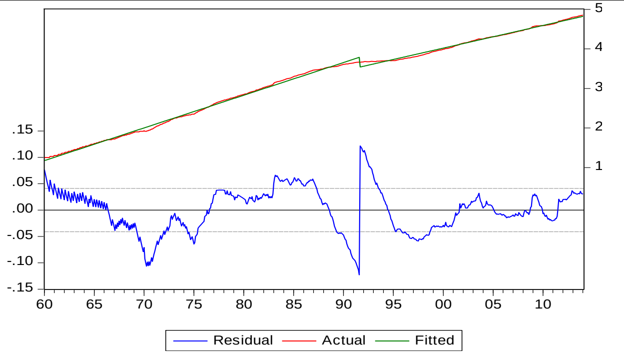
Long-term interest rate [1]



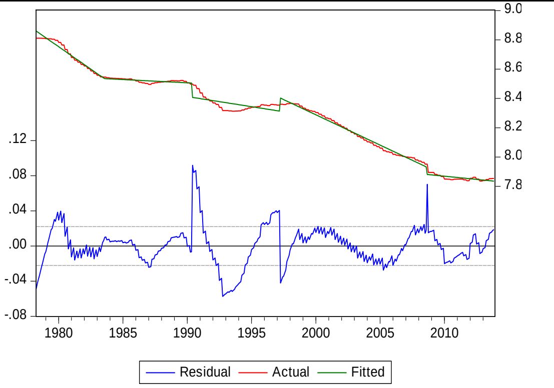
Index of industrial production [1]



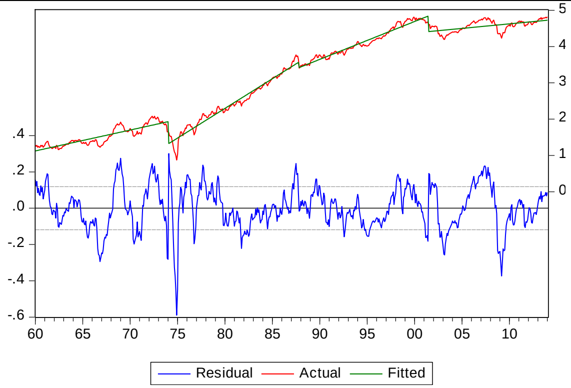
Broad money (M4)-T [1]



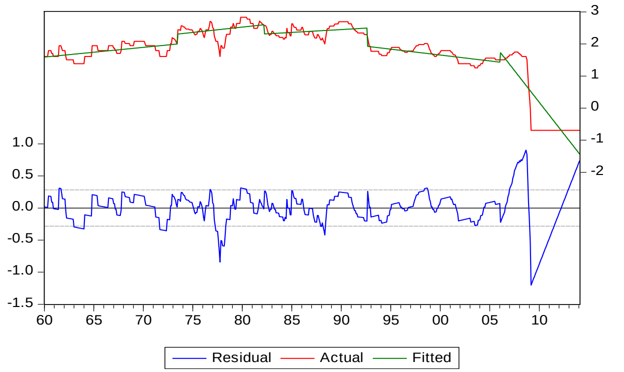
Manufacturing sector employment-T [4]

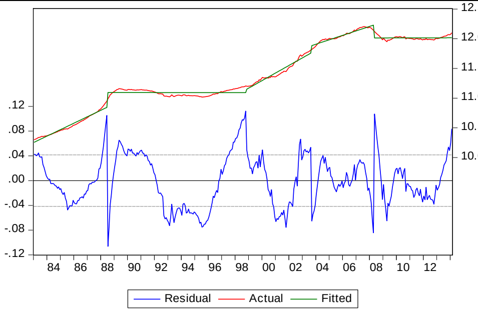
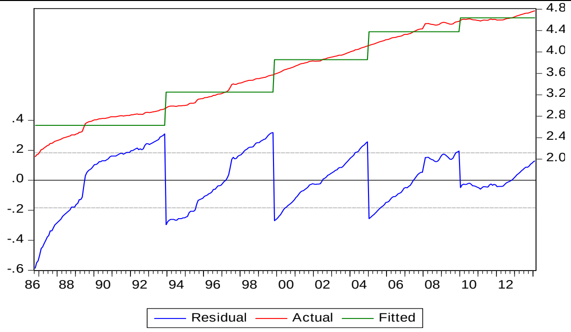
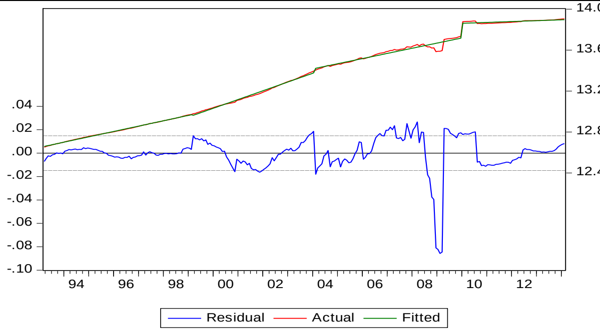
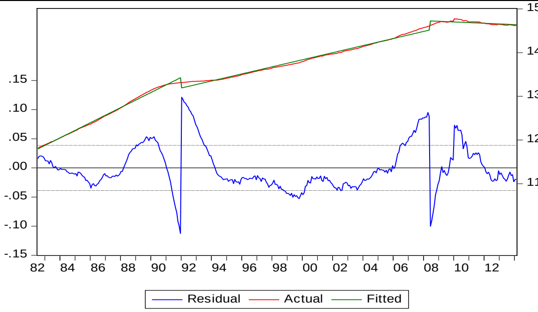
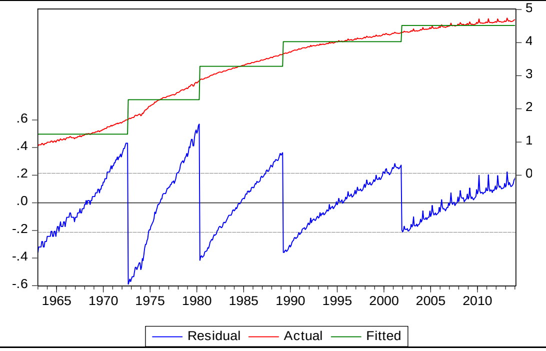
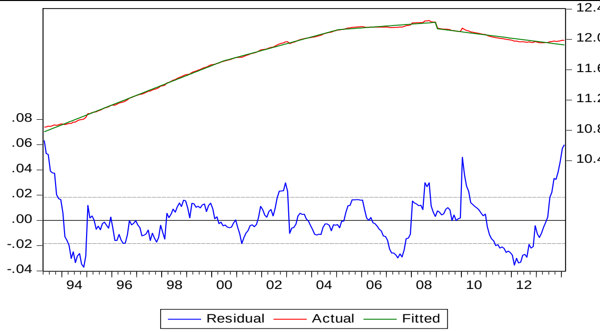
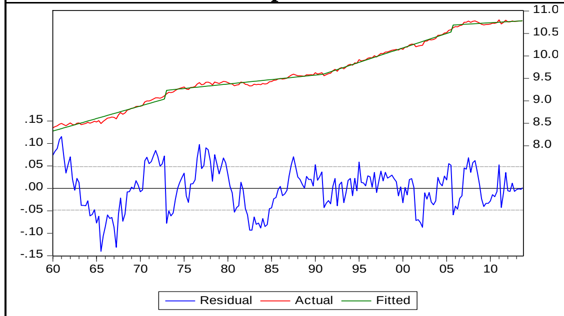
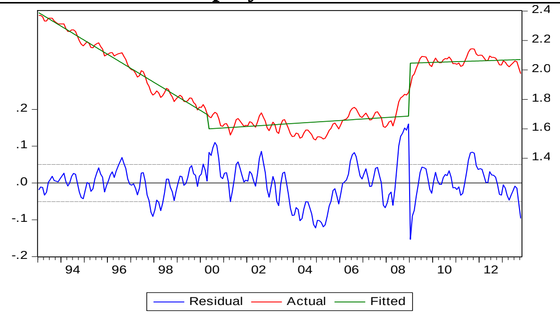
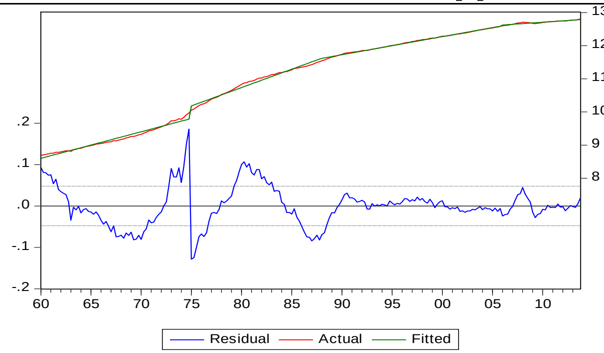


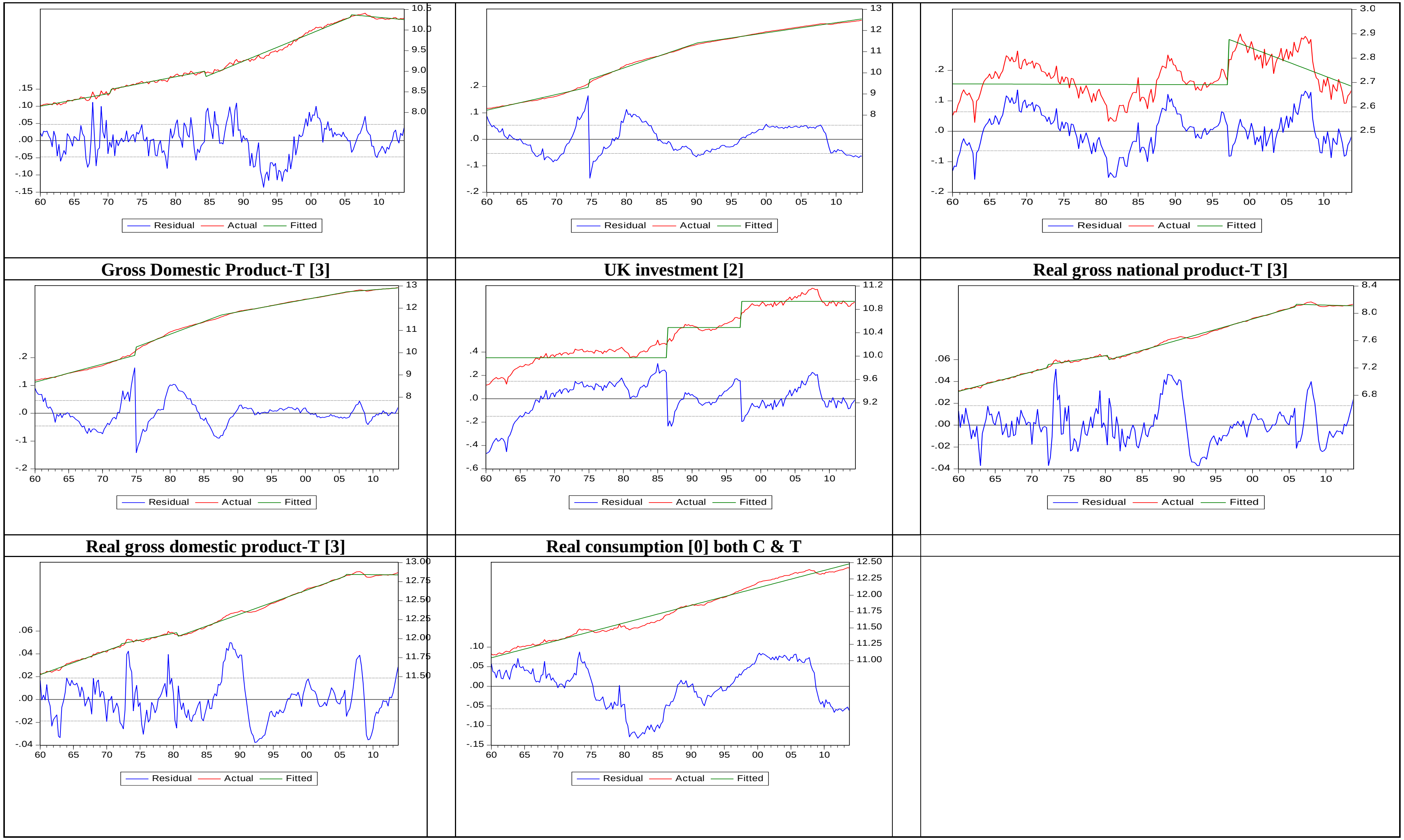
Share prices-T [3]



Short term interest rate-T [4]t [BLC]



Housing prices_m-T [4]		Narrow money (M1) [4]		Secured net lending to private sector [3]
				
Net lending to private sector (CC) [2]		**Manufacturing hourly earnings [4]**		**Unsecured net lending to private sector- T [3]**
				
UK Export-T [3]		**Unemployment rate-T [2]**		**Gross National Product-T [3]**
				
UK import-T [3]		**Net consumption-T [2]**		**Real investment-T 1**



Gross Domestic Product-T [3]

UK investment [2]

Real gross national product-T [3]

Real gross domestic product-T [3]

Real consumption [0] both C & T

Figure 4.2 Plots of Significant Multiple Structural Breaks of the MEFT Series

The numbers in square brackets refers to the number of significant breaks found based on BP algorithm. T refers to break(s) found in Trend
Source: author’s analysis.

4.5 Discussions and Economic Implications

The first significant structural break identified by Zivot and Andrew's one break and the BP multiple break approaches show some common characteristics but different in the identification of break points. Although Zivot and Andrew's (ZA) one break point approach does not have flexibility, the breaks identified by this method are in close proximity with the BP break points. ZA and BP approaches respectively found break dates with a time lag for the following series: *LCPI* (1974 vs 1978); *LIBR* (2008 vs 2008^{3bp}); *LMHE* (1974 vs 1972^{2bp}); *LEXR* (1981 vs 1982); *LLTIR* (1980 vs 1980); *LGNP* (1974 vs 1975) and *LGDP* (1974 vs 1975). The results highlighted the following facts: (1) the BP approach is more flexible, robust and able to identify more permanent shocks and structural shifts in the MEFT series than the ZA approach; (2) in most of the cases, the break dates identified by ZA approach correspond to the third break date identified in BP approach; (3) unlike the ZA approach, the BP approach provides more room to adjust the maximum bound and the trimming level as long as the sample size is large enough to minimise the distortions. The flexible power of the BP approach states that, for every $\epsilon > 0$, there exists an $M < \infty$ such that:

$$P(\min_{k \epsilon D_{T,M}} S_T(k) - S_T(k_1^0) \leq 0) < \epsilon.$$

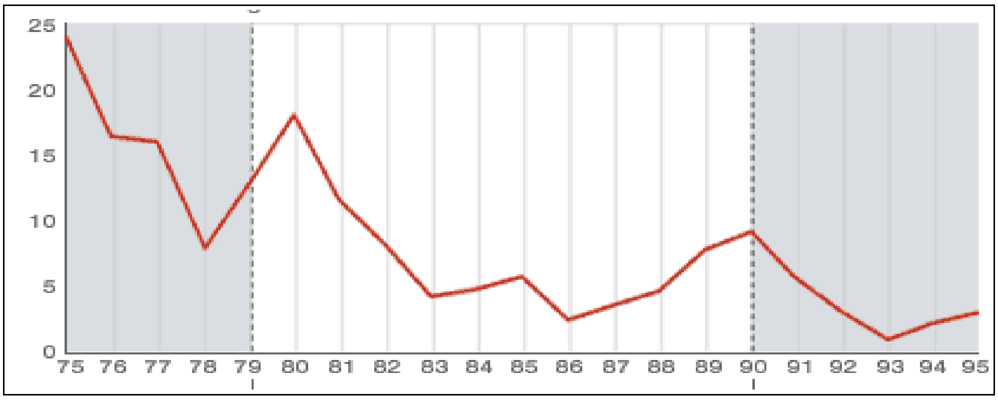
(4) the ZA approach identifies the break dates shortly before or after the onset of economic or financial shocks but the BP approach captures the structural break not only as soon as it happened but also its long-run impact after four to eight quarters. This implies that majority of the sudden changes can be detected by the ZA approach as a single and most important break but the gradual changes, as a growth proximity to MEFT series, are detected by the BP approach. Furthermore, majority (>75%) of the MEFT series are characterised by a gradual shift in the form of trend break rather than breaks on intercept. Therefore, it is highly recommended to use the BP approach to identify the correct timing of structural changes and to avoid misspecifications in empirical analysis. The multiple structural break BP approach identified major world events and persistent shocks in the UK financial, monetary, and macroeconomic sectors. The following section highlights how the break dates fit with events of the UK economy.

4.5.1 The Structural Breaks and Corresponding Events

To give some meaning to the permanent shocks, this section discusses the link between the identified structural breaks and the real economic events. It also provides further evidence that the statistical identification corresponds to the events that are historically observed during the specified period. The events robustly highlighted that the BP multiple structural breaks approach is a relevant method to determine credible and significant structural shifts for the UK economy. The following section identified and discussed the four structural breaks in relation to the real economic events.

First Structural Break (TB1)

The BP MSB results show that the first structural break for the 9 MEFT series: *LSPR*, *LSTIR*, *LMHE*, *LHPQ*, *LCON*, *LRGDP*, *LRGNP*, *LIM* and *LEX* rupture in early 1970s; *LCPI*, *LnST90R*, *LGNP*, and *LNGDP* in the mid and late 1970s; *LMSE*, *LLTIR*, *LIBR*, *LM1*, *LIIP*, and *LNINV* in the early/mid 1980s and early 90s; *LNLPS*, and *LRINV* in late 1990s; *LUKUE* in early 2000s. Majority of the first structural shifts, in the UK, have begun in the 1970s and equally followed by the shifts in 1980s and 1990s. The early 1970s world financial crisis that started after the OPEC oil price shock and the period towards the mid-1970s is associated with the second Banking crisis in the UK, which was occurred from 1973 to 1975. During this period, there was a dramatic crash in the property prices (hence *LHPQ*) which caused many small lending banks to crash and be threatened with bankruptcy. These banks were lending based on the 1960s and early '70s rising housing price. The sudden downturn in housing market prices coupled with hikes in interest rates (hence *LSTIR*), well before the November oil shock, left smaller institutions holding many loans secured by property with lower value than the loans (related to the *LUSNL* and *LSNL*). To alleviate these persistent shocks in the financial sector, the Bank of England bailed out around thirty of these smaller banks, and intervened to assist some thirty others. None of these banks was left unable to pay depositors. Because of this, the Bank of England lost an estimated £100 million[73].



Source: ONS (1999).

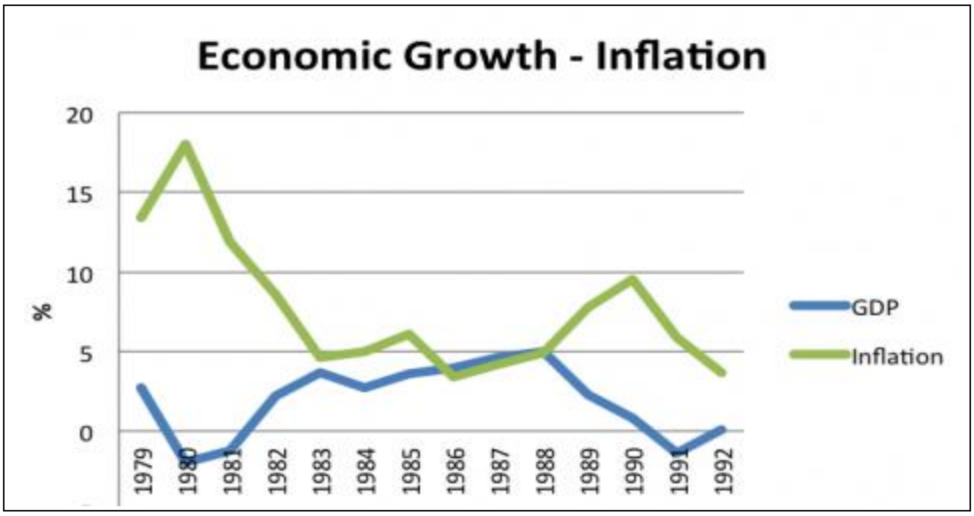
Figure 4.3 The Volatile Downward Movement of Inflation from 1970s to 1990s
(Hence, the breaks at 1974M01[ZA] and 1978M12[BP])

As a consequence of the crisis, the UK BoP (import and export) and real output (*LRGDP*) were immediately affected, which resulted in a significant structural shift in early/mid 1970s. The BP/ZA MEFT series first structural break also confirms that the macroeconomic and financial sectors were not operating smoothly. This is evidenced by the high concentration of breaks during the period from the early 1970s to the late 1990s where 79.8% of the breaks are found. The course of the

[73] The downturn was exacerbated by the global 1973-74 stock market crash, which hits the UK when it was already in the midst of the housing price crash (BoE, 2000).

economy has changed in the 1980s, which resulted in a high inflation in the UK. Among the MEFT series identified in the first significant breaks *LEX, LGNP, LNCON, LNGDP, and LRGDP* were immediately affected by the oil price crashes as compared to the financial series – *LCPI, LNST90R,* and *LSTIR*. This can also be seen on Figure 4.3 that presents CPI/RPI volatility and downturn from 1975 to 1995.

The MEFT series that showed the first significant break in the 1980s were *LMSE, LEXR, LIIP, LSPR, LLTIR, LMHE, LLPS,* and *LNINV*. The structural shift periods, where the persistent shocks are recorded, ranges from 1980M09 to 1988M03. This period is known as a period of economic volatility. At the beginning of the 1980s, one of the biggest problems facing the UK (and other developed economies) was a cost-push inflation. In the late 1970s, UK inflation reached to 20% (see Fig. 4.4), which was caused by rising oil prices and wage-push inflation. To tackle inflation, the UK government uses contractionary monetary measures, which negatively affected investment and consumption expenditure[74], reduced budget deficit through higher taxes and spending cuts and pursued monetarist policy to control the money supply (LM4)[75]. However, this tightening of fiscal and monetary policy combined with high value of Pound Sterling[76], consequently affected UK import.



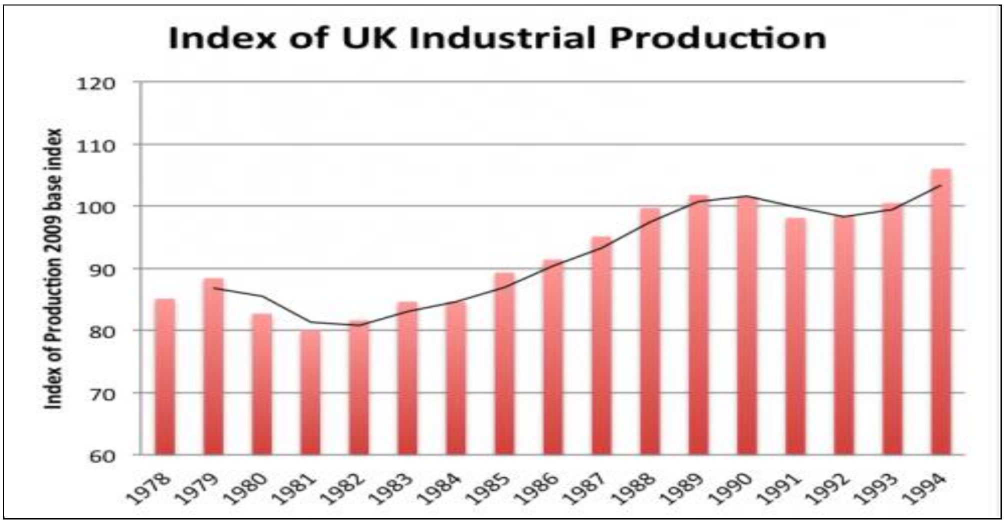
Source: Bank of England, (2000).

Figure 4.4 The Economic Growth and Inflation from 1970s to 1990s in the UK

The 1980s recession, which was caused by the action taken by the monetarist government to reduce inflation (tightening of monetary policy), lasted for 12 months - from 1980Q1 to 1981Q1. Subsequently, company earnings declined by 35%[77], unemployment rises by 124% from 1979 to 1984[78]. Furthermore, company earnings declined by 25%, budget deficit increases by 8% of GDP,

[74] ZA and BP break points for LINV – 1987Q2 and 1983Q3; LCON – 1985Q5 and 1987Q1.
[75] BP break point 2 for LM4 1991M09.
[76] BP Break point 1 and 2 1981M02, 1982M10.
[77] BP break point 1 for LNINV 1986Q3.
[78] ZA break point for LUKUE 1980M07.

unemployment rises 55% from 6.9% of the working population in 1990 to 10.7% in 1993. The mid and late 1990s structural shifts in MEFT series is associated with the major bond market correction and the Asian financial crisis that created exchange rate and banking crisis generated from stock market and real estate speculation along with the Asian currencies pegged to the U.S. dollar. Due to the 1981 severe recession, unemployment increases to 3 million and high unemployment persisted throughout the 1980s (*LMSE*[79] and *LMHE*[80]). After recovering from the 1981 recession, the UK experienced a long period of economic expansion. Towards the end of the 1980s, the growth rate reached record post-war levels (over 2% quarterly growth – equivalent to 8%, 12 month growth), hence, *LGDP*[81] and *LGNP*[82]. This growth rate caused inflation and a bigger current account deficit. By the late 1980s, the UK entered the ERM to keep inflation low, but inflation had once again reached double figures (see Figure 4.3 and 4.4). Furthermore, the 1980s and early 1990s UK manufacturing output was hit hard by recession of the 1981, but showed good recovery in later part of the 1980s (see Figure 4.4). The early 1990s recession hit consumer spending as much as industrial output (hence consumption expenditure, *LCON*[83]).



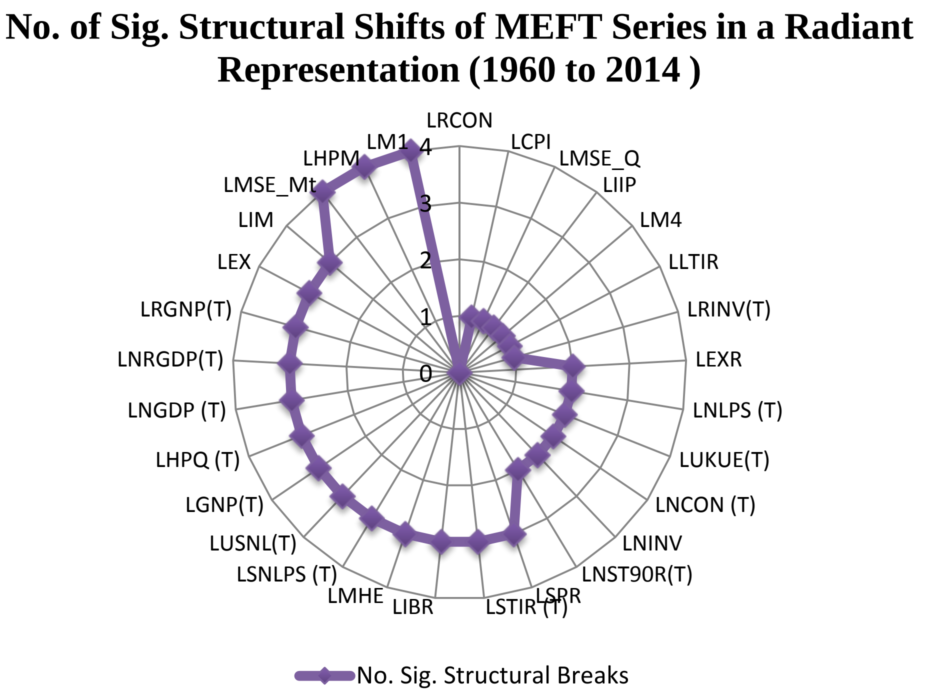
Source: ONS (1999).

Figure 4.5 Index of UK Industrial Production 2009 Base Index from 1970s to 1990s.

During the 1990s, oil price fell to the lowest since the 1988 budget. It followed by interest rate cut in October 1990 by 1% to 14%[84] to alleviate slowdown in activity. As shown in Figure 4.5, the significant structural shift of *LIIP* was felt from the early 1980s towards the mid-1980s[85]. The results in Table 4.8 for TB1 of MEFT series *LM4, LSTIR, LIBR, LM1, LSNLPS, LHPQ,* and *LRINV* show

[79] BP break point 1 for LMSE 1984M08.
[80] BP break point 1 for LMHE 1980M05.
[81] BP break point 2 for LGDP 1987Q4.
[82] BP break point 2 for LGNP 1988Q1.
[83] BP break point 2 for LCON 1990Q2.
[84] BP break point 1 for LIBR 1992M11.
[85] BP Break Point 1 for LIIP 1985M03.

a significant first break date in the 1980s. The *LSTIR* and *LIBR* structural breaks are related to the shock due to the cut in interest rate by 1% during early 1990s but rose to 6.5% in 1994. Money growth (*LM1*) also fell to nearly 5%. Thereafter, upward pressure in inflation continues, but interest rate increases from 1997 to take effect on prices, and inflationary pressure eases through the year to about 3.4% in 1998.



Source: author's analysis.

Figure 4.6 All MEFT Series against the Number of Significant Structural Shifts

The Second Structural Break (TB2)

Majority of the second sequential and significant breaks ruptured from early 1980s to early 2000s. The MEFT series sudden crashes and gradual changes identified in early 1980s are *LSPR, LSTIR, LMHE, LNGDP, LRGNP,* and *LIM.* This period is associated with the UK's early 1980s recession that hits output and employment negatively. The second structural shift, identified in the late 1980s and early 1990s, is related to *LMSE, LEXR, LNLPS, LGNP, LHPQ, LNCON,* and *LGDP*. The break points are associated with the early 90s recession. The shocks in this period hit consumer spending as much as industrial output. The structural shift in the monetary and financial sectors is identified in the late 1990s and 2000s. These series are *LMSEQ, LHPM, LIBR, LM1, LUKUE, LNINV,* and *LST90R*. Except the manufacturing sector and the UK total unemployment, all the MEFT series with TB2 are from the monetary and financial sectors. The financial and monetary variables are found to be more volatile than the macroeconomic variables. The financial sector series with TB2 are *LSTIR*, *LHPM*, *LIBR*, *LM1,* and *LST90R.*

The Third Structural Break (TB3)

The third SB is identified in the early and late 2000s for *LEXR, LSPR, LHPM, LIBR, LM1, LEXR, LSPR, LIBR, LM1, LGNP, LHPQ, LGDP, LRGDP, LGNP, LHPQ, LIM, LGDP, LRGNP*, and *LIM*. The third break is only found in the 1990s for *LMHE, LSTIR*, and *LMSEM*. Except the output (GDP and GNP), the rest are financial and monetary series. Similar to the second structural break, the third structural break is also concentrated in the financial sector. This period is associated with the 2000 Dot-com bubble that created a massive fall in equity markets from over speculation in technology stocks. The 'junk bond' crisis in 2001 and the September 11 attacks that caused high risk by hindering various critical communication hubs necessary for payment on the financial markets caused a significant shift in the course of the UK economy. The financial sector, through *LSPR, LEXR, LHP,* and *LLPS* shows the consequences of this shock. Moreover, the magnitude of the shock of this event has continued to the long-run period, i.e., from mid to late-2000s, which was evidenced by *LIBR, LM1, LUSNL, LGNP, LGDP,* and *LIM.* This period is associated with the consequences of the early 2000s breaks and the 2007/8 global financial crisis originated from the U.S. real estate crisis. This crisis caused the collapse of massive international banks, financial institutions and the equity market.

Table 4.8 The BP Sequential Series of Wald Tests for 4 Breaks vs. 3 Break $SEQ(l+1/l)$

MEFT Variables, Break Dates based on $SupFT(4/3)$								
LSNLPS	1968M05(T)	3.80	LHPQ	2002Q4	79.61***	LM1	2010M10	34.58***
LMSE_M	2008M09(T)	33.87***	LNGDP	2006Q1	84.65***	LMHE	2001M12	33.84***
LSTIR	2006M12(T)	443.37***	LHP_M	2008M05	580.16***	LRGNP	2003Q3	64.36***

Note: same as above
Source: author's analysis.

The Fourth Structural Break (TB4)

The fourth SB is identified for *LMSE, (2008); LSTIR, (2006); LHPM, (2008); LM1 (2010);* and *LMHE, (2001); LGDP,* and *LRGNP*. These persistent long-term shocks are believed to be the prolonged effects of the late 1990 crisis, particularly of the year 1997. This period is associated with the Asian financial crisis that caused exchange rate and banking crisis. The late 2000s (2008Q2 to 2009Q3) period is associated with the GFC and its impacts in the aftermath of the crisis. It is the deepest UK recession since the Second World War. Because of the crisis, manufacturing output declined by 7% at the end of 2008, affecting many sectors including banks and investment firms, with many well-known and established businesses having to collapse. Afterwards, overall output fell 0.5% in 2010Q4. The shock was persistent in the labour market, which unemployment rate rose to 8.1% (2.57m people) in August 2011 with the highest level since 1994[86] (ONS, 2015). The 2011Q4 until 2012Q2 period is associated with double dip recession due to the European Sovereign debt crisis. The double dip recession took place from 2011Q4 until 2012Q2. The latest break date identified by the BP approach was 2008M05. This period is associated with the crash in the housing prices and a significant structural shift also evidenced from the narrow money (M1) in 2010M10, and the manufacturing sector employment in 2008M9 with a gradual trend shift rather than sudden crashes. Although the global test identifies some variables with a maximum of 5 breaks, the sequential tests have not identified any one of the MEFT series with the maximum number of breaks (five breaks). Majority of the above series with four structural breaks are identified as financial sector variables. The first, second, third and the fourth breaks consistently show that the non-transitory shocks are found to be concentrated in the financial sector. This implies that the UK economy is characterised by four significant structural changes with high concentration of significant and persistent structural breaks in the financial sector.

4.5.2 Sudden Crashes, Gradual Changes, and Policy Implications

The Bai and Perron (1998, 2003, 2006) approach, which is recently embedded in advanced software, identifies *persistent shocks* on almost all MEFT series where the sudden and gradual changes have prolonged in the time horizon without reverting to the state of equilibrium. With respect to the sequence of structural changes, unlike the ZA approach, thirteen[87] of the MEFT series show sudden and significant changes or crashes: *LCPI*, *LMSE*, *LEXR*, *LIIP*, *LM4*, *LSPR*, *LLTIR*, *LHPM*, *LIBR*, *LM1*, *LMHE*, *LNINV*, and *LRCON*. The other 12[88] MEFT series are found to show gradual changes known as growth: *LSTIR*, *LSNLPS*, *LUKUE*, *LUSNL*, *LGNP*, *LHPQ*, *LNCON*, *LGDP*, *LRGDP*, *LNST90R*, *LRGNP*, and *LRINV*.

Taking the full time horizon of the 55 years period into account, the structural breaks in the financial and monetary sectors are characterised by both sudden and gradual changes. Eight financial sector variables out of the 13 MEFT series (67% of the overall MEFT series) show persistent shocks with long-term memory in the form of sudden crash with drift, while 9 financial sector variables out of the 12 MEFT series (75% of the overall MEFT series), show persistent shocks in the form of gradual changes (growth). Overall majority of the (over 75%) MEFT series with long-term shocks, identified with the BP approach, are from the financial and monetary sectors that highlights the importance of the *Credit Sector* (Credit Channel) of which the *Bank Lending Rate* (BLR), the *Interbank Lending Rate* (IBR), and the *Net Lending to Private Sector* (NLPS) are the most

[86] BP break 2 for LUKUE 2009M01.
[87] 8 of the series are from the financial sector.
[88] 9 of the series are from the financial sector.

prominent. The *Asset Price Channel* found to contain high number of structural shifts through the *Share Price Index* (SPR). The Interest Rate Channel is represented by the *Short-Term Interest Rate* (STIR) and finally the *Exchange Rate Channel is* characterised by the *Exchange Rate* (EXR) series.

Several important policy implications also emerged from the empirical results. These are (a) *MEFT series, as a stationary or nonstationary process, has an important policy implication*. The trend stationarity series suggests that price regulation policies may not be overimplemented in the economy. A target of non-increasing prices may be feasible and desirable as part of a sustainability strategy. MEFT series are characterised by trend stationary that implies constant growth rate but those characterised by trend nonstationary implies varied growth rate; (b) *the dangers of treating all MEFT series as nonstationary without accounting for structural breaks could lead to model misspecification.* If the data were incorrectly treated as nonstationary and the causality tests for MEFT series were applied to the first difference, then a spurious causality would result. Particularly, the financial sector variables should be treated prudently, as they contain more persistent shocks than the macro and monetary variables; (c) *there are overwhelming evidences in favour of the break-point stationarity hypothesis*, implying that MEFT series are characterised by the EMH, which emphasises on shocks permanent effect. Based on a consensus view, investors tend to have informal advantages in their home markets, if appropriate information is made available in relation to the transitory and permanent nature of MEFT shocks; (d) for a policy decision, *it is important to disentangle the permanent shocks from the transitory shocks.* Both types of shocks require different policy approaches. The former leads to changes in consumption and investment as it challenges household and firms' beliefs of the state of the economy, while the later dictates the absence of major economic and financial sectors changes so households and firms maintain their confidence at the time of boom and crashes.

It is also important to note that when favourable monetary policy news from Bank of England, for instance, become available in the home market, foreign investors raise their valuation by more than domestic investors do. This is because, domestic investors naturally have precise information and might have received the market news earlier; (e) the findings of the significant sequential structural shifts in the MEFT series also suggest that *majority of the shocks to MEFT series are permanent*, triggering a significant challenge in the course of the economy. The impact of policy changes on the financial and economic sectors are characterised by smooth progression, until the first break appears in the early 1970s. Furthermore, (f) in the context of the transmission mechanism, the results based on the ZA and BP approaches showed that a major change in monetary policy rate may have caused significant structural shifts due to persistent shocks in STIR and IBR. This informs economic agents that these structural shifts may not return to their original equilibrium over a period of time, which resulted in uncertainty. On the other hand, the presence of transitory (temporary) shocks inform economic agents that these shocks or changes will return to their original equilibrium over a period of time so, they will not make significant price and wage adjustments. Besides, the implication of persistent shocks in MEFT series is that it will not be possible to forecast future movements based on past behaviour. Therefore, macroeconomic forecasting model are required to employ adjustment mechanism to account for structural changes.

4.6 Conclusions

This Chapter addresses structural changes, macroeconomic innovations, and endogenously determined structural breaks using monthly and quarterly UK MEFT series. It employed the Zivot and Andrews (1992), and the Bai and Perron (1998, 2003a, 2006) methodologies to provide evidence of significant one to many structural breaks. The endogenously determined breaks are found to be associated with unstable economic, political, financial and other global impacts. The findings of persistent long-term structural breaks are useful to characterise the UK economic sectors. The empirical assessment provided some evidence against the long-term neutrality assumption. There is a vast amount of statistics and econometrics literature that cover issues related to structural changes from early 1980s to the present time. However, most of them are designed to determine one or two structural changes. Consequently, the problem of multiple structural changes has received less attention. The criticisms that have been raised on the estimation of a restricted number of structural breaks led to the emergence of the MSB approach. The empirical results provided convincing evidence of the need to identify and control multiple mean and trend shifts caused by the occurrence of large infrequent permanent shocks to economic and financial time series over the past six decades. The BP break point algorithm identified four significant structural breaks, which constitutes five regimes in the given time horizon. The study identified these cluster of breaks and the specific timings within the spectrum of the MEFT series.

The research is motivated by the growing interest in testing the momentary and persistent shocks of the MEFT series and, particularly, by the major events of the UK economic environment such as the 2007/8 GFC. The study examined the three sectors using a group of 25 key macroeconomic, monetary and financial (MEFT) series. To this effect, the study credibly answered the questions: do shocks to MEFT have a persistent effect? Are all macroeconomic variables exhibit nonstationarity? Are shocks persistent or short lived in a developed economy? Are MEF series respond similarly in the advent of economic and political shocks? And what is the structure of shocks hitting the economy like?

The Chapter begun by examining the MEFT series assuming consistency in the conventional ADF tests. It identified the break dates based on unknown one-time and multiple endogenously determined structural breaks using monthly and quarterly time series over the period of 1960 to 2014. The research aimed at investigating and characterising the time series property of the MEFT series. For that purpose, the empirical analysis assumed that breaks are positioned at different unknown dates of the individual series. Unlike those from traditional ADF UR test, the empirical results obtained from the ZA and the BP dynamic programming algorithm corroborate the statement that all MEFT series should not be characterised by a single nomenclature as nonstationary or stationary series.

Majority of the breaks are found from the early 1970s to the late 1990s. The absence of significant breaks after a sudden or gradual policy changes indicated the smooth operation of macroeconomic, financial and monetary policies. The cluster of breaks is associated with a range of factors from the oil price crash in the early 1970s to the 2007/8 GFC. Most notably, the impacts are observed on the financial series: *LIBR, LSTIR, LLTIR, LEXR, LM1, LM4, LSPR, LNLPS, LSNLPS,* and *LUSNL* than the macroeconomic series. The late 1970s escalating oil prices and the period of high inflation during the late 1970s were the second major causes for the output and price shocks. It is also important to highlight that the MEFT series with a significant first (majority), second (majority) and third (all) structural breaks are concentrated in the financial series. This strongly emphasised the fact that structural instability is highly volatile and persistent in the financial time series.

The results also confirmed that the UK economy is susceptible to external and internal forces, and the structural breaks correspond to international commodity price shocks, economic and GFC, government policy changes, CBI and unexpected policy changes or mistakes. The findings of sudden crashes and gradual changes in mean and trends of each series are useful for future empirical studies and policy analysis. The sequential test results of the 23 MEFT series found to have a significant single break at 1% sig. level and only 2 MEFT series (*LHP* and *LIBR*) at 5% sig. level. In terms of gradual and sudden structural shifts, 9 (37%) series showed significant sudden crashes and 15 (63%) of the series appeared to exhibit significant gradual changes in the form of growth. This implies that majority of the MEFT series are characterised by gradual structural changes rather than sudden crashes. As the majority of the series with permanent shocks are from the financial sector, the UK financial sector is believed to have suffered from structural instability in the form of gradual movements. The negative consequences of ignoring the interaction between the sectors and the gradual movements of permanent shocks have been observed in the UK financial and monetary policy approaches in the past six decades, including the recent GFC.

There are criticisms and questions raised on the estimation of MSB largely on the accuracy when the sample size is small. However, the inclusion of large sample size of up to 650 observations minimised the sample size related problems. The study contributed to the empirical literature. The contributions are summarised as follows: (1) *Testing the robustness of the Zivot and Andrew (1992) method using the BP (2003, 2006) approach*. The findings showed that, in the majority of the cases, the ZA approach is not a good match to the BP first time break (TB-1) but to one of the successive sequential breaks. (2) *Variation in break-date identification:* the ZA approach identified the break dates very close to the source of the shocks. The BP approach, on the other hand, identified not only the short-term impact of the relevant shocks but also how the consequences of these shocks could be felt in the long-run. (3) *Sudden and gradual changes*: structural shocks, characterised by sudden and gradual changes, are more pronounced in the financial sector and monetary aggregates than in the macroeconomic sectors. This supports the claim made by BGG (1998) based on the U.S. data. During the unprecedented events such as oil price shocks and GFC, majority of the financial series and monetary aggregates exhibit sudden and gradual changes than the macroeconomic series. (4) *Evidence of smooth economic operations*: the study provided evidence that the 1990s policy measures that provided political independence to the Bank of England and the inflation targeting monetary policy helped to stabilise price, production, income, consumption expenditure and fixed capital formations. The impact of this policy change was also felt in the financial market, causing significant shifts in the banking and monetary sectors. Additionally, (5) based on the one-time break ZA, and the BP multiple break approaches, the MEFT series are categorised into *four homogenous groups.* These are stationary series based on ZA (*LCPI, LEXR, LLTIR, LIBR, LMHE, LGNP*, and *LGDP*); Shocks with high degree of persistence (*LMSE*, *LSTIR, LHPM, LM1,* and *LMHE*); confirmation of unit root hypothesis based on stationarity of I(1) (*LIIP*, *LRCON*, *LRINV* and *LUKUE*), and the MEFT series with more than two breaks (all MEFT series except *LCPI, LIIP, LM4*, *LLTIR*, *LRCON*, *and LRINV*). Moreover, the empirical results provided further evidence concerning the sequencing of the impact of the crisis. Not surprisingly, the impact was felt more in the financial markets, specifically on *LSPR*, *LSTIR, LIBR*, *LNLPS*, *LHP, LEXR,* and monetary aggregates such as broad money and money supply, then upon real GDP during the recovery phase, followed by the interest rate and consumer price inflation.

The study addresses the problems with the traditional ADF method, and the ZA one-time break algorithm that suffers from size distortion and inability to identify the true break. It showed how these problems could be improved by reverting to a multiple structural breaks that is not affected by size distortions and is able to identify not only one break but also multiple breaks in the MEFT series. The following Chapter investigates the role of monetary policy and credit supply impulses, and the response of various sectors of the economy. The financial and monetary policy shocks that contains persistent long-run movements are investigated using Structural Vector Autoregression model based on contemporaneous and sign restrictions. The results obtained in this Chapter are incorporated into the SVAR modelling process. Accounting for structural breaks in SVAR model specification and estimation is a new practice. Additionally, the following Chapter compared the role of aggregate demand and aggregate supply shocks in the context of monetary policy and credit supply shocks. It will also address the role of borrowers' balance sheet (BS channel) and banks' lending role (BL channel) in the credit channel of the transmission mechanism.

CHAPTER 5

SVAR MODEL INVESTIGATION OF MONETARY POLICY & FINANCIAL FRICTIONS

5.1 Introduction

Structural Vector Autoregressive (SVAR) model received significant attention and its ability to simulate dynamic responses of variables to particular macroeconomic shocks has been recognised ever since Sims's (1980) seminal paper. The macroeconometric methodology for policy analysis becomes popular, as the model is identified with a set of restrictions that broadly consistent with micro and macroeconomic theory. The macroeconomic dynamic responses are used in the process to check the identification assumptions (Hall, 1995). SVAR models are a multivariate, linear representation of a vector of observables on its own lags and, possibly, other variables as a trend or a constant. SVARs make explicit identifying assumptions to isolate estimates of policy, private agents' behaviour and the effect on the economy while keeping the model free of the many additional restrictive assumptions. The reduced form relates endogenous variables to lagged endogenous (predetermined) and exogenous variables, while the structural VAR does the same, but also allowed for a contemporaneous interaction between the endogenous variables. Moreover, very few variables entered each structural equation, compared with the large number in the reduced form equations (Dungey and Pagan, 2000). The SVAR approach designed to avoid problems in dynamic simultaneous equation models that lead to "incredible" identification restrictions (Sims, 1980). In response to this problem, SVAR models are set to treat all variables as endogenous and have been used to document the effects of money on output (Sims and Zha, 2005), the relative importance of supply and demand shocks on business cycles (Blanchard and Quah, 1989), the effects of fiscal policy (Blanchard and Perotti, 2002), or the relationship between technology shocks and worked hours (Gali, 1999), among many other applications.

Investigating the practice by which monetary impulses transmit in an open or closed economy is a complex process. This is because different channels of the TM are working simultaneously with altering lags and the operating tools are changing more frequently before the full impact is realised. Although structural VAR models are widely used for policy analysis and to offer stylized facts about business cycle and MTM, they are not well suited for policy simulations for the following reasons: (a) it rarely imposes restrictions upon the dynamics in their implied structural equations, (b) even though constraints imposed, it may not be particularly restrictive so the methodology requires the structural innovations to be orthogonal, (c) the huge number of parameters and the structural equations underlying them are hard to interpret, and (d) the question of how the system responds to an unexpected change in a variable remains unanswered. The standard SVAR model assumes stable structural parameters over time, even if there are unexpected shocks that cause permanent structural shifts. There is very little known about immediate, short-run, and long-run impacts of a monetary policy shock in the presence of inconsistent parameters. In this context, the role of financial frictions and its immediate impact on the MEF sectors is not even studied. There is no empirical evidence that exists to suggest that the occurrence of structural breaks that change the variance of the data have no impact on the TM of the shocks. As empirical theory suggests, structural changes offer identifying power only if some parameters do not change. The difficult step in the identification process is to identify these parameters.

This study extends the existing literature by addressing the limitations of the structural VAR approach in the following ways: (a) modelling the structural systems, which involves the utilisation of exclusion restrictions up on the dynamics contained in each structural equations to allow easier interpretation of the system (b) it employs the restrictions in the form of sign and recursive contemporaneous structures, (c) it addresses the role of the credit channel and its sub conduits using an iterative process of the VAR and VECM approaches, (d) the problem with unexpected shocks in the time horizon can be improved by allowing structural breaks in the model. For this investigation process, variants of structural VAR models are imposed on different volatility regimes based on the statistical information gathered in Chapter 4 and through the conventional linear restrictions. Those structural parameters that are expected to change are augmented using indicator variables. As suggested by Rigobon (2003), the reduced form unconditional covariance matrix can be used to improve the identification of structural parameters that are assumed stable over time and across volatility regimes. The additional identification scheme in the volatility regimes can be exploited to identify the shocks without the need to resort to other type of identification restrictions.

This idea was first extended to SVAR models by Lanne and Lutkepohl (2008)[89]. The hypothesis that the DGP in a VAR model with constant parameters, apart from changes in the volatility of the disturbances is in general questionable with macroeconomic data (Bacchiocchi and Fanelli, 2015). Studies are beginning to recognise that structural breaks may have marked consequences in the transmission of the monetary policy shocks. The efficacy of monetary policy and the impact of financial frictions have often been the subject of heated debate and despite considerable research in the academic literature, there remains disagreement about its effect on the real economy. There is a growing evidence that it is not only the effect of monetary policy changes but also the acceleration and propagation of persistent shocks that play significant role to impact the output and price (Cloyne

[89] See also Lanne and Lutkepohl (2010), and Lanne et al. (2010).

and Hurtgen, 2014). A common approach for this purpose is to use the structural vector autoregression model (Phiromswad, 2015).

In the context of the new paradigm shift[90], it is important to investigate the effect of monetary policy on the movements of macroeconomic variables in terms of a small number of aggregate level shocks such as aggregate supply, aggregate demand and monetary policy shocks. The specific role of credit and financial market shocks were subsumed within one or the other of these aggregate macroeconomic shocks. Therefore, this Chapter addresses not only the role of monetary policy but also disentangle the impact of credit market shocks and quantify their role in driving the behaviour of macroeconomic, financial and monetary variables. In addition to investigating the behaviour of credit supply and monetary policy shocks, it examines (a) the role of aggregate demand and aggregate supply shocks, (b) the role of financial frictions in the real economy, and (c) the presence of bank lending and balance sheet channels in the UK credit sector.

To address these issues, a two regime structural VAR model is estimated for the UK economy. The approach involves estimating a set of financial, macroeconomic and monetary variables. In this approach, *first,* each variable is regressed on past movements of itself and the other variables in the system. *Second,* the unexplained component of each variable is then decomposed into the impact of different structural or fundamental shocks. The decomposition is not a straightforward process. Unless each shock is uniquely identified from the other restriction based on economic theories and agents' reaction to policy decisions, the decomposition process becomes an impossible task. The other novelty of this study is that it estimates the SVAR model with structural changes, despite the traditional assumption that the reduced form unconditional error covariance matrix varies, while the structural parameters remain constant. In this approach, different volatility regimes are accounted based on the SBs found in the data. This method improves the identification of structural parameters in SVARs as it allows both the error covariance matrix (ECM) and the structural parameters to change across the volatility regimes.

The empirical study sets and estimated $16(8 \times 2PR)$ equations, based on the two regimes and the IVs to account for the structural changes. The study finds that allowing the structural parameters to change does not affect the stability of the models. It also discovers the fact that credit supply shocks generate more volatility in the market than monetary policy shocks. Furthermore, the study shows that credit supply shocks account for most of the shocks in the macroeconomy, financial and monetary aggregates, particularly during the post-1992 and after the 2007 GFC. Whereas the impact of monetary policy shocks appeared to disappear after 8 quarters or 2 years, hence a short-run effect.

[90] A shift in the understanding of macroeconomics in the post-GFC.

It also highlighted that the credit supply shocks are more like aggregate supply shocks than aggregate demand shocks. They cause output and inflation to move in opposite directions due to two possible reasons: (a) credit supply shocks affect potential supply in the economy, or (b) due to its significant effect on exchange rate[91]. The robustness check based on sign restriction also shows that the results appear to be reliable. Allowing both the structural parameters and the ECM to change, reduces the “puzzles” that are usually the case in VAR models. The VAR and VEC models reveals that the UK credit market works through both bank lending and balance sheet channels, although the bank lending channel is appeared to be more prominent than the balance sheet channel.

The rest of the Chapter is organised as follows. The *second section* reviews the existing literature on monetary policy and credit supply shocks, *section three* describes the methodology, present data and the identification process. *Section four* and *five* present data with variable overview and specifies the SVAR model through identification of the shocks and SBs. *Section six* estimates the model and uses IRFs and FEVD to examine the properties of the monetary policy and credit supply shocks and highlights the main drivers of output, price, money supply, lending and equity prices both historically and the post-crisis period. *Section seven* investigates the UK credit channel using VAR and VEC approaches and *section eight* concludes.

[91] See Chapter 2 for the role of exchange rate in the five MP reaction functions.

5.2 Review of Relevant Literature

The central theoretical and empirical questions in monetary economics focus on understanding whether monetary policy and macroeconomic shocks affect real economy. To that end, monetary economists have been particularly interested in investigating the validity of the benchmark theories and examining the impact of monetary policy shocks on the economy over the business cycle. Since the seminal contribution by Sims (1980), VAR models have become the major tools to investigate the impulses of monetary and credit shocks in the MTM. According to Christiano et al. (1999), following contractionary monetary policy shock, economic activity declined quickly in a hump shaped manner, while the negative reaction of price level is more delayed and persistent. Peersman and Smets (2001) provide evidence for the euro area as a whole, while Mojon and Peersman (2001) investigate the effects of monetary policy shocks in the individual countries of the euro area.

Unlike earlier results, counterintuitive findings show increase in the price level following the monetary policy tightening. Sims (1992) first note these findings followed by Eichenbaum (1992) who name this as a "price puzzle". Among other suggestions, a typical approach used to improve the price puzzle is to add commodity prices into the system (Sims, 1992; Christiano et al., 1999). On the other hand, Giordani (2004) stresses the importance of including a measure of potential output into the VAR. A different approach is pursued by Bernanke et al. (2005), who point out that central banks look at practically hundreds of time series and therefore, in order to avoid omitted variables bias and ensure correct identification of monetary policy shocks, an econometrician should use richer datasets as well. Due to degree of freedom considerations, the inclusion of additional variables into VAR is limited. As a result of this, previous research makes use of factor analysis and augment the standard VAR with factors approximated principal components. Other solutions, especially in an open economy framework, structural models make use of non-recursive identification (Kim and Roubini, 2000; Sims and Zha, 2006a) or identification by sign restrictions (Canova and Nicolo, 2002; Uhlig, 2005).

From empirical viewpoint, literature (see for e.g., Bernanke and Blinder, 1992; Bernanke and Mihov, 1998) often use the VAR framework to describe and understand the behaviour of prices, monetary aggregates, interest rates, and output, as well as to conduct policy experiments. Extracting meaningful results from a reduced form VAR is a difficult task and requires cross-equation restrictions which should be credible and uncontroversial (Caglayan et al., 2012). Furthermore, the parameter stability assumption of autoregressive coefficients in a particular policy regime is questionable. To overcome this problem, three approaches have been proposed: (a) Bernanke and Blinder (1992), and Bernanke and Mihov (1998) use a recursive identification scheme where policy shock affects output with a lag, (b) Blanchard and Quah (1989), and Gali (1992), among others, employ identification by imposing zero restrictions on the long-run impact of monetary disturbances, (c) Lanne and Lutkepohl (2008) and Bacchiocchi and Fanelli (2015) employ the restriction based on the assumption that the transmission mechanism of the shocks does vary across volatility regimes. Since Sims's (1980) seminal paper MPT, typically, has been studied using a VAR approach.

Literature uses VAR models extensively to measure the response of target variables (output and price) to the shock of monetary instruments. Among the common variables used in various VAR model, interest rate, output, and inflation are the typical variables commonly represented as a monetary policy instrument and target variables. In all VAR models, variables are treated as endogenous. Despite VAR's complex nature, studies show that monetary policy has at least a short-term effect on consumption and investment (Bernanke et. al., 1998; Taylor, 1997). Several indicators of monetary policy stance have been used to test the effectiveness of monetary policy over the past three decades. Sims (1980) uses monetary aggregate, Eichenbaum (1992) employs non-borrowed reserves at the central bank, Faust et al. (2004) use Federal Funds futures, and Sims (1992) employs a short-term interest rate, which was the most widely accepted single indicator (Bernanke and Blinder, 1992).

The structural macroeconometric models, according to the Cowles Commission approach (SMCC)[92] with no restriction on the number of variables to be explained, were a real success. In the late seventies, however, a strong decline of the popularity of this approach was recognised, mainly because of: (1) a strong commercialisation of macroeconometric models, (2) the large size and complexity of these models, (3) rather poor prediction performance, (4) the so-called Lucas-criticism (policy-dependent parameters), and (5) the necessity of a large number of *a priori* restrictions for the identification of these models. Because of the decline in popularity of the SMCC approach, the search for a better model led to the development of Vector Autoregressive models (Sims, 1980). VAR models are Vector-generalisations of autoregressive models and can be, in the basic version, regarded as an unrestricted reduced form of a structural model, where the specification is purely determined on the information contained in the available data. Unlike SMCC, one does not need any additional non-testable *a priori* restrictions at least not in the basic version.

VAR introduces predetermined (by the monetary authority) instrumental variables to solve the simultaneity problem using the simultaneous equation models. However, Sims (1980:p5) argues that truly exogenous variables do not exist. He says "...many, perhaps most of the exogenous variables in the FRB-MIT model or in Fair's model (Fair, 1976) are treated as exogenous by default

[92] See also Hood and Koopmans (1953).

rather than as a result of their being good reason to believe them strictly exogenous". When solving simultaneous problems in VAR models, one chooses different identifying restrictions (Hall, 1975). In doing so, the model decomposes all variables into expected and unexpected parts. It is on the unexpected part where the identifying restrictions are imposed. VAR approach focuses on the shock component of the monetary policy actions rather than the systematic component. The main reason for this is that models respond in various ways to the experiment of a monetary policy shock. Furthermore, the monetary policy shocks are useful to trace the dynamics of the model and hence the shocks are neither large nor persistent.[93] Persistent shocks cause a statistically significant structural shift in the macro, financial and monetary sectors. The focus of VAR on monetary policy shocks can be justified: *first*, as the monetary policy instruments are controlled and managed by central banks, the traditional practice in the evaluation of monetary policy shocks assumes exogeneity of the policy variables. Moreover, the observed data on monetary policy variables result from the complex interaction between monetary policy and the state of the economy. However, the assumed exogeneity of monetary policy variables are invalid for the policy analysis (Afandi, 2005). Furthermore, VAR models treat all variables as endogenous and emphasised on the innovation terms of each structural equation in the system. Bernanke and Mihov (1998:p875) note that:

> "...the emphasis of the VAR-based approach on policy innovations arises not because shocks to policy are intrinsically important, but because tracing the dynamic response of the economy to a monetary policy innovation provides a means of observing the effects of policy changes under minimal identifying assumptions".

Hence, this justifies the emphasis of the VAR-based approach to monetary policy shocks (Gottschalk, 2001). *Second,* not all variations in central bank monetary policy actions are exhaustively explained by the policy reaction to the state of the economy. There is a segment, which is unaccounted for or unexplained by the policy reaction that referred to as a monetary policy shock/innovation. Christiano et al. (1999), argue that random fluctuations in central bank inclinations and central bank's decision-making process could give rise to monetary policy shocks. Moreover, the MPC members who are in charge of setting monetary policy do not often have uniform preferences regarding the relative weight to be given to output stabilisation or the inflation target. Consequently, the MPC decision-making process in central banks may follow unsystematic process, which depends on shifts within the committee. These random fluctuations become a useful source of monetary policy shocks that can be used to identify the effects of monetary surprises on

[93] Persistent shocks in the model also meets the suggestion made by Lucas (1980). Lucas, as in Bernanke et al. (1998) and Christiano et al. (1999), argue that one needs to test models as useful representations of the real world by exposing them to monetary, financial and other shocks in accordance to how actual economies would react. The more the model imitates and provide answers to simple questions, the more one would have faith on the models to answer harder questions.

macro variables. According to Bernanke and Mihov (1998), the other possible source of shocks is measurement errors caused by lags in the collection of data and frequent data revisions, which are common practices of national statistics authorities. Central banks observe the data with lag. They can observe, with time lag, the true state of the economy and reverse policy actions due to measurement errors.

Third, according to Favero (2001), VAR models of the MTM differ from the traditional dynamic system equation models due to the purpose of their specification and estimation. The dynamic system equation approach estimates the quantitative impact of policy variables on macroeconomic target variables. This is to determine the value to be assigned to the monetary policy instruments in order to achieve a given monetary policy target. The quantitative impact is summarised in the dynamic multipliers resulting from estimating the model. Thus, the outcome of this process provides monetary policy remedies. In contrast, VAR models are not estimated to yield advice on the best monetary policy. In the context of MTM, VAR models are estimated to quantify the response of macroeconomic variables to monetary impulses and provide empirical evidences. The evidences help to differentiate between alternative theoretical models of the economy. Unlike the dynamic multiplier, system models, the estimation of a VAR model provides impulse response functions, and forecast error variance decomposition.[94] Although VAR models provide useful insight, it is not a profoundly complete approach to provide the necessary information to monetary policymakers. Its exogeneity and *atheoretical* approach have been highly criticised.

There are three fundamental criticisms with respect to VAR models: (a) loss of efficiency due to a complete lack of theoretical information; (b) VAR models are, in principle, of very small size for intensive testing and estimation. Finding more than eight equations in a VAR model is very rare. Therefore, phenomena of large size with some level of complexity cannot be modelled adequately; (c) VAR models have, at least in the basic version, problems with policy simulations. The execution of impulse response analysis is problematic as the residuals of the equations of VAR models are highly correlated. VAR's emphasis on shock components of the monetary policy is also highly criticised (McCallum, 1999). McCallum argues that unsystematic portion of policy-instrument variability is small in relation to the variability of systematic component. McCallum (1999:p21) also states "... in the limit, that is, the variance of shock component could approach zero but this would not imply that monetary policy is unimportant for price level behaviour which is the main responsibility of central banks." Bernanke and Mihov (1998), on the other hand, uphold that the

[94] The impulse response function describes the impact of a shock to a variable in the system (MP instruments) at a particular point in time (t) on any of other financial and macroeconomic variables in the system (price or/and output) over subsequent period of time (t + s). FEVD provides useful information on the share of the total variance attributable to the variance of each structural shocks (Favero, 2001).

magnitude of monetary policy shocks, which indeed are intrinsically not important and does not really matter. What matters is that as long as tracing the dynamic response of the economy to a monetary policy shock provides a means of observing the effects of policy changes under minimal identifying assumptions, then the shocks do not have to be large or persistent.

Rudebusch (1998) argues that accuracy of VAR measures is highly required to estimate the impulse response function in order to be reliable and generate information from it. VAR measures of the policy shocks are expected to be accurate proxies of the true policy shocks. To investigate this issue empirically, Rudebusch (1998) analyses a series of unanticipated policy shocks based on forward-looking market time series as a benchmark for the VAR measure of the policy shocks. His analysis, based on the US data, show that Federal Funds (FFs) future contract series to be an unbiased predictor of the FFs rate. Responding to this issue, Sims (1998) argues that no assumption is ever made in the VAR literature that un-forecastable changes in the FFs rate are policy shocks. This raises some doubts on the claim made by Rudebusch (1998) that his FEVD series based on future contracts is an inadequate measure of the true monetary policy shocks. Although most results in the VAR literature are consistent with economic intuition, macroeconomic theory, the positive and significant reaction of the price level on impact to a monetary policy shock of most monetary models have difficulty of explaining. This anomaly first noted by Sims (1992) and labelled as “price puzzle” by Eichenbaum (1992), casts serious doubts on the ability of correctly identifying a monetary policy shock. If the central bank monitors and responds to larger information set than that of the VAR, what is referred to as a policy shock is actually a combination of a genuine policy shock and some endogenous policy reactions (Surico and Castelnuovo, 2009). Sims (1992) also argues that the central bank may have more information about future inflation than a simple VAR could adequately capture. The result of this omission is that a policy tightening in anticipation of future inflation would be incorrectly interpreted by the researcher as a policy shock. As long as monetary policy only partially offsets inflationary pressures, the VAR would deliver a spurious correlation between a tightening of policy and a rise in inflation, namely the “price puzzle”.

Another area of criticism against VAR is the issue of nonstationarity. VAR models ignore the nonstationarity issues. Literature, however, has not yet reached at a statement of consensus on how to handle unit roots and structural breaks within the VAR framework. There is a growing argument on this area as researchers continue to estimate VAR models, some with stationarity, and others with nonstationarity assumptions. When unit roots appear in the data, according to Sims et al. (1990), they are considered to be integrated, so transforming VAR models into a stationary set is not necessary. The issue here is whether the estimates have non-standard distributions rather than the regressors are integrated. It is often the case that the statistics have distributions not affected by the nonstationarity, in which case the hypothesis can be tested without transforming to stationarity regressors. If a VAR model is estimated on the level, the asymptotic distribution for the coefficients normalised by the square-root of the number of observations is singular, normal, and is identical to that for a model in which the cointegration vector is known exactly *a priori*. Even when distributions are affected by the presence of nonstationarity, it is not clear whether to transform the data before estimating the VAR model. Under the Bayesian approach, transformation of the data into stationarity is not needed but it remains as unresolved issue under the classical approach (Sims et al., 1990). Furthermore, the goal of a VAR analysis is to determine the interrelationships among the variables but not to determine the parameter estimates (Sims, 1998).

So far, the justification for the cointegrated VAR approach has been based on the assumption that the number of cointegrating vectors is known. Similarly, when two or more cointegration vector are found, they are not identified *a priori* and, hence; an additional identification problem has to be addressed. Imposing identifying restrictions on cointegrating vector, according to Jang and Ogaki (2003), can be complicated and inconsistent with some long-run restrictions a researcher may wish to impose to identify shocks. This was the main reason why Jang (2001) develops a method that does not require identification or estimation of individual cointegrating vectors regardless of the number of cointegrating vectors. It is also important to note that estimating VAR in levels helps to retain the necessary information that could have been lost when differencing the original data.

The only two advantages of the cointegrated VAR over the levels VAR in a system with some nonstationarity estimator are: (1) other things remain constant, estimators of impulse response functions from a cointegrated VAR are more precise than those from the levels VAR. Results from the levels VAR estimations can lead to exploding impulse response estimates even when the true impulse response is not exploding; (2) it is possible to impose short-run restrictions at the same time in the cointegrated VAR . On the other hand, one important advantage of the levels VAR is that it often produces consistent parameter estimates irrespective of whether the time series are integrated or not. It is therefore, arguably more robust than the cointegrated VAR model as it can be applied to the system with nonstationarity problems. For this reason, it is widely used in studies that are relying on impulse response functions, more specifically, in the analysis of the transmission mechanisms and measuring the impact of macro and financial variable shocks (Lanne and Lutkepohl, 2010).

Bernanke and Mihov (1998) show how the data series with unit root in a univariate UR test turn out to produce a multivariate stationary system. To test the presence of unit root in a VAR system, one needs to compute eigenvalues of the matrix of coefficients on lagged variables. These eigenvalues amount to the roots of characteristic polynomial of the system. The necessary and sufficient conditions for a stationary (or stable) system is that all roots of the characteristic polynomial have modulus less than unity. If the reverse characteristic polynomial is used to derive the roots, the stability condition becomes the one in which all roots have modulus greater than one. Thus, if an estimation of VAR on level data provides roots of its reverse characteristic polynomial, none of which has modulus less than unity, it is deemed as a stable VAR and the impulse response functions do not explode. This then mitigates one of those two disadvantages of the levels VAR, as stated above. Although this is the case to improve the performance of the VAR model in terms of stationarity, literature ignores the impact of structural break. The presence of unit root can be confused with the presence of persistent structural breaks. It is, therefore, important to account for structural break dates within the VAR/SVAR empirical model.

In summary, VAR and SVAR models can be used to characterise any vector of time series under a minimal set of conditions and on economic theory, respectively. Since VARs are reduced form models, identification restrictions, motivated by economic theory, are needed to conduct meaningful policy analysis. Reduced form VARs are typically unsuitable for forecasting out-of-sample. A generous parameterisation means that unrestricted VARs are not operational alternatives to either standard macroeconometric models, where insignificant coefficients are purged out of the specification, or to parsimonious time series models. This is because, with a limited number of degrees of freedom, estimates of VAR coefficients usually are imprecise and forecasts have large standard errors. Alternative modelling techniques provide different *a priori* information or different relative weights to sample and prior information. Bayesian methods can improve the problems in VAR as they can make in-sample fitting less dramatic and improve out-of-sample performance. While Bayesian VAR (BVAR) were originally developed to improve macroeconomic forecasts, they have evolved so that it is now used for a variety of purposes (Canova, 2007a). SVAR outperforms VAR models as it is a form of reduced VAR and restrictions are placed based on economic theory either in terms of short-run restrictions on the contemporaneous covariance, or in terms of restrictions on the long-run accumulated effects of the shocks. It gives more economic meaning for a macroeconomic analysis of a VAR model.

5.3 Review of Methodological Approaches

5.3.1 The Vector Autoregressive Approach

Structural VAR models provide an economic or informational rationale behind the restrictions necessary to identify monetary and credit supply shocks.[95] VAR studies of the MTM using Choleski decomposition rely on partial identification where only one of the underlying structural shocks is identified. This type of identification can be achieved by ordering the other variables in the VAR either side of the interest rate equation. Partial identification is usually problematic especially interest rates and other financial variables such as asset prices, which are usually determined jointly are included in a model. Consequently, relying on partial identification means that only one shock can be studied per model so another model is needed to look at identified monetary and credit supply shocks. In other words, each model only looks at one half of the transmission mechanism (Elbourne, 2008).

The model presented in this Chapter permits both stages to be looked at in two modes for each policy regime. The structure of the model is based on KR (2000). Structural VAR approach are quite successful in explaining all the puzzles that attracts the attention of recent literature on the effects of monetary policy (Grilli and Roubini, 1996). Equation (5.1) shows the structural form of the model in moving average form with $Z(L)$ an infinite order lag polynomial. This model describes the underlying economic structure. In VAR modelling, primarily, one estimates the reduced form as an autoregression, as in (5.1). Equation (5.2) shows the connection between the vector of orthogonalised structural shocks, e_t, and the reduced form errors. Here, Z_0 is the structural lag polynomial at lag zero. Following KR (2000), the UK economy is described by a structural form equation of the type:

$$Z(L)z_t = e_t, \tag{5.1}$$

$$e_t = Z_0 u_t \tag{5.2}$$

where $Z(L)$ is a polynomial lag of matrix operator L, z_t is an $n \times 1$ data vector, and e_t is an $n \times 1$ structural disturbances vector which is serially uncorrelated and $VAR(e_t) = \Lambda$ and Λ is a diagonal matrix, where diagonal elements are the variances of structural disturbances; therefore, structural disturbances are assumed to be mutually uncorrelated. The reduced form of VAR is estimated as:

$$Z_t = B(L)z_t + u_t, \tag{5.3}$$

where $B(L)$ is a matrix polynomial (without the constant term) in lag operator L and $var(u_t) = \Sigma$. The aim of the structural analysis is to investigate the impact of the shock of one variable on the

[95] See Bernanke (1986); Sims (1986); Blachard and Quah (1986).

other variables. This cannot be done with the model estimated in (5.3) as the errors are not independent of each other. For this reason, it is necessary to identify the structural form of the model in which each element in the error term is contemporaneously uncorrelated with the others. There are several ways of recovering the parameters in the structural form equations from the estimated parameters in the reduced form equation. Some methods give restrictions on only contemporaneous structural parameters. A popular and convenient method is to orthogonalise reduced form disturbances by Cholesky decomposition, as in Sims (1980), among others. However, in this approach of identification, one can assume only a recursive structure, that is a Wold-causal chain. Blanchard and Watson (1986), Bernanke (1986), and Sims (1986) suggest a generalised method (Structural VAR) in which non-recursive structures are allowed while still giving restrictions only on contemporaneous structural parameters. Let Z_0 be the coefficient matrix (non-singular) on L^0 in $Z(L)$, that is, the contemporaneous coefficient matrix in the structural form, and let $Z^0(L)$ be the coefficient matrix in $Z(L)$ without contemporaneous coefficient Z_0. That is,

$$Z(L) = Z_0 + Z^0(L), \tag{5.4}$$

then, the parameters in the structural form equation and those in the reduced form equation are related by:

$$B(L) = -Z_0^{-1} Z_0(L), \tag{5.5}$$

in addition, the structural disturbances and the reduced form residuals are related by $e_t = Z_0 u_t$, which implies:

$$\Sigma = Z_0^{-1} \Lambda Z_0^{-1\prime}. \tag{5.6}$$

maximum likelihood estimates of Λ and Z_0 can be obtained only through sample estimates of Σ. The right-hand side of Equation (5.6) has $n \times (n \times 1)$ free parameters to be estimated. Since Σ contains $n \times (n \times 1)/2$ parameters, at least $n \times (n \times 1)/2$ restrictions are required. This means by normalising n diagonal elements of Z_0 to $1's$, one employs at least $n \times (n \times 1)/2$ restrictions on Z_0 to achieve identification. In the VAR modelling with Cholesky decomposition, Z_0 is assumed triangular. However, in the structural VAR approach, Z_0 can be any structure as long as it has enough restrictions. Equations (5.4) to (5.6) show the connections between the reduced form and the structural form (KR, 2000). Depending on the type of restrictions imposed on a $SVAR$ model, there are three types of $SVAR$ models that can be distinguished as A model, B model and AB model. These are: (i) A model: in A model, B is set to I_n, so the minimum number of restrictions for identification is $n(n-1)/2$; (ii) B *model*: in B model, A is set to I_K, so the minimum number of restrictions to be imposed for identification is the same as A model, $n\ (n-1)/2$; (iii) AB *model*: restrictions can be placed on both matrices, so the minimum number of restrictions for identification is $n^2 + n(n-1)/2$. The parameters of a $SVAR\ AB\ model$ are estimated by minimising the negative of the concentrated log-likelihood function:

$$\ln \mathcal{L}_c(A,B) = -\frac{nT}{2}\ln(2\pi) + \frac{T}{2}\ln|A|^2 - \frac{T}{2}\ln|B|^2 - \frac{T}{2}tr\left\{\left(A^T B^{-1^T} B^{-1} A\right)\sum\nolimits_u^{\sim}\right\} \quad (5.7)$$

where $\sum_u^{\sim} = \frac{1}{T}\sum_{t=1}^{T}\widehat{u_t}\,\widehat{u_t}'$, and $\widehat{u_t} = Z_t - \sum_{l=1}^{p}\hat{A}Z_{t-l.}$ $\sum_u^{\sim}$, signifies an estimate of the reduced form variance-covariance matrix for the error process. This process leads to a non-linear system in terms of model A and B to be maximised subject to the identifying restrictions. Maximisation of this function is done by means of numerical methods. SVAR models use economic theory to determine the contemporaneous links between the variables (Bernanke, 1986; Blanchard and Watson, 1986; Sims, 1986). Structural VARs require "identifying assumptions" that allow correlations to be interpreted causally. These identifying assumptions can involve the entire VAR, so that all of the causal links in the model are identified in the model specification process. To achieve identification, one must restrict the structural parameters. There are *three* main classes of restrictions: the *first class* identifies the model's structural parameters by imposing linear restrictions. This class includes the triangular identification as described by Christiano et al. (1996) and the non-triangular identification of Sims (1986), King et al. (1991), Gordon and Leeper (1994), Bernanke and Mihov (1998), Zha (1999), and Sims and Zha (2006a). The *second class* concerns non-linear restrictions on the structural parameters and includes restrictions imposed on impulse responses, such as short and long-run restrictions studied by Blanchard and Quah (1993), and Gali (1992). Although these restrictions are non-linear on the structural parameters, they are linear on the set of impulse responses, and the *third class* extends the restrictions to account for structural brakes into the SVAR equations where the identification problem is caused by structural instability in simultaneous systems of equations.

Furthermore, the credit channel analysis employs VAR and VEC models to investigate the role of bank lending and balance sheet channels. VEC is a restricted VAR designed for variables with nonstationary series that are known to be cointegrated. The error correction term represents the cointegration since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. In a two variable system with one cointegrating equation without lagged difference terms, the VECM is represented as:

$$z_{2,t} = Bz_{1,t} \quad (5.8)$$

the corresponding VEC model becomes:

$$\Delta z_{1,t} = \alpha_1\left(z_{2,t-1} - Bz_{1,t-1}\right) + \epsilon_{1,t} \quad (5.9)$$

$$\Delta z_{2,t} = \alpha_2\left(z_{2,t-1} - Bz_{1,t-1}\right) + \epsilon_{2,t} \quad (5.10)$$

In the credit channel analysis, the rhs of the model is the error correction term. This term is zero in the long-run equilibrium when there is no cointegration. However, if z_1 and z_2 deviate from the long-run equilibrium, the error correction term will be non-zero and each variable adjusts to partially restore the equilibrium relation. The coefficient α_i measures the speed of adjustment of i^{th} endogenous variable towards the equilibrium. In the investigation of the credit channel, various combinations of the relevant data are set when testing for cointegration. When cointegration is found in the set, the VECM option applies, otherwise the VAR option is the appropriate specification.

Identification through Heteroscedasticity

To underline the impact of structural changes in SVAR model parameter, this section discusses the allowance made to SVAR model to improve parameter instability. Rogobon (2003) proposed an alternative way to solve the identification problem caused by structural instability in simultaneous systems of equations, which also extends to SVAR models. The characteristic feature of this approach is that when the data are characterised by (at least) two different regimes of volatility, the identification of the shocks can be achieved without linear constraints of the type in Equation (5.10). Considering a Structural VAR model for the vector $Z_t = (Z_{1t}, \ldots .Z_{nt})',$ the DGP is given by the system in Equation (5.6 and 5.10). Furthermore, it is also important to assume that (as in Bacchiocchi and Fanelli, 2015), $t = T_B$, where $1 < T_B < T$, the variance of the data changes in the sense that the sets of observations Z_1,…,ZT_B and ZT_{B+1},…,ZT are characterised by the VAR covariance matrices $\Sigma_{\varepsilon,1}$ and $\Sigma_{\varepsilon,n,}$ respectively, where,

$$\Sigma_{\varepsilon,i} \coloneqq \begin{bmatrix} \sigma_{11,i} & \sigma_{1n,i} \\ & \sigma_{2n,i} \end{bmatrix}, i = 1, 2, \ldots, n \qquad (5.11)$$

the statistical approach to the identification of SVARs given by Rigobon (2003); Lanne, and Lutkepohl (2008), has important implications for the transmission mechanisms of the shocks. In their work, the structural break at time T_B affects only the VAR error covariance matrix, and the IRFs computed on the sub-samples Z_1,…,ZT_B and ZT_{B+1},…,ZT have the same time pattern. However, in empirical macroeconomics, the assumption that the structural parameters do not vary across volatility regimes is the exception rather than the rule (Bacchiocchi and Fanelli, 2015). Relaxing the restrictive assumption that the changes in the volatility of the data that has no impact on the MTM is one of the contributions of this research to literature. There are two distinct SVARs employed for this study due to the relaxing of the restrictive assumption and the policy regimes. As it is known that some of the parameter coefficients have changed at time T_B (as shown in Chapter 4), VAR specification estimation deal with two distinct SVARs: one for the sub-sample Z_1,…,ZT_B and the other for the sub-sample ZT_{B+1},…,ZT. All the identification schemes are implemented in both regimes and sub-regimes. Considering the SVAR summarised in Equation (5.1 to 5.5) and assuming that at time $T_B, 1 < T_B < T$, the unconditional reduced form covariance matrix Σ_ε changes before and after the break.

5.3.2 Shock Identification through IRFs and FEVD

The standard criterion for identification of SVARs is a necessary condition given by Rothenberg (1971), called the "*order condition*". The order condition is implemented by simply counting the number of restrictions. For an SVAR to be identified, at least $n(n-1)/2$ restrictions must exist, where n represents the number of endogenous variables. Since Rothenberg's (1971) condition is only necessary, the question is whether the model is globally identified. Many authors have given sufficient conditions for global identification in the framework of traditional simultaneous-equation model.[96] If one mechanically applies these conditions to the identification of SVARs, where the structural covariance matrix is an identity matrix, the identification problem arises again. As argued by Bekker and Pollock (1986) and Leeper et al. (1996), linear restrictions on the covariance matrix of shocks generally imply non-linear restrictions on structural parameters. Therefore, checking whether a SVAR is globally identified is equivalent to checking whether a system of non-linear restrictions on the structural parameters has a unique solution. This, in general, is a difficult problem (Rubio-Ramirez and Waggoner, 2010).

Following Sims pioneering identification scheme, the RIS was extended to long-run-restrictions by Blachard and Quah (1989). As for the RIS of the short-run restrictions, the variables that are allowed to have a non-zero cumulative response to a given shock and the variables that are forced to have a cumulative response equal to zero are determined based on the ordering of the variables. In both the short-run and long-run restrictions, the Cholesky decomposition results in an *exactly identified* model. Gali (1992) identifies a Structural VAR model following the same line of research (as in Blackard and Quah, 1989), using short-run, long-run and zero restrictions from an IS-LM model. Gali also show that combining zero restrictions on both short and long-run impulse response functions could result in a non-linear problem that must be solved using numerical optimisation routines. If the short-run and long-run restrictions are imposed, it limits the usefulness of such methods.

Bayesian VAR model, for example, includes parameter uncertainty where the model-based analysis requires taking large number of parameter drawing from the posterior distribution and then

[96] Rothenberg (1971) gives general sufficient conditions for global identification for certain types of restrictions on traditional simultaneous equation models; Dhrymes (1978), Hsiao (1983), and Dhrymes (1994), among others, give other rank conditions for traditional simultaneous equation models.

simulating to produce the impulse responses or moments of interest. For the purpose of imposing short and long-run restrictions in exactly identified models, Rubio-Ramirez et al. (2010) propose a more efficient algorithm. They approach the problem in terms of finding an appropriate rotation matrix to satisfy the zero restrictions and eliminate the covariance constraint, which is non-linear in the coefficients of the problem. Consequently, it linearised the problem to allow the use of more efficient linear algebra. Following this approach, they establish further conditions under which a model is *globally identified* and *exactly identified*. Restrictions were first applied to *exactly identify* SVAR models. *Exactly identification* imposes strict assumptions on the number of zero restrictions and their location in the impact matrix. This, according to Sims, "incredible" identifying assumptions may be inconsistent with the identification of many shocks. On this ground, and to improve the restriction scheme, sign restrictions have been proposed as a robustness check and as an alternative method for identifying SVAR models[97]. To identify *under identified* SVAR models by sampling from all SVAR models that are consistent with the reduced form VAR model, it is possible to use sign restrictions. Therefore, a "band" of impulse response is generated, which can be pruned using a hypothesis testing criteria based on the sign of selected impulse responses (Binning, 2014). The researcher chooses the sign restrictions based on economic theory. As in Blachard and Diamond (1992, 1994); Uhlig (2005), the study uses *a priori* assumptions on signs of structural parameters to identify the structural shocks.

Another frequently used approach in literature is some form of ordering and normalisation between the variables contemporaneous relationships. Additional zero restrictions are often imposed on the coefficients in the system with some theoretical justification. SVARs in this tradition are typically estimated in either levels or first differences, taking the view that the persistence will either be captured by parameter coefficients in the first case, or should be eliminated before estimation in the second case (that is, the data is transformed to a stationary form). Rather than making this transformation, VECM methods use this information as part of the identification process between cointegrated nonstationary variables, although highly criticised. The identifying restrictions discussed above and the algorithms developed for a dynamic economic system are based on equality restrictions on the transformed structural parameters. One objective in studying this class of restrictions is to identify structural shocks. For example, according to the conventional wisdom (and many DSGE models), a contractionary monetary policy shock should raise the interest rate and lower output and prices. Thus, a successful identification should produce impulse responses that conform to this conventional wisdom (Lutkepohl, 2005). However, this approach is highly criticised, particularly in the post-GFC period that has brought a new macroeconomics

[97] See Faust (1998); Uhlig (2005); Canova; De Nicolo (2002).

understanding. The impact of contractionary MP is not always one-to-one, as shocks are greater than before due to the shock enlargement effect and spread into another form of impulses in the MTM.

In the process of shock identification, impulse responses trace out the response of current and future values of each of the variables to a one-unit increase (or to a one-standard deviation increase) in the current value of one of the VAR errors. This assumes that error returns to zero in subsequent periods and that all other errors are equal to zero. The implied thought experiment of changing one error, while holding the others constant, makes sense when the errors are uncorrelated across equations, so impulse responses are calculated for recursive and structural VARs. Once A is identified and Σ_u, is determined, the IRF process begins from:

$$z_t = A^{-1}Bz_{t-1} + A^{-1}u_t \tag{5.12}$$

$A^{-1}u_t = e_t$, IRF is calculated to a unit shock of u_t once A^{-1} is known. For a system that has been in a steady state for a while and suppose that the researcher is interested in tracing the dynamics of a shock to the first variable, in a two variable VAR: when a shock hits at time 0:

$$u_0 \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad ; \; z_0 = \begin{bmatrix} z_0 \\ R_0 \end{bmatrix} = A^{-1}u_0$$

so, for every $s > 0$,

$$z_s = A^{-1}Bz_{s-1}. \tag{5.13}$$

it is a practical way of representing the behaviour over time of z in response to shocks to the vector u. For SVAR representation; consider the following representation at time $t + s$:

$$\begin{bmatrix} z_{1t+s} \\ z_{2t+s} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \theta_{11}^0 & \theta_{12}^0 \\ \theta_{21}^0 & \theta_{22}^0 \end{bmatrix} \begin{bmatrix} \varepsilon_{1t+s} \\ \varepsilon_{2t+s} \end{bmatrix} + \cdots + \begin{bmatrix} \theta_{11}^s & \theta_{12}^s \\ \theta_{21}^s & \theta_{22}^s \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} + \cdots. \tag{5.14}$$

the impulse response (the structural dynamic multipliers) can be found as:

$$\frac{\delta z_{1t+s}}{\delta_{\varepsilon 1t}} = \theta_{11}^s, \frac{\delta z_{1t+s}}{\delta_{\varepsilon 2t}} = \theta_{12}^s$$

$$\frac{\delta z_{2t+s}}{\delta_{\varepsilon 1t}} = \theta_{21}^s, \frac{\delta z_{2t+s}}{\delta_{\varepsilon 2t}} = \theta_{22}^s \tag{5.15}$$

The structural impulse response functions ($IRFs$) are the plots of θ_{ij}^s vs s for $i, j = 1, 2$. In a more general term, these plots summarise how unit impulses of the structural shocks at time t impact the level of z at time $t + s$ for different values of s. The stationarity of z_t implies $\lim_{s \to \infty} \theta_{ij}^s = 0, i, j = 1, 2$ (see Lutkepohl, 2005). While impulse response functions trace the effects of a shock to one endogenous variable on to the other variables in the VAR, $FEVD$ separates the variation in an endogenous variable into the component shocks to the VAR. Thus, the variance decomposition provides information about the relative importance of each random innovation affecting the variables in the VAR.

$FEVD$ determines the share of fluctuations in relation to the impulse response analysis. More importantly, the process is able to separate the deviations in an endogenous variable and transform these component shocks to the vector autoregressive. It also tells how much of a change in a variable is due to its own shock and how much is due to shocks from other variables. In the short-run, most of the variation is due to own shock. Nevertheless, when the lagged variables' effect starts its impact, the percentage of the effect of other shocks increases over time (Lutkephol, 2005). If the innovations, which actually drive the system, can be identified, a further tool for interpreting VAR models is available. Suppose a recursive identification scheme is available so that the MA representation with orthogonal white noise innovations may be considered. The error terms in a VAR (SVAR) approach can be interpreted as the one-step ahead forecast errors. Forecast error variance decomposition determines the proportion of the variable of the errors in forecasting z_1 and z_2 at time $t+1$ based on information available at time h that is due to variability in the structural shocks ω_1 and ω_2 between times t and $t+h$. Accordingly, the FEVD can be derived based on the Wold reduced form MA representation of $z_{t+h.}$

$$z_t = \mu + \sum_{i=0}^{\infty} \Theta_i \omega_{t-i} \tag{5.16}$$

$$z_t = \mu + \omega_{t+h} + \Theta_1 \omega_{t+h-1} + \Theta_2 \omega_{t+h-2} + \cdots + \Theta_{h+1} \omega_{t-1} + \cdots$$

Therefore, the best linear forecast of z_{t+h} based on information available at time h is

$$z_{t+h/t} = \mu + \Theta_h \omega_t + \Theta_{h+1} \omega_{t-1} + \cdots$$

and the forecast error is represented as

$$z_{t+h} - z_{t+h/t} = \omega_{t+h} + \Theta_1 \omega_{t+h-1} + \cdots + \Theta_{h-1} \omega_{t+1},$$

using the Choleski decomposition, the forecast error, in terms of the structural shocks, the error of the optimal $h-\ step$ forecast is

$$z_{t+h} - z_t(h) = \sum_{i=0}^{h-1} \Phi_i u_{t+h-i} = \sum_{i=0}^{h-1} \Phi_i P P^{-1} u_{t+h-i}$$

$$= \sum_{i=0}^{h-1} \Theta_i \omega_{t+h-i} \tag{5.17}$$

as $\theta_i = \Phi_i P$ $(\theta_0 = \Phi_0 P = P)$, and $\omega_t = P^{-1} u_t$,

representing the mn^{th} element of Θ_i by $\theta_{mn,i}$ as before, the $h-step$ forecast error of the j^{th} component to y_t is

$$z_{j,t+h} - z_{j,t}(h) = \sum_{i=0}^{h-1} (\theta_{j1,i} \omega_{1,t+h-i} + \ \ldots + \theta_{jK,i} \omega_{K,t+h-i})$$

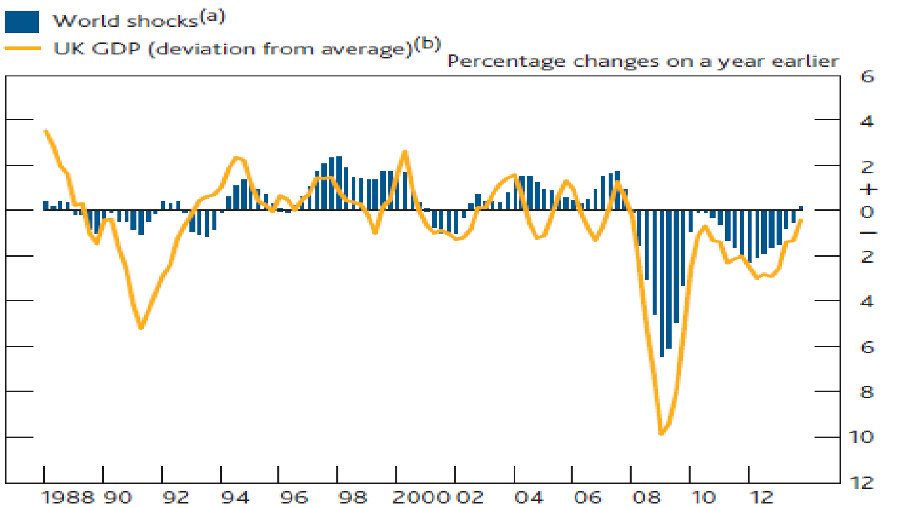
$$= \sum_{k=0}^{k} (\theta_{jk,0} \omega_{k,t+h} + \ \ldots + \theta_{jk,h-1} \omega_{k,t+1}) \tag{5.18}$$

Thus, the forecast error of the j^{th} component potentially consists of all the innovations $\omega_{1t}, \ldots, \omega_{Kt}$. Some of the $\theta_{mn,i}$ may be zero, so that some components may not appear. The Forecast Error Variance Decomposition provides an alternative way of presenting the dynamics of the system and information about the relative importance of each innovation in the VAR. The IR functions trace the effect of a shock to an endogenous variable on the variables in the VAR. By contrast, FEVD decomposes the variation in an endogenous variable into the component shocks to the endogenous variables in the VAR. It also gives information about the relative importance of each random innovation to the variables in the VAR (Lutkephol, 2005).

5.4 Variable Overview, Nonstationarity and Cointegration

5.4.1 Variable Overview

The time series data used for the open market structural dynamic system, SVAR analysis represents the external and domestic sectors of the UK economy. The external sector is represented by the US real index of industrial production (*IIP* in US dollars deflated by the US *CPI*) and the US Federal Funds Rate (*FFR*). The domestic sector is represented by real *GDP (Y* deflated by *CPI),* retail price index (*RPI*), consumer price index (*CPI*), the share price index (*SPI*), total credit to private sector (*CRED* deflated by *CPI*), real money supply represented by *M4* (*MS* deflated by *CPI*), monetary policy represented by official interest rate (*MP*), effective real exchange rate (*EX*) and bank lending rate (*BLR*). The exchange rate variable is included to account for the effects of the identified monetary shocks on the value of the domestic currency. The foreign variables are included as they contain useful information about the world business cycle and are particularly relevant to the UK economy. This inclusion is also helpful to resolve the "price puzzle" in VARs where the finding that the price level tends to increase in response to a contractionary monetary policy shock. The policymakers' expectation of future inflation is controlled by the foreign variables (*IIP* and *FFR*) which are the missing factors responsible for the "price puzzle"[98].



Source: Chowla et al. (2014).

Figure 5.1 The Historical Impact of World Shocks on the UK Economic Activity

Studies also find that the global business cycle is an important driver of domestic activity (see Figure 5.1). The foreign variables are included as it has a strong relationship with the UK economic activity. The inclusion of *GDP* to represent domestic activity is a standard practice. Inflation is included as in Dungey and Pagan (2000) rather than the price level as in Brischetto and Voss (1999). There are no nominal level variables in the model and the rate of change of prices seems to be more

[98] See CEE (1999).

logical to interact with real variables and a nominal interest rate. Unlike previous UK SVARS, the inclusion of the share price index and total private credit is to account for the financial sector. Additionally, the financial sector is also represented by the bank lending, monetary aggregates and lending to private non-financial sectors series.

The base rate is included to represent the monetary policy instrument. Since the independence of the Bank of England, monetary policy rate (interest rate) has been the chief instrument of monetary policy (see also Grenville, 1997; Dotsey, 1987). Haug et al. (2003) use a 90-day interest rate for New Zealand. The exchange rate is viewed as an important measure of the UK economy. It was one of the monetary policy targets before 1992 so it is important to account for the two periods with different policy targets such as inflation and exchange rates. The addition of real effective exchange rate (REER) is to capture real rather than nominal movements (see also Brischetto and Voss, 1999; Suzuki, 2004). As in KR (2000), this study specifies a VAR model with foreign and domestic set of variables represented by the following vector (X_t) and the alternatives (X_t') and (X_t''):

$$X_t = (IIP_t, FFR_t, Y_t, RPI_t, SPI_t, MS_t, MP_t, BLR_t, EX_t)$$
$$X_t' = (IIP_t, FFR_t, Y_t, CPI_t, SPI_t, MS_t, MP_t, BLR_t, EX_t)$$
$$X_t'' = (IIP_t, FFR_t, Y_t, CPI_t, CRED_t, MS_t, MP_t, BLR_t, EX_t)$$

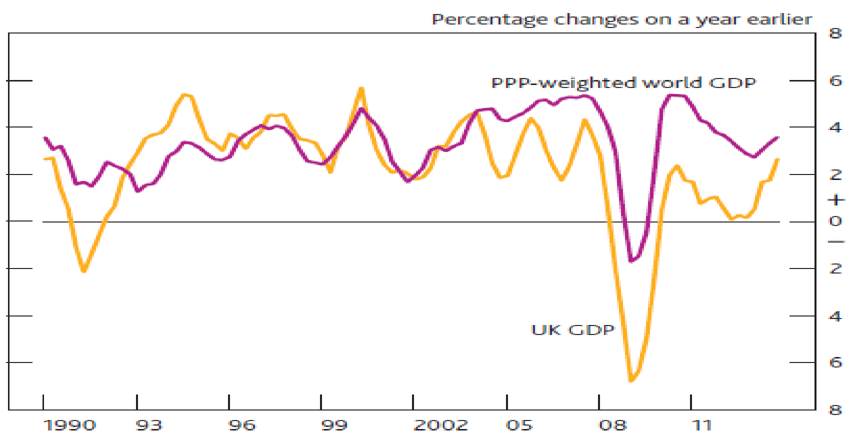
The variables account for the production, consumption, monetary and the financial sectors. These sectors are the major players in the UK economy (Harimohan, 2012; Barnett and Thomas, 2013). KR (2000) consider variables OPW and FFR that are determined exogenously relative to the policy shock. They serve as instruments to isolate exogenous monetary policy shocks. OPW and FFR also play as proxies for negative and inflationary supply shocks. Following Grilli and Roubini (1995), and KR (2000), this study introduces FFR because it is important in empirical models of an open economy to control for the component of domestic monetary policy that constitutes a reaction to foreign monetary policy shocks.

As shown above, the benchmark SVAR model employs a vector of 11 iterative macroeconomic, financial and monetary series of the UK economy. All the VARs are estimated with a combination of data in levels and some in first differences so that the results do not depend on some arbitrary data transformation. The variables represent a small open economy with domestic macroeconomic and banking sectors. The data series is divided into two groups based on the monetary policy target regimes as non-inflation targeting (pre 1992: 1960m1 to 1991m12) and inflation targeting regimes (post-1992: 1992m1 to 2014m12). The retail price index is used instead of consumer price index for the first regime due to data availability and the fact that RPI was the major price indicator until 2003. The share price index (equity price) is used in the first regime to represent the pre 1992 financial sector, as it is the most complete financial series from early 1960s. The study covers a period of 55 years of monthly frequency (1960m1 – 2014m12). All data are in natural logarithm except the exchange and interest rates. To maintain consistency in data frequency, the real GDP has been converted into monthly frequency using a linear projection method. Table 5.1 presents the data series used in the two SVAR models with description and sources.

Table 5.1a Structural VAR Model Data Sources and Description

Variables	Data and Description	Sources
LCPI (p_t^d)	Consumer Price Index	IFS & OECD
LCRED $(cred_t^d)$	Total Credit Supply (to Private Sector)	Bank of England
LFFR (ir_t^f)	US Federal Funds Rate	Federal Reserve Bank of New York, IFS & OECD
LIIP (iip_t^f)	US Index of Industrial Production	IFS & OECD
LGDP (y_t^d)	UK Real Gross Domestic Product	OECD & IFS and ONS
LM4 (m_t^d)	UK Broad Money	Bank of England
IR (ir_t^d)	UK Bank of England Base Rate	Bank of England & OECD
EXR (exr_t^d)	UK Real Exchange Rate	OECD & Bank of England
LRPI (rpi_t^d)	UK Retail Price Index	OECD & ONS
LSPI (spi_t^d)	UK Share Price Index	OECD
BLR (blr_t^d)	UK Bank Lending Rate	OECD, BOE & IFS

The UK economy is closely integrated with the rest of the world through the trade of goods and services, and the exchange of financial assets. This interconnectedness means that the UK economic environment is shaped, in part, by events in the wider global economy. These events can be external to the UK, or common to many economies, including the UK (Chowla et al., 2014).



Sources: Chowla et al., (2014).
Figure 5.2 The UK and World GDP Growth

For the selection of the individual and joint lags, the study employs the following two tests: *the VAR Lag Order Selection Criteria* (see Appendix Table 5.5A and 5.6A) and the *VAR Lag Exclusion Wald Tests* (see Appendix Table 5.7A and 5.8A). (1) The *VAR Lag Order Selection* Criteria[99] for

[99] See Appendix Table 5.1A and 5.3A for further information.

12 theoretical lags shows that 4 of the 5 criteria (AIC, SC and HQ, except FPE and LR)[100] indicate a joint lags of 2 in the case of the unrestricted VAR for both policy regime 1 and policy regime 2. (2) the *VAR Lag Exclusion Wald Tests* for 12 theoretical lags confirm the results of the first criteria in which the joint lags for that VAR specification is 2. The *Chi squared test statistics*, for lag exclusion and the probability values, shows that the hypothesis for zero coefficients of the corresponding lags is rejected. The test suggested that both lags should be retained for both regimes.

5.4.2 Nonstationarity and Cointegration

Nonstationarity is a common property to many macroeconomic and financial time series data. It highlights the fact that, a variable under consideration has no clear tendency to return to a constant value or a linear trend. Return to a fixed value or fluctuate around a linear trend in which case the deviations from trend are stationary. The problem is that statistical inference associated with stationary processes is no longer valid if the time series are realisations of nonstationary processes. Granger (1981) shows that macroeconomic models containing nonstationary stochastic variables can be constructed in such a way that the results are both statistically sound and economically meaningful. His work also provides the underpinnings for modelling with rich dynamics among interrelated economic variables. Nonstationary behaviour of the *ten* series is tested using unit root based on ADF, PP and KSPP (see Appendix Table 5.1A to 5.5A) and cointegration based on *Johansen* (see Appendix 5.9A to 5.12A). The unit root test confirmed that almost all of the series contain a unit root, but some are stationary in differences but some others have break stationary properties. The cointegration test also confirmed that there is no cointegration in the system when the series are in first difference. The ZA one-break and the BP MSB test results are used in DG and model specification processes.

The transformations of the data are intended to deliver stationary series so that the VAR can be estimated via OLS. However, unit root tests on the data suggest that there are two issues with the intended transformations. Majority of the series are found to be nonstationary according to the unit root ADF, PP, KPSS tests. These series appear to undergo a mean shift following the introduction of inflation targeting in the early 1990s. The data series also accounts for significant structural breaks identified in Chapter 4. To account for the mean shift in the VAR, a shift IVs are introduced into the system. The shift IVs take a value of 1 for periods with structural break, and 0 thereafter. The added IVs are useful to control the impact of structural shifts which otherwise cause distortion. This practice controls persistent shocks that otherwise propagate in the long memory of the series. Twelve indicator variables are introduced to the SVAR model for both policy regimes. The idea of

[100] LR: sequential modified LR test statistic (each test at 5% level); FPE: Final Prediction Error; AIC: Akaike Information Criterion; SC: Schwarz Information Criterion; HQ: Hannan-Quinn Information Criterion

including these SB indicator variables is to net out the average changes resulted from the fluctuations. For instance, the most significant SB for output was in 1998Q1. In the original data, the time from 1960Q1 to 1997Q4 takes "1", and from 1998Q1 onwards, takes "0". Apart from the data division, based on the two major policy regimes, adding indicator variables provide stable model estimation without the problem of data distortion. To check the model stability after adding the IVs, the Log-Likelihood-Ratio test statistics[101] is applied based on the assumption that the LR distribution is asymptotically χ^2.

$$LR = (T - m)(ln|\Sigma_{\mathrm{r}}| - \ln|\Sigma_{ur}|) \sim \chi^2(q) \tag{5.19}$$

Where T is the number of observations; m is the number of parameters used; Σ_r and Σ_{ur} are the determinants of the residual covariance matrix for restricted and unrestricted VAR, respectively, and q is the number of degrees of freedom. All equations are tested and the null (no dummies for SBs) are rejected. The indicator variables are included in the model as an exogenous variable so they do not appear in the IRFs and FEVDs. Further checks also conducted to test whether there is cointegration among the variables that have been transformed from levels to growth rates. If there is cointegration in the levels that would suggest nonstationarity, at which VEC model is the appropriate approach. It would also suggest that there were fewer permanent shocks than variables driving the underlying stochastic trends in the data. This is tested by estimating the VAR in levels and applying the method of Johansen (1992) to determine the potential presence of cointegration in the system. Given the potential deterministic mean shift in the series and the difficulties of identifying its order of integration, test for the presence of cointegration is important. The cointegration tests show that there is no enough evidence for the presence of long-run movements so the decision made to undertake a recursive VAR analysis rather than VECM is justified (see Appendix Table 5.9A to 5.12A).

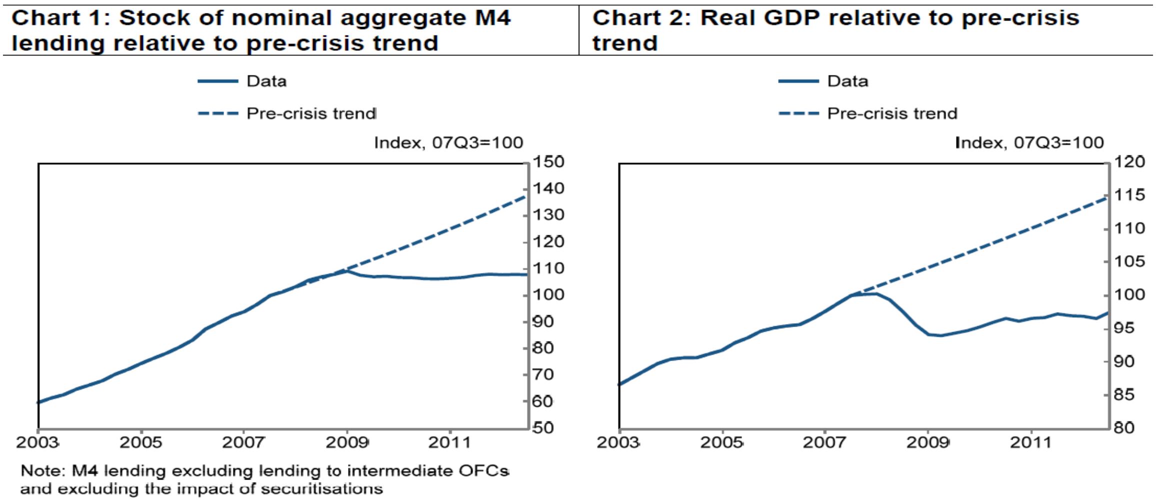
[101] Where T is number of observations, m is number of parameters in each equation obtained by no. of eq. (x) no. of lags + constant + no. of dummies; Σ ln of residual covariance matrix and q is degrees of freedom obtained from dummies multiplied by the number of equations.

5.5 Model Specification

The model specification and estimation is presented in two sections. The first section specifies and estimates the structural VAR for the UK economy and the second part investigates the UK credit channel based on VAR and VEC models.

5.5.1 Structural VAR of the UK Economy

The recent financial crisis has brought macroeconomists to a new paradigm of structural research focusing on the importance of macroeconomic and financial shocks. Since the advent of the financial crisis, the performance of the UK economy (in terms of GDP) has fallen by over 15%. With respect to the financial sector, the stock of bank and building society lending has fallen by around 25%, relative to the pre-crisis period, as shown in Figure 5.3.



Source: Bank of England (2013).

Figure 5.3 A Comparison of the Stocks of Nominal Aggregate M4, Lending and RGDP
Before and after the 2007 Global Financial Crisis.

Prior to the crisis, macroeconomists were typically interested in explaining the movements in macroeconomic variables in terms of only a small number of aggregate level shocks, such as aggregate supply, aggregate demand, and monetary policy shocks. As a result, the specific role of the macroeconomic and financial market shocks was subsumed within one or the other of these aggregate macroeconomic shocks. The SVAR approach involves estimating a set of variables where each of the macroeconomic, monetary and financial variables is regressed on past movements of itself and the other variables in the system. The unexplained component of each variable is then decomposed into the impact of different fundamental or 'structural' shocks. To perform this decomposition, each shock must be uniquely identifiable from the others using restrictions based on the timing of each shock, provided one has at least enough unique restrictions for the shocks to identify and decompose the movement of each variable into the effects of current and past movements of shocks (Barnett and Thomas, 2013).

5.5.2 The UK Policy Regimes in the SVAR Model

The benchmark model for the UK economy is represented by two models: (a) the $SVAR^{R1}$ model is estimated for policy regime 1 that covers the monthly data from $1960M1\ to\ 1991M12$. Until the 1970s, there was no specific target set by the monetary authority to measure the performance of the monetary policy decisions. During the 1920s and 30s, the indifference expressed by the UK government to the inflation rate revealed its unwillingness to give up the option of raising revenue by resorting to printing press, raising doubts about the likely consistency over time of its other policies. In the 20 years following the end of the 2nd World War, such a view was not generally accepted. The task of government was seen as judging the appropriate trade-off between output and inflation. The aim was to choose the optimal point on the Phillips Curve (PC). However, in the 1960s and 1970s, the trade-off deteriorated and it became apparent that there was no real long-run trade-off to exploit. Phillips (1958) wrote that the main objective of policy was to prevent continuously rising prices of consumer goods. A climate of low and stable inflation avoids the arbitrary redistributions of a random wealth tax, encourage investment, which in turn, may raise the rate of productivity growth. The target for the monetary aggregates was introduced in the 1970s, first for broad money, subsequently for narrow money, and then followed by the exchange rate. The exchange rate targeting mechanism was first introduced with an informal target and then with membership of the ERM with its explicit exchange rate target expressed in terms of the narrow band (BoE, 2000). Finally, due to various crises in the ERM, several countries have adopted an explicit inflation target, following the earlier lead of New Zealand and Canada, then followed by the UK, Sweden, Finland and a number of other countries.

(b) $SVAR^{R2}$ model, which covers the major time horizon of the "Great Moderation", the GFC, and the post-GFC periods, is estimated for policy regime 2. The period ranges from 1992M1 to 2014M12. This period signifies the inflation-targeting regime followed by the BoE independence from political control, announced in 1997. To study the IRFs of the credit and monetary policy shocks, the two regimes are modelled separately. Following the UK's departure from the ERM in 1992, it was clear that in the post German unification, any new framework would have to be based on domestic indicators of economic performance. The Treasury and the Bank discussed the alternatives, and the UK government announces a new framework built around an explicit inflation target. The *first* proposal was to set the objective of keeping underlying inflation, which was defined as the change in retail prices, excluding mortgage interest payments within a range of 1–4%. Subsequently, it was planned to aim at a rate of inflation in the long-term of 2% or less (BoE, 2000).

5.5.3 Identifying the Structural Shocks of the UK Economy

The choice of variables in the VAR reflects the theoretical set up of a New Keynesian small open economy model (see Svensson, 2000; Clarida et al., 2001). In particular, the VAR model comprises the monthly log of the macroeconomic, monetary and financial variables. The identification process focuses around the credit and monetary policy shocks. The nominal interest rate is chosen to capture monetary policy shocks, consistent with the fact that the central bank uses interest rate instruments in the monetary policy setting. This is in line with Rotemberg and Woodford (1997). They argue that central banks' behaviour to be well modelled by a policy rule that sets the interest rate as a function of variables such as output and inflation. Structural shocks in a Structural VAR model can be identified by placing restrictions on contemporaneous relationships. There are few simple theoretical macroeconomic models that explicitly include credit, and seemingly none that determine the timing of effects needed for identification in a Structural VAR. Therefore, previous studies and stylised facts are used to determine the identification restrictions outlined in this section. Let Z_t is defined as the $2 \times (8 \times 1)$ vector of the macroeconomic, monetary and financial variables. Assuming Z_t to be invertible so it can be written in terms of its moving average:

$$Z_t = B(L)v_t, \tag{5.20}$$

where v_t is a (8×1) vector of reduced form residuals assumed to be identically and independently distributed, $v_t - iid(0, \Omega)$, with positive definite covariance matrix $B(L)$ is the $(n \times n)$ convergent matrix polynomial in the lag operator L, $B(L) = \sum_{J=0}^{\infty} B_j L^j$. The innovations (v_t), are assumed to be written as linear combinations of the underlying orthogonal structural disturbances (ε_t), i.e., $v_t = A\varepsilon_t$. The VAR can then be written in terms of the structural shocks as:

$$Z_t = C(L)\varepsilon_t, \tag{5.21}$$

where $B(L)A = C(L)$. If A is identified, one can derive the MA representation in (5.20) as $B(L)$ is calculated from a reduced form estimation. To identify A, the $\varepsilon_t's$ are normalised so they all have unit variance. The normalisation of $cov\ (\varepsilon_t)$ implies that $AA' = \Omega$. With n variable system, this imposes 27 $(19 + 8)$ restrictions on the elements in A and B. However, as the A matrix contains 64 elements, to orthogonalize the different innovations, one needs 37 additional restrictions to uniquely identify the system. With eight variables VAR, the model identifies eight structural shocks. The two shocks that are of primary interest here are the shocks to monetary policy (ε_t^{MP}), and the shocks to consumer price index (ε_t^{CPI}). Following the standard practice in the VAR literature and only loosely identify the four shocks as inflation (or cost-push) shocks (moving prices before output) (ε_t^{CPI}), output shocks (ε_t^{Y}), exchange rate shocks (ε_t^{EX}), and foreign interest rate shocks (ε_t^{FFR}). The structural shocks are ordered as

$$\text{vector} = [\varepsilon_t^{IIP}, \varepsilon_t^{FFR}, \varepsilon_t^{Y}, \varepsilon_t^{CPI/RPI}, \varepsilon_t^{SPI/CRED}, \varepsilon_t^{MS}, \varepsilon_t^{BLR}\ \varepsilon_t^{MP}, \varepsilon_t^{EX}].$$

Regarding the order of the variables, the index of industrial production and the foreign interest rate are placed first and second, respectively. This arrangement assumes that these foreign variables can only be affected contemporaneously by exogenous foreign monetary policy (Bjornland and Jacobsen, 2013). This follows a plausible small country assumption. Furthermore, the standard restrictions in the closed economy is taken care of by placing output and inflation above the interest rate in the ordering, and by assuming zero restrictions on the relevant coefficients in the A matrix, as stated in Equations (5.1 and 5.2). It can also be assumed that money supply, output, and price do not react simultaneously to an exchange rate shock.

This provides 37 contemporaneous restrictions directly on the A matrix. The matrix is *over-identified*, as it only requires 28 restrictions to *just-identify*. No restriction is required on money supply from responding contemporaneously to shocks in output and price (i.e. A_{63} and $A_{64} \neq 0$), or foreign output, foreign interest rate, money supply and exchange rate from responding contemporaneously to monetary policy shocks ($ie\ A_{71}, A_{72}, A_{76}$ and $A_{78} \neq 0$). Based on macroeconomic theory, the following long-run restrictions are imposed: (i) a monetary policy shock can have no long-run effects on the level of the real exchange rate (ii) based on the plausible neutrality assumption, a monetary policy shock can have no long-run effects on real output. The restrictions can be found by setting the values of the infinite number of relevant lag coefficient in (5.21), $\sum_{j=0}^{\infty} C_{37J}$, and $\sum_{j=0}^{\infty} C_{47J}$ equal to zero[102]. There are now enough restrictions to identify and orthogonalise all shocks. Writing the long-run expression of $B(L) = C(L)$ as $B(1)A = C(1)$, where $B(1) = \sum_{j=0}^{\infty} B_j$ and $C(1) = \sum_{j=0}^{\infty} C_j$ indicating the (8 × 8) long-run matrix of $B(L)$ and $C(L)$, respectively. The long-run restrictions $C_{37_{(1)}} = 0$ and $C_{47(1)} = 0$ implies, respectively:

$$\begin{aligned} &B_{31}(1)A_{17} + B_{32}(1)A_{27} + B_{33}(1)A_{37} + B_{34}(1)A_{47} + B_{35}(1)A_{57} + B_{36}(1)A_{67} + B_{36}(1)A_{77} + \\ &B_{36}(1)A_{87} = 0, \\ &B_{41}(1)A_{17} + B_{42}(1)A_{27} + B_{43}(1)A_{37} + B_{44}(1)A_{47} + B_{45}(1)A_{57} + B_{46}(1)A_{67} + B_{46}(1)A_{77} + \\ &B_{46}(1)A_{87} = 0. \end{aligned} \tag{5.22}$$

The zero contemporaneous restrictions identify the non-zero parameters above the interest rate equation, while the remaining parameters can be uniquely identified using the long-run restriction, where $B(1)$ is calculated from the estimation of the reduced form of (5.21). Note that (5.22) reduces to:

$B_{34}(1)A_{48} + B_{35}(1)A_{58} + B_{36}(1)A_{68} = 0$ and $B_{85}(1)A_{57} + B_{86}(1)A_{67} + B_{87}(1)A_{77} = 0$,

[102] See Blachard and Quah (1989).

gives the zero contemporaneous restrictions. In identifying the benchmark Structural VAR, a method suggested by Amisano and Giannini (1997), often called the $AB - Model$, imposes enough restriction on both matrices, A_0 and B, and the latter is assumed to be a diagonal matrix. For the system to be just identified, it requires $2n^2 - \frac{n(n+1)}{2}$ or 92 restrictions on both A_0 and $B.$ Since B is assumed to be a diagonal matrix, 56 exclusion restrictions are imposed on it. Therefore, another 36 restrictions on A_0 are required for the system to be *just identified*. The non-recursive structure imposes $64 - 20\ [19] = 44\ [45]$ restrictions on A_0 for policy regime 1 and 2, respectively, so the system is *over-identified* and 20 [19] free parameters in A_0, and 8 in B have to be estimated. The identification scheme on the matrix of contemporaneous coefficients A_0 for pre 1992 policy regime and post-1992 policy regime with changing policy reaction function is specified as:

$$\begin{bmatrix} iip_t^f \\ ir_t^f \\ y_t^d \\ p_t^d \\ spi_t^d \\ m_t^d \\ ir_t^d \\ ex_t^d \end{bmatrix} A_0^{Reg^1} X_t = \left\{ \left\{ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{31} & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ A_{41} & 0 & A_{43} & 1 & 0 & 0 & 0 & 0 \\ A_{51} & 0 & 0 & A_{54} & 1 & 0 & 0 & A_{58} \\ 0 & 0 & A_{63} & A_{64} & 0 & 1 & 0 & 0 \\ A_{71} & A_{72} & 0 & 0 & 0 & A_{76} & 1 & A_{78} \\ A_{81} & A_{82} & A_{83} & A_{84} & A_{85} & A_{86} & A_{87} & 1 \end{bmatrix} \times 1(t \geq T_B) \right\} \right\} \begin{bmatrix} \varepsilon^{iip} \\ \varepsilon^{ir} \\ \varepsilon^{y} \\ \varepsilon^{p} \\ \varepsilon^{spi} \\ \varepsilon^{ms} \\ \varepsilon^{mp} \\ \varepsilon^{ex} \end{bmatrix}_t \qquad (5.23)$$

$$\begin{bmatrix} iip_t^f \\ ir_t^f \\ y_t^d \\ p_t^d \\ cred_t^d \\ m_t^d \\ ir_t^d \\ ex_t^d \end{bmatrix} A_0^{Reg^2} X_t = \left\{ \left\{ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{31} & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ A_{41} & 0 & A_{43} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & A_{53} & 0 & 1 & 0 & A_{57} & 0 \\ 0 & 0 & A_{63} & A_{64} & 0 & 1 & A_{67} & 0 \\ 0 & A_{72} & 0 & 0 & 0 & A_{76} & 1 & A_{78} \\ A_{81} & A_{82} & A_{83} & A_{84} & A_{85} & A_{86} & A_{87} & 1 \end{bmatrix} \times (t \geq T_B) \right\} \right\} \begin{bmatrix} \varepsilon^{iip} \\ \varepsilon^{ir} \\ \varepsilon^{y} \\ \varepsilon^{p} \\ \varepsilon^{cred} \\ \varepsilon^{ms} \\ \varepsilon^{mp} \\ \varepsilon^{ex} \end{bmatrix}_t \qquad (5.24)$$

the stated eight equations for each regime, with time varying parameters, correspond to and AB model, which can be written as $A_{ij}\varepsilon_t = B_{ij}u_t$:

$$A_{ij}\varepsilon_t = B_{ij}u_t;\ A_{ij}\varepsilon_t = \begin{bmatrix} 1 & B_{12} & B_{13} & B_{14} & B_{15} & B_{16} & B_{17} & B_{18} \\ B_{21} & 1 & B_{23} & B_{24} & B_{25} & B_{26} & B_{27} & B_{28} \\ B_{31} & B_{32} & 1 & B_{34} & B_{35} & B_{36} & B_{37} & B_{38} \\ B_{41} & B_{42} & B_{43} & 1 & B_{45} & B_{46} & B_{47} & B \\ B_{51} & B_{52} & B_{53} & B_{54} & 1 & B_{56} & B_{57} & B_{58} \\ B_{61} & B_{62} & B_{63} & B_{64} & B_{65} & 1 & B_{67} & B_{68} \\ B_{71} & B_{72} & B_{73} & B_{74} & B_{75} & B_{76} & 1 & B_{78} \\ B_{81} & B_{82} & B_{83} & B_{84} & B_{85} & B_{86} & B_{87} & 1 \end{bmatrix} \begin{bmatrix} u^{iip} \\ u^{ir} \\ u^{y} \\ u^{p} \\ u^{cred} \\ u^{ms} \\ u^{mp} \\ u^{ex} \end{bmatrix}$$

The non-zero coefficients A_{ij} in the SVAR set up specifies that variable j affects variable i instantaneously (see Equation 5.23 and 5.24). The coefficients on the diagonal are normalised to one, while the remaining non-instantaneous reaction entries signpost that those entries in the matrix are constrained to be zero. The B_{ij} matrix is an orthoginal matrix where all B_{ij}^s are equal to zero except the diagonals where $B_{i=j}$. For specific identification purpose of the two regimes, the assumption embodied in the SVAR identification setup is an exactly identified system $\left[\frac{n(n-1)}{2} = \frac{8(8-1)}{2} = 28\right]$, indicating that there are 28 parameters to be recovered from the above identification restrictions for regime-1, which made the system exactly identified. There are $2n^2 - \frac{n(n+1)}{2} = 92$ restrictions on both A_0 and B. Each equation in the above two matrices is identified in the row of the system. The rows represent a structural equation for the exogenous and endogenous variables as follows:

$\boldsymbol{SVAR_{eq-1}}$

$R1_{(1960m1-1991m12)}: iip_t = c_t + \sum_{i=1}^{k} A_1^i iip_{t-i} + B_{11}\varepsilon_t^{iip}$

$R2_{(1992m1-2014m10)}: iip_t = c_t + \sum_{i=1}^{k} A_1^i iip_{t-i} + B_{11}\varepsilon_t^{iip}$

$\boldsymbol{SVAR_{eq-2}}$

$R1_{(1960m1-1991m12)}: ir_t^{us} = -A_{21}^0 iip_t^f + \sum_{i=1}^{k} A_{21}^i iip_{t-i}^f + \sum_{i=1}^{k} A_2^i ir_{t-i}^f + C_2 + B_{22}\varepsilon_t^{ir^f}$

$R2_{(1992m1-2014m10)}: ir_t^{us} = -A_{21}^0 iip_t^f + \sum_{i=1}^{k} A_{21}^i iip_{t-i}^f + \sum_{i=1}^{k} A_2^i ir_{t-i}^f + C_2 + B_{22}\varepsilon_t^{ir^f}$

$SVAR_{eq-1}$ and $SVAR_{eq-2}$ represent the external shocks as the U.S. index of industrial production (iip) and the Federal Funds Rate (ffr). The domestic economy variables are not presented both contemporaneously and with lag in the above equation, since the US index of industrial production does not react to the domestic economy. The same is true with the US Federal Funds Rate.

$\boldsymbol{SVAR_{eq-3}}$

$R1_{(1960m1-1991m12)}: y_t^d = -A_{31}^0 iip_t^f + A_3(L)X_t + C_3 + IV_{y_t} + B_{33}\varepsilon_t^{y^d}$

$R2_{(1992m1-2014m10)}: y_t^d = -A_{31}^0 iip_t^f + A_3(L)X_t + C_3 + IV_{y_t} + B_{33}\varepsilon_t^{y^d}$

$\boldsymbol{SVAR_{eq-4}}$

$R1_{(1960m1-1991m12)}: rpi_t^d = -A_{41}^0 iip_t^f - A_{43}^0 y_t^d + A_4(L)X_t + C_4 + IV_{rpi_t} + B_{44}\varepsilon_t^{rpi^d}$

$R2_{(1992m1-2014m10)}: p_t^d = -A_{41}^0 iip_t^f - A_{43}^0 y_t^d + A_4(L)X_t + C_4 + IV_{p_t} + B_{44}\varepsilon_t^{p^d}$

$\boldsymbol{SVAR_{eq-5}}$

$R1_{(1960m1-1991m12)}: spi_t^d = -A_{51}^0 iip_t^f - A_{54}^0 rpi_t^d - A_{58}^0 ex_t^d + A_5(L)X_t + C_5 + IV_{spi_t} + B_{55}\varepsilon_t^{spi^d}$

$R2_{(1992m1-2014m10)}: cred_t^d = -A_{53}^0 y_t^f - A_{57}^0 ir_t^d + A_5(L)X_t + C_5 + IV_{cred_t} + B_{55}\varepsilon_t^{cred^d}$

$SVAR_{eq-6}$

$R1_{(1960m1-1991m12)}: m_t^d = -A_{63}^0 y_t^d - A_{64}^0 rpi_t^d + A_6(L)X_t + C_6 + IV_{m_t} + B_{66}\varepsilon_t^{m^d}$
$R2_{(1992m1-2014m10)}: m_t^d = -A_{63}^0 y_t^d - A_{64}^0 p_t^d - A_{67}^0 ir_t^d + A_6(L)X_t + C_6 + IV_{m_t} + B_{66}\varepsilon_t^{m^d}$

$SVAR_{eq-7}$

$R1_{(1960m1-1991m12)}: ir_t^d = -A_{71}^0 iip_t^F - A_{72}^0 ir_t^F - A_{76}^0 m_t^d - A_{78}^0 exr_t^d + A_7(L)X_t + C_7 + IV_{ir_t} + B_{77}\varepsilon_t^{ir^d}$
$R2_{(1992m1-2014m10)}: ir_t^d = -A_{72}^0 ir_t^f - A_{76}^0 m_t^d - A_{78}^0 ex_t^d + A_7(L)X_t + C_7 + IV_{ir_t} + B_{77}\varepsilon_t^{ir^d}$

$SVAR_{eq-8}$

$R1_{(1960m1-1991m12)}: exr_t^d = -A_{81}^0 iip_t^f - A_{82}^0 ir_t^f - A_{83}^0 y_t^d - A_{84} rpi_t^d - A_{85}^0 spi_t^d - A_{86}^0 m_t^d - A_{87}^0 ir_t^d + A_8(L)X_t + C_8 + IV_{exr_t} + B_{88}\varepsilon_t^{exr^d}$
$R2_{(1992m1-2014m10)}: exr_t^d = -A_{81}^0 iip_t^f - A_{82}^0 ir_t^f - A_{83}^0 y_t^d - A_{84} p_t^d - A_{85}^0 cred_t^d - A_{86}^0 m_t^d - A_{87}^0 ir_t^d + A_8(L)X_t + C_8 + IV_{exr_t} + B_{88}\varepsilon_t^{exr^d}$

where A_{ij}^0, for $i = 1, \ldots, 8$ and $j = 1 \ldots 8$, are the coefficient of contemporaneous relation; $A_i(L)$ is the i^{th} row of matrix $A(L)$ indicating the lagged variables X_t; $C_1 \ldots C_8$ are intercepts, $\varepsilon_t^{iip^f}, \varepsilon_t^{ir^f}, \varepsilon_t^{y^d}, \varepsilon_t^{p^d}, \varepsilon_t^{spi^d}$ $\varepsilon_t^{cred^d}, \varepsilon_t^{m^d}, \varepsilon_t^{ir^d}, \varepsilon_t^{blr^d}$[103] and $\varepsilon_t^{exr^d}$, are the structural shocks associated with the respective equations; B_{ii}, for $i = 1 \ldots 8$, is the diagonal element of matrix B; and finally IVs are shift indicator variables, determined by structural break tests (see Chapter 4). There are 12 IVs, one indicator variable for each equation (6 for each policy regime), that accounts for the structural breaks as shown in Table 5.1b. To test, if the inclusion of the IVs improves the stability of the SVARs, two VARs (restricted and unrestricted) are estimated, one with the exogenous indicator variable but the other without the indicator variable. The test is conducted using the Log-Likelihood Ratio (LR) test statistics[104]. The LR is a χ^2 distribution so the decision to reject the null hypothesis or not is made based on a certain value of the χ^2 distribution critical value which is computed as $\chi^2_{(6,0.050)} = 12.592$ based on the degrees of freedom and 5% sig. level. The LR in all of the 12 models are greater than 12.592, which leads to the rejection of the χ^2 null. Therefore,

[103] This variable is included at a later stage to account for the IRF and FEVD of the financial sector.
[104] LR is a statistical test used to compare the goodness of fit of the two regime based models. One of the model (without IV, the null model) is a special case of the alternative model (with IV at the break point). The LR test expresses how many times more likely the data are under one model than the other (Casella and Berger, 2001). All indicator variables are exogenous to the model.

accounting for the structural break using the indicator variables has an effect and the inclusion of the indicator variable is justified.

The Structural VAR Equations

Equation 1 and *2* represent the exogenous shocks originating from the world economy particularly from the U.S. The U.S. is the leader of the world economy and the rest of the world follows the performance of the U.S. economy. The two foreign variables are not affected by movements in any domestic market both contemporaneously and with lag. While the index of industrial production is treated as fully exogenous, the FF rate depends contemporaneously on the index of industrial production variable reflecting that this variable plays as a proxy for measures of anticipated inflation. It is expected that $A_{21}^0 < 0$. This is the Federal Funds rate reacts positively to the index of industrial production. The negative sign, therefore, means the respective explanatory variable (iip) has positive effect on the Federal Funds rate, since that variable appears with negative coefficient in the equation.

Table 5.1b Indicator Variables Accounting for Structural Breaks

Variables (Endogenous)	Exogenous Variable	Regime-1 Break Date (TB1)	Regime-2 Break Date (TB2)	Log-Likelihood Ratio (LR statistics)	$\chi^2_{(0.050)}$ Critical
LCPI (p_t^d)	IV_{p_t}	1978M12***	2001M12**	51.247**	(v=5)=11.070
LCRED $(cred_t^d)$	IV_{cred_t}	1991M10***	2008M6 ***	52.281**	(v=5)=11.070
LGDP (y_t^d)	IV_{y_t}	1974M6***	1998M4**	51.567**	(v=4)=9.488
LM4 (m_t^d)	IV_{m_t}	1991M9***	2008M1**	50.926**	(v=6)=12.592
IR (ir_t^d)	IV_{ir_t}	1982M4***	2006M1***	50.606**	(v=7)=14.067
LEXR (exr_t^d)	IV_{exr_t}	1984M6**	2002M3***	49.645**	(v=10)=18.307
LRPI (rpi_t^d)	IV_{rpi_t}	1973M9***		53.518**	(v=5)=11.070
LSPI (spi_t^d)	IV_{spr_t}	1974M1**	1998M2***	53.127**	(v=5)=11.070

Note: "*", "**" and "***" represents significant at 10%, 5% and 1% level, respectively according to the Bai-Perron (2003) and ZA (1992) algorithms. The LR has a χ^2 distribution and the statistics are calculated and compared with the χ^2 critical value based on the number of degrees of freedom. The ** in column 5 represents significant at 5% level. Source: author's analysis.

Equation 3 and *4* specify the goods market equilibrium. Following KR (2000), interest rate, exchange rate, money supply and credit supply are assumed not to affect the level of real activities, contemporaneously. Instead, they affect the level of real activity with > 0 periods lag. Therefore, in the third equation they appear as lagged explanatory variables only and iip appears as a contemporaneous variable. As in KR, the price level responds contemporaneously to foreign (iip_t^f) and domestic output (y_t^d). The domestic price is assumed to not respond contemporaneously to the magnitude of all variables except iip and y because the domestic price is administratively set below the international level. But it does indirectly have an effect through output that responds contemporaneously to the iip_t^f. It is also expected that $A_{41}^0 < 0$ and $A_{43}^0 < 0$. *Equation 5* captures the financial market equilibrium (spi_t^d for regime 1; $cred_t^d$ for regime 2) in which the demand for credit is assumed to react contemporaneously to all variables and positively to the aggregate demand (output) and the interest rate, except exchange rate. That is $A_{53}^0 < 0$, and $A_{57}^0 < 0$. However, spi_t^d is set to contemporaneously respond to aggregate demand, price and exchange rate in regime 1. In determining the loan rate, creditors such as banks are assumed to respond instantaneously to the policy rate A_{57}^0. Thus ε_t^m, and ε_t^{cred} are money demand and bank credit demand, and also bank/credit supply shocks. *Equation 6* represents the money supply relation, where the money supply (m_t^d) is assumed to respond instantaneously and positively to the short-term interest rate, the price level and output. The expected sign of A_{67}^0 depends on the measure of monetary aggregate used. Money supply is represented by a broad money ($M4$). M4 contains deposits, which are interest bearing financial assets so its demand by the public is expected to react positively to short-term interest rate changes and hence $A_{67}^0 < 0$. In addition, as in KR (2000) and Brischetto and Voss (1999) restriction of $A_{64}^0 = 1$ is not imposed.

Equation 7 represents the money demand, which is assumed to be the reaction function of the monetary authority sets the interest rate after observing the current value of money, exchange rate, international interest rate and lagged values of all variables in X_t. The short-term interest rate assumed to contemporaneously respond to iip_t^f, ir_t^f, money supply (m_t^d), and exchange rate (exr_t^d) in regime 1. The exchange rate is included in the dynamic system because of its high pass-through effect. In addition, by controlling the components of monetary instruments that responds to depreciation of the pound and the monetary instrument innovations that are true exogenous contractions in monetary policy, are more likely to be identified and should lead to a depreciation of the currency. The reason for these variables to enter the feedback rule contemporaneously is that the data on money and exchange rate are available immediately. Variables such as output and the price level are not included because the data are not immediately available to the monetary authority. The contemporaneous variables are expected to affect the policy rate positively and likewise $A_{71}^0 < 0, A_{72}^0 < 0, A_{76}^0 < 0$ and $A_{78}^0 < 0$. In regime 2, monetary policy rate is set to react contemporaneously to ir_t^f, money supply and exchange rate. The reason to assume the reaction differently in regime 1 and regime 2 is due to the monetary policy conduct during the specified periods. Before setting inflation as a monetary policy target, the monetary policy authority used various target variables such as ir_t^f, ms and the exchange rate. However, after the 1992 inflation targeting policy, the monetary policy responded contemporaneously to inflation (with lag), money supply (as in equilibrium condition) and exchange rate as a monetary pass-through mechanism. While this reaction function, in both cases, represents the systematic reaction of monetary authority to the state of the economy, $\varepsilon_t^{ir^d}$represents the monetary policy shocks not accounted for in the systematic reactions. The contemporaneous variables are expected to affect the policy rate positively so $A_{72}^0 < 0$, $A_{76}^0 < 0$ and $A_{78}^0 < 0$. Finally, *Equation 8*, the arbitrage equation of the exchange rate, describes the financial market equilibrium. Due to its role as a forward-looking asset price, the exchange rate is set to react instantaneously to all other variables in both regimes.

The Structural VAR estimation process takes four steps. *First*, the time series property for each variable is examined by stationarity test using ADF, KPSS and PP followed by lag determination and joint lag exclusion tests. These tests determine the stationarity, lag length and provide information to allow for one and two endogenously determined structural breaks. These unit root tests not only address the nonstationarity issue facing SVAR modelling, but also determine the number and nature of shift indicator variables to be included in the model. Based on the ZA and BP algorithms, the identified structural break dates are accounted for in the form of shift indicator variables (IVs). The long-run property of each variable is also examined based on cointegration rank test (Trace and Max-Eigen statistics). *Second*, the eight possible specifications of the SVAR model are estimated for the two regimes. With alternate of the two additional variables, the structural VAR model produces about 20 dynamic structural system equations. *Third*, the IRF and FEVD are re-estimated for both monetary policy and credit supply shocks to determine the response of these shocks to the financial, aggregate supply and aggregate demand shocks. *Fourth*, robustness and plausibility checks are carried out by imposing sign restrictions to validate the IRF and FEVD output produced based on the contemporaneous zero restrictions.

5.6 Estimation and Empirical Results

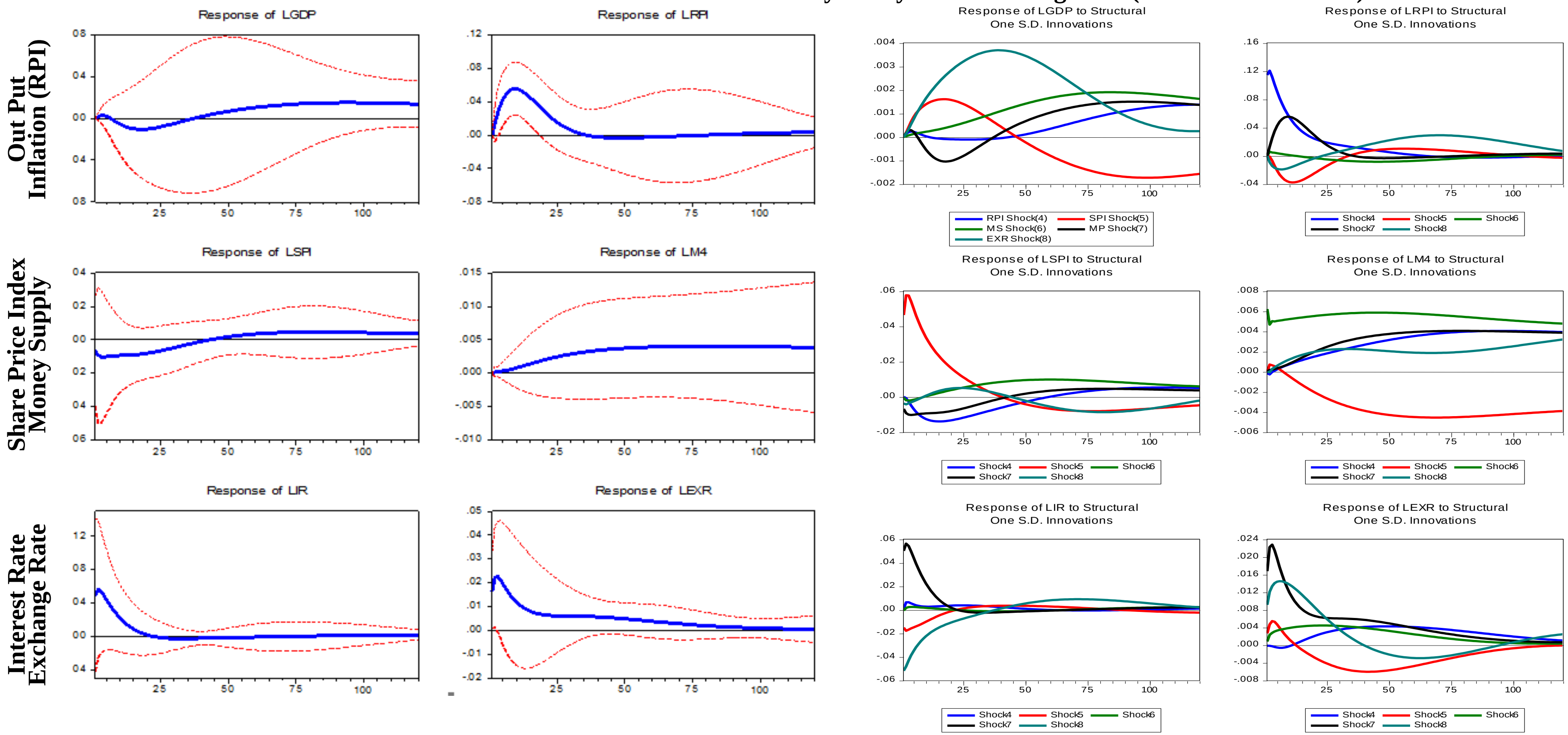
5.6.1 Effects of Monetary Policy Shock

This section discusses the response to monetary policy shocks in policy regime 1 and policy regime 2, based on the impulse response functions. Figure 5.4 displays the impulse response of output, price, share price index, money supply, interest rate, and exchange rate, respectively, to contractionary monetary policy shocks of the structural decomposition in the transmission mechanism. The responses are graphed with probability bands represented as 0.10 and 0.90 fractals (as suggested by Doan, 2004, with small amendments). In all cases, the monetary policy rate is normalised to increase by one standard deviation. The plots imply that a contractionary monetary policy shock has the useful effects on *y, p, cred, ir,* and *exr*. The shock has a negative impact on *y, spi, the* ir^d and the *exr* and positive initial impact on the *retail price index* (the price puzzle) and *ms.* The exchange rate depreciates for a while then shows a steady trend of appreciation. The positive deviation of *retail price index* preceded by a short-term upward movement has been highly persistent. This persistent movement could be a sign of economic stability. However, the *y* shows stable movement for a short period on its trend then shifted below its trend for a period of two years before it moves above the trend line and remained persistent throughout the period under consideration. Regarding financial variables *spi, ms* and *exr*, all remain above the trend after a period of shocks with a downward movement, implying a period of market reaction that attains persistency due to measures taken by the government to move towards a specific MP target.

The IRFs (Figure 5.4) also show that the monetary policy shock impulse causes a positive response of *output, retail price index* due to price rigidity; *exr* and *ir* followed by a decline in these variables for about 1 to 2 years. Quantitatively, because of the MP shocks, output falls by 0.2% to 1% for about 2 years then increases by 0.4% for the following 2 years until the effect dies out. The effect on inflation is negative, as expected, after a short period increase by 0.6 percentage point. The evidence also shows that initial increase in inflation is a phenomenon referred to as a “price puzzle” (see Sims, 1992). This puzzle is explained by a cost channel of the interest rate; where (at least part of) the increase in firms borrowing costs is offset by an increase in prices.[105] Finally, price (retail price index) initially responded to the monetary policy shocks by increasing (by about 4bps) for over a year, then declined in the following year. The decline in price continues to the long time horizon. Furthermore, the index of share prices remains below the zero base line for about 40 months, then moves above the zero base line in the long time horizon. The IRFs also display that the share price index continues to increase with a peak level of 1bp. Hence, the initial effect (within 3-5 months) is non-trivial.

[105] See Ravenna and Walsh (2006); Chowdhury et al. (2006).

Structural one S.D. Innovations ± 2 S.E. Monetary Policy Shocks in Regime 1 (1960M1 to 1991m12)



Individual Variable Responses **Cumulative Responses to Various Shocks**

Figure 5.4 Structural Responses to Monetary Policy and Other Shocks (Regime-1)

GDP (%), Inflation (percentage points), Share Price Index (percentage points), Money Supply (%), Interest Rate (percentage points), and Exchange Rate (percentage points). SVAR Impulse Response based on 95% confidence interval.

Source: author’s analysis.

The effects on interest rate and exchange rate show a similar trend. After a temporary positive response, the interest rate declined for about 2 years. However, the exchange rate, gradually and continuously falls for about 10 years (120 months), after a short period rise. This shows that exchange rate responds slower than the interest rate. Overall, the pre-inflation targeting period response to the MP shock was significant in the financial sector than the non-financial sectors. This can be evidenced by the response in retail price index, interest rate, share price index and the exchange rate. The confidence interval line tends to narrow down for all variables except money supply (M4) which shows that the majority of the results are significant. The cumulative share of the response accounted in the innovations of monetary policy to the macroeconomic, financial and monetary series is reported in Table 5.3 below. The table summarises the proportion of the FEVD accounted by the series included in the vector of endogenous variables in the short-run, during the period when inflation was not the monetary policy target (1960 to 1992).

Table 5.2 SR and LR Cumulative Responses to Monetary Policy Shock-1
(Pre-1992, Regime 1)

	Endogenous Variables					
Responses to MP Shock	*y*	*rpi*	*spi*	*ms*	*md*	*exr*
Short-run	-	+	-	+	+	+
Long-run	+	-	+	+	-	-
Overall Effect	>0	<0	>0	>0	=0	=0

Source: author's analysis.

Table 5.2 summarises the short-run and long-run aggregate responses to the monetary policy impulses. Output responded negatively in the short-run but moved upward after a period of 2 years. Price responded positively for about 18 months then moves downward towards the trend, which implies a zero effect. The cumulative effect for the output remains positive, while price remains negative. On the other hand, both equity price and money supply display more of a positive movement than the other variables. Finally, the policy rate and the exchange rate show a brief period of positive reaction followed by a downward movement towards the trend. This shows a sign of stability after a period of reaction to a monetary policy changes. The responses correspond to the economic theory. The FEVD emphasises that the contribution from monetary policy shocks to the exchange rate (up to 49%) is more trivial than the other variables. The response of exchange rate was extensive during the first 2 years. Next to exchange rate, the equity price (share price index) also responded, in a less extensive manner but consistently by 4% to 5%. The effect of the monetary policy shock confirms that the financial sector responded in both magnitude and direction than the macro and monetary variables. As shown in the combined IRFs (see Figure 5.4) money supply has responded with a continuously increasing trend for all shocks except the share price index. However, the probability bands at this point are getting wider which underlines the uncertainty in the responses.

Table 5.3 The Proportion of the Forecast Error Variance Decomposition

		Forecast Error Variance Decomposition [Regime1]					
Innovation	Forecast	Proportion of forecast error variance of the endogenous variables					
	Months	GDP	RPI	SPI	$M4$	IR	EXR
IIP	1	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.037	0.288	0.001	0.170	0.0121	0.033
	3	0.067	0.670	0.032	0.242	0.015	0.082
	4	0.070	1.080	0.139	0.279	0.010	0.173
	5	0.059	1.474	0.308	0.294	0.016	0.3023
	10	0.092	2.947	1.300	0.274	0.217	1.368
	15	0.164	3.681	1.854	0.238	0.297	2.996
	20	0.136	3.951	2.014	0.221	0.244	5.247
	24	0.165	3.969	1.988	0.222	0.217	7.509
FFR	1	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.007	0.027	0.002	0.312	0.164	1.017
	3	0.031	0.158	0.028	0.380	0.222	1.695
	4	0.109	0.344	0.074	0.437	0.216	2.203
	5	0.273	0.551	0.137	0.470	0.188	2.661
	10	2.601	1.668	0.478	0.498	0.189	4.708
	15	5.846	2.669	0.663	0.441	0.311	6.285
	20	8.109	3.415	0.719	0.382	0.335	7.217
	24	8.996	3.834	0.723	0.349	0.316	7.546
GDP	1	99.960	0.000	0.000	0.000	0.000	0.000
	2	99.596	0.060	0.116	0.003	0.107	0.077
	3	98.967	0.106	0.369	0.010	0.195	0.236
	4	98.191	0.125	0.693	0.018	0.215	0.470
	5	97.271	0.127	1.048	0.026	0.190	0.772
	10	89.917	0.077	2.838	0.068	0.238	3.162
	15	79.069	0.052	4.313	0.129	0.904	6.536
	20	68.140	0.045	5.223	0.220	1.500	10.28
	24	60.782	0.042	5.532	0.324	1.697	13.33
RPI	1	0.526	99.462	0.000	0.000	0.000	0.000
	2	0.551	98.213	0.004	0.124	0.593	0.292
	3	0.442	96.304	0.110	0.139	1.921	0.691
	4	0.343	93.701	0.456	0.143	3.766	1.073
	5	0.359	90.463	1.048	0.140	5.925	1.417
	10	3.094	71.533	5.349	0.101	15.72	2.280
	15	7.863	58.149	8.190	0.075	19.661	2.214
	20	11.760	51.179	9.187	0.080	20.056	1.974
	24	13.788	48.253	9.261	0.107	19.530	1.830
SPI	1	0.001	0.000	97.287	0.004	2.077	0.615
	2	0.001	0.008	96.312	0.067	2.291	0.548
	3	0.002	0.075	95.181	0.086	2.508	0.480
	4	0.002	0.237	93.926	0.093	2.686	0.431
	5	0.001	0.488	92.576	0.092	2.839	0.390
	10	0.039	2.517	85.046	0.064	3.430	0.253
	15	0.143	4.712	77.572	0.085	3.920	0.289
	20	0.239	6.410	71.181	0.205	4.275	0.487
	24	0.287	7.357	66.988	0.386	4.423	0.682
$M4$	1	0.086	0.055	0.000	0.000	0.000	0.000
	2	0.603	0.145	0.841	97.07	0.063	0.004
	3	1.020	0.101	1.041	96.027	0.086	0.094
	4	1.348	0.087	1.065	95.149	0.128	0.234
	5	1.586	0.109	0.974	94.448	0.183	0.436
	10	2.112	0.603	0.601	91.073	0.742	1.930
	15	2.362	1.429	1.421	86.476	1.905	3.606
	20	2.615	2.329	3.202	80.932	3.532	4.990
	24	2.806	3.027	4.932	76.345	4.946	5.778
IR	1	0.083	0.007	4.159	0.005	46.139	48.979
	2	0.096	0.363	4.752	0.027	50.066	43.849
	3	0.095	0.505	4.954	0.052	52.006	41.129
	4	0.084	0.547	5.096	0.072	52.838	39.593
	5	0.071	0.554	5.237	0.086	53.031	38.675
	10	0.178	0.533	5.744	0.120	50.562	37.184
	15	0.380	0.576	5.732	0.127	47.409	36.981
	20	0.446	0.685	5.516	0.123	45.125	36.839
	24	0.444	0.798	5.357	0.120	43.807	36.524
EXR	1	0.041	0.004	1.859	0.174	73.911	21.893
	2	0.113	0.003	2.712	0.571	72.295	21.368
	3	0.389	0.005	3.191	0.754	70.069	22.082
	4	0.746	0.009	3.349	0.909	67.652	23.338
	5	1.122	0.016	3.320	1.052	65.268	24.778
	10	2.794	0.030	2.495	1.757	55.232	31.148
	15	4.344	0.045	1.952	2.483	48.485	34.217
	20	5.932	0.193	1.923	3.184	44.063	34.478
	24	7.088	0.434	2.244	3.691	41.561	33.412

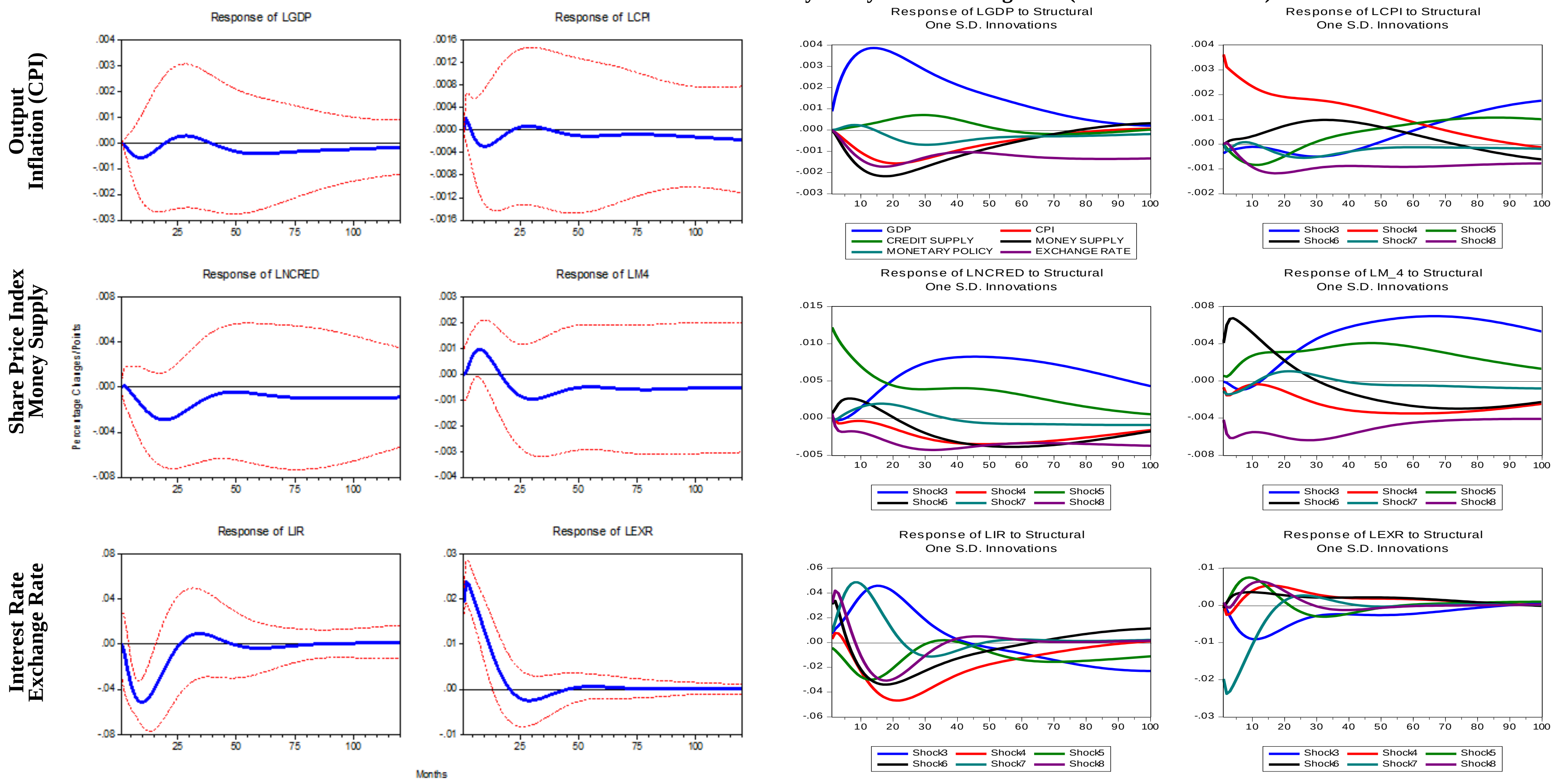
Source: author’s analysis.

Inflation, on the other hand, responded positively in the short-run to all variable innovations except exchange rate and share price index. The changes in exchange rate accounted for more to the monetary policy shock and least to the price shock. The exchange rate responded positively during the first year to all innovations except the shock from share price index. Similarly, the combined IRFs clearly show that the financial sector shock causes a negative reaction in the macroeconomic, monetary and financial sectors as compared with the other innovations.

In terms of order of importance, the international variable innovation, *iip* (ε^{iip}), contributes more to *p, exr* and *ms*. Specifically, ir^f (ε^{ir}) contributes more to *y, exr* and *p; y* (ε^{y}) contributes more to itself, *exr* and *spi*; *p* (ε^{p}) contributes more to itself, ir^d and *y*; *spi* (ε^{spi}) contributes more to itself, ir^d and *p*; *ms* (ε^{ms}) contributes more to itself, *exr*, and *ir*; *ir* (ε^{mp}) contributes more to itself, *exr* and *spi* and finally *exr* (ε^{ex}) contributes more to itself, ir^d, *y* and *ms.* The intuition behind this is that the monetary policy shock impacts the financial sector more than the rest of the economic sectors in the pre-inflation targeting regime. In comparison to the first time horizon (pre-1992), regime 2 (post-1992), shows that the monetary policy shock has a negative impact on *y, p, cred*, and *exr* and positive impact on *p* (short period), *exr* (short period) and *ms*. It also shows that the exchange rate appreciates by 0.04 percentage points for almost two years, then continued to be persistent and remained on its trend after a brief period of depreciation. As expected, the monetary policy shock showed a negative impact on credit supply *(cred).* This implies that high cost of borrowing discourages consumption and investment. Total credit to private sector falls for 2 years, towards 24 months. Furthermore, the results confirm that monetary policy shocks can remain in the financial sector for a period of 2 years, particularly in the credit market before consumers' confidence bounce back. As clearly displayed on the IRFs (Figure 5.5), the size of total credit to private sector remains stable with slight degree of increase, and then continue to decline during the post-financial crisis period.

The *second* interesting outcome of the monetary policy shock impact is the exchange rate. Unlike regime 1, *exr* in regime 2 becomes more stable and persistent. After a brief period of upward responses, exchange rate sharply declined towards 24 months by 0.04%. Afterwards, following a 10 months' appreciation, *exr* remains stable throughout the period under consideration. This implies that exchange rate has not been significantly affected by the GFC. The UK economic reality also substantiate this result, as exchange rate has not been markedly changed in the run up to the recent financial crisis. Apart from *exr,* the other financial variables such as money supply and monetary policy rate remain persistent for a long period. There has been a positive reaction towards 10 months then the response declines and remains below its trend. Price also shows a remarkable variation during regime 1 and regime 2. Unlike regime 1, *cpi* remains persistent after a short period (10 -12 months) and remains close to its targeted trend.

Structural one S.D. Innovations ± 2 S.E. Monetary Policy Shocks in Regime 2 (1992M1 to 2014M12)



Individual Variable Responses to MP shock **Cumulative Responses to Various Shocks**

Figure 5.5 Structural Responses to Monetary Policy and other Shocks (Regime-2)

GDP (%), Inflation (percentage points), Credit (%), Money Supply (%), Interest Rate (percentage points), and Exchange Rate (percentage points). SVAR Impulse Response based on 95% confidence interval.

Source: author’s analysis.

This outcome directly corresponds to the Bank of England's policy target that moves from 1 to 4 percent inflation target to 2 percent for output and price stability. Overall, marked response to the monetary policy shocks is observed in all variables in the short time horizon and all variables show stable movement towards the zero band in the long time horizon. This clearly shows that the response to monetary policy shock is a short-run phenomenon. In comparison, the reaction of the interest rate and the exchange rate is by far significantly higher than the other responses. In terms of magnitude, the financial sector is remained to be one of the most important sectors that strongly reacts to the monetary policy innovations. The outcomes highlight the important question and respond positively to the questions raised at the initial stages of this study: should monetary policy takes into account only inflation and output or should it include performance indicators of the financial sector in the decision making process to determine the short term interest rate?

Table 5.4 summarises the short-run and long-run aggregate responses to monetary policy shocks. It shows that output and price responded negatively in the short-run but positive in the long-run. However, the cumulative response in the entire time horizon was negative and remained below the trend. On the other hand, money supply reacted positively to a monetary policy shock in the short-run but negatively in the long-run with overall negative response. Another interesting result worth commenting is the policy rate and the exchange rate in both cases. The negative short-run and a brief period positive response is followed by an almost zero response in the remaining time horizon. This shows that a sign of stability after a period of reaction to a monetary policy changes.

Table 5.4 SR and LR Directions of Responses to Monetary Policy Shock-2
(Post-1992 Regime 2)

	Endogenous Variables					
Response to MP Shock	*y*	*cpi*	*cred*	*ms*	*md*	*exp*
Short-run	-	-	-	+	-	-
Long-run	+	+	+	-	+	+
Overall effect	<0	<0	<0	<0	=0	=0

Source: author's analysis.

Output declines steadily in the year after the shock, to almost 0.1 percent lower after 12 months. Following a volatile estimated response in the first year, *p* steadily decline. The maximum response of inflation is short lived of about the same period as in *y*. Inflation lowers by about 0.3 percentage points than the baseline. The relatively slow response of inflation to a monetary policy shock is a well-established result. The turning point of output and inflation is almost similar in a sense that both moved upward after a similar period. Credit, on the other hand, responds to monetary policy shock slowly but negatively than output and inflation. However, the response at the turning point is slower than both inflation and output. Credit is 0.3% below counterfactual levels after 15 months or five quarters. It begins to recover after 15 months and reaches to the baseline after 1 year. It is interesting to note that, unlike previous studies, while the initial response of credit is small, it appears to respond immediately to the monetary policy shock. However, many studies show that credit responds negatively to a monetary policy shock with a period of lag. Often, previous studies have used bank credit to represent total credit, mainly because the studies have focused on the credit channel. However, the immediate response of credit to monetary policy shock in the benchmark SVAR model was found to be robust to using only the component of credit provided by banks to private sector. Following the initial appreciation, the exchange rate depreciates. Consistent with uncovered interest rate parity, it is also important to note that the Killian bootstrapped 90% confidence interval for the impulse response function narrows down across the time horizon, implying that the impulse responses are statistically significant at conventional confidence interval levels. In general, the impulse response of monetary shock is the major response during the pre-IT period. The credit response to monetary policy shock remains below the base line but the monetary response disappears in a short span of time. This implies that the policy in the pre-IT period was aimed at stabilising the monetary base and exchange rate rather than prices.

The FEVD (see Table 5.3 and 5.5) reports the proportions of error of forecast, generally by SVAR, that are attributable to shocks to each of the variables in the model. The study choses a 24 months for FEVD as a representative period for short-term forecast errors of monetary and financial variable shocks. Table 5.5 reports the FEVD for regime 2. It highlights how the proportions of the forecasted errors attributed to each variable's shock. Each column reports, for six different domestic variables, the proportion of the forecast error explained by structural shocks to each of the eight explanatory variables, listed on the left hand side of the table. For a given time horizon, the entries in a given column sum up to one, subject to small differences for rounding to 100. In the short-run, shocks to inflation and *output* own shocks are important for *output* forecast errors. However, as the horizon prolongs, the exogenous global variables, *IIP* and *FFR*, play a greater role.

This is consistent with previous studies such as Brischetto and Voss (1999), Dungey and Pagan (2000) and KR (2000). For inflation, its own shocks are responsible for almost all of the short-term forecast error. Over longer horizon, shocks to *IIP* and *output* are increasingly important. Shocks to the interest rate have been only small part of *output* and *inflation* forecast errors (2% and 0.5%, respectively). It is also important to note that the monetary policy rate has little influence (only up to 7%) on variables such as *output* in the long-run. Over the short time horizon, the forecast errors for *credit* are explained by shocks to total credit to private sector, the interest rate and the exchange rate. Not surprisingly, in the longer time horizon, shocks to major macroeconomic variables such as *output*, *price*, *IIP*, and *FFR* play greater role.

Table 5.5 The Proportion of the Forecast Error Variance Decomposition

Forecast Error Variance Decomposition [Regime 2]							
Innovation	Forecast	Proportion of forecast error variance of the endogenous variables					
	Months	*GDP*	*CPI*	*CRED*	*M4*	*IR*	*EXR*
IIP	1	0.000	0.000	0.000	0.000	0.000	0.000
	2	2.394	0.868	0.761	0.000	0.170	0.340
	3	3.798	0.987	1.740	0.381	1.383	0.340
	4	5.847	1.017	1.664	0.510	1.653	0.328
	5	7.301	1.075	1.598	0.759	1.676	0.714
	10	11.179	1.886	1.500	1.080	1.534	2.067
	15	12.023	2.131	1.493	1.068	1.510	2.331
	20	12.177	2.171	1.491	1.065	1.506	2.366
	24	12.207	2.178	1.491	1.065	1.505	2.373
FFR	1	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.582	0.528	0.067	0.043	1.035	1.462
	3	1.407	0.874	0.935	0.398	1.343	2.926
	4	2.358	0.912	0.957	1.515	1.311	4.162
	5	3.280	1.177	0.935	1.654	1.296	4.508
	10	5.119	1.768	0.952	1.667	1.278	5.392
	15	5.393	1.843	0.953	1.659	1.274	5.433
	20	5.442	1.853	0.953	1.658	1.273	5.439
	24	5.451	1.855	0.953	1.657	1.272	5.440
GDP	1	99.775	0.000	0.000	0.000	0.000	0.000
	2	97.371	0.456	0.002	0.001	0.104	1.541
	3	93.441	1.260	0.002	0.017	0.378	4.083
	4	89.003	2.199	0.002	0.084	0.726	6.784
	5	84.561	3.198	0.002	0.188	1.057	9.330
	10	66.925	8.209	0.002	0.704	1.662	18.424
	15	56.140	12.564	0.004	0.846	1.233	23.152
	20	44.563	17.461	0.056	0.635	0.652	25.624
	24	48.941	15.806	0.026	0.752	0.810	25.215
CPI	1	1.586	98.403	0.000	0.000	0.000	0.000
	2	1.699	97.135	0.023	0.207	0.167	0.026
	3	1.759	96.333	0.019	0.288	0.164	0.047
	4	1.833	95.680	0.015	0.291	0.127	0.094
	5	1.903	95.018	0.016	0.267	0.121	0.172
	10	2.144	91.816	0.178	0.153	0.388	0.785
	15	2.386	89.886	0.679	0.116	0.492	1.267
	20	2.737	88.829	1.501	0.093	0.423	1.366
	24	3.057	88.091	2.305	0.094	0.364	1.261
CRED	1	0.011	0.002	99.280	0.102	0.000	0.000
	2	0.068	0.010	99.301	0.153	0.007	0.343
	3	0.093	0.011	99.223	0.195	0.005	0.270
	4	0.093	0.009	99.156	0.212	0.015	0.281
	5	0.080	0.020	99.062	0.213	0.048	0.347
	10	0.370	0.219	97.537	0.179	0.744	0.761
	15	2.391	0.283	93.787	0.200	2.359	0.693
	20	6.634	0.276	87.401	0.285	4.083	0.792
	24	11.021	0.586	80.852	0.363	4.926	1.523
M4	1	0.113	0.158	0.432	75.167	0.000	0.000
	2	0.243	0.193	0.202	72.994	0.048	22.106
	3	0.304	0.614	0.145	71.322	0.308	19.848
	4	0.336	1.222	0.136	70.047	0.854	17.337
	5	0.345	1.974	0.147	68.934	1.534	14.976
	10	0.278	7.156	0.249	64.972	3.498	7.852
	15	0.314	13.505	0.306	62.560	2.936	5.378
	20	0.660	19.430	0.335	59.315	2.357	4.697
	24	1.259	22.955	0.359	55.563	2.502	5.113
IR	1	2.454	0.271	1.467	13.873	0.000	78.893
	2	3.156	0.958	1.875	14.414	0.756	76.214
	3	4.011	0.962	2.780	13.932	3.434	71.417
	4	5.027	0.748	3.873	12.464	8.151	64.115
	5	6.127	0.605	4.913	10.476	14.027	54.987
	10	11.123	3.473	7.001	4.104	30.859	21.075
	15	14.253	9.663	6.875	3.258	28.016	14.821
	20	15.546	16.335	6.575	3.125	22.276	15.627
	24	15.525	20.980	6.358	2.929	18.760	16.443
EXR	1	0.101	0.011	0.057	0.669	92.652	3.087
	2	0.291	1.053	0.172	0.306	91.519	3.839
	3	0.707	1.314	0.266	0.291	90.663	3.743
	4	1.308	1.263	0.367	0.335	90.003	3.328
	5	2.035	1.117	0.474	0.409	89.282	2.854
	10	6.272	1.028	0.985	0.923	82.799	2.325
	15	9.764	2.864	1.317	1.179	74.723	4.145
	20	11.644	5.659	1.473	1.146	68.632	5.843
	24	12.179	7.719	1.522	1.106	65.528	6.479

Source: author’s analysis.

This finding is related to a broader pattern observed in the FEVD. As shown in the above table, the innovations to the international variables become more important as time passes across the spectrum of domestic variables. This reflects the role that these exogenous factors play in determining the long-run movements of the domestic variables in structural dynamic models. In terms of the relative importance of MP shock, the FEV decomposition emphasises that the contribution from monetary shocks was more on exchange rate than the other variables. The exchange rate accounted from 15% to 79%. However significant it seems, the IRFs uncovered that this large responses of the innovation of MP shock lasts only for 2 years, followed by a persistent move towards 2014. Short-term interest rate accounted for 0.7 to 19 percentage points of the MP shock followed by *price*, which accounted for up to 21 percentage point, *output* up to 16% and *cred* up to 6.4%. Similar to regime 1, the financial variables exhibit high level of response than the macroeconomic and monetary variables. In terms of the overall order of importance in regime 2, *iip* innovations (ε^{iip}) contribute more to domestic variables such as output; ir^f (ε^{ir}) contributes more to output and ir^d; y (ε^{y}) contributes more to itself, p (ε^{p}), and *exr* ; p (ε^{ex}) contributes more to itself, y and *exr*; *cred* (ε^{cred}) contributes more to itself, y and interest rate; Money supply (ε^{ms}) contributes more to itself, p and *exr;* ir^d (ε^{mp}) contributes more to itself, *exr*, p and y; and finally, *exr* (ε^{ex}) contributes more to ir^d, y, p and itself.

The pre and post-IT periods show marked differences so is worth commenting. (a) Price responded to more than output for a one standard deviation of MP shock impulses during the pre-IT period. (b) The response of output to the monetary policy shock was negligible in this period. (c) The strong response is noted on the exchange rate, which is a true reflection of the characteristics of the regime. On the contrary, in the post-IT regime, the responses show marked differences. This regime highlights remarkable events in the UK monetary policy. (d) There are marked positive responses in all sectors with exchange rate being the highest response followed by price and output. This implies that the actions taken by the government to grant independence to the Bank of England from political control and the inflation targeting monetary policy strategy seem to have met its expected objectives in the run up to the GFC, while giving less attention to the financial sector bubble. However, there was a growing response of price than output across the short-run time horizon. To conclude, the pre and post-IT periods IRFs and FEVD highlight the degree of the functionality of monetary policy and the growing role of the credit supply shock that is gradually replacing the role of MP shocks. In terms of the dynamics of the MEF innovations, in the business cycle, pro-cyclicality behaviour is evident.

5.6.2 Effects of Credit Supply Shock

Due to lack of sufficient data, the variable, *total credit supply to private sector,* is only included in the policy regime 2. Figure 5.6 (left) shows the median impulse response of the six variables in the SVAR model to a credit shock normalised to have an approximately a 1.2 percentage point impact on a credit supply shock that leads to around 11% fall in the real stock of credit to private sector in about 6 years. A credit supply shock revealed no significant effect on output initially, and then increases by up to 0.1bp after 30 months. The credit supply responded to its own shock followed by a sharp decline by up to 0.5bp for 2 years, then declined persistently towards the zero base line when the monetary policy variable is in the model. This fall remains the same when the monetary policy response was switched off. The fall in the level of output triggered a decline in inflation initially. This is relevant to the sticky price theory. The peak response in price could be as much as 1.2% per annum. This suggests that credit supply shocks might have a significant effect on potential supply so that the output gap moves little despite the fall in output under this shock. This also implies that there is a cost channel effect, as also in Barth and Ramey (2002), where higher borrowing costs feed through into the price level because borrowing is an input into production. This concept is discussed as EFP in Chapter 6. One can also interpret this in terms of a credit shock that may induce movements in the exchange rate that causes a temporary impact on inflation through higher import prices. The UK is an exporter of financial services[106] and a credit supply shock is likely to induce a reduction in the supply of these services. To keep the trade balance at a sustainable level, it requires an exchange rate depreciation (see Figure 5.6) to induce a general increase in non-financial exports to fill the gap left by the financial sector exports.

The real equity price represented by a monthly percentage change in the FTSE All-Share Index (FASI) deflated by the GDP deflator series falls in response to a credit supply shock (see Figure 5.7 below). The real equity price response to the credit shock shows an immediate upward movement followed by persistent decline but remains above the zero band line. This implies that the effects on activity and risk *premia* outweigh the boost from lower real risk-free rates, which unambiguously fall under the equity price response. The analysis of credit supply shock is informative as it highlights the credit response to macroeconomic, financial, monetary, and its own shocks in both pre and post-IT regimes. The insight behind this is that credit is the most important variable that responds to the shocks generated in the financial intermediaries than the role-played by the monetary policy shock. This outcome highlights the need for further investigation to quantify the impulse and response of the shocks in the credit sector.

[106] The UK exports of financial services was nearly £60bn in 2013, which represents 3.5 of GDP (Lea et al., 2015).

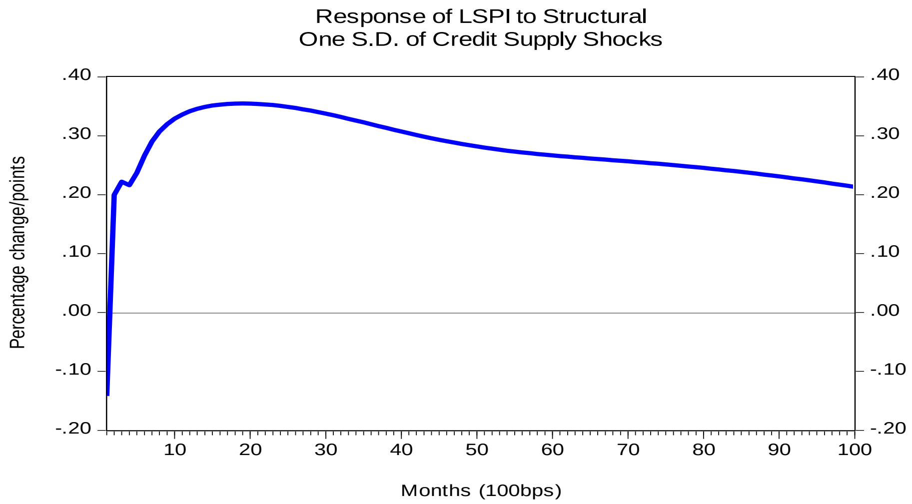


Figure 5.6 Equity Price Response to a Credit Supply Shock

Equity Price (FTSE-All Share Price Index), GDP (%), Inflation (percentage points), Credit (%), Money Supply (%), Interest Rate (percentage points), and Exchange rate (percentage points), Regime 2.

Source: author's analysis.

Credit Supply and Monetary Policy Shocks

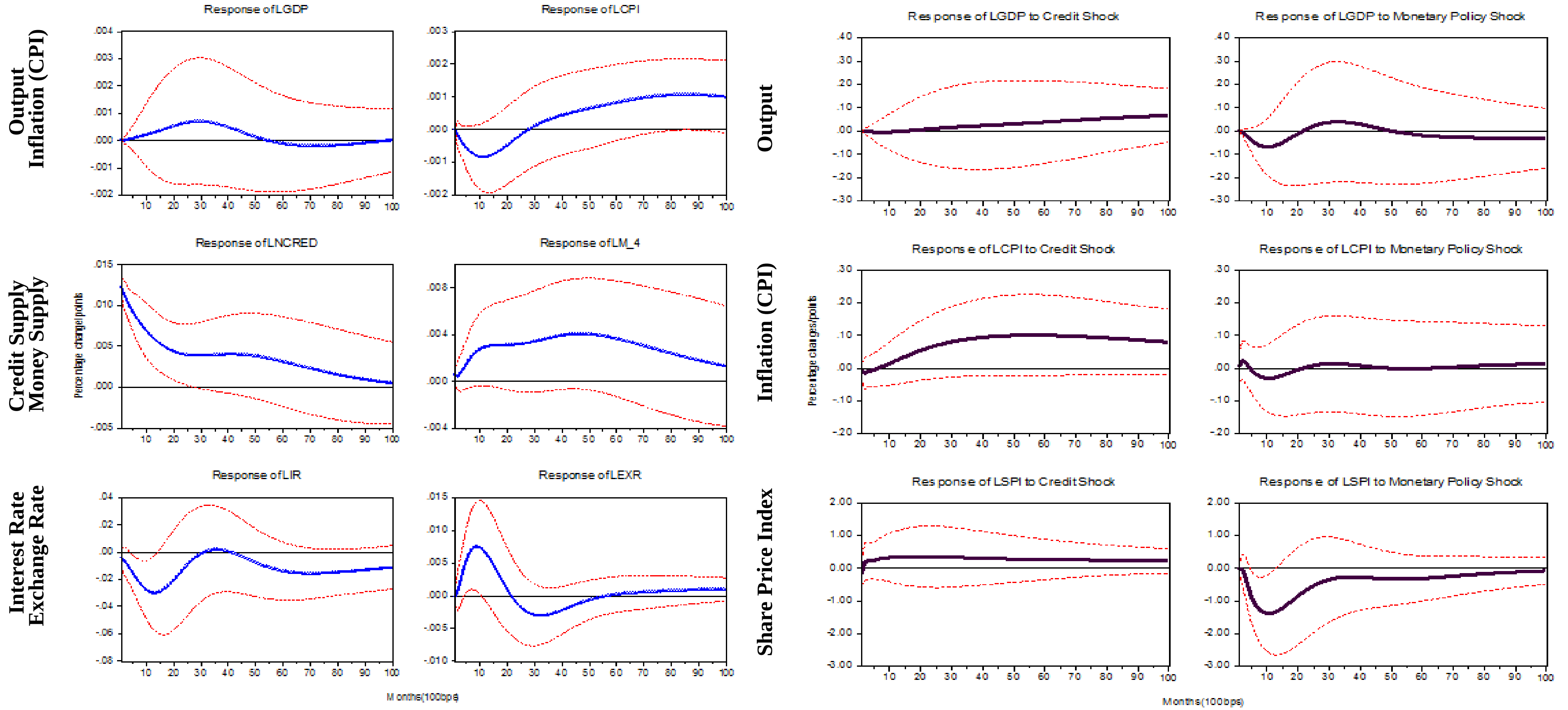
It is also useful to compare a credit supply shock with a monetary policy shock to shed some light on the magnitude of the impact resulted from either the credit sector volatility or from monetary policy shocks. One way of comparing the response of macroeconomic variables is by looking at the response to credit and MP shocks that are both scaled to deliver an initial impact on target variables (output and price). For the sake of comparison, the monetary policy shock is switched off in the credit supply shock equation and vice versa. The results illustrate that when the monetary policy response switched off, the path for both output and inflation responds fairly identically over the 20 months. The equity price responds positively to credit shocks but negatively to monetary policy shocks for about 10 months. However, the response to the monetary policy shock remains below the zero band line while the equity price response remained above the zero band line. This seems to be a sensible maturity matched comparison between a change in monetary policy and a credit supply shocks. Joyce et al. (2011) note that £200bn of asset purchases would initially be required to deliver a fall of 1bp in 10 year government yields. In terms of the movement of these indicators, *output* and *share price index* are characterised as *pro-cyclical* with *credit supply* shock and only *output* as *pro-cyclical* with *monetary policy* shock. On the contrary, *price* and *share price index* are characterised as *counter-cyclical* with *credit supply shock* and *output* as *counter-cyclical* with the monetary policy shock. *Share price index* and *price* also show some *acyclical* behaviour with credit supply and monetary supply shocks, respectively. This implies that when monetary policy indicator is not included in the credit supply model, the credit supply shock is positively correlated with *output* and *share price index*. Monetary policy shock, on the other hand, is negatively correlated with part of the *output* movement and the *share price index,* while the credit supply shock is negatively correlated with *price*.

Share price for credit supply shock and price for monetary supply shock, respectively, show no correlation in the given time horizon (see Figure 5.6). Monetary policy shocks have a permanent negative impact on equity price (FTSE-All Share Price Index) than the credit supply shock. There is also a distinct difference between the responses to the credit and MP shocks in terms of the direction of average movements. The credit shock responses caused permanent positive effects while the monetary policy shocks occasioned by mixed movements of *output* and *price* but a permanent negative movement for the *share price index*. This infers that credit supply shocks have long-run effects than the monetary policy shocks. As shown in Figure (5.7) above, the responses to the credit shocks have persistent and permanent upward movements throughout the short and long time horizons as compared to the responses to the monetary policy shocks. Both money and credit supply shocks also show that changes in monetary policy has bigger impact than effects only from credit supply shocks in the short-run. This probably implies the direct cash-flow effects on mortgages linked to bank rate. It is also important to note that a credit supply shock is affecting the rates on new borrowing so would take some time to affect actual cash-flows. This supports the premise that the *exchange rate* depreciates under a credit supply shock (see Figure 5.7), whereas it should move in an opposite direction to a monetary policy tightening. *Equity prices* show opposite movements for credit supply and monetary policy shocks. However, the negative response for monetary policy shock is greater than the positive movement of equity price caused by a credit shock. This suggests that equity prices are affected more by a monetary authority decision than the credit supply changes in the financial market.

Moreover, over the medium term, the effects of monetary policy and credit supply shocks are somehow comparable except the equity price. A MP shock increases the response of output and price by 0.5% and 0.2%, respectively, but lowers the equity price by 1.5%. The equivalent credit supply shocks initial impact builds up towards long-term upward movement from 0.5% to 1% changes over the long time horizon. *Price* on the other hand, increases by more than double of the change in *output*, which continues persistently from the midterm towards the long time horizon. The monetary policy shock impact is almost double the central case impact from the central bank studies on the effects of QE (see Joyce et al., 2011) but is within the range of estimates of one of the studies used to make up that central case (see Kapetanios et al. 2012). Joyce et al. (2011) also show that the MP shock reflects the average impact of bank rate and QE over the sample period rather than QE alone. For this reason, the impact is expected to be slightly larger than the sole impact of QE. The changes in the bank rate have direct cash-flow effects on household income and are likely to have an exchange rate influence that are not factored into the bank's QE estimates.

Response to Structural One S.D. Innovations ± 2 S.E. of Credit Supply Shocks (1992M1 to 2014M12)

Structural one S.D. Innovations ± 2 S.E. Monetary Policy & Credit Supply Shocks (1992M1 to 2014M12)



Response to Credit Supply Shocks

Response to Credit Supply and MP Shocks

Figure 5.7 Structural Responses to a Credit Supply and MP Shocks

GDP (%), Inflation (percentage points), Credit (%), Money Supply (%), Interest Rate (percentage points), Exchange Rate (percentage points), and Share Price Index (percentage points). SVAR Impulse Response based on 95% confidence interval.

Source: author’s analysis.

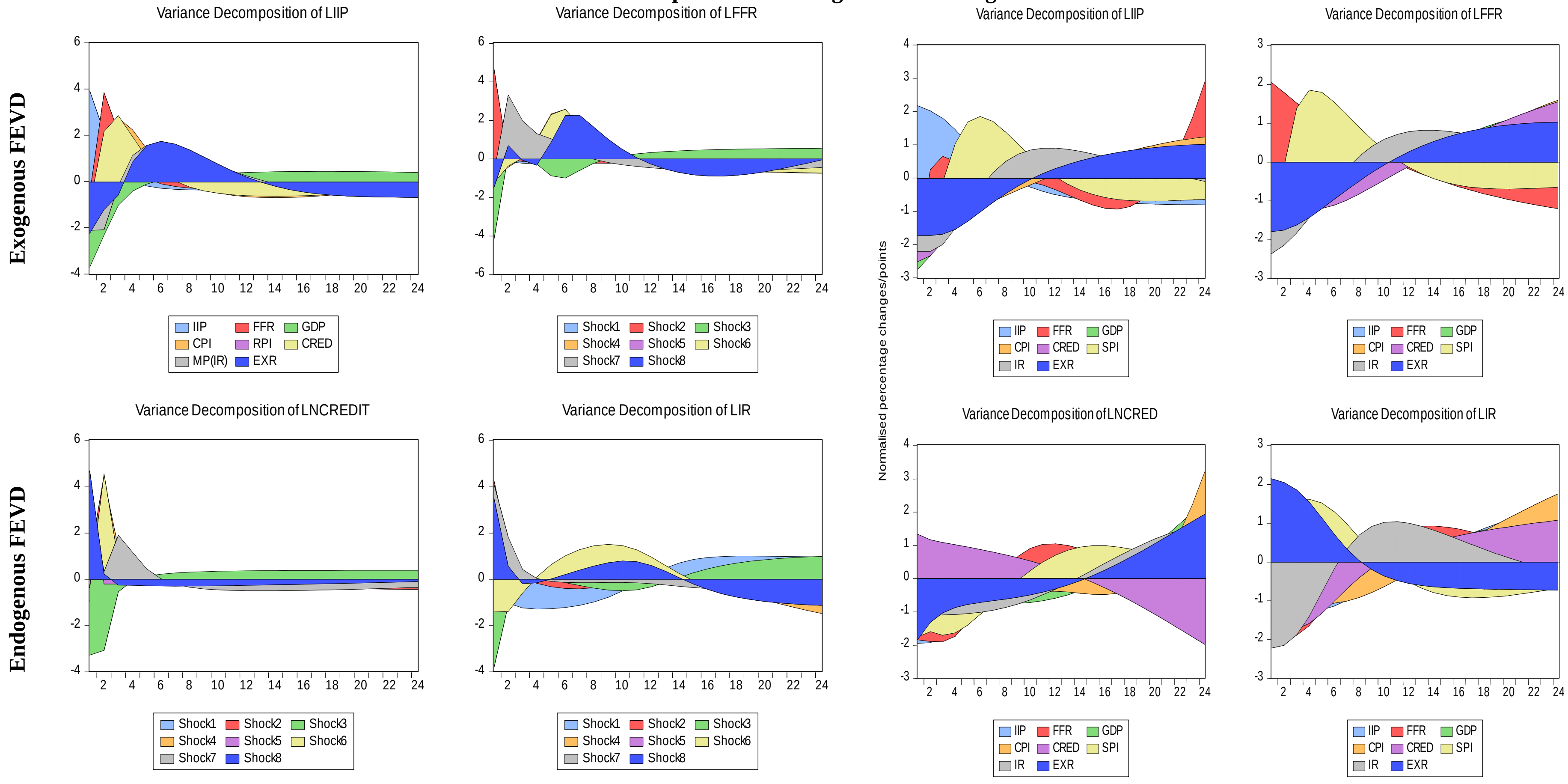
When the shock is scaled to move on the zero base line of the bank rate, the effect on output, after two years, is only around 1%. Therefore, a credit shock that leads to a 100 base point impact on longer term has two to three times the impact of an equivalent increase on bank rate. Largely, the monetary policy shock estimates should be thought of as upper bound estimates. Similarly, Canova and De Nicolo (2002) show that sign restricted SVARs often produce large contemporaneous responses to monetary policy shocks. From this outcome, one can conclude that monetary policy shock is more of a short-term effect that triggers a negative response but the credit supply shock is characterised by a long-term impact that does not die out shortly.

Forecast Error Variance Decomposition

This section analyses the importance of credit and monetary policy shocks over the five decades time horizon and specifically during the recent GFC. This involves running a sequence of dynamic forecasts starting at a particular point in time. The first forecast is a base projection that takes the value of each variables at the start of the decomposition (reflecting the impact of shocks occurred before the starting bps) and maps out how each variable would return to its trend path in the absence of further shocks. The base projection will also reflect the impact of the shift IVs introduced in 1993. Given this base projection, the path of each structural shock is then sequentially included into the SVAR until the resulting forecast is equivalent to the observed data. The marginal impact of each shock is then recorded to produce the historical decomposition.

Table 5.6 reports the variance decomposition of credit supply and monetary policy rate over the whole sample, starting from 1960M1 to 2014M12. The decomposition suggests that the credit supply shocks look plausible when seen in the context of the past 55 years of the UK monetary and credit history. Credit supply shocks appear to be the dominant driver of movements in credit spreads. Table 5.6 also show that the credit supply variation accounts for 71% to 99% of its own variation, which supports the theory of propagation and acceleration mechanism of the financial sector. In comparison, the proportion of FE variation of IR accounts for only 14% to 84% to the monetary policy variation. In terms of time horizon, the contribution of the credit supply FE variation is not only a short-run but also long-run phenomena, which accounts for 71% of its own variation after two years while the IR FE variation accounts for only 14% after two years. Contractionary credit supply shocks were the key drivers behind the rise in Spreads in the midst of the secondary banking crisis in the mid-1970s, following the U.S. and UK bank failures in the mid-1980s, and especially in the post-2007 financial crisis. Positive shocks were also important in pushing down Spreads in the first wave of financial liberalisation in the early 1980s and in the 2003-2007 credit boom. The importance of the foreign variable shocks from the industrial production and the shocks of FFR are mirrored in the decomposition of equity price and exchange rates.

Forecast Error and Variance Decomposition of Endogenous and Exogenous Variables to Various Shocks



FEVD in Regime 1 (1960M1 to 1992M12) **FEVD in Regime 2 (1993M1 to 2014M12)**

Figure 5.8 FEV Decomposition Responses to MP and Credit Supply Shocks

GDP (%), inflation (percentage points), credit (%), money supply (%), interest rate (percentage points), and exchange rate (percentage points) in Regime 1 (left chart) and Regime 2 (right chart). SVAR Impulse Response based on 95% confidence interval.

Source: author's analysis.

Table 5.6 The Proportion of the Forecast Error Variance Decomposition (Regime 1 & 2)

Forecast Error Variance Decomposition [Regime1 & 2]							
Innovation	Forecast	Proportion of forecast error variance of the endogenous variables					
	Months	GDP	CPI	$CRED$	SPI	IR	EXR
$CRED$							
	1	0.024	0.004	98.815	0.121	0.010	1.006
	2	0.137	0.045	97.436	0.212	0.011	2.136
	3	0.202	0.068	96.734	0.148	0.009	2.763
	4	0.223	0.063	96.182	0.189	0.031	3.116
	5	0.211	0.053	95.612	0.323	0.078	3.323
	10	0.334	0.051	92.066	1.240	0.851	3.955
	15	2.283	0.046	86.598	1.660	2.514	5.247
	20	6.910	0.099	78.463	1.492	4.244	7.385
	24	12.003	0.312	70.770	1.270	5.062	9.337
$MP(IR)$							
	1	0.275	0.383	10.141	0.000	83.998	0.275
	2	0.990	0.208	10.979	0.766	81.501	0.990
	3	1.039	0.187	11.280	3.438	77.009	1.039
	4	0.842	0.487	11.328	8.246	69.411	0.842
	5	0.665	1.053	11.020	14.391	59.566	0.665
	10	2.977	4.064	5.8308	32.662	22.973	2.977
	15	7.779	5.324	3.1337	29.372	15.656	7.779
	20	12.585	5.978	3.1478	23.395	14.646	12.582
	24	15.962	6.355	3.7783	19.857	14.126	15.962

Source: author's analysis.

The credit supply shocks explain most of the fluctuations in credit growth relative to trend both in the 2003 to 2007 boom and in the subsequent financial crisis. The pre-1992 period FEV decomposition has a remarkable difference in terms of the credit shock (see Figure 5.8). The response to the credit shock from 1960s to early 1990s is relatively weak as compared to the later period. There was weak credit growth in the late 1960s and mid-1970s, which led to the secondary banking crisis and the operation of direct control on credit such as the Supplementary Special Deposits Scheme or "Corset". This also contributes to the swings in credit growth in the early to mid-1980s, reflecting the impact of financial liberalisation from 1979 onwards and the bank failures of the mid-1980s. Overall, this suggests that the identified credit supply shock in the SVAR model is plausible.

One important similarity, however, is that credit and interest rate responded strongly with high magnitude to their own shocks. This shows that the monetary policy follows not only a forward-looking but also a backward-looking reaction functions in the policy making process. The second important shock that accounts for the credit shock is the exchange rate. It highlights the importance of international trade, followed by the interest rate shock. The credit shock is the second most important shock, followed by the exchange rate shock, which accounts for the interest rate shock. This implies that both the credit sector, i.e., the financial intermediaries, and the monetary sector are inseparable. This is similar to the conclusion made by Beck et al. (2014), who argue that monetary and financial stability cannot be separated and that the health of financial intermediaries creates money and monetary policy transmission.

Remarkably, credit supply shocks appear to play less of a role in the Lawson Boom of the late 1980s and in the subsequent recession and slow recovery of the early to mid-1990s. Much of the credit growth is attributed to a preference or capital market substitution shocks. This reflects the fact that Spreads move relatively little, or if anything, in the same direction as credit. The strong negative impact of the capital market shocks during the first half of the 1990s is similar with the evidence that after the recession of the early 1990s, non-financial companies were keen to restructure their balance sheets by repaying bank debt and substituting towards capital market finance (see Barnett and Thomas, 2013; Salmon, 1995).

The Charts in Figure 5.7 also show that the standard macroeconomic shocks appear to explain most of the historic movements in *output* and *credit supply* shocks. It also appear to have been important, especially over the past 10 to 15 years. This is clearest when one separates the average monetary policy response in Figure 5.7. Credit supply shocks, adding to GDP growth during the pre-crisis period, played a significant role in driving weak GDP growth during the financial crisis. Interestingly, the charts show that monetary policy was moving to offset the impact of those shocks in both the pre and post-crisis periods. The contributions from monetary policy shocks, however, suggest that the zero bound may have meant that the initial response of policy (to all shocks) was lower than that might have been expected. Much of the initial slowdown in growth in late 2008 and early 2009 appears to have been the result of a negative demand shock. That could reflect the effect of overseas credit supply shocks on world demand, as also found in Helbling et al. (2011). Looking at both VD diagrams, the chart that displays regime 2 highlights the importance of the credit supply shocks over the monetary policy shock. There is also an element of evidence in policy regime 1, although the sector was not as prominent as the post-inflation-targeting period.

5.6.3 Robustness and Plausibility Checks

This section discusses the robustness and plausibility of results that refer to the central case assumptions against two alternative specifications based on altered identifying restrictions. Identification using short-run restrictions places zero on A_0. There are some drawbacks of this identification scheme, although no consensus is reached yet. In particular, standard DSGE models rarely provide such zero restrictions (Canova and Pina, 2005). Long-run restrictions may also incompletely disentangle permanent and transitory shocks (Cooley and Dwyer, 1998). The alternative identification strategy is through employing sign restrictions to provide a more solid bridge between economic theory and the VARs. It is, therefore, plausible to check robustness and acceptability of the econometric results obtained based on the zero contemporaneous restrictions.

Sign restriction achieves identification by restricting the sign (and/or shape) of impulse responses to structural shocks[107]. Economic theory, as in DSGE models, contain a large number of sign restrictions usable for identification purposes. The key assumption in this identifying restriction is that financial market shocks have no contemporaneous effects on *output*. Using the sign restrictions, the study tests the robustness of this assumption by considering the alternative scheme based on the assumption that financial market variables react to the macroeconomic shocks with 2 months' lag. *Credit* and *equity price* responded to financial market shocks in the first period. These are probably less palatable restrictions for identifying the macroeconomic shocks but it would allow gauging how much the contemporaneous sign/timing restriction on the credit supply shock might be accounted for its impact. The sign restriction that accounts for the movements of impulse and responses are shown in Table 5.7 below.

Table 5.7 Summary of Identifying Restrictions under the Alternative Assumptions

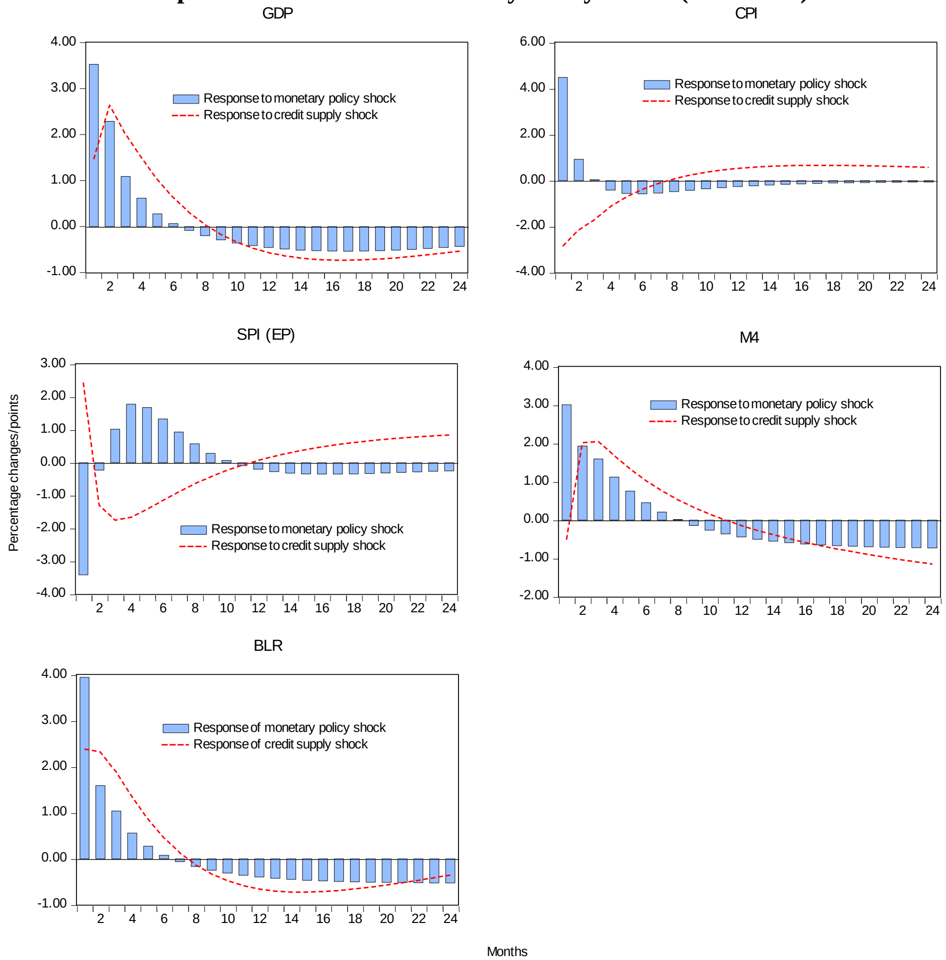
Shocks/Variable	GDP	CPI/RPI	CRED	SPI (equity price)	Policy rate	M4
Aggregate supply	-ve	+ve	?	0	?	0
Aggregate demand	+ve	+ve	?	0	?	0
Monetary policy	?	?	-ve	?	1	0
Credit demand	?	+ve	-ve	?	0	-ve
Credit supply	?	?	1	?	-ve	+ve
Equity price	?	?	?	1	+ve	0

Source: author's analysis, "?" represents a sign that could be either "-ve" or "+ve" depends on circumstances.

The robustness checks based on the alternative sign restriction produce similar results to the benchmark SVAR models in the pre and post-1992 policy regimes. The impulse response analysis reported in Figure 5.8 show that a credit supply shock pushes up on inflation and has a larger impact on credit than an equivalently-sized monetary policy shock. Responses to the monetary policy shock under this identification schema, however, is different from the baseline model. The *output* response of a monetary policy shock is as strong as the response to a credit supply shock. The inflation response is implausibly large relative to the impact on *output*. The inflation response lasts for about 10 months then becomes similar in trend with the response to the monetary policy shock. This suggests that the monetary policy shock is quite sensitive to the sign/timing restrictions whereas the credit supply shocks have similar quantitative impacts across the sign/timing specifications. As shown in Figure (5.8), the IRFs produced based on structural sign restriction produces a fairly similar replication of the IRFs based on the contemporaneous restriction. Focusing on output and price, both monetary policy targets responded more to the credit supply shock than the monetary policy shock.

[107] See Faust (1998); Canova and De Nicolo (2002); Uhlig (2005).

Response to Credit and Monetary Policy Shock (Post-1992)



Response to Credit and Monetary Policy Shock (Pre-1992)

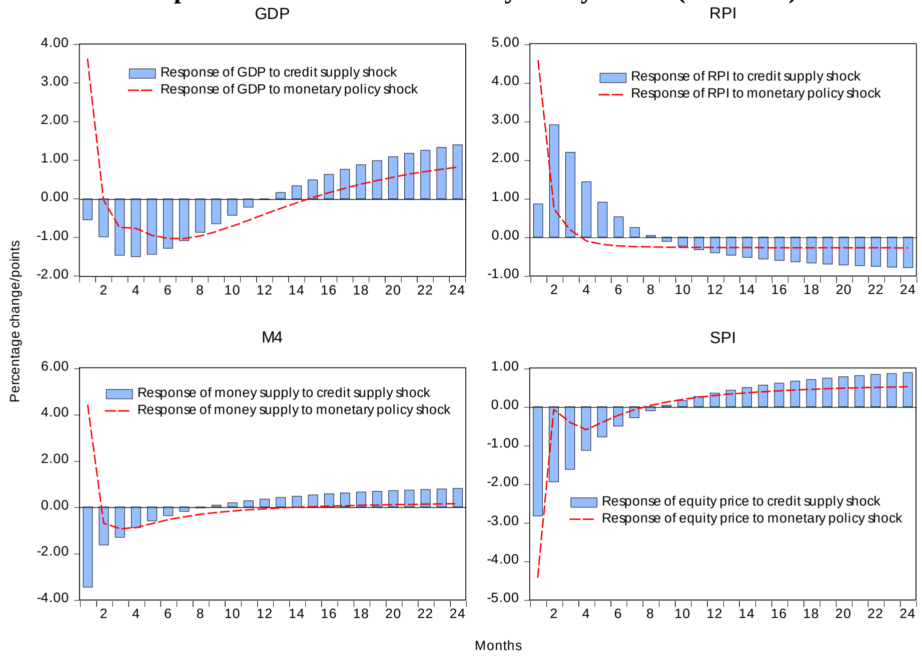


Figure 5.9 Responses to Monetary Policy and Credit Supply Shocks

IRFs based on sign restriction for median responses of GDP (%), inflation (percentage points), CPI (%), Money Supply (%), and Equity Price (percentage point) to MP and credit supply shocks. SVAR Impulse Response based on 95% confidence interval.

Source: author's analysis.

The IRFs of the time/sign restriction also provide further evidence that output and price respond to the opposite direction for credit supply shock (see GDP and RPI charts), while moving equitably to the same direction for monetary policy shock (see GDP and RPI charts in the third and fourth column). The outcomes of the IRFs confirm that credit supply shock behaves as an aggregate supply shock while monetary policy shock is characterised by an aggregate demand shock. This confirms that the outcomes in policy regime 1 and policy regime 2 are valid and reliable. Similarly, the credit supply shock is recognised as an aggregate supply shock that causes negative correlation between *price* and *output*, while monetary policy shock results in positive correlation between the movement of *price* and *output* in the transmission mechanism.

Quantitatively, the monetary policy shock in the pre-1992 (pre-IT) period moves output to -1.0 unit, price (retail price index) moves towards -0.5 unit. In the long time horizon, output moves upward crossing the zero baseline at exactly 15 months, while price remains below the zero baseline. This is a characteristic of aggregate demand shock. In the same policy regime, when credit supply shock moves *price* to about 3.0 unit level, *output* reduces to 1.5 unit level (see GDP and CPI charts). This opposite relationship is a feature of aggregate supply shock. As shown in the charts (Figure 5.8), the response of *price* and *output* to credit supply shock moves in opposite directions with output moving to -1.5 unit while price moves upward to 3.0 unit (see GDP and CPI charts in pre-1992). Money supply and share price index moves similarly to both credit and monetary policy shocks except during the first 2 to 3 months.

In the post-1992 policy regime (see Figure 5.8), a fairly similar characteristics are observed. *Output* and *price* responded in exactly opposite manner with -0.5 unit and +0.5 unit, respectively, in the short and long time horizons to the credit supply shocks. The response to monetary policy shocks moves the two target variables in the same direction of -0.5 unit and -0.5 to 1.0 unit, respectively. *Share price index* responded negatively to the credit supply shock for about a year, reducing to 2 units below the zero baseline. Money supply increases to 2 units and remains above the zero baseline for about a year then declines below the baseline. This implies that the *share price index* (financial market) reacts negatively without lag for about 1 to 2 months to a credit supply shock but gradually increases once the market is settled. This could be due to the impact of market speculation.

As a credit control mechanism, money supply is expected to respond positively to provide additional credit when there is credit supply shortages. It is followed by gradual decline as the impact of the shock decreases in the financial market. The bank lending rate in the credit channel responds similarly to both monetary policy and credit supply shocks for about 8 months then remains below the zero baseline. The intuition behind this is that banks are impacted by both monetary policy and credit supply shocks to adjust their lending rate in order to maintain their expected revenue and profit. Overall, the aggregate supply and aggregate demand simulations of monetary policy and credit supply shocks are clearly depicted in the post-1992 than the pre-1992 period. This is specifically, due to the adoption of the inflation targeting policy in 1992, which was followed by the 1997 BoE independence.

The robustness checks highlight the role of credit supply shocks and its impact on target variables. The importance of the credit channel highlights the depth and extent of the recent GFC and provides information on the real consequences of the financial market shocks. Although the credit channel and its effect on the real economy is moderately understood from a theoretical perspective, investigating their quantitative impacts on the real economy is vital. Unlike previous studies, this investigation disentangles the credit channel into the bank lending channel and the balance sheet channel, which represents credit providers such as banks and borrowers net worth such as firms, respectively. As shown above, the credit supply shock is found to cause a stronger response of output, price, share price index, money supply and the bank lending rate. This implies that the credit channel is the strongest channel in the monetary policy transmission mechanism that not only transmit but also accelerate and propagate the monetary policy shocks that affect output and price more than the impact of MP shock alone. The study of the role of the credit channel and its conduits is able to quantify the responses and account for the financial market frictions. Thus, it is worth investigating this channel and its interaction in the MTM. The following section investigates the role of the credit channel in the UK monetary policy transmission mechanism and financial system through evaluating the balance sheet and the bank lending channels. The outcome of the investigation highlights the source of major macroeconomic and financial shocks pass through before hitting the policy targets. As the two conduits of the credit channel represents the role of the lender and borrowers, the magnitude of the shocks pass through the bank lending channel and the balance sheet channel insights the specific contributions made by the financial institutions and firms in the economy.

5.7 The Credit Channels and their Interactions

It is important to note that the trade, financial and uncertainty channels rarely operate in isolation. Instead, they are active simultaneously, and feedback loops among channels that can amplify the effect of shocks. The uncertainty channel, in particular, amplifies both trade and financial mechanisms. Therefore, it leads consumers and firms to be unsure about what the ultimate effect of world shocks will be. A financial shock such as an isolated failure of a financial institution abroad might be transmitted through the credit channels. Nevertheless, it could also affect households and firms sense of economic uncertainty. The study by Taglioni and Zavacka (2013) suggest that if domestic agents become more uncertain in response to events abroad, this can amplify their response to shocks, via second-round effects through the trade and financial channel. They also find that exporters' production plans are heavily affected by their uncertainty about the foreign trading environment.

Previous studies attempted to quantify monetary transmission strength using VAR models to measure the responses to an unanticipated tightening of monetary policy and then used forecast error variance decomposition (FEVD) obtained from these models for inference (Christiano et al., 1999; Kim and Roubini, 2000, hereafter, KR). They measure the strength of MTM using the percentage of variations in output explained by monetary policy. Most of these studies analyse one country or a group of similar countries. Cecchetti (1999) uses the maximum response of output and inflation as a measure of monetary policy effectiveness. This study follows the latter approach to approximate the MTS by the maximum amplitude of output response of a 100 base unit's response to the monetary policy shocks. This method is preferable to FEVDs when analysing a one-country case. This is because, countries are at different stages of development and their economies face different degrees of uncertainty and disturbances. Using a single method across countries could result a misleading outcome, as the variation may not be only due to the amplitude but also their economic structure. Previous studies (Bernanke and Gertler, 1995; Baum et al., 2003) put significant emphasis on identifying retrenchment in the credit supply when addressing the importance of the credit channel of the MTM from shifts in supply resulting from a credit channel.

Monetary policy triggers changes in macroeconomic variables through the transmission mechanism. Although different arguments exist on the monetary transmission channels, the two prominent views on MTM, the so-called "*money view*" and "*credit view*" (see Ch-3), have been accepted by most macroeconomists (see Taylor, 1995). The traditional 'money view' works through the interest rate channel, money channel, and exchange rate channel and the 'credit view' works through the bank lending channel and the balance sheet channel (see Figure 5.10). The asset price channel that works through wealth effects due to the monetary policy and the expectations channel is determined by the agents' rational expectations. The working of these channels provide insight on how the monetary policy functions in the real economic environment. CEE (1999) explain that monetary policy decisions and the economic events after them are the effects of all the shocks to the economy. Thus, to explore the effects of monetary policy on the economy is to test the effects of monetary policy shocks that causes further movements in the transmission channels.

The study employs the methodological approaches in the form of VAR, VEC and SVAR models, following Bernanke and Blinder (1992), and Iacoviello and Minetti (2008). The methods are employed to measure the effects of credit supply shocks in the MTM. The study examines the differential effects of monetary policy shocks on credit activities (money supply, loans and cost of capital) and macroeconomic activities (output, consumer price index, and exchange rate). The research estimates six VAR and VEC models and identifies the credit channel as the most important channel. The channel transmits, accelerate and propagate monetary policy impulses in the transmission mechanism. Since the seminal paper of Bernanke and Blinder (1988), macroeconomic literature has shown a renewed interest in the credit channel of monetary policy TM in the post-crisis period. According to this view, widespread imperfections in the credit market, such as asymmetric information and imperfect contract enforceability, causes consumers and firms a wedge between the opportunity cost of internal funds and the cost of external funds. In turn, this external finance premium depends on monetary policy.

Tight monetary policy that raises market rates of interest and the external financial premium discourages investment and consumption. The explanation of this link can be seen in two conduits. *First,* the *balance sheet view* asserts that monetary policy affects borrowers' net worth and debt collateral. According to this view, the bridge between monetary policy and the external finance premium is represented by the financial position of borrowers. A conservative monetary policy affects borrowers' net worth, by either reducing their current cash flows (increasing interest on debt burdens) or the value of their pledgeable assets. This feeds back to the external finance premium required by external lenders. Tight money drains reserves and retail deposits on the liability side of banks' balance sheets so banks could respond by increasing their funding through managed liabilities (such as certificates of deposit) or shrinking assets (loans and securities). According to Iacoviello (2011) and Iacoviello and Minetti (2008), in the presence of an upward sloping supply for managed liabilities, banks may find it too costly to fully offset the reduction in retail deposits and opt to reduce their assets. *Second*, according to the *bank lending view*, monetary policy works by affecting bank assets (loans) and bank liabilities (deposits). Monetary policy not only shifts the supply of deposits but also shifts the supply of bank loans (see Bernanke and Gertler, 1995 for a review of the credit channel).

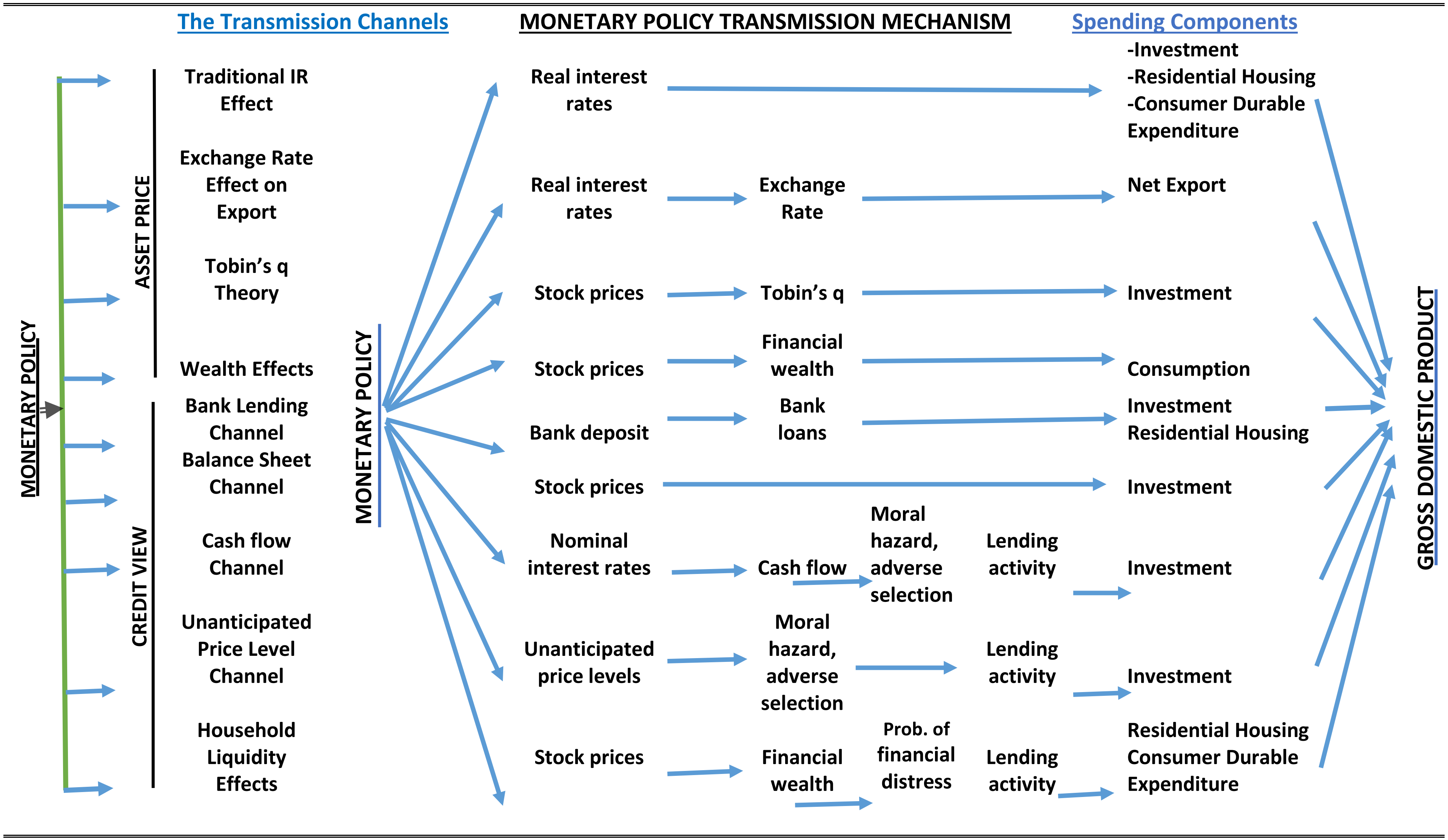


Figure 5.10 The Link Between Monetary Policy and GDP in the Transmission Mechanism

Source: author's adaptation.

Expansionary monetary policy, for example, increases bank reserves and deposits also increases the quantity of bank loans which ultimately investment spending and aggregate output. The main argument behind this channel is that the impact is relatively stronger on loans than on securities. It is well documented that loans and securities are imperfect substitutes because loans are riskier and less liquid. Consequently, tight money causes an inward shift of credit, causing shrinkage of supply that affects borrowers with limited access to non-bank sources of external funding.

To enhance the empirical relevance of both conduits of the credit channel, the bank lending and balance sheet channels have been incorporated into general equilibrium models through costly-state-verification (see Bernanke et al., 1999). A key result from these models is that the strength of both channels and therefore the broader credit channel increases with the level of financial frictions. In the presence of financial frictions, where costs of monitoring (state-verification-cost) are more prominent, monetary policy has a larger impact on external finance premiums through the credit channel. It is important to emphasise that previous studies have failed to identify the credit channel as a distinct alternative to the other channels of the MTM, such as the more traditional cost of capital channel (Bernanke and Gertler, 1995). Rather, it is argued to be a mechanism in which frictions in credit markets amplify the effect of monetary policy on real economic activity (see Figure 5.10).

5.7.1 The Balance Sheet and the Bank Lending Channels

Iacoviello (2005) analyses the transmission of monetary policy in a general equilibrium framework based on the assumption that the strength of borrowers' balance sheet affects their debt capacity. Bernanke and Blinder (1988) provide a theoretical analysis of the bank lending channel (BLC) in an extended IS-LM framework. To assess the presence and strength of the transmission channels, this study estimates six AR and EC models. The models uncover the two credit conduits of the UK transmission mechanism. The cointegration vector established the long-run relationship between these variables. For vectors with no cointegration relationship, the VAR model is used to establish the autoregressive relationship. For vectors in VARs that are integrated with order I(1), and if there is enough evidence that cointegration relationship exists, the VECM estimates the impulse response and variance decomposition functions. Following Iacoviello and Minetti (2008), and Iacoviello (2011), a VAR in level is estimated for variables *Real Output* (GDP_t), *Price* (CPI_t), *Monetary Policy Rate* (MPR_t), *Asset price* (AP_t), *Housing Loan* (HL_t −real asset/housing loans from banks), *Spread* (SP_t) and ratio of *HL from non-FIs to total HL* (MIX_t). All variables are defined as logarithm except for the interest rates and CPI inflation. The vector of endogenous variables is:

$$Y_t = (GDP_t, CPI_t, MPR_t, AP_t, HL_t, SP_t, MIX_t)'. \tag{5.25}$$

When more than two variables are considered, more than one cointegrating relationship is expected to exist among the variables so the VEC model allows multiple error correction terms in each equation. Therefore, the VECM is defined as

$$\Delta Y_t = A(L)\Delta Y_t + \Lambda Y_{t-1} + \varepsilon_{t,} \tag{5.26}$$

where L is the lag operator, and ε_t is an error term. The rank of Λ is defined as $\Lambda = \alpha\beta'$, where α and β are $p \times r$ matrices, and p is the number of variables in Y, is denoted by r. β is a vector of cointegrating relationships, and α is a loading matrix defining the adjustment speed of the variables in Y to the long-run equilibria defined by the cointegrating relationships of each of the VAR combinations. The optimal lag length is selected based on all criteria and take the most common lag number. Each VAR combination has different level of lag lengths based on the common lag length taken from the Information Criteria. Bernanke and Blinder (1988), in their model, describe the demand side of an economy with a given price level. As an extension of the IS-LM, Bernanke and Blinder's model can be augmented with an aggregate supply equation like the usual IS-LM[108] model. The balance sheet equation of banks in this model is:

$$B^b + L^s + E = (1-\tau)D, \tag{5.27}$$

where B^b are bonds held by banks, L^s denotes supply of loans, E denotes excess reserves, τ is the required reserve rate, and D are deposits of non-banks. As in Holtemoller (2002), an equilibrium on the credit market can be characterised as follows:

$$\underbrace{\lambda\left(R^{l^+}, R^-\right)(1-\tau)D}_{L^S} = \underbrace{L(R^{l^-}, R^+, Y^+)}_{L^D}, \tag{5.29}$$

The supply of loans depends negatively on the interest rate on bonds R, positively on the interest rate on loan R^l , and on the amount of deposits not needed to fulfil the reserve requirement. $\lambda(R^{l^+}, R^-)$ is a function comparable to the money multiplier. The demand for loans L^D depends negatively on the interest rate on loans and positively on the interest rate on bonds, and positively on the scaling variable income, Y. Combining equilibrium on the money market and on the credit market with the IS equation yields commodity-credit relationship which is commonly known as the CC relationship:

$$Y = Y(R^{l^-}, R^-). \tag{5.29}$$

The interest rate on loans depends positively on the interest rate on bonds and income, but negatively on money supply M^S, which is considered as exogenous policy variable in this model:

$$R^L = R^L(R^+, Y^+, M^{S^-}). \tag{5.30}$$

[108] The LM relation, which describes output-interest rate combinations for which money supply and money demand are equal at a given price level, as well as the IS equation describes output-interest rate combinations for which the planned and actual expenditures on output are equal.

The bank lending channel focuses on the importance of bank lending and is summarised as follows: restrictive monetary policy has an impact on both the LM and the CC relationships so the interest rate on loans increases and income decreases. The effectiveness of the bank lending channel depends on three conditions: (a) loan supply has to react on monetary policy actions, (b) non-banks have no perfect substitutes for bank loans, and (c) expenditures of firms and households depend on loan supply[109]. Bernanke et al. (1999) model the balance sheet channel (BSC) and specify a DSGE model with nominal rigidities, monopolistic competition, and a credit market with heterogeneous agents. They argue that firms have the possibility to borrow from banks or to finance their investments by internal financing. Due to monitoring costs, the external finance premium depends on net wealth of the borrower. The variation in the EFP enlarges the effects of monetary policy, which is known as a financial accelerator. The effectiveness of the balance sheet channel depends on two operative conditions, if (a) monetary policy has a systematic impact on the EFP and (b) the EFP does systematically affect aggregate output. It is also important to note that the presence of BSC has microeconomic implications. Under the assumption that the EFP of different borrowers is not affected in the same way, monetary policy does not only change the aggregate level of economic activity but also the income distribution. Therefore, it is plausible to assume that the monetary policy effect on the financing costs of households and small firms is stronger than on the financing costs of big firms (Holtemoller, 2002).

5.7.2 The VAR and VEC Models of the UK Credit Channel

There are six VAR/VEC models estimated to determine characteristics of bank lending channel and balance sheet channel. The first VAR/VEC represents the benchmark model that includes the variables under consideration. Following Iacoviello and Minetti (2008) and Iacoviello (2005)[110], and the above supply and demand relationships of the two credit channels, the major 'four' VARs are constructed as follows:

The First VAR/VEC Model (also called loans DSE):

It includes *GDP*, *CPI* inflation, *short-term interest rate*, *real asset prices*, *housing loans* (banks and other FIs, and total loans by banks and other FIs). The assumption behind the *loan system equation* is that tight money reduces loans, which causes a fall in loan demand and is consistent with the

[109] See Bernanke and Blinder (1988); Kashyap et al. (1994); Bardsen and Klovland (2000); Iacoviello and Minetti, (2008).

[110] The identification process in this study follows Gali (1992), Gerlach and Smets (1995) and Angeloni et al. (2003). They identify periods of tight money using a combination of long-run restrictions (corresponding to the long-run neutrality of monetary shocks), of the widely used short-run restrictions such as delays in the effects of interest rate shocks on GDP, and prices. See also Christiano et al. (1999), and Rotemberg and Woodford (1997) for models that generate long-run monetary neutrality while being consistent with the assumption that contemporaneous output and the price level do not respond to a monetary policy shock.

traditional MTM. A reduction in loans is not a necessary condition for a credit channel as external sources can provide alternative credit to households to compensate a reduction in wealth by borrowing. Hence, tight money could increase loan demand that could overwhelm any contraction in loan supply resulting from a credit channel (Iacoviello and Minetti, 2008). The housing loan is included in the first VAR/VEC model of the loan system equation to account for the quantitative relevance of a possible credit channel in the transmission mechanism.

The Second VAR/VEC Model (also called Spread DSE):

It includes *GDP*, *CPI inflation*, *short-term interest rate*, *real asset prices* and *the Spread* between a mortgage interest rate on housing loans and a benchmark interest rate. The selection of these vectors is based on a theoretical background that a rise in the Spread between the mortgage rate and a safe rate of comparable maturity (e.g., a government bond) could capture the increase in the EFP associated with a credit channel, specifically the BSC. Furthermore, in the *lending rate system equation*, the Spread between mortgage rate and a long-term benchmark rate represents a time varying liquidity premium, which is not associated with agency or monitoring costs as in the case of asymmetric information theory. The study tackled this issue by matching the maturity of the benchmark safe rate with the actual length of fixity of the mortgage rate. This dynamic system equation is also called *Spread system equation*.

The third VAR/VEC Model (also called MIX DSE):

Includes *GDP*, *CPI inflation*, *short-term nominal interest rate*, *real house prices*, and the *ratio of housing loans* by all ‘‘non-depository’’ financial institutions and the state to all housing loans. As in IM (2008), the term MIX is given to differentiate the system equation from the loans and Spread system equation. The Mix will plausibly increase as households try to compensate the reduction in bank mortgages with mortgages by other institutions. However, in the presence of imperfect substitutability between bank and other mortgages, this compensation is likely to be partial and the reduction in bank supply could affect demand for housing loan that households need to meet their housing demand. Therefore, the VAR/VEC process of the MIX requires two steps to analyse whether monetary policy affects the MIX (*VAR 3*), and if so to analyse whether changes in the MIX affect the housing market (*VAR 4*). This stage is also called a *Mix system equation* as the households mix two loans of two sources. Two strands of the credit channel are identified at this stage as (i) VAR/VEC that includes SIR and (ii) VAR/VEC that excludes SIR.

The Fourth VAR/VEC Model (second version of MIX DSE):

The fourth set of VAR/VEC model tests if monetary policy affects the MIX. This VAR/VEC model includes *GDP*, *CPI inflation*, *external finance MIX* and *real asset prices*. The variable combinations in the model help to look at the effects of an exogenous MIX, called an EFP. If the MIX has, any explanatory power in an asset price reduced form equation that includes income and inflation, its incremental explanatory power supports the existence of an independent bank lending channel[111]. The analysis of the finance MIX was first proposed by Kashyap et al. (1993), also used by Iacoviello (2005), who analysed the response of the MIX between bank loans and commercial paper to innovations in the FF rate. This has been used in the analysis of a lending channel in the automobile market (Ludvigson, 1998). Oliner and Rudebusch (1996) also note that the MIX does not completely solve the endogeneity problem because a change of the Mix could capture a change in the quality composition of borrowers. Suppose that banks specialise in funding households with a weak financial position; an increase of the Mix after tight money could reflect a ‘‘flight to quality’’ from risky households to households with a stronger financial position. In this case, the increase of the MIX would be the result of the working of a households’ balance sheet channel rather than a bank lending channel. Therefore, whenever the combined evidence from the third and the fourth VARs indicate the presence of a bank lending channel, a robustness analysis is carried out to test this alternative explanation (see Table 5.8). In particular, evidence on risk of mortgages[112] is used in order to assess whether depository institutions fund riskier households than non-depository ones. Moreover, the inclusion of MIX in the model reflects the heterogeneous demand pattern of different cohorts of households. According to Iacoviello and Minetti, (2008), the depository and non-depository institutions have no systematic tendency to finance groups of households with different structural characteristics.

Asset prices are used in all the specifications as a cyclical indicator. There are reasons to believe that asset prices are more suitable to this analysis. *First,* since quantitative in the housing market, adjusting sluggishly, prices could be more informative in capturing changes in housing demand in the short-run. *Second*, house prices can play a crucial role in the transmission of monetary policy through credit supply shifts. On one hand, house prices affect borrowers’ wealth and credit capacity[113], on the other hand, they influence lenders’ net worth and, potentially, the amount of credit they extend. Specifying the VARs using quantities rather than prices would omit these interactions.

[111] The STIR is not included in this equation (as in Ludvigson, 1998). In the presence of the STIR, changes in the MIX marginally reflect non-monetary effects. If the BLC is operative, then MP should affect the MIX, and the MIX should affect the asset prices, but there should be no reason to expect that the MIX affects asset prices when some variables that captures MP stance is included in the VAR. Therefore, the innovation in the MIX captures both MP shocks and non-policy induced shocks such as credit crunch episodes (IM, 2008).
[112] As proxy - by the default ratio of mortgages, by the number of repossessions, or by the amount of loan loss provisions made by mortgage financiers.
[113] See Aoki et al. (2004), and Iacoviello, (2005), for a theoretical model.

Table 5.8 Variables and the Identification Scheme for VARs 1 to 5

VAR/VEC Models	Variables included	Identification of	Identification scheme
1	GDP, CPI, interest rate, real asset prices, real total loan from banks (loans system equation)	Monetary policy shock,	-Short and long-run restrictions, assuming monetary shock does not affect GDP and CPI simultaneously. It has no impact on all the variables in the long-run.
2	GDP, CPI, interest rate, real asset prices, mortgage rate (Spread system equation)	Monetary policy shock,	-Restrictions of short and long-run time horizons,
3	GDP, CPI, interest rate, real asset prices, MIX (MIX system equation)	Monetary policy shock,	-Combinations of short and long-run restrictions,
4	Mix system equation without interest rate	Mix shock,	-Recursive system: assuming the MIX shock does not affect GDP and CPI simultaneously.
5	GDP, CPI, MIX, real asset prices [test of BLC & BSC]	Mix shock,	

Note: variables: GDP (real GDP), CPI (consumer price index), MPR (monetary policy rate), AP (real asset/house prices), HL (real asset/housing loans from banks), LB (real total loans from banks), SP (mortgage rate, RM, minus benchmark safe rate, RL), MIX (ratio of housing loans from ''non-banks'' to total housing loans).
Source: authors' representation in the spirit of IM (2008).

Identifying the Shocks in the Credit Channel

The monetary shocks in the structural VARs 1 to 3 are identified using a combination of short and long-run restrictions. In particular, the study adopts the common trends approach proposed by King et al. (1991). The approach uses the cointegration properties of the data to achieve identification using both short and long-run restrictions. When a group of variables in a VAR is cointegrated, a useful specification for the dynamic system equation is a Vector Error Correction Model (VECM). A VECM places reduced rank restrictions on the matrix of long-run impacts from a VAR. KPSW (1991)[114] separate between structural shocks with permanent effects on the level of the variables from shocks with only temporary effects. As discussed in Chapter 4, the permanent shocks are those that do not revert to the equilibrium trend line, showing that there is a long-run comovement. Furthermore, these long-lasting shocks are sources of the common stochastic trends among the series (IM, 2008). IM also note that the number of these shocks equals the number of variables in the system less the cointegrating relationships between them. The remaining transitory shocks equal the number of cointegrating relationships (intuitively, a cointegrating vector identifies a linear combination of the variables that is stationary, so that shocks to it do not eliminate the steady state). The monetary shock is identified as a transitory innovation that does not affect GDP and CPI inflation contemporaneously, but that can have impact effects on all the other variables. In addition, to satisfy long-run neutrality of the shocks, both by having zero long-run effect on GDP (and the other real variables) and by keeping relative asset prices and consumer goods constant.

Therefore, GDP, CPI inflation, real asset prices and all other variables will revert to their initial steady state once the effects of the shock die out. The ADF unit root tests with structural break on

[114] Refers to King, Plosser, Stock and Watson (1991).

the levels of the series suggest that the variables are integrated of order 1. The results from the cointegration tests are mixed, but tend to indicate, in the first three VARs, at least three cointegrating vectors exist: one vector could correspond to a long-run stationary real interest rate (cointegration between nominal interest rate and inflation), another to a long-run cointegration between asset prices and output. The third cointegrating vector could hint, depending on the VAR, at a stable long-run ratio between HL and total loans (VAR 1), stationary Spread (VAR 2), stationary MIX (VAR 3). For this reason, the specifications select a common rank of 3, where the tests indicate four cointegrating vectors (see Table 5.9).

Table 5.9 Lag Number, Cointegration and Model Selection

AR Name	Variables	Lag Levels in VAR/VEC	Trace & Eigenvalue No. of Cointegration Eqn.	What Model
Benchmark	GDP, CPI, HP, BLOAN, BLR, STR/REV_STR, MIX, EXR	LR(7),FPE(7),AIC(8), SC(1),HQ(2)	Trace(3); Maximum Eigenvalue (2)	VEC
Loan System Equation	GDP, CPI, SIR, HP, HL, TL	LR(7),FPE(7),AIC(8), SC(1),HQ(2)	Trace(2); Maximum Eigenvalue (1)	VEC
Lending rate S. Equation	GDP, CPI, SIR, HP, HL, BLR	LR(7),FPE(5),AIC(8), SC(2),HQ(2)	Trace(2); Maximum Eigenvalue (2)	VEC
Spread S. Equation (FF)	GDP,CPI, SIR, HP, SP	LR(7),FPE(7),AIC(8), SC(1),HQ(2)	Trace(1); Maximum Eigenvalue (1)	VAR (differenced)
MIX S. Equation (with SIR)	GDP, CPI, SIR, HP, MIX	LR(5),FPE(5),AIC(8), SC(2),HQ(2)	Trace(1); Maximum Eigenvalue (1)	VAR (differenced)
Mix S. Equation (w/out SIR)	GDP, CPI, MIX, HP	LR(5),FPE(5),AIC(5), SC(2),HQ(5)	Trace(0); Maximum Eigenvalue (0)	VAR levels

Source: author's analysis.

The identification restrictions imposed on the monetary shock are similar to all other cases. Based on this, the first three VARs are specified in the form of a Vector Error Correction Model (VECM) with maximum Eigenvalue 2 and Trace 3 (as in Table 5.9). The following three models are identified as VARs at levels and log differenced. In all specifications, the identifying of tight money using short and long-run restrictions turn out to be successful. The contractionary monetary shock elicits a rise in the interest rate and a negative response of GDP and inflation, which are all suggestive of a tight monetary policy. As stated in Christiano et al. (2000), getting the selection scheme correct and in accordance with the MP theory, is an evidence of successful selection scheme. The VAR/VECM impulse responses account for the qualitative features of a wide range of monetary business cycle models in which monetary shocks have delayed transitory effects on economic activity. VAR 4 uses a recursive scheme to identify a MIX shock, ordering the MIX after GDP and consumer price inflation and before real house prices. Economic theory is silent about the permanent effects of a MIX innovation. The MIX system equation has two conduits, one with the SIR and the other without the SIR. This arrangement helps to identify the non-monetary policy impacts in the transmission mechanism, particularly of the credit channel.

The first stage of the analysis specifies the baseline model with five variables vector $Y_t = (gdp_t, cpi_t, ir_t, hp_t, mix_t)$. The VAR is estimated for the UK data from 1980Q1 to 2014Q4. The estimation sample is chosen to include pre-financial crisis and post-financial crisis periods, which helps to study the dynamics in the credit channel. It is a rational insight to deduce that the recent GFC may have affected the credit markets by reducing the market for securitised mortgage products. Specifically, this is the main reason why this Chapter is extended to address the role of the traditional transmission channel with greater emphasis on the credit supply shocks. The credit supply shock is associated with a change in the MIX. The sample period can be viewed as two distinct periods. As shown in Chapter 4, the pre-financial crisis has a lower probability of structural changes and low frequency of financial shocks on the credit market but the post-financial crisis has a reasonably higher probability of structural changes and high frequency of financial shocks.

The variables in the models are a mixture of stationary or integrated of *I(1)* as specified by ADF, KPSS, and ZA tests in the presence of a structural break. In order to eliminate residual serial autocorrelation, two lags are chosen as indicated by all lag length criteria (Akaike, Schwarz, Hannan-Quinn, Final Prediction Error and LR, see Appendix 5). The baseline model is estimated with two lags. As suggested by Sims et al. (1990), the VAR is estimated consistently in levels. The empirical analysis allows cointegration to minimise loss of information in the differencing process. The Johansen's test procedure is used to confirm the presence of cointegrating relationship. These are Trace statistics and Maximum Eigenvalue statistics. The Trace statistics tests the presence of cointegrating relationship against stationarity of the series while the Eigenvalue statistics tests the presence of "r" cointegrating relationship against the alternative "r+1" cointegrating relationship. Both types of Johansen's CI tests confirm that there is a sign of at least three cointegrating relationships in the series (see Table 5.9 and Table 5.10A to 5.14A). The benchmark, loan and the lending rate system equations have cointegrating relationships, so VEC model is the appropriate specification to determine IRFs and FEVDs. Furthermore, the stability test shows that the baseline VAR satisfies the stability condition as all roots of characteristic polynomial lie within the unit circle (see Appendix 5.16A).

5.7.3 The VAR and VEC Model Results and Discussions

The Impulse Response and FEVD Analyses

Figures 5.10A to 5.14A present the impulse response of all eight variables in the baseline model. The IRFs show the response to a short-term interest rate shock that accounts for a monetary policy loosening in the sample period. A loosening monetary policy shock has the commonly found effect on the interest rate. The short-term monetary policy rate decreases towards the end of the first year then increases for over two years then declines towards the end of the second year (see Figure

5.10A). It is also shown that the impulse response of the reverse of the short-term monetary policy rate increases following monetary policy loosening, meaning the true interest rate decreases during the first year of the short-run period.

Monetary Policy Shocks

It is shown that the monetary policy shock is offset by a gradual decrease in the interest rate followed by a period in which the SIR goes below the steady state. As Woodford (2003) indicates, such behaviour of the interest rate response is regarded as good monetary policy conduct. The monetary policy loosening decreases inflation in the first and second year, which is known as a "price puzzle". However, this effect is insignificant and is often observed in VAR studies for the UK. The impulse response of inflation behaves similarly to the one in Den Haan et al. (2007). They find that the price level sharply increases during the first two quarters after monetary policy tightening but returns to the original level within one year. Unlike the U.S. case, the 'price puzzle' is not widely observed and inflation has not increased significantly. This is consistent with the New Keynesian price stickiness theory, although a cost channel explains the increase in the price level following a monetary policy tightening (Barth and Ramey, 2002).

Output first increases following monetary policy easing, responding positively for a period of 12 quarters to the shock and reaching its peak after 2 years then declines. The impulse response of the MIX does provide evidence for the presence of a *bank lending channel*, particularly in the first 20 quarters after the shock. It responds significantly to a shock in monetary policy. Iacoviello and Minetti (2008) also find an immediate and significant response of MIX to monetary policy shocks for Finland, Germany, and the UK. They argue that financial liberalisation could have had a minor role in increasing the substitutability between retail deposits and wholesale funding in these countries. They also explain the significant positive relationship between the MIX and the monetary policy with the "low market efficiency of the bank funding". On the movement of MIX, Milcheva (2013) explains that in the first few quarters' both bank and market-based financial intermediaries take advantage of the low interest rates and provide more mortgage loans, so the MIX remains unchanged. On the other hand, financial intermediaries can increase mortgage supply due to cheaper funding. Consequently, the EFP could have decreased which means that the wholesale funding is cheaper than retail deposits on the margin. Thus, banks can start issuing non-reserve liabilities so they can provide more mortgages. In the UK case, there has been a positive and significant response of MIX, which can be explained as reasonably efficient financial market in terms of bank funding.

Credit Supply Shocks

Changes in the MIX could shift the EFP, financial frictions, facing bank-dependent borrowers independently from the bank lending channel of monetary policy. As shown in Figure 5.10A, the increase in the variable MIX may be due to either an increase in bank mortgages or a decrease in the market mortgages relative to total mortgages. Similarly, Halvorsen and Dag Henning (2014) note that the difficulty to visualise exogenous lending shocks, exclusive to non-depository lenders, is because of the fact that lending shocks do not encompass banks. An increasing mortgage supply by market-based financial intermediaries should then cause a house prices increase, as the shocks could have made banks to increase the supply of mortgage. However, they should have the reverse effect on the MIX. Thus, according to Halvorsen and Dag Henning (2014), if market-based lending shocks are present, the effects of the MIX shock on house prices would indeed be restrained and not overstated. As mentioned above, the MIX should not pick up mortgage demand shocks. As Abildgren (2012) notes, a change in mortgage demand would affect both types of credit in rough proportion and thus leave the MIX fairly unchanged.

If the MIX has any explanatory power in a house price equation that includes output, inflation and the short-term interest rate as controls, it could be associated with a shock to the availability of credit. An exogenous shock increasing credit supply is, for instance, associated with financial innovations (e.g. securitization) or changes in regulation, as emphasised by e.g. Atta-Mensah and Dib (2008), Gerali et al. (2010), and Peersman (2010). Financial innovation or regulatory arbitrage can lead to a reallocation of capital and to an unequal increase in mortgage supply by traditional banks and market-based financial intermediaries. Likewise, a positive credit supply shock can be associated with a strengthening of the financial position of financial intermediaries (as in Gertler and Karadi, 2011), a decline in credit default risk (as in Atta-Mensah and Dib, 2008; Christiano et al., 2010) or a decrease in risk aversion (Gilchrist et al., 2009; Peersman, 2010).

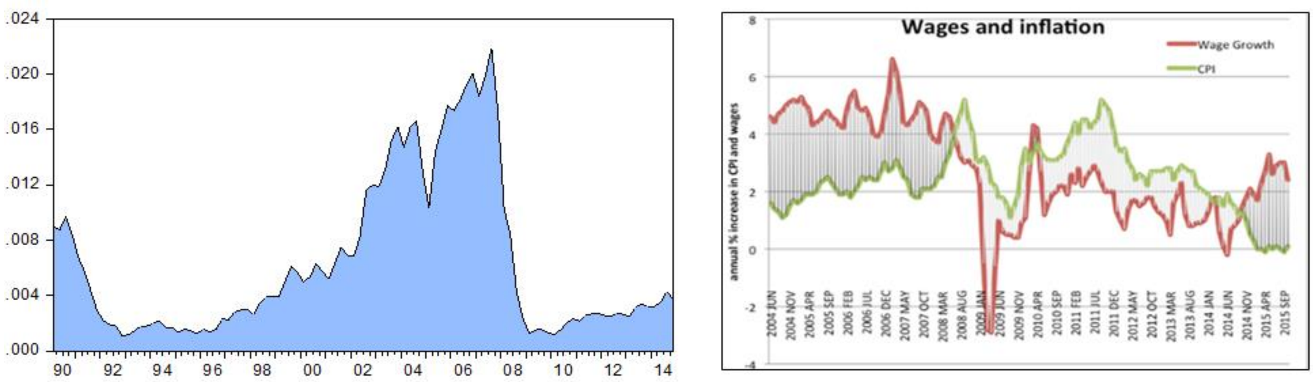
Figure 5.10A also presents the impulse responses of all variables from the baseline model to a credit supply shocks. The MIX increases immediately to 20 quarters following the shock then returns to its equilibrium level only slowly. One could argue that the credit supply shock could instead reflect changes in interest rates. However, it is not the case here as a shock to the Mix increases the MP rate, while loose monetary policy should have decreased it. The positive interest rate response is related to banks' funding dependency in the money market, as argued by Halvorsen and Dag Henning (2014). The response of the interest rate is insignificant and only slightly different from zero. Output increases slightly and insignificantly for about three and a half years. The results from the MIX shock differ slightly from previous research for Norway and the UK (see Halvorsen and Dag Henning, 2014). They find that a negative shock to a credit MIX has a significant effect on house prices only in the first two quarters. Furthermore, it leads to a significant decline in the interest rate. The authors also argue that the interest rate response could be associated with the more active response of the UK and Norwegian central banks that counteract the tightening in bank lending.

The following section discusses the VAR and VEC dynamic system models to highlight the outcome of the successive analyses.

5.7.4 Shocks Stemming from Marginal Changes of STIR

The First Attempt in VAR-01

The baseline VAR model that includes variables *gdp, cpi, hp, b-loan, blr, stir, mix,* and *exr* shows the presence of 3 Traces and 2 Maximum Eigenvalues is specified as a cointegrating type of the VEC model. Following the baseline VEC model, the first attempt in VAR represents the *Loan system equation*. The UK banking system is characterised by a banking model comprising banks and building societies with a market share of around 90%. As of the late 1980s, estate agents and centralised mortgage lenders have competed with depository institutions in mortgage provision. After the UK aggressive mortgage market in the late 1980s, these institutions, also called non-depository, have seen their market share decline in the 1990s (Iacoviello and Minetti, 2008). The major share of funds of the non-depository institutions[115], such as building societies, insurance companies, investment trusts, and mutual funds is came from the wholesale market. This is mainly to shield these institutions from increasing fluctuations in retail deposits. The UK, as studies show[116], has one of the fully integrated, and developed funding markets in the EU, which is known to have strong financial regulations (FR), although the FR has been questioned in the post-crisis period as it, failed to safeguard the market from the collapse of the world financial market.



Source: own analysis and ONS (2015).

Figure 5.11 The Mortgage Market Share of (1990 to 2014), CPI and Wage Movements

Evidently, Figure 5.11 shows how the mortgage market share has been growing exponentially from 1996 to 2008, particularly with high level of credit provision from 2006 to 2008 (see left side chart) while wage and price have remained stagnant before wage growth crashes in 2007/08. UK banks have reasonably easy access to the wholesale market and the constraint imposed on the wholesale

[115] Non-depository institutions sell securities or insurance policies to the public to fund their lending. Unlike commercial banks, they do not accept time deposits.
[116] See Diamond and Lea (1992); Iacoviello and Minetti (2008).

funding of building societies is not binding. The only major inefficiency in the UK banking system in the pre-GFC period (1980s and early 1990s), according to Diamond and Lea (1992), was due to the limit on the issuance of unsecured debt by Building Societies. There was a sharp rise of market rates in the late 1980s, which hits major lenders financially with heavy pre-payments, as they had to adjust their rates due to the changes in the funding rate index (Libor). As retail savings rates sluggishly responded to market shares, banks and building societies manage to avoid this adjustment (Lea et al., 1997). On the other hand, the mortgage market has a low efficiency with a market share of less than 10 percent non-depository institutions, which represents a small buffer to shield households from a reduction in mortgages from banks and building societies (Iacoviello and Minetti, 2008). Figure (5.11) also depicts how the mortgage market share increases exponentially from 2000 to 2007 until it drops sharply in 2008 due to the GFC followed by slow positive movement from 2012 onwards.

Intuitively, the evidence supports the existence of a credit channel in the form of bank lending channel. The presence of the *bank lending* credit channel leaves some room for a *balance sheet channel*. As shown in the evidence, tight money reduces impact on mortgages of depository institutions while total loans decline only slightly and with some lag. Figure (5.12) shows that real house prices, for instance, react negatively (as expected). In VAR-2 *Spread* is constructed as the difference between the average mortgage rate on mortgages (known as risky rate) and the 3-months Treasury bill rate (known as riskless rate). As the majority of mortgages in the UK have a reviewable rate at the discretion of the lender, a 3-month Treasury bill rate is used as a benchmark to compute *Spread* as the difference of the two rates. Table 5.10 reports Forecast Error Variance Decomposition of real BL, real HL, CPI inflation and other macroeconomic variables. The quantified decomposition illustrates that IR, IP, HP and BL, in order of priority, responded to contractionary MP. This implies that, apart from output and price, housing prices responded by up to 13 percent to monetary policy shocks.

Table 5.10 Forecast Error Variance Decomposition [Loan S E]

Period	S.E.	LOG(IP)	CPI	IR	LOG(HP)	LOG(RHL)	LOG(BL)
1	0.0085	0.4706	7.0448	92.4845	0.0000	0.0000	0.0000
2	0.0113	0.9645	10.364	86.2408	0.0639	0.0805	2.2853
3	0.0144	3.8270	10.590	78.5253	0.4364	0.2387	6.3821
4	0.0170	6.1076	11.1277	72.9380	1.4495	0.6395	7.7375
5	0.0198	8.0893	10.9905	69.4204	2.8562	0.8208	7.8225
10	0.0324	11.5738	9.5499	60.3698	10.9965	0.8941	6.6157
15	0.0419	11.8760	9.6514	58.0425	12.6880	1.1766	6.5651
20	0.0496	12.1692	9.8604	57.6592	12.6226	1.2280	6.4604
24	0.0546	12.2629	9.8966	57.3591	12.6990	1.3654	6.4167

FEVD of total Real BL, Real HL and other macroeconomic variables to a monetary contraction
Source: author’s analysis.

The addition of *Spread* and removing bank total loan and housing loan provide a preliminary insight to investigate the presence of a *broad credit channel*. VECM-02 runs from 1980Q1 to 2014Q4. This period includes the reforms of the system of UK's 1980s and 1990s housing finance: the 1986 Building Society Act, the 1990s inflation targeting, the BoE independence, and pre and post-crisis period. The response of *Spread* to a ±1 S.E. bands of monetary shock remains marginally positive for about 2 years. The FEVD (Table 5.11) of the monetary policy shock in VAR-02 *Spread system equation* shows that up to 10.6 percent of the MP shock is accounted to output, 9 percent and 8 percent to asset price and Spread shocks, respectively.

VAR02- Spread System Equation

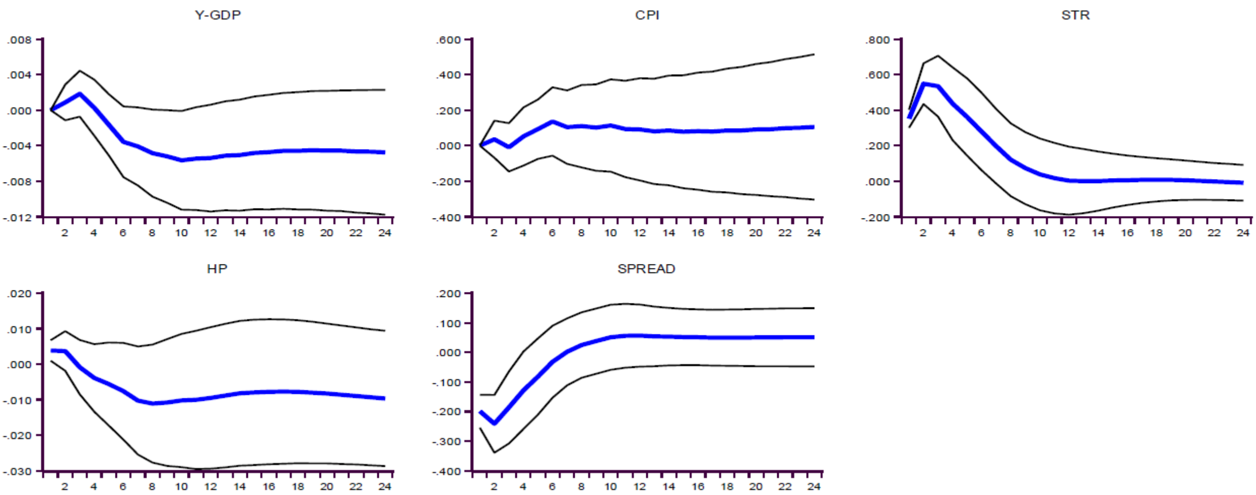


Figure 5.12 Response of a ±1 S.E. bands to a Monetary Policy Shock [Spread SE]
Response of the Spread between Mortgage rate and Long-term Safe Rate of Equal Maturity to a Monetary Contraction. Impulse Response based on 95% confidence interval.

Table 5.11 Forecast Error Variance Decomposition [Spread SE]

Period	S.E.	LOG(IP_UK)	CPI	R_UK	LOG(HP)	SPREAD
1	0.0085	0.1346	4.7749	95.0904	0.0000	0.0000
2	0.0111	0.4537	7.3052	91.5041	0.0246	0.7123
3	0.0139	3.2760	6.5526	89.4742	0.1994	0.4977
4	0.0163	5.6888	6.3670	86.8458	0.7172	0.3811
5	0.0192	7.1794	5.8085	84.9904	1.6955	0.3261
10	0.0314	7.7123	4.9544	75.5279	8.0511	3.7542
15	0.0395	7.7868	5.4296	71.5818	8.7351	6.4666
20	0.0458	9.4589	6.2107	68.9266	8.7257	6.6778
24	0.0503	10.6025	6.9329	65.9384	8.9977	7.5284

FEVD of MP shocks based on VAR-02, Spread System Equation of a monetary contraction
Source: author's analysis.

Figure (5.13), MIX system equation with monetary policy shock in the model, depicts that the variable MIX displays a brief decline for over a year then increases towards the long time horizon (24 base point). This implies that a fall in the mortgage supply of banks and BS was stronger than the fall in the mortgage supply of non-depository institutions. In the MIX system equation, the contractionary monetary policy increases price but decreases output. Housing price (HP) also decreases because of the rise in MP rate. The MIX system equation FEVD (Table 5.12) also reported that HP and MIX accounted for 13 percent and 35 percent of the shock, respectively. When MP rate is excluded from the model, a positive innovation in the MIX reduces Real House Prices (HP) significantly towards the baseline for over ten quarters (see Figure 5.14). Output, price and MIX also decline because of a one standard error change in MIX. The VAR-03 and VAR-04 results support the presence of a *bank lending channel.* On one hand, the causality from monetary actions to the MIX show that monetary policy can affect the competition of mortgage supply. On the other hand, the positive marginal explanatory power of the MIX hints at the relevance of the composition of external finance premium for housing demand.

VAR-03: Mix System Equation (with STIR)

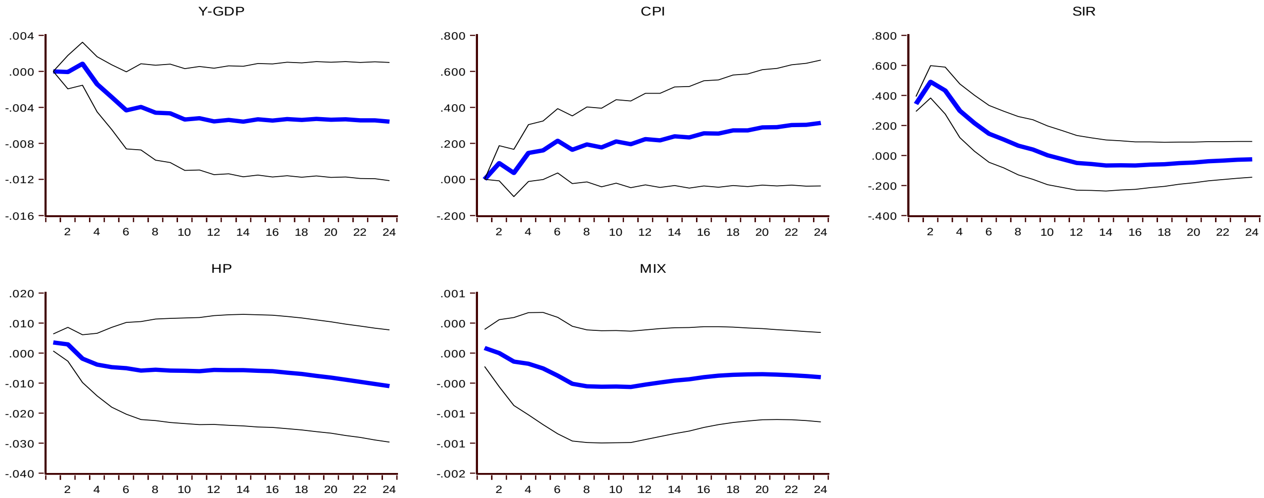


Figure 5.13 Response ±1 S.E. bands to a Monetary Shock [MIX SE, IR]
Response of MIX (housing loans from non-banks over total housing loans) to a monetary contraction.
MIX system equation. Impulse Response based on 95% confidence interval.

Table 5.12 Forecast Error Variance Decomposition [MIX SE, IR]

Period	S.E.	LOG(IP)	CPI	IR	LOG(HP)	MIX
1	0.0079	0.0218	7.6893	92.2887	0.0000	0.0000
2	0.0097	0.0409	11.7643	87.8056	0.0163	0.3727
3	0.0124	0.4047	12.8973	85.6378	0.0791	0.9808
4	0.0157	0.7541	14.2696	81.0207	0.8067	3.1487
5	0.0197	1.6519	13.4562	73.2221	2.5334	9.1362
10	0.0348	4.7132	7.8823	42.5057	11.618	33.279
15	0.0432	5.0397	8.2003	37.5893	13.296	35.874
20	0.0487	4.9416	9.3659	37.4523	13.082	35.157
24	0.0526	4.8925	9.8384	37.2839	13.123	34.861

FEVD MP Shocks based on VAR-03, Mix System Equation of a monetary contraction
Source: author's analysis

In the absence of the STIR, up to 20 percent of the shock is accounted for output while up to 63 percent is for MIX (see Table 5.13). This sheds some light that the bank lending channel is working in the absence of the interest rate channel. Given the high efficiency of the funding market, the relevance of monetary policy for the MIX would appear controversial. In this context, it would have been equally plausible to find a weak link between monetary policy and the composition of finance. Given the low efficiency of the mortgage market, the effect of the MIX on house prices is in line with reasonable expectations. After entering the mortgage market in the 1980s, non-depository institutions have seen their market share decline.

VAR-04 & 05: Mix System Equation (without STIR)

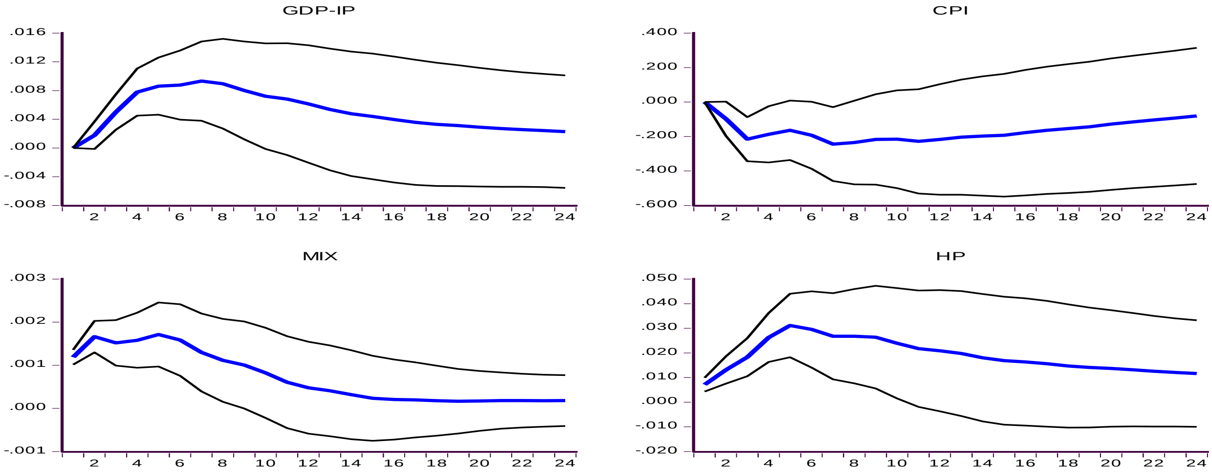


Figure 5.14 IRs of a ±1 S.E. bands to a Shock in the MIX Variable without STIR
Response of house prices to a positive MIX innovation. Impulse Response based on 95% confidence interval.

Table 5.13 Forecast Error Variance Decomposition [MIX SE]

Period	S.E.	LOG(IP)	CPI	MIX	LOG(HP)
1	0.0084	5.4213	0.0019	94.576	0.0000
2	0.0106	9.1899	0.1794	89.157	1.4732
3	0.0140	11.858	0.3474	85.265	2.5284
4	0.0177	12.795	1.2320	83.580	2.3922
5	0.0219	12.069	2.2227	82.848	2.8594
10	0.0360	11.890	5.7013	75.806	6.6016
15	0.0437	13.175	8.4018	70.799	7.6226
20	0.0493	16.322	9.6017	66.776	7.2998
24	0.0535	19.952	9.9085	63.251	6.8881

FEVD of monetary policy shocks based on VAR-04, MIX variable [MIX system equation]
Source: author's analysis.

As argued by Kashyap and Stein (1994), in the presence of non-negligible costs for switching from one lender to another, the argument of the ‘‘marginal’’ lender could fail and the relative sizes of the bank and non-bank intermediary sectors could matter. Taking all movements into account, the following tables (Table 5.14 and 5.15) set out the criteria for the presence of bank lending and balance sheet channels and summarises the presence and absence of these channels based on the VAR and VEC models. In summary, the evidence in Table 5.15[117] confirms the presence of both broad credit channel and the bank lending channel in the Germany and France financial sectors but

[117] Results for Germany, France and the U.S. are obtained from Iacavellio (2005) and Iacoviello and Minetti (2008).

Iacoviello and Minetti's (2008) investigation of the credit channel confirmed the absence of the credit channel in the US. However, this research, as in Iacoviello and Minetti (2008), discovered

Table 5.14 The Bank Lending and Broad Credit Channels in the UK

	Criteria	The Credit Channel in the UK	
The Broad Credit Channel	-MP shock has impact on EFP -The EFP affects output	Contractionary MP increases Spread Shocks in EFP systematically affects output to decline	-Meets both criteria. *Conclusions*:- The Broad Credit Channel exists in the UK,
The Bank Lending Channel	-Loan supply reacts on MP shock -Non-banks loan do not react to MP shock -Expenditure of HHs and firms depend on loan supply	-Loan system equation: BL reacts to MP shock, -HL also declines as Non-bank loan do not react to MP shock, -Mild reaction by households and firms,	-Meets at least 2 of the three criteria, the third criteria also met in some cases. *Conclusions*:- The Bank Lending Channel exists.

Source: author's review and representations.

the presence of a *bank lending* and the *broad credit* (*balance sheet)* channels in the UK. The evidences (see Table 5.15) also show that there was a significant response in bank total loan and housing loan, the difference between mortgage rate and the riskless benchmark rate (Spread), MIX-ratio of housing non-bank loan to total housing loan, total housing loan, and the real house prices.

Table 5.15 Summary Assessment of Four OECD Countries' Credit Channel

Country	Response to MIX increase					Which credit channel?	
	Bank loan And housing loans	Spread=bank mortgage-benchmark rate	Mix (Housing loans non-bank/Total Housing loans	Real house prices		Balance sheet channel (Broad CC)	Bank lending channel (Narrow CC)
UK	BL(↔)(↓) HL(↓)	Spread (↔)(↑)	Mix (↑)	HP(↓)	Conclusions	Yes/Possible (Likely)	Yes More evidence
Germany	BL(↓) HL(↓)	Spread(↑)	Mix (↑)	HP(↓)	Review	Possible	Yes
France	BL(↓) HL(↔)	Spread(↑)	Mix (↑)	HP (↔)		Yes	No
US	BL(↓) HL(↓)	Spread(↔)	Mix (↔)	HP(↓)		No/Possible	No

Source: author's analysis. The arrows represent the movement of each variable response.

With the exception of Spread and MIX, the responses in the credit market show some similarity with the U.S. The intuition behind this outcome is that the UK economy is a small open market influenced by external forces such as the U.S. economy. Most notably, the findings show that the narrow credit (BL) channel works more actively than the broad credit (BS) channel in the UK. More importantly, the balance sheet channel does not appear to show strong evidence which slightly contradicts to the common notion of what happened during the crisis. The balance sheet channel governs the strength of firms' balance sheet and their ability to borrow so the role played by this channel in the credit supply chain is found to be less significant as compared to the strength of the banks' balance sheet.

5.8 Conclusions

Structural VAR models are popular tools in the analysis of the MTM and sources of business cycle fluctuations. The traditional SVAR approach has been questioned in many grounds. Its mechanism in imposing restrictions upon the dynamics of the implied SVAR equations, its lack of orthogonal restrictions in structural innovations, the presence of huge number of parameters, and the structural equations that make the interpretation difficult and the inability to respond to an unexpected structural shifts. This study contributed to the existing literature by imposing further restrictions such as exclusions, recursive contemporaneous structure and accounting for unexpected structural shifts. A structural VAR that accounts for structural break is not a common practice. This study claims originality of its structural methods to the UK credit and monetary innovations, SVAR approach that accounts for the structural breaks to allow parameter movements, and the autoregressive and cointegration investigations of the credit channel. The cointegration model in the form of VEC is also employed to investigate the presence of the bank lending and balance sheet channels. Three of the five VAR investigations displayed long-run relationships that led to the estimation of VEC models to examine the UK bank lending and balance sheet channels.

The Chapter is presented into two parts. The *first* part investigated the behaviour of credit supply innovations in the framework of aggregate supply and aggregate demand shocks. The *second* part investigated the credit channel of the MTM and evaluated the presence of bank lending and balance sheet channels. Using an open economy Structural VAR model, it examined the endogenous relationships between credit and other key macroeconomic variables, in particular, monetary and credit policy of the UK economy. The IRFs and FEVD were used to discover the path and quantify the impact of shocks in the MEF factors on complete time path of the MTM. The IRFs and FEVD indicated that, at short time horizon, shocks to the interest rate, the exchange rate, and past shocks to credit are important to explain structural movements of credit supply. Over longer time horizons, shocks to output, inflation and commodity prices have greater role in the transmission mechanism. The research also discovered that the exogenous international shocks are responsible for a large proportion of forecast errors in the long time horizon. The model determined that a shock to the interest rate, increasing it by 20 base points would result in the level of credit being almost half of a percentage point lower after 11 base points. If monetary policy subsequently reacts in a manner consistent with its past behaviour, credit would continue to decline for about 50 base points (over four years), when it is almost 0.88% lower than the counterfactual level. It then slowly retraces from the declining trend. The timing of the response of credit appeared to be similar to that of inflation, reaching the maximum response after about 15 base points or five quarters.

The structural VAR model estimated for the pre and post-IT periods highlighted that, in response to shocks to credit and monetary policy played an effective role in stabilising the economy. The impact of the credit shock on output, price and the exchange rate was almost completely offset by the response of monetary policy. More importantly, monetary policy is not completely counteract higher inflation, which is above baseline for about two years after the shock to credit. However, inflation remains to be higher over this period when monetary policy was passive to the macroeconomic consequences of the credit shock. Changes in credit are also moderated because of monetary policy's response. The robustness checks based on sign restriction confirmed that the model is robust. It produced similar IRFs as in the zero contemporaneous restrictions and confirmed the role of aggregate supply and demand shocks. The first sample period spans to the financial deregulation and the adoption of inflation targeting. A further caveat is that the Killian-bootstrapped confidence intervals are relatively narrow except money supply (M4) in pre-1992 so making conclusive statement is plausible. Nonetheless, the model presents credible economic interactions, both in their timing and magnitude. The relaxed assumption of parameter invariant to volatility regimes helped to reduce "price puzzles" and other stability conditions. Accounting for structural changes in the SVAR model also aided to identify the specific and relevant impacts of monetary and credit shocks on price and output. The empirical analysis outcomes presented in the first part of this Chapter are based on both the central case assumptions of aggregate demand and supply shocks, and the time invariant assumption of structural parameters.

Both structural VAR models ($\mathrm{SVAR}^{\mathrm{REGIME}\ 1}$ and $\mathrm{SVAR}^{\mathrm{REGIME}\ 2}$) identified based on the contemporaneous zero and sign restrictions highlighted several qualitative and quantitative evidence: *first*, as a response to credit supply shock, prices and output move in fairly opposite direction. This implied that the UK credit shocks appeared to be more like aggregate supply shocks than aggregate demand shocks. A contraction in credit supply is likely to push down on GDP and up on inflation due to exchange rate effects, as shown in the IRFs and FEVDs. *Second*, credit supply shocks are likely to have direct quantitative effects that work over and above the impact on borrowing rates. This implied that more than the borrowing rates, credit supply shocks amplify the impact on lending through the cost of borrowing than the monetary policy shock. *Third*, in the run up to and the GFC, credit supply shocks appeared to be more prominent to explain most of the volatilities. The study also confirmed that, unlike the monetary policy arrangements, the aggregate supply disturbances are found to be the most important shocks than the aggregate demand shocks. Therefore, the long-run effect of the MP and credit shocks seemed to have forced credit supply shocks to contribute to the deviation of the mortgage rate from the benchmark riskless rates (also called *Spread*). This deviation is captured by aggregate supply shocks. If one assumes that this assertion is valid, it reinforces the above two concluding remarks. *Fourth,* the VAR and VECM assessments highlighted the role of a credit channel in the UK monetary transmission mechanism. The evidence in the *second* part of the study showed that the credit channel works through both the bank lending and the balance sheet channel, although the bank lending channel appeared to be the most prominent. This supports the argument that bank lending channel plays the major role in transmitting, accelerating and propagating the monetary impulses. The "Spread SE" showed that during monetary contraction, the interest rate shock accounted for more than 66% of the shocks to the credit market. On the other hand, the "MIX SE" confirmed that the housing price and the interest rate shocks accounted for more than 50% of the shocks. Furthermore, the "Loans SE" highlighted that the house price and monetary policy shocks play significant role in the UK economy. According to the third VAR "MIX SE", the MIX variables accounted for over 63% of the shock.

The study also confirmed that more than a third of the fall in output, relative to the pre-crisis period, could be explained by the aggregate supply shocks (credit supply shocks) than the aggregate demand shocks. The IRFs and FEVDs also quantified the range of impacts across the different identification schemes. The median and maximum oscillations of the specifications, which include quantity effects, suggested that the most likely impact from 2.5% to 5% of the total 10% fall of the UK GDP relative to trend includes the credit supply response to monetary policy impulses. Based on the criteria of the broad and narrow credit channels, the IRFs and FEVD provided enough evidence for the presence of the two credit channels. The contractionary MP shock impacts the EFP, which consequently affects output that highlighted the presence of the broad credit channel. The presence of the bank lending channel is tested based on the loan system equation. The evidence showed that when bank loans react to MP shock, housing loan declines as non-banking loan do not react to compensate the shortage in bank loans. Further evidence was also obtained from the mild reaction of household expenditure. Therefore, one can deduce that the major players in the UK financial market are financial 'depository' institutions relative to the firms' ability to distort the financial market. This sheds some light that, due to the traditional belief of the monetary policy strategy, policymakers have failed to give more emphasis to the bank lending channel and its role in accelerating the financial frictions in the run up to the crisis. Consequently, the significant amount of damage is witnessed in the financial sector and the impacts are felt in all sectors of the economy. Finally, the assessment in the investigation of the bank lending and balance sheet channels is of the motivations to further investigate the role of FF and its mechanism as a financial accelerator in a NK dynamic stochastic general equilibrium framework. This is the subject of Chapter 6.

CHAPTER 6

FINANCIAL FRICTIONS IN AN ESTIMATED NEW KEYNESIAN DSGE MODEL: A BAYESIAN APPROACH

6.1 Introduction

> "...the global financial crisis has done great damage and this has understandably led to questions as to whether the disaster might have been avoided, or its severity reduced, had policies been different. The aspects of policy that have most obviously been called into question have to do with the regulation of the financial system. But it is also worth asking whether alternative monetary policies might have made a difference..."
>
> (Woodford, 2012:p2)

A Bayesian Dynamic Stochastic General Equilibrium (B-DSGE) models use modern micro and macroeconomic theory to explain and envisage comovements of aggregate time series over a business cycle (Del Negro and Schorfheide, 2013). The stochastic general equilibrium model comprises a broad class of macroeconomic models that spans the standard Neoclassical growth model discussed in King et al. (1988) as well as New Keynesian monetary models with numerous real and nominal frictions that are based on the work of Smets and Wouters (2003), and CEE (2003, 2005). "A common feature of these models is that decision rules of economic agents are derived from assumptions about preferences, technologies, and the prevailing fiscal and monetary policy regime by solving intertemporal optimization problems. As a consequence, the DSGE model paradigm delivers empirical models with a strong degree of theoretical coherence that are attractive as a laboratory for policy experiments" (Del Negro and Schorfheide, 2013:p57).

Over the past two decades, the New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) models have become one of the main tools to study economic fluctuations and monetary policy transmission mechanism. DSGE models provide a coherent structure for policy analysis and they are proved to forecast time series as well as BVAR models (SW, 2003). However, many aspects of the modelling practice need to be improved, particularly on its linkage to the financial sector. The recent GFC has prompted a re-evaluation of modelling strategies concerning financial linkages. Financial markets are highly imperfect due to information asymmetries between lenders and borrowers, costly verification of financial contracts and the possibilities of bank bankruptcies and contagions (Lombardo and McAdam, 2012). Therefore, a feature of financial markets is that lenders tend to demand a premium over riskless interest rates as compensation against such uncertainties. In the data, the premium tends to be counter-cyclical (i.e. it tightens in economic downturns) thus amplifying the effect of economic downturns. Premia aside, borrowers may also be restricted in the absolute amount of funds available to them. The strength of such financial frictions and the soundness of the financial system have implications for how central banks conduct monetary policy and assess inflationary pressure and risks. The widening of Spreads and deterioration in private lending from late 2007 onwards prompted a number of central banks to loosen monetary policy and engage in various forms of enhanced credit support, reflecting concerns that tensions in financial markets would spill over to the wider economy.

However, many DSGE models largely assume frictionless financial markets (with few notable exceptions, SW, 2007 for Euro Area, and Christiano et al., 2003, among others). This appeared to confirm that there are still unanswered questions as to the importance of financial channels in the MTM. Some empirical and theoretical analyses identified financial channels as a key amplifier and a source of business-cycle fluctuations (see e.g. Bernanke et al., 1999). Others suggest that their impact may be relatively minor (see Meier and Mueller, 2006) or stronger during extreme financial distress such as the Great Depression, the Asian Crisis (see Gertler et al., 2007) as well as the most recent global financial turbulence.

Notwithstanding, this study builds on the recent attempts made to model the UK data using the current generation of micro-founded DSGE models, following SW (2003, 2007) and BGG (1999), supplemented with a number of standard parameters of financial market frictions. Several recent works (see SW, 2003, 2014; Merola, 2015; Bernanke, 2007) mainly focus on the problems of integrating the financial system in the macroeconomic models and highlight the importance of various frictions that may endanger the real economy. The introduction of the financial system would probably make it possible to describe the cyclic behaviours of the economy and to give microeconomic explanations to the evolutions of some financial sizes that have been ignored until now. The introduction of an evaluation system, using a macroeconomic model with a financial structure will make it possible to have a more complete view of the shocks affecting both sectors of the economy. Additionally, the practice helps to quantify their impact on the real economy (see Goodhart et al., 2006). Several assumptions are made for the implementation of these models, namely the perfect rationality of the agents, efficiency of the various markets, and the neutrality of finance vis-à-vis the real economy. Banks play an active role in the real economy and they are not simply part of the amplification process but are highly integrated with the activities of the economy. The recent GFC highlighted the interconnection between the financial sphere and the diligence of the business cycle. Theoretical reviews and empirical investigation began to question the utility to actively integrate the financial intermediation in the dynamic stochastic general equilibrium models. The macroeconomic modelling exercise that integrates the financial accelerator strand into a New Keynesian DSGE model is very recent.

Since late 1980s, two strands of financial frictions literature have emerged. The *first* strand has developed from the seminal paper of Bernanke and Gertler (1989). Financial frictions have been incorporated into a general equilibrium model. This approach was further developed by Carlstrom and Fuerst (1997, CF hereafter) and merged with the New Keynesian framework by Bernanke et al. (1999), which is now becoming the workhorse of financial accelerator model. In this model, frictions arise because monitoring a loan applicant is costly, which drives an endogenous wedge between the lending rate and the risk free rate. This means that financial frictions affect the economy through prices of loans. The *second* strand, introduced by Kiyotaki and Moore (1997) and extended by Iacoviello (2005), introduces financial frictions via collateral constraints, assuming the agents' heterogeneous behaviour in terms of the rate of time preference. In this case, agents are divided into lenders and borrowers and the financial sector intermediates between these groups and introduces frictions by requiring that borrowers provide collateral for their loans. This approach introduces financial frictions that affect directly the quantity of loans. The second strand of literature concludes that financial shocks (namely, shocks that either increase the cost of loans or decrease the demand of credit) explain a large share of contraction in the economic activity. Despite the ongoing macroeconomic research that attempts to incorporate the banking sector in DSGE models, the financial accelerator mechanism of BGG remains to be a valid approach in a number of prominent central banks and institutions (Gerke et al., 2012; Gilchrist and Zakrajsek, 2011).

To address the limitations of the existing DSGE models and investigate the role of the financial sector of the UK economy, this Chapter examined the role of financial frictions and to what extent financial transmission channels have accounted for output collapse by amplifying shocks in the business cycle. For this purpose, this study extends the SW (2003, 2007) model by adding financial frictions for the UK data. To estimate the parameters for the model and the stochastic process governing the structural shocks in the UK economy, the study uses the same set of shocks and macroeconomic series, as in the SW model, together with an additional shock (i.e. the Spread shock), and financial variable shocks. The study estimated a Bayesian New Keynesian DSGE model on the UK quarterly time series data from 1955Q1 to 2014Q4 that covers various policy regimes. The Bayesian DSGE approach has become very popular in recent times both in academia and among central banks as it can address a number of key issues in business cycle analysis (SW, 2007; Adolfson et al., 2007; Gertler et al., 2008). This research contributed to the understanding of the role of financial accelerator mechanism in the UK and quantified the contribution of various shocks to output, monetary policy and price. It conveyed the essence of the argument that financial market turmoil generate a powerful source of propagation through a financial accelerator mechanism.

This study differs from previous studies in several aspects. *First,* while Gilchrest et al. (2009) estimate only the elasticity of the external finance premium, the estimation herein includes a broader set of parameters related to the financial accelerator mechanism. *Second,* this study found strong evidence in favour of the presence of financial frictions, as proven by the higher estimate of the elasticity of the external finance premium. *Third,* their conclusions in favour of the model with financial frictions are not supported by accurate model comparison. The main contributions of this study are threefold: *first,* unlike previous studies, it extends the estimation time horizon to the current period and assess the implications of the recent crisis. *Second,* as in SW (2007) and Merola (2015), the study included macroeconomic and financial shocks in the Bayesian estimation. This is an important feature to the model, given that very often cyclical downturns are preceded by wider Spreads[118]. *Third,* this study is one of the few attempts made to develop a Bayesian (NK) DSGE model for the UK economy across the two policy regimes. There are some small DSGE models estimated for the UK economy but only few of them incorporate the financial accelerator mechanism. Most importantly, this is the first study in terms of its coverage of the four policy regimes the UK has experienced from the pre-IT to the post-GFC period.

The results of this study are not at odds with those found in the models with the banking sector. The Spread shock that affects entrepreneurs' borrowing costs has similar effects to a financial shock that affects the demand of credit (also found in SW, 2003, 2007; Merola, 2015) on the U.S. data. Thus, the model is able to capture macroeconomic dynamics as expansion and collapse of the economic activity during the last decades and the conduct of the UK monetary policy. This is a notable outcome, which highlights how the SW model with a FAM yield results similar to those obtained in a larger-scale models. The results also revealed that the role of financial frictions exacerbates at the time of financial crisis that overhauls the role of investment. In this ground, it is able to show quantitatively that the response of output to investment without a FAM reduces to 2% while the response of output to financial frictions remains high in both periods. The model with the financial accelerator mechanism performed better than the one without the financial accelerator mechanism. The DSGE model with a FA mechanism represented the data well and showed that the role of investment significantly reduced in the run up to the financial crisis and gradually replaced by the Spread shock. Spread shocks constitutes about 13% to 14% of output decline as compared to the 2% to 4% decline that constitutes for investment shocks.

The rest of the paper is structured as follows. *Section 2* reviews relevant literature on a range of approaches on how introducing financial frictions into a DSGE model and presents empirical

[118] The Spread shock is suitable to capture the effect of financial tightening on firms' borrowing capacity. See also Faust et al. (2012).

specifications, leading to the Bayesian approaches. *Sections 3* and *4* present the model structure, data and parameters. *Section 5* and *6* discuss estimation, model evaluation and the posterior estimation results with respect to priors, IRFs, conditional and historical decompositions, which highlight the historical relevance of disturbances for macroeconomic performance with a particular focus on the most recent financial crisis. *Section 7* discusses the credit policy, and *Section 8* concludes by highlighting the findings of the DSGE model particularly the role of financial frictions and the target variables such as output and prices.

6.2 Review of Empirical Literature

6.2.1 Financial Frictions and the Current DSGE Models

Mainstream business cycle models disregard the role of financial frictions in the last twenty years. Although past episodes such as the Asian crisis, the Great Depression and the Japanese recession, among others in the 90s magnified the prominence of financial frictions in business cycle, the role of finance in macroeconomy has been a second order of importance when explaining aggregate fluctuations. The common practice in a large scale DSGE modelling in the run up to the GFC was to conduct business cycle analysis based on price and wage stickiness of the New Keynesian assumption and with frictions on multiple margins of adjustments[119]. They cover the period before the financial crisis and the financial sector has played no role in both cases. On the contrary, the general equilibrium theory recognises the importance of financial frictions for business cycle fluctuations more than two and a half decades ago. Bernanke and Gertler (1989); Kiyotaki and Moore (1997) and Bernanke et al. (1999) lay the foundation, highlighting the importance of financial factors for business cycle fluctuations through adopting general equilibrium models. The over relaying trust on the financial sector ability of self-adjustment has been called into question since the 2007/8 crisis. Largely, the search of new knowledge and deeper understanding have inspired in-depth examination in general equilibrium modelling with a financial sector where this thesis is attempted to contribute. The search for the role of financial frictions is a promising avenue of research (Beck et al., 2014) that benefits not only academia but also the wider monetary and financial policy decisions.

Del Negro et al. (2013) extend the SW (2007) NK-DSGE model by including financial frictions in the spirit of Bernanke et al. (1999) and estimate with data that covers up to the beginning of the recent GFC. Their work show that as soon as the financial stress enlarged in 2008, the model successfully predicted a sharp contraction in economic activity. A modest and persistent decline in inflation is also obtained when state dependent nominal rigidities are introduced. Gertler and Kiyotaki (2010, GK hereafter) note that the current crisis has witnessed a significant disruption of financial intermediation, bringing the analysis of the role played by financial intermediaries for business cycle fluctuations at the forefront of research. The pre-crisis period literature emphasised credit market constraints on non-financial borrowers and treated intermediaries as a non-existence (Beck et al., 2014).

BGG (1999) are the first to introduce financial frictions into a calibrated DSGE model with sticky prices. They argue that this friction leads to a FAM that improves the ability of a standard model to

[119] See also prominent examples in Christiano et al. (2005) and SW (2003, 2007).

explain normal cyclical fluctuations. They also note that, if these frictions are quantitatively important for cyclical fluctuations, models for monetary policy analysis need to incorporate them to improve the ability of the standard model to explain and measure fluctuations that amplifies by financial frictions. Following BGG, Christensen and Dib (2005) evaluate the importance of credit market frictions that amplify and spread the effects of momentary shocks on macroeconomic variables. They estimate a sticky-price DSGE model with FAM parameters similar to that of BGG on the U.S. data. The structural parameters, which include the financial accelerator, are estimated using post-war U.S. macro data and a maximum-likelihood procedure with a Kalman filter. To evaluate the importance of the accelerator mechanism, the authors compare the impulse responses of macro variables with and without the financial accelerator mechanism. They also re-estimate a constrained version of the model in which the financial accelerator is turned-off.

Earliest studies such as BGG (1989, 1999), CF (1997), Prescott and Townsend (1984), and Townsend (1979) introduce these frictions in the form of asymmetric information costs that banks face when they agree on a loan contract. These costs represent the percentage of the value of a loan that banks cannot recover when there is default. BGG (1999) solve a financial accelerator model characterised by these asymmetric information costs and derive an expression for EFP that firms face when they borrow from banks. BGG represent these costs as:

$$\frac{E[R_r^k\ ]}{R_t} = v\left(\frac{Q_{t-1}K_t}{N_t}, \mu\right) v'\left(\frac{Q_{t-1}K_t}{N_t}, \mu\right) > 0\ , v'(\mu) > 0 \tag{6.1}$$

where $E[R_r^k\ ], R_t, Q_{t-1}, K_t\ , N_t, \mu$ represent the borrowers' expected returns to capital, risk free rate, price of capital, capital stock, borrowers' net worth, and the monitoring cost coefficient, respectively. Equation (6.1) implies that the EFP, $\frac{E[R_r^k\ ]}{R_t}$, is positively correlated with a borrower's leverage, given by $\frac{Q_{t-1}K_t}{N_t}$ and the monitoring cost coefficient, μ. Aysun et al. (2011) set a DSGE version based on the BGG (1999) framework but uses $1-\mu$ as a measure of bankruptcy recovery rate to represent financial frictions. This version of FF measures the proportion of a firm's value creditors can recover from a defaulting firm. According to Aysun et al. (2011), the bankruptcy recovery rate provides a close match to the source of financial frictions in costly state verification models. The potential problem with this representation is that the recovery rate only accounts for the defaulting businesses rather than the entire financial sector. The second equation that BGG (1999) add to a standard New Keynesian model is the evolution of net worth given by:

$$N_{t+1} = f(N_t\ Q_t\ K_t\ R_t) f'(\mu) > 0 \tag{6.2}$$

equation (6.2) shows that as the monitoring cost coefficient increases, the effect of a shock on net worth, through its effects on returns to capital, asset prices and capital stock, also increases. The high amplitude of net worth, in turn, implies larger responses of leverage and external premium. Firms decrease investment in response and generate a fall in asset prices and thereby a further fall in net worth. The fall in net worth causes a further increase in the EFP and a larger drop in output. Given these representations, if a central bank changes its policy rates, it can affect the economy in two ways: *first*, lending Spreads are affected directly. *Second,* by altering asset prices, central banks can have an effect on firms' leverage and therefore, affect the level of lending as well as borrowing. In each case, the effect of central bank's policy on borrowing Spreads is positively related to the level of financial frictions in the economy. In line with this argument, Gertler et al. (2007) find that the impulse responses to shocks in models with positive monitoring costs are substantially higher than those from models without monitoring costs.

Christiano et al. (2011) argue that the recent crisis of the financial market uncovered that business cycle modelling can no longer abstract from financial factors - they appear both *prima facie* and using more advanced methods, to be the main source and propagation mechanism of this downturn. The main macroeconomic question has also shifted with an increased emphasis on financial aspects. It is also clear that the standard business cycle approach of modelling labour markets without explicit unemployment has its limitations[120]. Motivated by the failing of the existing business cycle models to address the importance of financial market frictions, they attempt to resolve these limitations by integrating recent progress in labour market modelling into a comprehensive monetary business cycle model of a small open economy. They address the quantitative effects of financial shocks on investment and output and how unemployment is affected by a sudden and temporary decrease in export demand or an increase in corporate interest rate spreads.

The financial accelerator has been the most common approach to incorporate financial frictions into a DSGE framework (Bernanke et al., 1999; Cespedes et al., 2004). Such framework has been employed to capture firms' balance sheet effects on investment by relying on a one-period stochastic optimal debt contract with costly-state verification. Such setting allows to endogenously determining external finance premium above the risk-free interest rate. This approach has also been applied to capture balance sheet effects in the banking sector (Choi and Cook, 2004). In terms of its empirical relevance, Christiano et al. (2007) show, for the Euro Area and the U.S., that the financial accelerator plays a relevant role in amplifying shocks that move prices and output in the same direction[121] (e.g. monetary policy shocks) as well as in explaining the business cycle. However, a

[120] Apart from the obvious drawback of not having implications for unemployment, the standard approach also relies on wage mark-up shocks to explain a large fraction of the variation in main macro variables such as GDP and inflation. It also tends to induce little persistence in hours worked as these are modelled and are costless to adjust.

[121] Aggregate demand shocks.

key weakness of the financial accelerator is that it only addresses one aspect of many possible financial frictions.

One of the important lessons from the crisis was that financial markets matter for macroeconomic developments and should be taken into account when constructing macro models. Since the crisis, there has been a growing interest in theoretical framework and macroeconomic modelling to incorporate financial frictions. Models with imperfect financial markets, previously at the margin of professional interest, promptly entered into the mainstream. They were used to answer questions important from policymakers' point of view. These are: (i) the impact of financial shocks on the economy (Gerali et al., 2010; Brzoza-Brzezina and Makarski, 2011), (ii) the optimal monetary policy in the presence of financial frictions (Curdia and Woodford, 2010; De Fiore and Tristani, 2009; Carlstrom et al., 2013; Kolasa and Lombardo, 2014), (iii) the effectiveness of alternative monetary policy tools (Lombardo and McAdam, 2010), or (iv) the impact of capital regulations on the economy (Angelini et al., 2010). Broadly, there are two approaches on how literatures introduce financial frictions into the traditional DSGE model. The *first* strand of literature introduces a credit constraint on non-financial borrowers while the *second* group imposes the constraint on financial intermediaries. This distinction is important to understand FF and the DSGE model from both an expositional and a historical perspective (Beck et al., 2014).

CF (1997) endogenise financial frictions by introducing an *agency problem* between the lender and the borrower. Essentially, these models depart from the standard Real Business Cycle (RBC) setting assuming the presence of two agents: consumers and entrepreneurs. In this setting, entrepreneurs have the opportunity to create capital from the consumption good. To finance this production they invest their own wealth and borrow funds from households subject to a friction. The friction is that the idiosyncratic productivity of entrepreneurs is not readily observable by others. Consumers can observe the productivity of entrepreneurs at a cost. The optimal contract between the households and the entrepreneur which takes the form of debt ensures that the latter does not take advantage of his/her superior information.

Kiyotaki and Moore (1997) depart from the costly state verification but introduce financial frictions via *collateral constraints.* They assume that agents are heterogeneous in terms of their rate of time preference, which divides them into lenders and borrowers. In this case, credit constraints arise because lenders cannot force borrowers to repay their debt, unless debt is secured. Therefore, credit constraints take the form of collateral constraints. The flow of funds from lenders to borrowers is motivated by the preference heterogeneity: the lender is more patient – s/he has a higher discount factor than the borrower. In their framework a durable assets such as land is used both as a production input and as a collateral for borrowing. Creditors protect themselves against the risk of default by collateralising durable assets such as borrowers' land. The borrower gets the loan equal to the value of collateralisable assets, which is the present value of current landholding and thus facing a financing constraint. Consequently, this leads to the fact that the production level depends upon collateralisable wealth. Therefore, the higher the net worth, the higher the volume of credit extended so that high investment leads to higher production. The interaction between credit limit and asset price is a powerful transmission mechanism through which the effect of shocks persist, amplify, and Spread out (Beck et al., 2014). The financial sector intermediates between these groups introduce frictions by requiring that borrowers provide collateral for their loans. Hence, this approach introduces frictions that impact directly the quantity of loans. Iacoviello (2005) develops a model based on KM (1997) by introducing housing as collateral in a New Keynesian DSGE model where households drive utility from housing services. Other prominent applications that relies on this framework include Calza et al. (2009) who analyse the impact of mortgage market characteristics on monetary transmission. Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2011) use DSGE models with collateral constraints and monopolistic competition in the banking sector to examine the impact of financial frictions on monetary transmission and a credit crunch scenario. Similarly, Iacoviello and Neri (2010) estimate a model with collateral constraints on U.S. data to determine the role of housing market shocks on the economy.

Christiano et al. (2010), and Goodfriend and McCallum (2007, GM hereafter) enhance a standard DSGE model with a competitive banking sector and a multiplicity of financial assets which differ in their returns. Gerali et al. (2010) and Aslam and Santoro (2008) take further steps and extended a DSGE model with a monopolistically competitive banking sector. In this setting, loans to the private sector using either deposit or bank capital, are subject to an exogenous leverage ratio. This implies that bank capital has a fundamental role in determining credit supply conditions. Since bank capital is accumulated through retained earnings, a shock hitting the profitability of banks will impair their ability to raise new capital. Banks with a lower capital position reduce the amount of loans they are willing to supply (Beck et al., 2014), thus deepening the initial contraction. Equally, Gerali et al. (2010) estimate the model with Bayesian techniques and evaluate the contribution of shocks in the banking sector to the slowdown of 2008. They find that shocks in credit supply can have dramatic real effects. A reduction in bank capital forces banks to raise interest rates which results in a lower demand for loans by households and firms, that in turn forces to reduce consumption and investment.

While financial frictions amplify the effects of monetary shocks compared to what can be observed in a standard NK model, imperfect bank pass-through dampens the effect of changes in the real rate of interest. Gertler and Karadi (2011) propose a quantitative model of unconventional monetary policy. In their model, financial intermediaries face endogenous financial constraints due to the presence of a moral hazard problem. Specifically, after collecting household deposits, the bank manager can divert a fraction of the assets and declare bankruptcy. Hence, banks collect households' deposits if their expected value is such that there is no incentive to divert assets. This implies that the ability of a bank to attract deposits and to extend loans to firms is positively related to its current net worth and to its expected future earnings. This entails that financial intermediaries' leverage ratios are endogenously constrained. In this framework, a shock that disrupts banks' capital reduces lending and borrowing through increased credit costs, which amplifies the effects of a downturn. The design of unconventional monetary policy builds on the fact that the central bank acts as an intermediary by borrowing funds from savers and lending them to investors. Assuming that central banks always honour their debt, it does not face constraints on its leverage ratio. In a period of financial distress, the central bank can support credit flows. The authors find that as long as the efficiency costs of public interventions are limited, the welfare gains spreading from active credit policies may be quite significant (Gertler and Karadi, 2011).

In the models discussed above, credit transactions are market-based but do not assign any role to financial intermediation. Financial intermediaries play a prominent role in modern financial systems. As reported by Gerali et al. (2010) in 2006 bank deposits in the Euro area accounted for more than 75% of households' short-term financial wealth. For firms, bank lending accounted for almost 90% of total corporate liabilities in 2005. In the decade before the financial crisis, measured output growth in the UK financial services sector averaged over 6% per year, compared with overall UK GDP growth of 3% per year. The sectors' share of the economy also grew significantly and by more, than in most other major advanced economies (BoE, 2011).

The *second* stream of research originates from the benchmark BGG (1989) model where financial frictions are incorporated into a general equilibrium model. Following BGG, CF (1997) extended the financial frictions model then merged with the New Keynesian framework by Bernanke et al. (1999), which becomes a foundation for successive financial friction prototypes. The main foundation of the second stream of research originates from the fact that monitoring borrowers financial position is costly, which ultimately drives an endogenous wedge between the lending rate and the risk free rate (called EFP). This compels the fact that financial frictions affect the economy via prices of loans rather than via quantities of loans. The external finance premium setup has been extensively used by Christiano et al. (2003) to analyse the role of financial frictions during the Great Depression and by Christiano et al. (2008) to study business cycle implications of financial frictions. GM (2007) provide an endogenous explanation for steady state differentials between lending and money market rates. In a similar framework, Curdia and Woodford (2009) derive optimal monetary policy in the presence of time-varying interest rate Spreads in a simple model with heterogeneous households. While both approaches allow for the introduction of financial frictions into the macro model, the acceleration factor in the transmission mechanisms of the two approaches differ substantially. To develop a successful macro-financial framework, it is important to understand how the financial friction mechanism works in a micro-founded general equilibrium models. It is also essential to understand the behaviour of financial accelerator mechanism when the economy is stable and under stress as in the case of pre and post-GFC. Besides, understanding the cyclical and counter cyclical response of EFP in an estimated DSGE model is vital.

The strategy of introducing frictions in the accumulation and management of capital follows the variant of the BGG (1999) model implemented in CMR (2003). They introduce financial frictions into the model through the accumulation and management of capital, assuming no asymmetric information between borrower and lender, hence, no risk to lenders. In the case of capital accumulation, the borrower and lender are actually the same households, who put up the finances and later reaps the rewards. When real-world financial frictions are introduced into a model, intermediation becomes distorted by the presence of balance sheet constraints and other factors. They also assume that working capital is frictionless. The amount that banks are willing to lend to an entrepreneur under the standard debt contract is a function of the entrepreneur's net worth. When a shock that reduces the value of the entrepreneurs' assets occurs, it diminishes their ability to borrow. Subsequently, entrepreneurs acquire less capital, less investment and ultimately slows down the economy.

Recently, Gambacorta and Signoretti (2014) study the design of monetary policy in a model with financial frictions on U.S. data. Using a simplified version of Gerali et al. (2010), they examine the performance of augmented TR that adjusts the policy rate in response to asset prices and credit indicators, comparing to the standard rules that feature strict or flexible inflation targeting. Their result shows that even if financial stability does not represent an explicit policy target, MP rules that enhanced financial stability may be desirable in the presence of supply-side shocks. It shows that financial frictions crucially affect the trade-offs faced by monetary policy. Their study also confirms that the gains with respect to strict inflation targeting are substantially amplified in the presence of high private sector indebtedness. The introduction of elements of financial frictions mechanism (FFM) in the standard DSGE model is still debatable. The recent global financial crisis gave significant amount of impetus to policy researchers. It conveys some consensus that the FFM is a major contributor to the macroeconomic shocks. Although there are some indications that the FFM is relevant to the DSGE setup, there is still no consensus on how the financial frictions are represented and introduced in a standard DSGE model. In this regard, dynamic modelling with a financial frictions based on the New Keynesian approach has become a growing challenge, which is attracting a growing macroeconomic research interest, particularly in the post-GFC period. The following section discusses the variants of DSGE models with financial intermediaries and reviews the existing DSGE modelling approaches in relation to the introduction of FAM.

6.2.2 Variants of DSGE Models and Empirical Evaluations

There are variants of DSGE models based on the way financial intermediaries are introduced. GM and GK introduce financial frictions on the side of the lender (financial intermediaries). CMR (2006) introduce financial frictions on the side of capital managers, individuals (entrepreneurs) but not through the lender. Other aspects of the models that account for substantial difference are financial shocks. According to CMR (2006), there are three shocks related to the financial sector of the economy. These are the financial wealth shock (also called financial frictions shock), banking sector technology shock, and the relative value of excess reserves shock (also called financial intermediary shock). There are only two types of shocks in GM (2007) model in the financial sector. These are banking productivity shock or loan productivity shock, which is also called a financial intermediary shock, and effective collateral shock or financial distress shock.

In GM's (2007) DSGE model, financial sector plays a crucial role to explain the dynamics of the economic variables. To account for the financial intermediaries, they incorporate banks in the model with two key features: money demand and collateral in the production function. The introduction of money and banking accounts for `liquidity service yield' in the model to represent loans with collateral. Therefore, interest rate for this loan is lower than a default free instrument with no collateral. Consequently, money and banking in the model force interbank interest rate to be lower than the default free instrument with no collateral. According to GM (2007), loans with and without collateral cannot be equally given as it produces an excess supply of interbank credit. In GK's (2009) DSGE model, financial frictions are created on the side of the financial intermediary with no financial shocks. Their model is composed of households who maximise a utility function on consumption and labour with a budget constraint and two classes of firms located at a continuum of areas. The key ingredient of GK's model is the banking sector with an agency problem. Their model assumes that at the end of each period a banker may divert a fraction of deposits to his/her family. They argue that if a banker diverts this fund for his/her own personal gains; creditors get just a fraction of their deposits from the bank. One possible financial shock incorporated to GK's model is a randomised form of probability that banker exits next period while the other financial shock is incorporated as a randomisation of the fraction those banks can divert to their family. The authors treat these two financial shocks as constant parameters.

Although, there exists a number of approaches to introduce financial frictions in a DSGE model, there is little agreement on whether to focus the attention on financial disruption, which could be between household and banks; banks and other banks; entrepreneurs and banks; or firms and banks. Studies (such as Arend, 2010) argue that it is not clear whether incorporating an explicit financial intermediary shock makes a real contribution to the model. It is also not clear that financial frictions in the financial intermediary sector are able to propagate other types of shocks. Christiano et al. (2011) also note that for financial intermediaries to play a significant role in the DSGE model the financial frictions have to be incorporated inside the FIs component; otherwise financial intermediaries will make no difference in the model.

A key aspect of the KM (1997) model is that firms obtain finance from banks by issuing equities. When net worth is reduced due to capital shocks (as in GK), the incentive compatibility constraint will become tighter which will heighten the agency problem and make banks to have less available funds to lend to firms. Consequently, they will not be able to buy as much equity from the firms. This brings the price of capital down but increases interest rates causing a contraction of the supply of loan funds. Furthermore, the agency problem in the banking sector causes the financial frictions. Since creditors recognise the bank's incentive to divert funds, they will restrict the amount they lend to the bank so banks face a borrowing constraint, leaving them with less available funds to lend to the firms. This in turn affects the aggregate activity in the economy. The bank optimisation problem in the maximisation of the value function of the bank is subjected to an incentive constraint (to ensure that bank does not divert funds) and a flow of funds (loans equal net worth plus deposits and interbank borrowing) (Dib, 2009). From the optimisation problem of the bank, one can manipulate the parameters in order to generate the agency problem in household channel and in the interbank channel, where banks obtain funds to lend to firms.

As in BG (1989) and KM (1997), financial market frictions are incorporated into a DSGE model by introducing an agency problem between borrowers and lenders. The agency problem works to introduce a wedge between the cost of external finance and the opportunity cost of internal finance, which adds to the overall cost of credit that a borrower faces. The size of the external finance premium also depends on the condition of borrower’s balance sheets. When borrower’s percentage stake in the outcome of an investment project increases their incentive to deviate from the interests of lenders’ also increases. KM (1997) also note that strong economy strengthen banks’ balance sheet and reduces the external finance premium. The declining EFP encourages borrowers to spend more and this improves the overall economic activity. So, the main question here is that - what does bring about a crisis? According to BG (1989) and KM (1997), a crisis is a situation where balance sheets of borrowers deteriorate sharply due to a sharp worsening in asset prices, causing the external finance premium to jump. The impact of the financial distress on the cost of credit then depresses real activity. Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and others suggest that disruption of financial intermediation is a key feature of both recent and historical crisis.

As noted by KM (1997), financial intermediaries have the skills in evaluating and monitoring borrowers, which makes it efficient for credit to flow from lenders to non-financial borrowers. They introduce an agency problem that potentially constrains the ability of intermediaries to obtain funds from depositors. When the constraint is binding, the intermediary's balance sheet limits its ability to obtain deposits. In this instance, the constraint effectively introduces a wedge between the risky and the riskless loan rates. This wedge spread widely during a crisis, which in turn sharply raises the cost of credit that non-financial borrowers face. GK (2009), on the other hand, are able to find that a shock that triggers the financial frictions in the form of negative capital quality shock of around 5% permits to explain the deep downturn of the U.S. economy. Under standard business cycle model, this is not possible since models fall short of explaining the fall in the macroeconomic aggregates during this crisis. CMR (2006) compare the performance of their model for U.S. and the European Area using the root mean square forecast error criterion. They find mixed results for the different macroeconomic variables. In some cases, their model outperform other models in forecasting the variables of the model but not in some other cases. Paying particular attention to the GDP forecast, the authors show that their model for the Euro Area perform similarly as compared with the other models and represented the U.S. data well. Furthermore, they show, in the model for the E.A. and the U.S., that the key driver of the GDP fluctuation is the financial frictions shock. Their model also permits an explanation to the "boom-bust puzzle" of the late 1990s and early 2000s by combining financial shocks and the marginal efficiency of investment (MEI) shock.

In their findings, Jerman and Quiadrini (2009, JQ hereafter) demonstrate that models considering only technology shocks are not able to explain the business cycle fluctuation of real and financial flows for the U.S. economy. Incorporating financial shocks improve the model performance for macroeconomic variables (specifically labour) and financial flows variables. Particularly, financial shocks permit to explain the recent financial crisis and also the downturns in the recessions of 1990-1991 and 2001. JQ highlight that tighter credit conditions have a crucial role in explaining the recession for the U.S. economy since mid-1980s. Based on the *second moments*, the authors concluded that incorporating financial shocks into the model allow them to match the volatility of some variables with the data for some key macroeconomic variables such as GDP, investment, and hours worked. GM (2007) show that incorporating money and banking in the model permits to fit in the steady state, the aggregate variables and interest rates to the U.S. observable data. The model is successful in matching the data for working time, capital output ratio, interbank rate, and collateralised external finance premium. Among the currently, existing DSGE models, the SW (2007) model that augment the financial accelerator mechanism, is suitable to capture much of the historical developments in the U.S. and Euro Area financial markets that led to the GFC. The model accounts for the output contraction in 2008, as well as the widening of Spreads, and supports the argument that financial conditions have amplified the shocks in the business cycle and the intensity of the post-crisis recession.

Gelain (2010) estimates a DSGE model to assess the external finance premium in the Euro Area. He estimates a New Keynesian DSGE model in the spirit of SW (2003, 2007), featured with financial frictions stated by BGG (1999) for the Euro Area. Gelain's work confirms that the model with financial frictions can generate a series for the premium, without using any financial macroeconomic aggregates, highly correlated with available proxies for the premium (about 65% with the 'A' graded corporate bonds Spread). He also found that the estimated premium is not necessarily counter-cyclical as theoretically argued by BGG and empirically found for the Euro Area by Queijo von Heideken (2009).

In a recent paper, Merola (2015) provides a quantitative assessment of the impact of financial frictions on the U.S. business cycle. Merola augmented DSGE model and compares the original SW model (2003, 2007) with an alternative version improved with the financial accelerator mechanism using Bayesian techniques over a sample to 2012 for the U.S. data. Merola represents the banking sector with a financial accelerator mechanism to assess its contribution before and after the financial crisis but the data, coverage has a limited scope to cover the post-GFC period. Beck et al. (2014) survey the role of financial intermediaries and financial frictions in the transmission of monetary policy and discuss how DSGE models have been designed to incorporate the financial intermediary. They also discuss the model design with the new banking regulatory and supervisory framework. Similarly, DiCecio and Nelson (2007) estimate DSGE model for the United Kingdom based on CEE (2005) to address nominal rigidity and wage stickiness. Their estimates show that price stickiness is a more important source of nominal rigidity in the United Kingdom than wage stickiness. Brzoza-Brzezina et al. (2013) estimate a standard DSGE model with financial frictions and compare two standard extensions of the New Keynesian framework for the U.S. data. In the first model, they represent FF using collateral constraints in the spirit of KM (1997) and their second model the FF is represented using EFP following CF (1997), and BGG (1999). They analyse the two variants using moment matching IRFs and business cycle accounting. They find that the business cycle properties of the EFP framework are more in line with empirical evidences. They also address that the collateral constraint model fails to produce hump-shaped impulse response and generates volatilities of the price of capital and rate of return on capital that are inconsistent with the data by a large margin.

Lombardo and McAdam (2012) study financial market frictions in a model for the Euro Area using a DSGE model of SW (2003) type and a New Area Wide Model (NAWM) of Christiano et al. (2008) supplemented with a number of standard financial frictions in a Bayesian approach. The aim of their study was to provide a unified framework for policy analysis that emphasises financial market frictions alongside the more traditional model channels. They find that relative to a model without financial frictions, the simulation properties are mostly not qualitatively affected. Furthermore, the model's ability to track and enhance the understanding of the evolution of financial variables and the strength of financial channels make it a valuable addition to modelling work in the Euro Area. Villa and Yang (2011) study financial intermediaries in an estimated DSGE model for the United Kingdom in the spirit of GK (2011). They estimate the model with UK data using Bayesian techniques, validate the fit of the model and evaluate the empirical importance of nominal, real and financial friction shocks. GK (2011) find that banking frictions seem to play an important role in explaining the real business cycle. Additionally, the banking sector shocks seem to explain about more than half of the fall in real GDP in the recent crisis and a credit supply shocks accounted for most of the weakness in bank lending. However, GK's study failed short of analysing and comparing the outcome with the shocks of non-financial friction.

Additional empirical evidences are also provided by Christensen and Dib (2008) and Gilichrist and Zakrajsek (2012b). They estimate a DSGE model with a financial accelerator mechanism, characterised by an EFP as in CF (1997) and Bernanke et al. (1999). Their research shows evidence that there is a significant accelerator mechanism in the U.S. business cycle fluctuations over the period 1973 to 2008. Particularly, their findings indicate that rises in the EFP leads to significant declines in investment and output. However, a recent literature by Beck et al. (2014) note that a clear-cut improvement with respect to the benchmark NK model is not clearly represented. Villa (2013) performs a similar exercise considering the NK model based on SW (2007) and compare it with two alternative frameworks. The first one is a SW (2007) type model augmented with costly state verification based on Bernanke et al. (1999) and the second one is purely estimated in the spirit of SW (2003, 2007). The two NK frameworks are estimated with the Euro Area quarterly data over the period 1980 to 2008. The results show that the SW framework, augmented with financial frictions in the spirit of GK (2011), delivers a series of the Spread that commoves more strongly with its available proxies and outperforms the other models in terms of the predictive power of inflationary pressure.

Christiano et al. (2010) estimate a SW (2007) type DSGE model augmented with a detailed description of the financial sector. In their model, financial intermediaries finance working capital requirements by producers and entrepreneurs' long-term projects. Loans are financed with deposits paying a non-contingent nominal rate. Entrepreneurs' projects are risky because they are subjected to idiosyncratic shocks. Their model features both agency problems, which result in a financial accelerator and liquidity constraints on banks. They estimate the model on the Euro Area and the U.S. data. The model is enriched with shocks to preferences, technologies and policies. In relation to the demand for capital, they include two financial shocks in their model: the "risk shock" for the dispersion of returns on investment that affects the borrowing and lending propensities, and the "financial wealth shock" for the changes in total value of equity of the economy. These shocks explain a substantial fraction of economic fluctuations. The risk shock, in particular, explains more than a third of the volatility of investment in the Euro Area and over 60 percent in the U.S. They also find that the amount of credit extended by financial intermediaries affects the behaviour of the economy even in normal times. They argue that low growth since the second half of 2008 is partially the result of a shift in banks' preferences for liquidity.

A strong correlation between equity payouts and debt payments with GDP is documented by JQ (2012). They treat the enforcement constraint as a source of financial shocks. They estimate a SW (2007) model extended with the financial shock and a variable presenting financial flows and debt repurchase to assess the relevance of the financial shocks. Variance Decomposition of the estimated model shows that the financial shock contributes significantly to the volatility of real variables. Iacoviello (2015), in his recent paper, estimates a model with banks and financially constrained households and firms using a Bayesian method. The study is motivated by the losses suffered by financial intermediaries and exacerbated by their inability to extend credit to the real economy. He concludes that financial shocks account for more than one-half of the decline in GDP during the last recession. Although, there are some strong line of arguments in representing the role of financial frictions in the general equilibrium modelling process, Beck et al. (2014) note that the role of DSGE models should not be dismissed. Literature discussed so far highlight the presence of various methods of introducing financial frictions into a standard DSGE model. Among the strands of NK-DSGE models with financial frictions, the SW (2003, 2007) model is found to be more demonstrative for the UK macroeconomy. Previous studies conducted so far on the UK data focus more on the pre GFC movements of macroeconomic and financial shocks. The overlapping generations (OLG) and the New Keynesian framework with capital parameter have been extensively used in the pre-crisis period to address the impact of macroeconomic shocks on output and price. However, the vast majority of the old and NK DSGE models have failed to capture the mechanism of comovement and impact of financial market frictions, which was pronounced in the recent and post-global financial crisis. In this spirit, following SW (2003, 2007), BGG (1999) and Merola (2014), the following section discusses the DSGE model calibration, RBC theory and the Benchmark New Keynesian models with and without a Financial Accelerator Mechanism (FAM).

6.3 The DSGE Model Structure

Agents and their Decision Problem

The model economy is populated with the following agents: households, producers, fiscal and monetary authorities and financial intermediaries. Households consume, accumulate capital stock and work. They supply labour, purchase goods for consumption, and hold money and bonds. Producers produce final goods and capital goods in several steps. Firms hire labour, produce and sell differentiated products in monopolistically competitive goods markets. Each firm sets the price of the good it produces, but not all firms reset their price during each period. Households and firms are assumed to behave optimally that the former maximise the expected present value of utility, and the later maximise profits. Fiscal authorities use taxes to finance exogenously given government expenditure and monetary authorities conduct monetary policy conferring to the MP rule (TMPR). The central bank controls the nominal rate of interest.

The Bayesian model simulation and calibration is based on a representative general equilibrium model of Bernanke (2007) and SW (2007). The general overview presents the type of agents' objective and problems in the decision making process. In this setup, frictions arise because monitoring a loan applicant is costly, which drives an endogenous wedge between the lending rate and the risk free rate called EFP. The equations given in the SW model describe the choices of three major types of decision makers: *households*, who choose consumption and hours worked optimally, under a budget constraint; *firms*, who decide how much labour and capital to employ; and the *central bank*, which controls monetary policy. The parameters in the equations are estimated using Bayesian statistical techniques so that the model approximately describes the dynamics of output, consumption, investment, prices, wages, employment, and interest rates of the UK economy. The model incorporates several types of frictions that slow down adjustment to shocks, including sticky prices and wages, and adjustment costs in investment to accurately produce the inactive behaviour of some of the agents in the economy (SW, 2003). Each agent of the model economy behaves in a certain way.

6.3.1 Households

The economy consists of a large number of identical representative households. The representative households seek to maximise utility U in an economy. Aggregate economic activity is analysed based on a representative households of measure *one*. The expected discounted flow of utility arises from chosen streams of consumption and leisure. Households are the owners of physical capital and can invest in new capital outside of the cash-in-advance constraint. Period t wage income can be used to finance investment in new capital even though it cannot be used for period t consumption. The households are infinitely lived agents who decide on their consumption, savings and work-time to maximise their intertemporal utility function. Following SW (2003) and Christiano et al. (2005) and in the spirit of BGG, each household j chooses labour supply/hours worked $L_t(j)$, consumption $C_t(j)$, capital holdings for the next period K_t, bonds $B_t(j)$, investment $I_t(j)$ and capital utilisation $Z_t(j)$, to maximise the following objective functions:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[(C_{t+s}^{\tau}(j) - \lambda C_{t+s-1})^{1-\sigma_c} \frac{1}{1-\sigma_t} \right] \exp\left(L_{t+s}(j)^{1+\sigma_l} \frac{\sigma_c - 1}{1+\sigma_l} \right)$$

subject to the following budget constraint:

$$C_{t+s}(j) + I_{t+s}(j) + \frac{1}{\varepsilon_t^b R_{t+s} P_{t+s}} (B_{t+s}(j)) - T_{t+s}$$
$$\leq \frac{B_{t+s-1}(j)}{P_{t+s}} + \frac{W_{t+s}^h(j) L_{t+s}(j)}{P_{t+s}} + \frac{R_{t+s}^k Z_{t+s}(j) K_{t+s-1}(j)}{P_{t+s}}$$
$$-\alpha(Z_{t+s}(j) K_{t+s-1}(j) + \frac{Div_{t+s}}{P_{t+s}} \tag{6.3}$$

and the capital accumulation equation:

$$K_t(j) = (1-\delta)_{t-1}(j) + \varepsilon_t^i \left[1 - \vartheta \left(\frac{I_t(j)}{I_{t-1}(j)} \right) \right] I_t(j) \tag{6.4}$$

where T_{t+s} are lump sum taxes or subsidies and Div_t are the dividends distributed by the intermediate goods producers and the labour unions. δ is the depreciation rate, $\vartheta(.)$ is the adjustment cost function, with $\vartheta(\gamma) = 0$, $\vartheta'(\gamma) = 0, \vartheta''(.) > 0$. There is external habit formation captured by the parameter λ. The one-period bond is expressed on a discount basis. ε_t^b is an exogenous premium in the return to bonds, which might reflect inefficiencies in the financial sector leading to some premium on the deposit rate versus the risk free rate set by central bank, or a risk premium that households require to hold the one period bond. ε_t^b follows the stochastic process:

$$ln\varepsilon_t^b = \rho_b ln\varepsilon_{t-1}^b + \eta_t^b, \eta_t^b \sim N(0, \sigma_b) \tag{6.5}$$

and ε_t^i is a stochastic shock to the price of investment relative to consumption goods and follows an exogenous process:

$$ln\varepsilon_t^i = \rho_i ln\varepsilon_{t-1}^i + \eta_t^i, \eta_t^i \sim N(0, \sigma_i) \tag{6.6}$$

Households choose the utilisation rate of capital. The amount of effective capital that households can rent to the firms is:

$$K_t^s(j) = Z_t(j) K_{t-1}(j) \tag{6.7}$$

The income from renting capital services is $R_t^k Z_t(j) K_{t-1}(j)$, while the cost of changing capital utilisation is $P_t a\big(Z_t(j)\big) K_{t-1}(j)$. In equilibrium households will make the same choices for consumption, hours worked, bonds, investment and capital utilisation. Without the j index, the First Order Condition is as follows:

$$(\partial C_t) = \Xi_t = exp\left(\frac{\sigma_c - 1}{1 + \sigma_l} L_t(j)^{1+\sigma_l}\right)(C_t - \lambda C_{t-1})^{-\sigma_c} \tag{6.8}$$

$$(\partial L_t) = \left[\frac{1}{1 - \sigma_c}(C_t - \lambda C_{t-1})^{1-\sigma_c}\right] exp\left(\frac{\sigma_c - 1}{1 + \sigma_l} L_t^{1+\sigma_l}\right)(\sigma_c - 1)L_t^{\sigma_l} = -\Xi_t \frac{W_t^h}{P_t}$$

$$(\partial B_t)\ \Xi_t = \beta_\varepsilon^b R_t E_t\left[\frac{\Xi_{t+1}}{\pi_{t+1}}\right] \tag{6.9}$$

$$(\partial I_t)\ \Xi_t = \Xi_t \varepsilon_t^i \left(1 - \vartheta\left(\frac{I_t}{I_{t-1}}\right) - \vartheta'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)\right) + \beta E_t\left[\Xi_{t+1}^k \varepsilon_{t+1}^i S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)\right] \tag{6.10}$$

$$(\partial \overline{K}_t)\ \Xi_t^k = \beta E_t\left[\Xi_{t+1}\left(\frac{R_{t+1}^k}{P_{t+1}} Z_{t+1} - a(Z_{t+1})\right) + \Xi_{t+1}^k(1 - \delta)\right] \tag{6.11}$$

$$(\partial u_t)\ \frac{R_t^k}{P_t} = a'(Z_t) \tag{6.12}$$

where Ξ_t and Ξ_t^k are the Lagrange multipliers associated with the budget and capital accumulation constraints, respectively. Tobin's $Q_t = \Xi_t^k / \Xi_t$ and equals one in the absence of adjustment costs.

6.3.2 Intermediate Labour

Households supply their homogeneous labour to an intermediate labour union, which differentiates the labour services, sets wages subject to a *Calvo* scheme and offers those labour services to intermediate labour packers. Labour used by the intermediate goods producers L_t is a composite made of those differentiated labour services $L_t(i)$. As with intermediate goods, the aggregator is the one proposed by Kimball (1995). The labour packers buy the differentiated labour services, pack L_t, and offer it to the intermediate goods producers.

$$L_t = \left[\int_0^1 L_t(l)^{\frac{1}{1+\lambda_{\omega,t}}}\, dl\right]^{1+\lambda_{\omega,t}}, \tag{6.13}$$

There are labour packers who buy the labour from the unions, package L_t, and resell it to the intermediate goods producers. Labour packers maximise profits in a perfectly competitive environment. From the First Order Conditions of the labour packers:

$$L_t(l) = \left(\frac{W_t(l)}{W_t}\right)^{-\frac{1+\lambda_{\omega,t}}{\lambda_{\omega,t}}} L_t, \tag{6.14}$$

Combining this with the zero profit condition, an expression for the wage cost for the intermediate goods producers is:

$$W_t = \left[\int_0^1 W_t(l)^{\frac{1}{1+\lambda_{\omega,t}}} dl \right]^{\lambda_{\omega,t}}, \qquad (6.15)$$

subject to:

$$\left[\int_0^1 H\left(\frac{L_t(i)}{L_t}; \varepsilon_t^w \right) di \right] = 1 \ \ (\mu_l, t) \qquad (6.16)$$

where W_t and $W_t(l)$ are the price of the composite and intermediate labour services respectively, and H is a strictly concave and increasing function characterised by $H(1) = 1$, ε_t^w is an exogenous process which reflects shocks to the aggregator function that result in changes in the elasticity of demand and therefore in the mark-up. When ε_t is constrained as $\varepsilon_t^w \in (0, \infty)$, ε_t^w follows the exogenous $ARMA$ process:

$$ln\epsilon_t^w = (1 - \rho_w) ln\varepsilon^w + \rho_w ln\epsilon_{t-1}^w - \theta_w \eta_{t-1}^w + \eta_t^w, \eta_t^w \sim N(0, \sigma_w)$$

combining, the First Order Conditions result in:

$$L_t(i) = L_t H'^{-1} \left[\frac{W_t(i)}{W_t} \int_0^1 H'\left(\frac{L_t(i)}{L_t} \right) \frac{L_t(i)}{L_t} di \right] \qquad (6.17)$$

the labour unions are an intermediary between the households and the labour packers. The mark-up above the marginal disutility is distributed to the households. However, union is also subjected to nominal rigidities, according to *Calvo*. Unions can readjust wages with probability $1 - \xi_\omega$ in each period. For those that cannot adjust wages, $W_t(l)$ will increase at the deterministic growth rate γ and weighted average of the steady state inflation π_t and of last period's inflation (π_{t-1}). For those that can adjust, the problem is to choose a wage $W_t(l)$ that maximises the wage income in all states of nature where the union is stuck with that wage in the future. Under *Calvo* pricing with partial indexation, the optimal wage set by the union that is allowed to re-optimise its wage is from the following optimisation problem:

$$\max_{\widetilde{W}_t(i)} E_t \sum_{s=0}^{\infty} \xi_\omega^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} \left[\widetilde{W}_t(i) (\Pi_{l=1}^s \gamma \pi_{t+l-1}^{\iota\omega} \pi^{1-\iota_w} - W_{t+s}^h \right] L_{t+s}(i)$$

$$L_{t+s}(i) = L_{t+s} H'^{-1} \left(\frac{W_t(i) X_{t,s}^w}{W_{t+s}} \tau_{t+s}^w \right)$$

where $\widetilde{W}_t(i)$ is the newly set wage, ξ_w^s is the Calvo probability of being allowed to optimise one's wage, $\tau_t^w = \int_0^1 H'\left(\frac{L_t(i)}{L_t}\right) \frac{L_t(i)}{L_t} di$ and

$$X_{t,s}^w = \begin{Bmatrix} 1\, for\ s = 0 \\ (\Pi_{l=1}^s \gamma \pi_{t+l-1}^{\iota w} \pi^{1-\iota_w}) for\ s = 1, \ldots, \infty \end{Bmatrix}$$

the First Order Condition is given by:

$$E_t \sum_{s=0}^{\infty} \xi_w^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} L_{t+s}(i) \left[X_{t,s}^w \widetilde{W}_t(i) + \left(\widetilde{W}_t(i) X_{t,s}^w - W_{t+s}^h \right) \frac{1}{H'^{-1}(z_{t+s}^w)} \frac{H'(x_{t+s}^w)}{H''(x_{t+s}^w)} \right] = 0 \qquad (6.18)$$

where $x_t^w = H'^{-1}(z_t^w)$ and $z_t^w = \frac{W_t(i)}{W_t} \tau_t^w$.

The aggregate wage index in this case is given by:

$$W_t = (1-\xi_w) \widetilde{W}_t H'^{-1} \left[\frac{\widetilde{W}_t \tau_t^w}{W_t} \right] + \xi_w \gamma \pi_{t-1}^{\iota w} \pi^{1-\iota_w} W_{t-1} H'^{-1} \left[\frac{\gamma \pi_{t-1}^{\iota w} \pi^{1-\iota w} W_{t-1} \tau_t^w}{W_t} \right] \qquad (6.19)$$

the mark-up of the aggregate wage over the wage received by the households is distributed to the households in the form of dividends (see the budget constraint households).

6.3.3 Goods Producers

Capital Goods producers

Capital goods producers differentiate their goods according to the need of entrepreneurs. This process demands an adjustment cost which permits a variable price of capital. The adjustment cost function is modelled, as in Badaraw and Levieuge (2011) and SW (2007) as:

$$\phi(I_t, K_t) = \frac{\phi}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 K_t,$$

with $\phi > 1$. I_t denotes the aggregate investment expenditures, K_t is the aggregate capital stock and δ is the depreciation rate of capital. The evolution of the capital stock is given by:

$$K_{t+1} = (1-\delta) K_t + I_t \qquad (6.20)$$

entrepreneurs produce wholesale goods by combining capital (K) bought from capital producers and labour supplied by household (H) and by entrepreneurs themselves (H^f, constant and normalised to one). The production technology is a Cobb-Douglas function with constant returns to scale:

$$Y = \Theta_t K_t^{\xi} \left[H_t^{\Omega} \left(H^f \right)^{1-\xi} \right]^{1-\alpha} \qquad (6.21)$$

where $1 - \xi$ represents the shares of income going to entrepreneurial labour and Θ is an exogenous technology parameter. Entrepreneurs' optimisation program consists in maximising profit. Revenues from the production process minus production costs like wages, capital adjustment costs and capital investment. The expected return on capital is equal to the expected marginal productivity of capital after deduction of adjustment costs and taking into account the residual value of capital. Given that credit contracts last only for one period (but can be renewed each period), the entrepreneur is required to sell its capital at the end of this period in order to reimburse her/his debt to the bank.

Intermediate Goods Producers

Intermediate goods producer i use the following technology:

$$Y_t(i) = \varepsilon_t^{\alpha} K_t^{\alpha} (I)^{\alpha} [\gamma^t L_t(i)]^{1-\alpha} - \gamma^t \Phi \qquad (6.22)$$

where $K_t^{\alpha}(I)$ is capital services used in production, $L_t(i)$ is a composite labour input and Φ is a fixed cost. γ^t represents the labour-augmenting deterministic growth rate in the economy and ε_t^{α} is total factor productivity and follows the process:

$$ln\varepsilon_t^a = (1-\rho_z)ln\varepsilon^a + \rho_z ln\varepsilon_{t-1}^a + \eta_t^a, \eta_t^a \sim N(0,\sigma_a) \tag{6.23}$$

the firm's profit is given by:

$$P_t(i)Y_t(i) - W_t L_t(i) - R_t^k K_t^s(i) \tag{6.24}$$

where W_t is the aggregate nominal wage rate and R_t^k is the rental rate of capital. Cost minimisation yields the following First Order Conditions:

$$\big(\partial L_t(i)\big): \Theta_t(i)\gamma^{(1-\alpha)t}(1-\alpha)\epsilon_t^a K_t^s(i)^{\alpha} L_t(i)^{-\alpha} = W_t \tag{6.25}$$

$$(\partial L_t(i)): \Theta_t(i)\gamma^{(1-\alpha)t}\alpha\varepsilon_t^a K_t^s(i)^{\alpha-1} L_t(i)^{1-\alpha} = R_t^k \tag{6.26}$$

where $\Theta_t(i)$ is the Lagrange Multiplier associated with the production function and equals marginal cost MC_t. Combining these First Order Conditions and noting that the capital-labour ratio is equal across firms implies:

$$K_t^s = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k}L_t \tag{6.27}$$

the marginal cost MC_t is the same for all firms and equal to:

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}W_t^{1-\alpha}R_t^{k\alpha}\gamma^{-(1-\alpha)t}(\varepsilon_t^a)^{-1} \tag{6.28}$$

under *Calvo* pricing with partial indexation, the optimal price set by the firm that is allowed to re-optimise results from the following optimisation problem:

$$\max_{\tilde{P}_t(i)} E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} \left[\tilde{P}(i)\left(\Pi_{l=1}^s \pi_{t+l-1}^{\iota_p} \pi_t^{1-\iota_p}\right) - MC_{t+s}\right] Y_{t+s}(i)$$

subject to:

$$Y_{t+s}(i) = Y_{t+s} G'^{-1}\left(\frac{P_t(i)X_{t,s}}{P_{t+s}}\tau_{t+s}\right) \tag{6.29}$$

where $\tilde{P}_t(i)$ is the newly set price, ξ_p^s is the *Calvo* probability of being allowed to optimise one's price, π_t is inflation defined as $\pi_t = \frac{P_t}{P_{t-1}}$, $\left[\frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}}\right]$ is the nominal discount factor for firms which equals the discount factor for the households that are the final owners of the firms,

$$\tau_t = \int_0^1 G'\left(\frac{Y_t(i)}{Y_t}\right)\frac{Y_t(i)}{Y_t}di \text{ and}$$

$$X_{t,s} = \left\{\begin{matrix} 1\, for\ s = 0 \\ \left(\Pi_{l=1}^s \pi_{t+1}^{\iota_p} \pi_*^{1-\iota_p}\right) for\ s = 1, \dots, \infty \end{matrix}\right\}$$

the First Order Condition is given by:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} Y_{t+s}(i)\left[X_{t,s}\tilde{P}_t(i) + \left(\tilde{P}_t(i)X_{t,s} - MC_{t+s}\right)\frac{1}{G'^{-1}(z_{t+s})}\frac{G'(x_{t+s})}{G''(x_{t+s})}\right] = 0 \tag{6.30}$$

where $x_t = G'^{-1}(z_t)$ and $z_t = \frac{P_t(i)\tau_t}{P_t}$.

Their aggregate price index in this case is given by:

$$P_t = \left(1-\xi_p\right)P_t(i)G'^{-1}\left[\frac{P_t(i)\tau_t}{P_t}\right] + \xi_p \pi_{t-1}^{\iota_p}\pi_*^{1-\iota_p}P_{t-1}G'^{-1}\left[\frac{\pi_{t-1}^{\iota_p}\pi_*^{1-\iota_p}P_{t-1}\tau_t}{P_t}\right] \quad (6.31)$$

Final Goods Producers

The final good Y_t is a composite mode of a continuum of intermediate goods $Y_t(i)$ as in Kimball (1995). The final goods producers buy intermediate goods, package them into Y_t, and sell them to consumers, investors and the government in a perfectly competitive market. They maximise profits as:

$$max_{Y_t,Y_t(i)}\, P_tY_t - \int_0^1 P_t(i)Y_t(i)di$$

subject to:

$$\left[\int_0^1 G\left(\frac{Y_t(i)}{Y_t};\varepsilon_t^p\right)di\right] = 1 \quad \left(\mu_{f,t}\right) \quad (6.32)$$

where P_t and $P_t(i)$ are the price of the final and intermediate goods respectively, and G is a strictly concave and increasing function characterised by $G(1) = 1. \varepsilon_t^p \in (0,\infty). \varepsilon_t^p$ follows the exogenous $ARMA$ process:

$$ln\varepsilon_t^p = \left(1-\rho_p\right)^{ln\varepsilon^p} + \rho_p^{ln\varepsilon_{t-1}^p} - \theta_p\eta_{t-1}^p + \eta_t^p, \eta_t^p \sim N\left(0,\sigma_p\right) \quad (6.33)$$

combining the First Order Conditions with respect to $Y_t(i)$ and Y_t is given by:

$$Y_t(i) = Y_tG'^{-1}\left[\frac{P_t(i)}{P_t}\int_0^1 G'\left(\frac{Y_t(i)}{Y_t}\right)\frac{Y_t(i)}{Y_t}di\right] \quad (6.34)$$

as in Kimball (1995), the assumptions on G implies that the demand for input $Y_t(i)$ is decreasing in its relative price, while the elasticity of demand is a positive function of the relative price (or a negative function of the relative output).

6.3.4 Financial Intermediaries

Introducing FIs into a standard NK-DSGE model provides insight to the source of financial frictions. In the Keynesian model, financial markets are assumed to work perfectly. In particular, agents can make deposits and take loans in any quantity at the risk free rate R_t, fully controlled by the central bank. However, this will no longer be the case in the New Keynesian model. Implementing any credit imperfections require distinguishing between borrowers and lenders. As in both External Finance Premium (EFP) and Collateral Constraint (CC) versions of the NK DSGE models, financial frictions emerge at the level of capital management where its ownership needs to be separated from the households. Therefore, it is essential to introduce a new type of agent, named *entrepreneur*, who specialises in capital management (SW, 2003, 2007).

Entrepreneurs finance their operations, i.e. renting capital services to firms, by taking loans from the banking sector, which refinance them by accepting deposits from the households. The financial intermediation between households and entrepreneurs is subject to frictions, resulting in interest rate Spreads or quantity constraints. In the EFP version, financial frictions arise because management of capital is risky. Individual entrepreneurs are subject to idiosyncratic shocks, which are observed by them for free, while the lenders can learn about the shocks only after paying monitoring costs. This costly state verification problem (Townsend, 1979) results in a financial contract featuring an endogenous premium between the lending rate and the risk-free rate, which depends on borrowers leverage. Since the banking sector is perfectly competitive and entrepreneurs are risk neutral, banks pay interest on household deposits equal to the risk-free rate and break even every period (see SW, 2007 and Merola, 2015). Banks finance their loans by issuing time deposits to households at the risk-free interest rate $R_{t.}$ It is assumed that the perfectly competitive banking sector is owned by risk-averse households. This, together with risk-neutrality of entrepreneurs, implies a financial contract insulating the lender from any aggregate risk. Hence, interest paid on a bank loan by entrepreneurs is state contingent and guarantees that banks break even in every period.

Furthermore, following the work of BGG (1999) and CMR (2009), the financial frictions component of the SW model, replacing the arbitrage condition between the return to capital and the risk rate, is introduced as:

$$E_t\left[R_{t+1}^k - R_t\right] = -b_t + \zeta_{sp,b}\left(q_t^k + k_t - n_t\right) + \sigma_{w,t} \tag{6.35}$$

and

$$R_t^k - \pi_t = \frac{r_*^k}{r_*^k + (1+\delta)} r_t^k + \frac{(1+\delta)}{r_*^k + (1-\delta)} q_t^k - q_{t-1}^k, \tag{6.36}$$

where $\zeta_{sp,b}$ is a spread parameter, $R_t^k$is the gross nominal return on capital for entrepreneurs, n_t is entrepreneurial equity, and $\sigma_{w,t}$ captures mean-preserving changes in the cross-sectional dispersion of ability across entrepreneurs (CMR, 2009) and follows an AR(1) process with parameters $\rho_{\sigma w}$ and $\sigma_{\sigma w}$. b_t is an exogenous process drives a wedge between the intertemporal ratio of marginal utility of consumption and the riskless real return $R_t - \mathbb{E}_t[\pi_{t+1}]$, and follows an AR(1) process with parameters. The second condition describes the return on capital, while the first one governs the Spread between the expected return on capital and the riskless rate [if $\zeta_{sp,b} = 0$ and the financial friction shocks are zero, (6.1) coincides with (6.35) and (6.36)]. The condition in Equation 6.37 describes the evolution of entrepreneurial net worth:

$$\begin{aligned} n_t = {} & \zeta_{n,R^k}\left(R_t^k - \pi_t\right) - \zeta_{n,R}(R_{t-1} - \pi_t) + \zeta_{n,qK}\left(q_{t-1}^k + k_{t-1}\right) + \zeta_{n,n} n_{t-1} \\ & - \frac{\zeta_{n,\sigma\omega}}{\zeta_{sp,\sigma\omega}} \sigma_{\omega,t-1} \end{aligned} \tag{6.37}$$

in addition, the set of measurement in Equation (6.52) is augmented as follows:

$$Spread \;=\; SP_* + 100\mathbb{E}_t\left[R_{t+1}^k - R_t\right] \tag{6.38}$$

where the parameter SP_* measures the steady state spread. The *priors* are specified for the parameter $SP_*, \zeta_{sp,b,}$ in addition to $\rho_{\sigma w}$ and $\sigma_{\sigma w}$, and the parameters such as the steady state default probability (F_*) and survival rate of entrepreneurs (γ_*) are to be fixed[122].

6.3.5 Government Policies and the Monetary Authority

The central bank uses a Taylor-type rule[123] which takes the following form in the benchmark case:

$$r_t^n = \beta_0 r_{t-1}^n + (1-\beta_0)\left(\beta_\pi \pi_t + \beta_y Y_t\right) \tag{6.39}$$

where r_t^n is the deviation of the nominal interest rate from steady state and Y_t is the output gap (log-deviation of output from steady state). The Taylor rule can be modified to include other variables besides inflation and output. Finally, the equilibrium on the goods and services markets is represented as:

$$Y_t = C_t + C_t^f + C_t^b + I_t + G_t \tag{6.40}$$

the central bank follows a nominal interest rate rule by adjusting its instrument in response to deviations of inflation and output from their respective target levels. In a New Keynesian approach, the monetary policy is conducted according to a Taylor rule[124], targeting deviations of inflation and GDP from the deterministic steady state, allowing additionally for interest rate smoothing[125]:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\rho_R}\left[\left(\frac{\pi_t}{\pi_*}\right)^{r_\pi}\left(\frac{Y_t}{Y_t^*}\right)^{r_y}\right]^{1-\rho}\left(\frac{Y_t/Y_{t-1}}{(Y_t^*)/(Y_{t-1}^*)}\right)^{r_{\Delta y}}\epsilon_t^r \tag{6.41}$$

where R^* is the steady state nominal rate (gross rate) and Y_t^* is natural output[126]. As in SW (2007), the parameter ρ_R determines the degree of interest rate smoothing. Y denotes GDP, $\pi_t = \frac{P_t}{P_{t-1}}$, and r are iid normal innovations (the standard deviation is σ_R). The exogenous monetary policy shock ϵ_t^r is determined as:

$$ln\epsilon_t^r = \rho_r ln\epsilon_{t-1}^r + \eta_t^r \tag{6.42}$$

the government budget constraint is of the form:

$$P_t G_t + B_{t-1} = T_t + \frac{B_t}{R_t} \tag{6.43}$$

122 See also Curdia et. al. (2013).
123 The Taylor type rule is identified as the dominant monetary policy practice in the UK. See Chapter 2 for further information.
124 But is adjusted in accordance with the findings in Chapter 2.
125 See Chapter 2 for further information on interest rate smoothing.
126 The natural output level is defined as the output in the flexible price and wage economy without mark-up shock in prices and wages. Persistent mark-up shocks may therefore result in persistent conflict between the stabilising inflation and the output gap and therefore in persistent deviations of inflation from the inflation target.

where T_t are nominal lump-sum taxes (or subsidies) that also appear in household's budget constraint. Government spending expressed relative to the steady state output path $\varepsilon_t^g = G_t/(Y\gamma^t)$ follows the process:

$$ln\varepsilon_t^g = (1-\rho_g)ln\varepsilon^g + \rho_g ln\varepsilon_{t-1}^g + \rho_{ga} ln\varepsilon_t^a - \rho_{ga} ln\varepsilon_{t-1}^a + \eta_t^g, \eta_t^g \sim N(0, \sigma_g) \tag{6.44}$$

which allows for a reaction of government spending to respond to the productivity process.

6.3.6 Net Worth, Resource Constraint and Market Equilibrium

Integrating the budget constraint across households and combining with the government budget constraint and the expressions for the dividends of intermediate goods producers and labour unions give the overall resource constraint for market equilibrium. The capital rental market is in equilibrium if production equals demand by households for consumption and investment and the government (SW, 2007):

$$C_t + I_t + G_t + a(Z_t)K_{t-1} = Y_t \tag{6.45}$$

proceeds from selling capital, net interest paid to the bank, constitute end of period net worth. To capture the phenomenon of ongoing firms that enter and exit the market and to ensure that entrepreneurs do not accumulate enough wealth to become fully self-financing, it is assumed that each period a randomly selected and time-varying fraction $1 - \epsilon_{v,t}v$ of them go out of business, in which case all their financial wealth is rebated to the households. At the same time, an equal number of new entrepreneurs enter, so that the total number of entrepreneurs remain constant. Those who survive and enter receive a transfer T_E from the households. This ensures that both entrants and surviving bankrupt entrepreneurs have at least a small but positive amount of wealth, without which they would not be able to buy any capital.

Aggregating across all entrepreneurs and using

$$R_{E,t+1}Q_t K_t \left[\overline{a}_{E,t+1} \left(1 - F_{1,t+1}\right) + (1-\mu)F_{2,t+1} \right] = R_t L_t \tag{6.46}$$

yields the following law of motion for net worth in the economy:

$$V_t = \varepsilon_{v,t}v \left[R_{E,t}Q_{t-1}K_{t-1} - \left(R_{t-1} + \frac{\mu F_{2,t} R_{E,t} Q_{t-1} K_{t-1}}{L_{t-1}} \right) L_{t-1} \right] + T_E \tag{6.47}$$

the term in the square brackets represent the total revenue from renting and selling capital net of interest paid on bank loans, averaged over both bankrupt and non-bankrupt entrepreneurs. Finally, as monitoring costs are real, the aggregate resource constraint from the NK model (6.45) needs to be modified so that it becomes:

$$c_t + i_t + g_t + \mu F_{2,t} R_{E,t} Q_{t-1} K_{t-1} = y_t \tag{6.48}$$

however, to ensure compatibility across the models, y_t represents net monitoring costs as a proxy for output. The variables are log linearized around their steady state and those that are not indexed by time represent steady-state values. To begin with, output (y_t) is composed by:

$$y_t = \frac{c}{y}c_t + \frac{i}{y} + i_t + \varepsilon_t^g + r^k\left(\frac{k}{y}\right)z_t^k + \left(\frac{k}{y}\right)f\left(1 - \frac{r}{f}\right)\left(1 - \frac{1}{lev}\right)(f_t + p_{t-1}^k + k_t) \quad (6.49)$$

where c_t stands for consumption, i_t for investment and g_t is exogenously determined public spending. As in SW (2007) the steady state ratios $\frac{c}{y}$ and $\frac{i}{y}$ are defined as[127]:

$$\frac{c}{y} = 1 - \frac{g}{y} - \frac{i}{y}, \text{ and } \frac{i}{y} = [\gamma - (1 - \delta)]\frac{k}{y}, \quad (6.50)$$

the cost associated with capital utilisation is measured by the $r^k\left(\frac{k}{y}\right)z_t^k$ term. The term $\left(\frac{k}{y}\right)f\left(1 - \frac{r}{f}\right)\left(1 - \frac{1}{lev}\right)(f_t + p_{t-1}^k + k_t)$ measures the bankruptcy costs. As in SW, it is assumed that public spending follows an $AR(1)$ process with an iid −normal error term and is also affected by the productivity shock[128] as follows:

$$\varepsilon_t^g = \rho_g\varepsilon_{t-1}^g + \eta_t^g + \rho_{ga}\eta_t^a \quad (6.51)$$

the steady state variables and the indexed variables are presented in Table 6.1 below. All the other variables are log-linearized and move around the stated steady state. The log-linearized version of the model components are presented in the appendix (see Appendix 6.3A).

Table 6.1 Steady State and Indexed Variables

Steady state variables	Definitions
γ	Growth rate
δ	Depreciation rate of capital
g/y	Public spending-to-output ratio
c/y	Consumption-to-output ratio
i/y	Investment-to-output ratio
k/y	Capital-to-output ratio
$r^k\left(\frac{k}{y}\right)z_t^k$	
r^k	Rental rate of capital
z_t^k	The capital utilisation rate
$\left(\frac{k}{y}\right)f\left(1 - \frac{r}{f}\right)\left(1 - \frac{1}{lev}\right)(f_t + p_{t-1}^k + k_t)$	
k_t	Capital
r	The risk-free interest rate
p_{t-1}^k	The lagged value of capital stock
f	External funding cost
lev	The leverage ratio (capital-to-net worth ratio) in the corporate sector

Source: author's review and representations

[127] The steady state variables are defined in Table 6.1.
[128] The latter is empirically motivated. Estimation of the exogenous spending includes net exports, which is likely to be affected by domestic productivity developments.

6.4 Data and Parameters

The model with financial frictions presented in Equations (6.2 to 6.45) is estimated using the stated prior information, as in Bayesian techniques. The DSGE model is estimated using *eight* key macroeconomic quarterly UK time series observable variables, shown in Table 6.2: log (ln) of real GDP, real consumption, real investment, real wage, hours worked, consumer price and retail price indices, GDP deflator, the monetary base rate and the *premia*- Spread. The data are collected and cross-checked using various sources. The nominal data are converted to real vectors using the GDP deflator. A full description of the variables is given in the Table below.

Table 6.2 Observable Variables Definition and Sources

Observable Variables[129]	Symbols	Variable Definitions	Data Sources
$dlnGDP_t$	y_t	Log of real output	ONS and IFS
$dlnCONS_t$	c_t	Log of real consumption	ONS and IFS
$dlnINV_t$	i_t	Log of real investment	ONS and IFS
$lnGDPdef_t$	yd_t	Log of real output deflator	BOE, OECD, IFS
$dlnW_t$	w_t	Log of real wage	ONS
$lnHOURS_t$	l_t	Log of hours worked	BoE and OECD, IFS
$dlnP_t$	π_t	Log of consumer price index	ONS and OECD
$RATE_t$	r_t	BoE base rate	BoE, OECD
$SPREAD_t$	s_t	Financial frictions indicator	BoE, OECD, author's calculation

Note: multiple data sources are used when single sources are not adequately complete and to verify correctness.

The data generation process follows SW's DSGE model used for the Euro Area augmented with the FAM and to some extent BGG and as recommended by the BoE. The natural log difference observable variables are real GDP, real consumption, real investment, the inflation (GDP deflator), and the real wage. Furthermore, natural log of hours worked, the nominal monetary policy rate and the corporate Spread[130] are also included. The data sample covers from 1955 to 2014 at a quarterly frequency. The corresponding measurement equations are:

[129] Definition and sources of data used for DGP are presented in Appendix 6.

[130] The first three variables are obtained from the Office for the National Statistics (ONS). Wage and hours worked are obtained from the Bank of England and OECD Databases (with confirmation from IFS). The interest rate is obtained from the BoE with close comparison with OECD. The Corporate Spread is defined as the difference between the riskless 10 years government bond and the Treasury bill rate. In the U.S. case, De Graeve (2008) and Gertler and Lown (2000) show that the high yield Spread (<BBB) is the best indicator of the external finance premium. Merola uses the BAA-AAA Spread as it is available over a longer time span. A more detailed description of the data is given in the Appendix 6.

$$Y_t = \begin{pmatrix} dLNGDP_t \\ dLNCONS_t \\ dLNINV_t \\ dLNW_t \\ LNHRS_t \\ dLNP_t \\ RATE_t \\ FF/\,SPREAD_t \end{pmatrix} = \begin{pmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{l} \\ \bar{\pi} \\ \bar{r} \\ \bar{s} \end{pmatrix} + 100 \begin{pmatrix} y_t - y_{t-1} + z_t \\ c_t - c_{t-1} + z_t \\ i_t - i_{t-1} + z_t \\ w_t - w_{t-1} + z_t \\ l_t \\ \pi_t \\ r_t \\ prem_t \end{pmatrix} \tag{6.52}$$

where L and dL stand for 100 times log and log difference, respectively; $\bar{\gamma} = 100(\gamma - 1)$ is the common quarterly trend growth rate for real GDP, consumption, investment and wages; $\bar{l}$ is steady-state hours worked, which is normalised to be equal to zero; $\bar{\pi} = 100(\pi - 1)$ is the quarterly steady-state inflation rate; $\bar{r} = 100(\beta^{-1}\gamma^{\sigma_c}\bar{\pi} - 1)$ is the steady state nominal interest rate. In the specification of the model without financial frictions, the Spread is not included in the list of observable variables. Given the estimates of the trend growth rate and the steady-state inflation rate, the latter is determined by the estimated discount rate. *Firstly*, the mode of the posterior distribution is estimated by maximising the log posterior function, which combines the prior information on the parameters with the likelihood of the data. In the *second* step, the Metropolis-Hastings algorithm is used to get a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model[131]. The model is estimated over two periods and further sub divided into two sub-sample periods. The full sample period covers from 1955Q1 to 2014Q4; a pre-crisis sample period covers from 1955Q1 to 2007Q3; and the crisis and post-crisis period is from 2007Q4 to 2014Q4. The sub-sample periods are analysed and discussed based on the pre and post time references based on the major structural shifts in the UK economy identified in Chapter 4. The estimation process conducted using a NK Bayesian DSGE model with and without the financial accelerator mechanism.

The full sample includes various monetary regimes such as the monetary targeting in the late 1970s and early 1980s; exchange rate management, culminating in the UK membership of ERM; the adoption of inflation targeting in October 1992 and the central bank independence of 1992 and 1997, the global financial crisis from late 2007 and the post-crisis recession period. The pre-crisis sample also includes different monetary regimes similar to the full sample excluding the post-GFC period.

[131] All estimations are carried out with the latest Dynare (4.2.4). Excluding the first 50,000 draws, a sample of 250,000 draws was created for the estimation. To define the transition probability function that generates the new proposed draw, Hessian resulting is used from the optimization procedure. Two methods were used to test the stability of the sample. The first convergence diagnostic is based on Brooks and Gelman (1998) and compares between and within moments of multiple chains. The second method to evaluate the stability is a graphical test based on the cumulative mean minus the overall mean (see Bauwens et al. 2000). An exact statistical test for the stability of the sample is complicated by the highly autocorrelated nature of the MH-sampler. From an economic point of view, however, the differences between subsamples and independent samples of size 100,000 or more are negligible.

6.5 Estimation and Model Evaluation

6.5.1 The Bayesian Estimation

The specification of prior distributions for the majority of parameters closely follows the SW model and BGG, to some extent. The first step in Bayesian estimation is setting the prior distribution of selected parameters. The prior describes the available information prior to observing the data used in the estimation. In the second step, the Kalman filter is used to calculate the likelihood function of the data. Combining prior distributions with the likelihood of the data gives the posterior kernel, which is proportional to the posterior density. The posterior distribution of the model's parameters is summarised by the model and the mean. In the calibration process, the study follows the standard process in Bayesian estimation of DSGE models. Some parameters are fixed in the estimation procedure as in SW (2007). Parameters that are weakly identified are calibrated using the observable variables.

As in SW (2007) and CEE (2005), some parameters are fixed prior to estimation because the data contain little information about them. The remaining parameters are computed accordingly with the steady state relationships reported in Table 6.2. Most of the calibrated parameters, reported in Table 6.3, are related to the steady-state value of variables observed in the economy (Villa and Yang, 2011). The calibrated values of the capital income share, the discount factor, the depreciation rate and the price elasticity of demand are standard in literature. As the data set do not contain information on employment and wage, the elasticity of labour supply, the relative utility weight of labour and the habit persistence parameter are calibrated such that the average hours of work is equal to 0.30 (Villa and Yang uses 0.33), which is a commonly used value in the literature ranging from 0.30 to 0.40. The discount factor β is set equal to 0.99, implying an annual steady-state real interest rate of 4% (or equivalently a quarterly rate of 1%). The parameter θ is set equal to 6, implying a steady-state price mark-up of 20%, also a common value used in the literature. The depreciation rate δ is assigned by the commonly used values of 0.025. The parameter of the Cobb–Douglas function, α, is set equal to 0.3. As in BGG, in order to have an annualised business failure rate, $F(\overline{\omega})$, of 3% (0.75% quarterly), a steady state risk Spread, $R^k - R^n$, equal to 200 basis points, and a ratio of capital to net worth, K/NW, of 2 (or equivalently a leverage ratio of 0.5). The idiosyncratic productivity variable, $log(\omega)$, to be log-normally distributed with variance equal to 0.07, and the fraction of realised payoffs lost in bankruptcy, μ, is set to 0.12. The steady-state share of consumption is set equal to 0.60. Table 6.3 presents summary of the calibrated parameters based on fixed and estimated parameters.

Table 6.3 The Calibrated Parameters of the DSGE Model

Parameter		Value
	Fixed Parameters	
δ	Capital depreciation rate	0.025
λ_w	Steady-state wage mark-up	1.5
g_y	Exogenous spending-GDP ratio	0.18
ε_p	Curvature parameters of Kimball aggregator in goods market	10
ε_w	Curvature parameters of Kimball aggregator in labour market	10
	Estimated Parameters Initialisation	
β	Discount factor	0.99
θ	Goods elasticity of substitution	6
α	Capital share on output	0.30
$F(\overline{\omega})$	Annualised business failure rate	0.03
$R^k - R$	Annual steady state risk premium	0.02
$\frac{K}{NW}$	Capital to net worth ratio	2
μ	Payoff lost in bankruptcy	0.12
$\frac{C}{Y}$	Consumption-output ratio	0.6
σ_ω	Idiosyncratic productivity variable ω	0.07

Source: calibration, author's representation, various sources[132].

The remaining parameters governing the dynamic of the model are estimated using a Bayesian procedure. They mostly pertain to the nominal and real frictions in the model and the exogenous shock process. Table 6.7 and 6.8 report the assumptions for the prior distributions of the estimated parameters. The locations of the prior mean correspond to a large extent to those in relevant studies on the UK economy by Villa and Yang (2011), Harrison and Oomen (2010), DiCecio and Nelson (2007) and Cecioni and Neri (2011).

6.5.2 The DSGE Model Evaluation

The full sample 1955Q1 to 2014Q4 is used to estimate the two DSGE models without the financial crisis period (1955Q1 to 2007Q3) and with the financial crisis and recession periods (1955Q1 to 2014Q4). Table 6.5 reports the log-marginal likelihood computed via Laplace Approximation (LA) and the Kass and Raftery (KR) criterion based on the log of the Bayes Factors. Both model specifications, with and without the FAM, are estimated using 7 observable variables and 7 shocks. Table 6.4 presents the log-marginal likelihood for the two strands of the DSGE models over the two alternative estimation samples. The first Bayesian model comparison is conducted based on the Bayes Factor (BF)[133] decision rule shown in Table 6.4. The estimation results of the alternative

[132] See SW (2007); BGG (1999); Merola (2015); Gelain (2010).

[133] Bayes factor is the ratio of the posterior odds of H_1 (hypothesis 1) to its prior odds, regardless of the value of the prior odds. When the hypotheses H_1 and H_2 are equally probable a priori so that $Pr(H_1) = Pr(H_2) = 0.5$, the Bayes Factor is equal to the posterior odds in favour of H_1. However, the two hypotheses may well not be equally likely a priori (Kass and Raftery, 1995).

model specifications with and without the financial frictions mechanisms are compared based on their performances. The comparison is followed by the discussion on the estimates of each parameter.

Table 6.4 The Bayes Factor Decision Rule Criteria

Support for MOD_{NOFA}	Very slight evidence against MOD_{NOFA}	Slight evidence against MOD_{NOFA}	Strong evidence against MOD_{NOFA}	Very strong evidence against MOD_{NOFA}
$BF_{FANOFA} < 1$	$1 < BF_{FANOFA} < 3$	$3 < BF_{FANOFA} < 10$	$10 < BF_{FANOFA} < 100$	$BF_{FANOFA} > 100$

Source: Kass and Raftery, (1995) and author's analysis, where MOD_{NOFA} refers to DSGE model with no Financial Accelerator Mechanism; MOD_{FA} refers to DSGE model with Financial Accelerator Mechanism.

There are various ways to evaluate the best fit between the model with and without the FAM. The two frequently used ways are comparing the fitted values with the actual or quarterly data and computing marginal likelihood via Laplace Approximation statistics (SW, 2007; Gelain, 2010). First, the models' marginal data density is calculated. The model with financial frictions is labelled as MOD_{FA} and the alternative model without financial friction is labelled as MOD_{NOFA}. The Bayes Factor is computed as, $BF_{FA\backslash NOFA} = \frac{P\left(\frac{Y}{MOD_{FA}}\right)}{p\left(\frac{Y}{MOD_{NOFA}}\right)}$. The BF is interpreted, as suggested by Jefferys (1961).[134]

Table 6.5a Log Data Density (Sample-1: 1955Q1 to 2014Q4)

Log data density	Model with FA	Model without FA	Bayes factor $\left(\frac{FA}{NOFA}\right)$
Laplace approximation	-1880.71	-2108.02	$\exp^{227.31}$
Harmonic mean	-1879.02	-2107.05	$\exp^{228.03}$

Source: author's analysis (using dynare-MatLab)

Table 6.5b Log Data Density (Sample-2: 1955Q1 to 2007Q3)

Log data density	Model with FA	Model without FA	Bayes Factor $\left(\frac{FA}{NOFA}\right)$
Laplace approximation	-1606.62	-1656.85	$\exp^{50.23}$
Harmonic mean	-1605.10	-1656.45	$\exp^{51.35}$

Source: author's analysis (using dynare-MatLab)

Following Adolfson et al. (2007), Figure 6.1 and Figure 6.2 report the model fit and the actual values of the series used in the estimations. The two Figures report the Kalman Filter (KF) estimates of the observed variables, computed as the posterior mode of the estimated parameters in the benchmark model along with the actual variables. The two Figures characterise the KF estimates for the full sample period 1955Q1 to 2014Q4 and the sample period from 1955Q1 to 2007Q3, respectively. The first sample includes the external finance premium observation but the second set of variables do not include this variable. The red line corresponds to the one-step

[134] Jeffery's suggestion of interpreting Bayes factors are the main rule of thumb in Bayesian Econometrics.

ahead forecasts implied by the estimated model and the blue line represents the data. Roughly, these estimates correspond to fitted values in a regression. It is evident from the Figures; the in-sample fit of the baseline model is quite satisfactory for all variables considered in both sample periods. The graphs[135] shown in Figure 6.1 is reasonably intuitive but it gives no clear insight of which model is a better fit for the data in this case. For this reason, a statistics property is required to evaluate the model fit. According to the rule of thumb given by Kass and Raftery (1995, known as 'the KR criterion'), and a slightly different KR criteria given by Jefferys $BF_{FA/NOFA} = \frac{P\left(\frac{Y}{MOD_{FA}}\right)}{p\left(\frac{Y}{MOD_{NOFA}}\right)}$, when the factor is between 1 and 3, there is a very slight evidence against MOD_{NOFA}, when it is between 3 and 10 there will be slight evidence against the DSGE model without the FAM (MOD_{NOFA}). When the BF is between 10 and 100, it is interpreted as a strong evidence against the model without the FAM (MOD_{NOFA}), and finally if the BF is more than 100, it suggests that there is a very strong evidence against the model without the FAM. The decision rule is shown in Table 6.4. The model evaluation process confirms that there is strong evidence against the model without the financial accelerator effect. Thus, it is imperative that this outcome gives an initial verdict that the introduction of the financial accelerator mechanism improves the model's ability to fit the data. This implies that a DSGE model without the introduction of the FAM does not represent the data well and is likely to provide a misleading information.

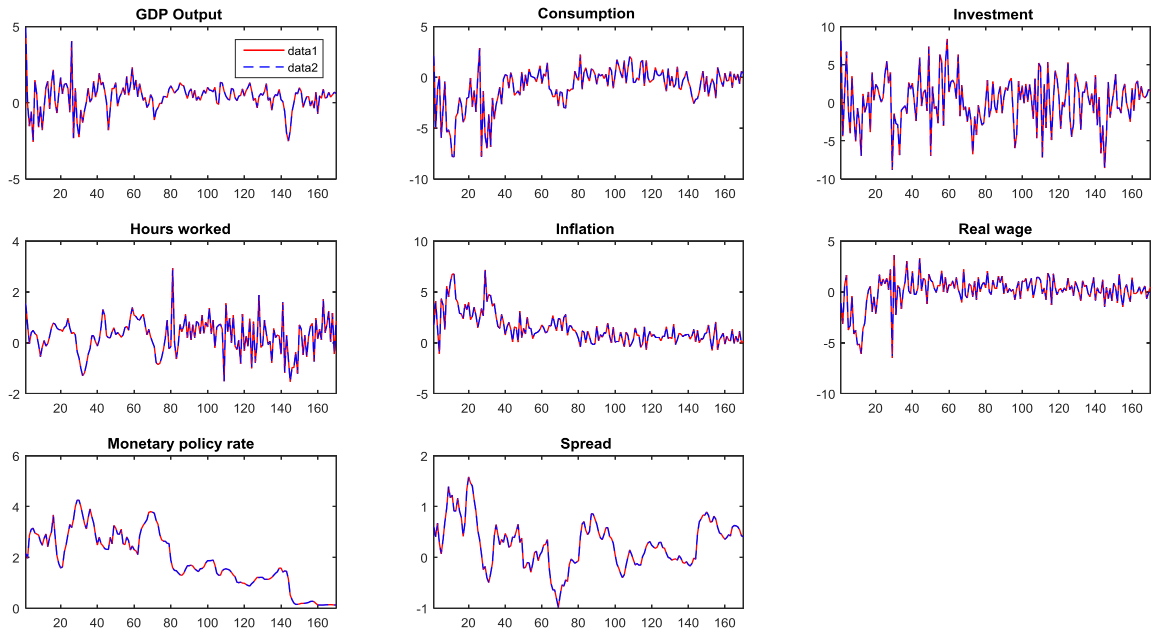


Figure 6.1 Data and Fitted Values of the Model with FAM for the Full Data
Data -dashed blue line; Fitted Values - solid red line

[135] MatLab generated graphs for actual and estimated graphs.

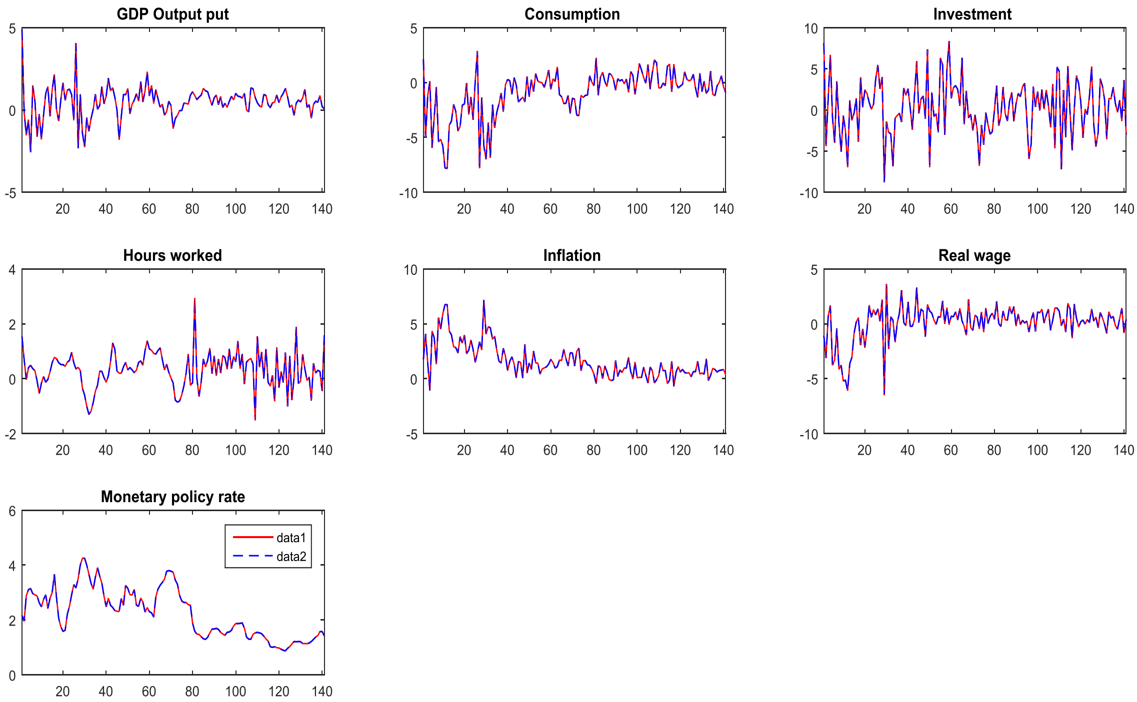


Figure 6.2 Data and Fitted Values of the Model without the FAM
Data - dashed blue line; Fitted Values -solid red line [pre-crisis period]

To evaluate the model with the financial accelerator mechanism, an alternative criterion is the log of BF, which is determined from the difference between the log of marginal likelihood functions of the model with and without the financial factor:

$$\log\left(BF_{ij}\right) = \log\left(p(Y\backslash M_i)\right) - \log\left(p\left(Y\backslash M_j\right)\right) \tag{6.53}$$

where $p(Y|M_i)$ and $p(Y|M_j)$ are the marginal likelihood functions of model i and model j[136], respectively. If the values of $2\log(BF_{ij})$ is less than one, the evidence is in favour of MOD_{NOFA}, otherwise the evidence supports the model with the financial accelerator mechanism. Alternatively, the criteria suggests that if the BF is above 10 provides very strong evidence, values between 6 and 10 provide strong evidence and finally values between 2 and 6 provide positive evidence in favour of the model with the financial accelerator mechanism. Values between 0 and 2 are not worth mentioning (see Merola, 2015; Gelien, 2010). To make a balanced comparison, the two models, with and without the financial accelerator mechanism, attribute the same number of shocks and are estimated using the same observable variables. This leads to the specification and estimation of the models using 7 observable variables and 7 shocks[137].

[136] The marginal likelihood is commonly calculated using the modified harmonic mean because it works for all sampling methods and is not sensitive to the sample size. Here, the Laplace Approximation (LA) method is used. It assumes that the posterior distribution is close to a normal distribution. The advantage of using the LA is that it can generate an approximation of the marginal likelihood quickly, given the normality assumption and the estimated mode. Furthermore, the LA works very well in practice and it is often very close to the modified harmonic mean.

[137] This version of the SW model with financial frictions, based on 7 variables and 7 shocks, is very close to the specification in De Greave (2008).

Table 6.6 Comparison of Marginal Likelihood via Laplace Approximation

Estimation Sample	Log(ML) Model without financial accelerator	Log(ML) Model with financial accelerator	KR criterion 2log(BF)
1955Q1-2007Q3	-1656.85	-1606.62	100.46
1955Q1-2014Q4	-2108.02	-1880.71	454.62

Note: this is log data density approximation of the alternative specification of the model

Source: author's calculations (with dynare-MatLab)

The model stated as MOD_{NOFA} switches off the effect of exogenous disturbances to the Spread while MOD_{FA} allows the effect of exogenous disturbances to the Spread. The variables and shocks choice allow the estimation process to account for differences in the performance of the two models to the presence of the endogenous financial frictions. The log-marginal likelihood computed via Laplace Approximation and the Bayes Factor comparison confirm that the DSGE model performance improves when the financial frictions mechanism is included, especially when the estimation is carried out over the full sample (1955Q1 to 2014Q4). The marginal likelihood improves by 50.23 log-points and 227.31 log points when the estimation is carried out on the pre-crisis sample and the post-crisis sample (full sample period), respectively. Based on the KR criterion, there is a very strong evidence in favour of the model with financial accelerator mechanism under both estimation samples. The results show that the Log (Maximum Likelihood) increases for the model with the financial frictions mechanism. When the global crisis period is included in the estimation sample, as shown by the KR and Jeffery criteria, the model with the financial accelerator mechanism has over-performed in comparison with the model without the financial frictions. Therefore, the initial model comparison provides first-hand evidence that the financial frictions mechanism in a New Keynesian Bayesian DSGE model is an important feature in both pre and post-crisis periods. This would suggest that a NK DSGE model with a FAM provides better information for policy decision not only during normal times but also during crises periods. Although KR and Jeffery provides useful information to assess the validity of the DSGE models with and without the FAM, the role of each financial and macroeconomic shock need further investigation to assess to what extent the introduction of financial frictions into the DSGE models represent the UK real business cycle. To address this, further analysis based on Bayesian posterior distribution is essential.

6.6 Prior Distributions and Posterior Estimations

6.6.1 Prior Distributions

The remaining 31 parameters, which mostly pertain to the nominal and real frictions in the model as well as the exogenous shock process, are estimated. Table 6.7 and 6.8 report the assumptions for the prior distributions of the estimated parameters. These common parameters, the priors, are set according to SW (2003). Following the priors for the Euro Area data, the *gamma* distribution is used for parameters measuring elasticity. For the unbounded parameters, the *normal* distribution is used for posterior estimation process. For the parameters measuring the response to inflation in the Taylor rule, a lower bound is used so that the Taylor principle is satisfied. Furthermore, in terms of the assumption of inverse distributions[138], $inverse\ gamma$ distribution is used for the standard deviation of the shocks with a loose prior of two degrees of freedom and a mean of 0.10; the elasticity of the EFP with respect to firm leverage is set as *inverse gamma* distribution with mean 0.05 and infinite variance. The *beta* distribution is used for all parameters bounded between 0 and 1, typically the autoregressive coefficients. Following the BGG parameters, the *beta* distribution is also assigned to the *entrepreneur's rate of survival*. Table 6.7 and Table 6.8 summarise the priors and the distributions assigned to each parameters with their specific mean and standard deviation.

As in SW, CEE and Merola, the priors on the stochastic processes are harmonised as in SW (2007). The persistence of the $AR(1)$ processes is *beta* distributed with mean 0.5 and standard deviation 0.2. A similar distribution is assumed for the MA parameter in the process for the price and wage mark-up. The quarterly trend growth rate is assumed to be normally distributed with mean 0.4 (quarterly growth rate) and standard deviation 0.1. The steady-state inflation rate (mean=0.625, σ=0.20) and the nominal interest rate (mean=0.25, σ=0.10) follow a *gamma* distribution with a mean of 2.5 percent and 1 percent on an annual basis. Five parameters are restricted in the estimation procedure. The depreciation rate δ is fixed at 0.025 (on a quarterly basis) and the exogenous spending, GDP ratio, g_y is set at 17.5%. Estimating these parameters is a complex process unless the investment and exogenous spending ratio were used directly in the measurement equation as in SW, (2007).

There are other three parameters that are not yet identified. These are the steady-state mark-up in the labour market (λ), which is set at 1.5; the curvature parameters of the Kimball aggregators in the goods; and labour market (ε_p and ε_w), both set at 10 (as in SW, 2003). The parameters describing the monetary policy rule are based on a standard Taylor rule: the long-run reaction on inflation and the output gap are described by a normal distribution with mean 1.5 and 0.125 (a

[138] See SW (2003, 2007).

quarter of 0.5) and standard errors of 0.25 and 0.05, respectively. The persistence of the policy rule is determined by the coefficient on the lagged interest rate (interest rate smoothing), which is assumed to be normal around a mean of 0.75 with a standard error of 0.1. The *prior* on the short-run reaction coefficient to the change in the average output gap is 0.125 ($\sigma = 0.05$). The parameters of the utility function are assumed to be distributed as follows. The intertemporal elasticity of substitution is set at 1.5 with a standard error of 0.375; the habit parameter is assumed to fluctuate around 0.7 with a standard error of 0.1, and the elasticity of labour supply is assumed to be around 2 with a standard error of 0.75. DSGE estimations have relied on these standard calibrations. Based on CEE (2005), the prior on the adjustment cost parameter for investment is set around 4 with a standard error of 1.5 and the capacity utilisation elasticity is set at 0.5 with a standard error of 0.15. Finally, there are three parameters describing the price and wage setting. The *Calvo* probabilities are assumed to be around 0.5 for both prices and wages, suggesting an average length of price and wage contracts of half a year, which is compatible with the findings of Bils and Klenow (2004) for prices. The prior mean of the degree of indexation to past inflation is also set at 0.5 in both goods and labour markets, with 0.15 standard error.

6.6.2 Posterior Estimation Results

The posterior distribution of all estimated parameters is obtained following two successive steps. (1) the posterior mode and an approximate covariance matrix, based on the inverse Hessian matrix evaluated at the mode, is obtained by numerical optimisation on the log posterior optimisation of the log posterior density, (2) the posterior distribution is explored by generating draws using the Random Walk Metropolis-Hastings algorithm with sample of 250,000 draws (Villa and Yang, 2011; SW, 2007 and An and Schorfheide, 2006). This section presents the estimation results[139]. The results are obtained from two DSGE model specifications: a) a NK DSGE model with a financial frictions mechanism, and b) a NK DSGE model without a financial frictions mechanism. The sample periods and variable arrangements of the two models help to understand to what extent the recent GFC has affected the main forces driving economic fluctuations and the role of the financial sector in the UK economy. The posterior estimation results shed some light to appreciate whether the recent global financial crisis has highlighted the role of financial factors, which ultimately could have altered the mechanisms of the UK monetary transmission.

6.6.3 Posterior Distribution of the Estimated Parameters

In the following sections, the model with FAM refers to eight shocks, including the Spread shock, in the set of the 8 observable variables. The preliminary results obtained from the model comparison are substantiated by the estimation results from MOD_{FA} and MOD_{NOFA} , reported in Table 6.7 and

[139] The Bayesian DSGE model estimations are conducted using Dynare-MatLab Version 4.2.4.

6.8. The results provide evidence that during the recent GFC, financial factors have played a major role in transmitting shocks in the UK monetary TM. The higher estimate of the elasticity of the external finance premium to the leverage ratio ($\frac{\omega}{lev}$), in the 1955Q1-2014Q4 sample, suggests that during the period of the global financial crisis, financial institutions (e.g. banks) become more sensitive to deterioration of corporate balance sheets, and have reacted by raising the EFP for high-risk corporate firms.

The posteriors obtained based on the data set and the priors are quite informative on the parameters. Referring to the structural shocks, the Spread shock is the most volatile (increases from 0 to 2.7) when FA mechanism is in operation. In both sample periods, productivity shock and government spending shocks are less volatile but persistent both with FA and without FA mechanism; preference shock is relatively volatile when FA mechanism is not in operation but less volatile when FA is in operation. Turning to the behavioural parameters, the study employs two *Calvo* adjustments for price and wage parameters. Assuming that in each period a typical firm is allowed to adjust its price with a probability of $1 - \xi$, its price remains unchanged with probability of ξ. The estimated *Calvo* parameter for price and wage stickiness is assumed to follow a beta distribution with mean 0.5, which corresponds to changing prices every two quarters on average. The posterior *Calvo* parameter for wage adjustment (ξ_w) in the post-crisis period shows small changes from 0.85 without the FAM to 0.88 with a FAM. This implies that firms re-optimise on average every five quarters in both sample cases with a slight increase when FA is in operation. When FA is in operation, the frequency of adjustment increases from five quarters to six quarters that implies that wage stickiness marginally increases. On the other hand, the posterior *Calvo* parameter for price adjustment (ξ_p) with assumed prior beta distribution shows marginal increase from 0.66 (without FAM) to 0.70 (with FAM). This implies that firms re-optimise on average every three quarters when FA is not in operation but increases to four quarters when the FAM is in operation, implying an increase in price stickiness. Similar trend is also observed in the full sample period (1955 to 2014) with 0.81 to 0.85 for wage adjustment, while 0.66 to 0.72 for price adjustment. In terms of their marginal increases, the results of the two sample periods are similar. In both cases, there is enough evidence to suggest that price and wage stickiness increase when the financial accelerator mechanism is included in the model. Fairly similar results are also obtained by Villa and Yang (2011) with marginal differences for the UK.

Table 6.7 Estimation results: sample 1955Q1 – 2007Q3

Estimated Parameters and Shape of the Distributions					Without financial accelerator		With financial accelerator	
Parameters		Prior			Posterior		Posterior	
		Shape	Mean	s.d.	mode	s.d.	mode	s.d.
Autoregressive and Moving Average Shocks								
ρ_a	AR term in productivity shock	Beta	0.5	0.2	0.99	0.011	0.956	0.021
ρ_b	AR term in spread shock	Beta	0.5	0.2	-	-	0.849	0.050
ρ_β	AR term in preference shock	Beta	0.5	0.2	0.19	-	0.928	0.027
ρ_g	AR term in gov. spending shock	Beta	0.5	0.2	0.99	-	0.999	0
ρ_i	AR term in investment shock	Beta	0.5	0.2	0.28	-	0.985	0.008
ρ_r	AR term in interest rate shock	Beta	0.5	0.2	0.03	0.019	0.244	0.067
ρ_p	AR term in inflation shock	Beta	0.5	0.2	0.99	0.002	0.990	0.007
ρ_w	AR term in wage shock	Beta	0.5	0.2	0.99	-	0.997	0.002
μp	MA term in price shock	Beta	0.5	0.2	0.85	0.082	0.714	0.110
μw	MA term in wage shock	Beta	0.5	0.2	0.99	-	0.943	0.018
Principal Adjustments of Behavioural Parameters								
φ	Investment adjustment costs	Normal	4	1.50	7.46	1.146	7.277	1.202
σ	Consumption	Normal	1.5	0.38	0.25	-	0.451	0.056
h	Habit in consumption	Beta	0.7	0.10	0.47	0.072	0.659	0.046
ξw	Wage Calvo adjustment	Beta	0.5	0.10	0.85	-	0.882	0.034
σL	Labour supply	Normal	2	0.75	2.59	-	3.030	0.758
ξp	Price Calvo adjustment	Beta	0.5	0.10	0.66	0.060	0.701	0.055
ιw	Wage indexation	Beta	0.5	0.15	0.15	0.050	0.238	0.069
ιp	Price indexation	Beta	0.5	0.15	0.21	0.088	0.161	0.073
z_k	Steady-state capital utilization rate	Beta	0.5	0.15	0.55	0.033	0.943	0.027
ϕ_p	Fixed cost in production	Normal	1.25	0.13	1.36	0.103	1.416	0.113
ρ_π	T.R. coefficient on inflation	Normal	1.5	0.25	1.41	0.105	1.407	0.359
ρ	T.R. interest rate smoothing	Beta	0.75	0.10	0.86	0.025	0.831	0.044
ρ_y	T.R. coefficient on output	Normal	0.125	0.05	0.003	0.020	0.001	0.008
ρ_{dy}	T.R. coefficient on d(output)	Normal	0.125	0.05	0.303	0.027	0.205	0.041
π	Steady-state inflation rate	Gamma	0.625	0.20	0.583	0.154	0.477	0.195
$100[\beta^{-1} - 1$	Steady-state nominal interest rate	Gamma	0.25	0.10	0.894	0.053	0.345	0.131
l	Steady-state hours worked	Normal	0	2.00	-	1.491	1.793	2.256
$trend$	Trend growth rate	Normal	0.4	0.10	0.323	0.015	0.434	0.041
ηga	Response of g. Spending to prod.	Normal	0.5	0.25	0.219	0.086	0.011	0.156
a	Capital share in production	Normal	0.3	0.05	0.098	0.016	0.114	0.031
lev	Leverage ratio	Normal	1.7	0.2	-	-	1.630	0.229
w	Elasticity external risk premium	Normal	0.05	0.02	-	-	0.036	0.013
Structural Shocks								
σ_a	Productivity shock	Igamma	0.1	2	0.99	0.065	0.922	0.068
σ_b	Spread shock	Igamma	0.1	2	-	-	0.491	0.182
σ_β	Preference shock	Igamma	0.1	2	4.99	-	0.078	0.023
σ_g	Government spending shock	Igamma	0.1	2	1.63	0.086	1.741	0.108
σ_i	Investment shock	Igamma	0.1	2	1.29	0.093	0.705	0.088
σ_r	Interest rate shock	Igamma	0.1	2	0.33	0.022	0.322	0.031
σ_p	Inflation shock	Igamma	0.1	2	0.62	0.059	0.474	0.062
σ_w	Wage shock	Igamma	0.1	2	0.46	0.028	0.386	0.031

Note: entries under the headline prior specify the mean and the standard deviation of the prior distribution. Entries under the headline Posterior specify the estimates of the mode and the standard deviation.
Source: author's analysis (Dynare-MatLab).

Table 6.8 Estimation results: sample 1955Q1-2014Q4

Estimated Parameters and Shape of the Distributions					Without financial accelerator		With financial accelerator	
Parameters		Prior			Posterior		Posterior	
		Shape	Mean	s.d.	mode	s.d.	mode	s.d.
	Autoregressive and Moving Average terms							
ρ_a	AR term in productivity shock	Beta	0.5	0.2	0.989	0.009	0.943	0.023
ρ_b	AR term in spread shock	Beta	0.5	0.2	-	-	0.422	0.246
ρ_β	AR term in preference shock	Beta	0.5	0.2	0.185	0.082	0.940	0.021
ρ_g	AR term in gov. spending shock	Beta	0.5	0.2	0.999	0.007	0.999	0.004
ρ_i	AR term in investment shock	Beta	0.5	0.2	0.277	0.069	0.986	0.007
ρ_r	AR term in interest rate shock	Beta	0.5	0.2	0.026	0.019	0.272	0.058
ρ_p	AR term in inflation shock	Beta	0.5	0.2	0.988	0.002	0.994	0.005
ρ_w	AR term in wage shock	Beta	0.5	0.2	0.986	0.021	0.998	0.016
μp	MA term in price shock	Beta	0.5	0.2	0.845	0.082	0.773	0.092
μw	MA term in wage shock	Beta	0.5	0.2	0.994	0.006	0.956	0.014
	Principal Adjustments of Behavioural Parameters							
φ	Investment adjustment costs	Normal	4	1.5	7.455	1.146	9.490	1.178
σ	Consumption	Normal	1.5	0.38	0.251	0.080	0.518	0.058
h	Habit in consumption	Beta	0.7	0.1	0.466	0.072	0.762	0.042
ξw	Wage Calvo adjustment	Beta	0.5	0.1	0.810	0.031	0.853	0.028
σL	Labour supply	Normal	2	0.75	2.592	0.610	2.454	0.628
ξp	Price Calvo adjustment	Beta	0.5	0.1	0.663	0.039	0.728	0.053
ιw	Wage indexation	Beta	0.5	0.15	0.152	0.049	0.202	0.063
ιp	Price indexation	Beta	0.5	0.15	0.213	0.087	0.139	0.063
z_k	Steady-state capital utilization rate	Beta	0.5	0.15	0.547	0.033	0.972	0.013
ϕ_p	Fixed cost in production	Normal	1.25	0.13	1.364	0.103	1.475	0.111
ρ_π	T.R. coefficient on inflation	Normal	1.5	0.25	1.413	0.104	1.508	0.198
ρ	T.R. interest rate smoothing	Beta	0.75	0.1	0.885	0.022	0.852	0.025
ρ_y	T.R. coefficient on output	Normal	0.125	0.05	0.306	0.010	0.310	0.004
ρ_{dy}	T.R. coefficient on d(output)	Normal	0.125	0.05	0.303	0.023	0.200	0.031
π	Steady-state inflation rate	Gamma	0.625	0.2	0.582	0.146	0.512	0.177
$100[\beta^{-1} - 1$	Steady-state nominal interest rate	Gamma	0.25	0.1	0.894	0.040	0.351	0.125
l	Steady-state hours worked	Normal	0	2	-5.336	1.038	2.343	2.107
$trend$	Trend growth rate	Normal	0.4	0.1	0.323	0.058	0.417	0.035
ηga	Response of g. Spending to prod.	Normal	0.5	0.25	0.219	0.125	0.013	0.136
a	Capital share in production	Normal	0.3	0.05	0.097	0.027	0.129	0.026
lev	Leverage ratio	Normal	1.7	0.2	-	-	1.165	0.025
w	Elasticity external risk premium	Normal	0.05	0.02	-	-	0.121	0.013
	Structural Shocks							
σ_a	Productivity shock	Igamma	0.1	2	0.985	0.065	0.917	0.060
σ_b	Spread shock	Igamma	0.1	2	4.997	0	3.436	2.694
σ_β	Preference shock	Igamma	0.1	2	1.635	0.086	0.064	0.014
σ_g	Government spending shock	Igamma	0.1	2	1.291	0.092	1.605	0.089
σ_i	Investment shock	Igamma	0.1	2	0.333	0.022	0.652	0.106
σ_r	Interest rate shock	Igamma	0.1	2	0.622	0.058	0.295	0.022
σ_p	Inflation shock	Igamma	0.1	2	0.468	0.028	0.460	0.056
σ_w	Wage shock	Igamma	0.1	2	0.985	0.065	0.376	0.026

Note: entries under the headline prior specify the mean and the standard deviation of the prior distribution. Entries under the headline Posterior specify the estimates of the mode and the standard deviation.
Source: author's analysis (Dynare-MatLab).

In terms of the degree of changes in indexations, similar behaviours have been observed in both sample periods. When FA is in operation, the posterior degree of wage indexation (ι_w) increases from 0.15 to 0.24 while the posterior degree of price indexation (ι_p) decreases[140] from 0.21 to 0.16 before the GFC. This implies that during the full sample period, wage adjustments were more

[140] Similarly, SW for the U.S. data, and Villa and Yang (2011) also found results of similar context.

prominent than price adjustments in the UK. This also confirms that the model with FA mechanism represents the UK data well. The decrease in price indexation and the increase in wage indexation also imply higher price stickiness than wage stickiness in the DSGE model with the FAM than the one without the FAM. Price stickiness is characterised by the resistance of a price or set of prices to change, despite changes in the economy. This suggests that a different price is optimal when the FAM is in operation as compared to the wage index at the period of financial crisis. This also entails the need for more wage adjustments than price adjustments during financial stress, as prices do not respond quickly as compared to wages.

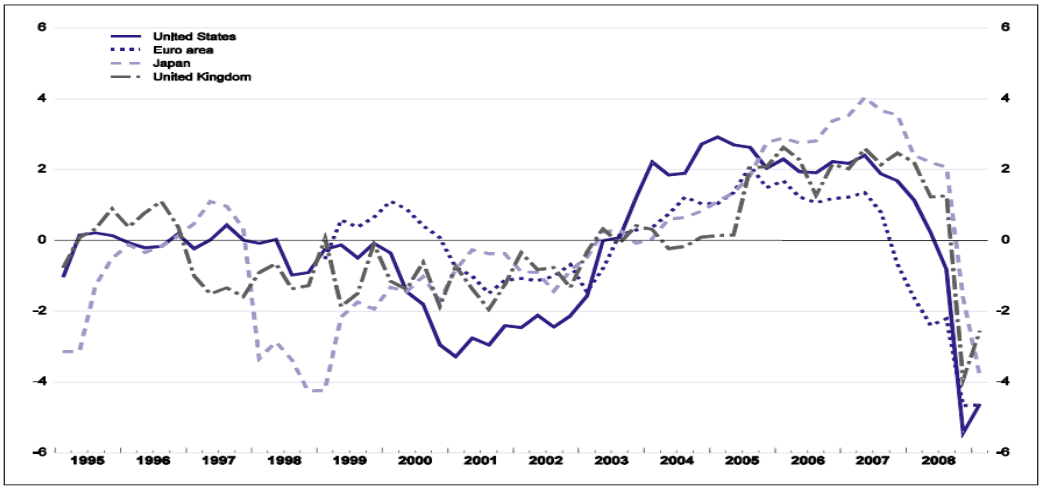
The steady state capital utilisation (z_k) is close to its prior when the FA mechanism is not in operation but almost double when FA mechanism is in operation in both the full data sample and before the GFC. One implication of high capital utilisation is that it reduces the impact of changes in output on the rental rate of capital and therefore, smooths the response of marginal cost to fluctuations in output (SW, 2003). The elasticity of the cost of changing investment is greater than that assumed *a priori*. This suggests that there is a positive response of investment in the value of capital both in the FA and without the FA cases, which happened to be the case in the UK.

The estimated elasticity of consumption expenditure is found to be lower than the assumed *a priori,* suggesting a negative response of expenditure (on average) during both pre and post-crisis periods. The habit formation parameter is lower than assumed *a priori* in pre-financial crisis period but higher than the assumed *a priori* during post-financial crisis period. This suggests that individual's consumption habit changes in post-financial crisis than pre-financial crisis period. The financial parameters such as the *leverage ratio* and the elasticity of the external finance/risk premium are lev and w, respectively. The response in the leverage ratio (also known as survival rate) is lower in both pre and post-crisis period than the assumed *a priori*. However, the leverage ratio is much lower than the assumed *a priori* in the full data sample, which suggests the presence of firms' capital shortage during the financial crisis. It is also important to note that the close proximity of the posterior for the survival rate to the prior implies a steady state leverage ratio of about 10, which is a reasonable rate of FIs in the UK.

The elasticity of external risk premium is much higher than the assumed *a prior* in the full data but is lower than *a prior* in the data that excludes the crisis period. This clearly indicates that the EFP increases during financial crisis than the normal period. Turning to the monetary policy parameters in the Taylor rule reaction function, the mean of the reaction coefficient to inflation is estimated closer to its prior distribution in the full sample than the sample that excludes the crisis and post-crisis periods. This implies that there was no significant response of high inflation during the crisis period. The results also confirm that there is a slightly higher degree (0.8 vs 0.75) of interest rate smoothing. Interestingly, monetary policy appears to react to the output level with a coefficient of 0.306 and 0.310 in the full data but reacts lower than assumed *a prior* in the pre-crisis period. The higher reaction as compared to the *prior* distribution is similar to DiCecio and Nelson (2007); and Villa and Yang (2011). Finally, the exogenous shock variables such as the government spending, preference and investment shocks are the most volatile in pre-crisis period. However, Spread and to some extent government spending shocks become the most volatile in the full sample. It is important to highlight that in a closed economy model (i.e. this study), government shock is likely to capture trade movements; its high level of shock could be interpreted as a signal of the exogenous disturbances from trade. The productivity shock is found to be persistent with a coefficient of 0.99 both in pre and in post-crisis periods.

As compared to other similar studies on the U.S. and EEA data, (e.g. Gilchrist, et al., 2009; SW, 2007, Merola, 2015; Gelain, 2010), the estimate of the elasticity of the EFP provides a stronger support in favour of the role of financial frictions as a mechanism of amplification of shocks[141]. The estimate of the UK EFP is marginally higher than the above studies. Merola (2015) estimates the leverage ratio over the U.S. data sample 1967 to 2012 as 1.67 in comparison to this study for the UK data sample 1955 to 2014 with the leverage ratio of the sample that includes the crisis period is 1.17 for MOD_{FA} and 1.63 for pre-crisis sample (MOD_{NOFA}); 1.73 for the U.S.. In line with the historical data, reported in Gilchrist et al. (2009), the lower estimate of the leverage ratio compared to the pre-crisis period captures the ongoing process of deleveraging in the corporate sector. The estimation results of the exogenous shocks show that the demand shock become persistent but less relevant when the financial accelerator mechanism is in operation. This persistence of demand shock implies (similar to SW, 2003; Merola, 2015) that during the GFC demand shocks have been partially replaced by exogenous disturbances introduced by movements of Spread in the financial sector. Comparing the UK financial condition with the rest of the world, as shown in Figure 6.3, the indices clearly show that the Chinese financial condition quickly recovers as compared to the UK. The estimates of the parameters describing the financial frictions mechanism are able to replicate the observed series. Figure 6.3 reports the financial condition indices for the European Area, Japan, United States and the United Kingdom (OECD, 2010).

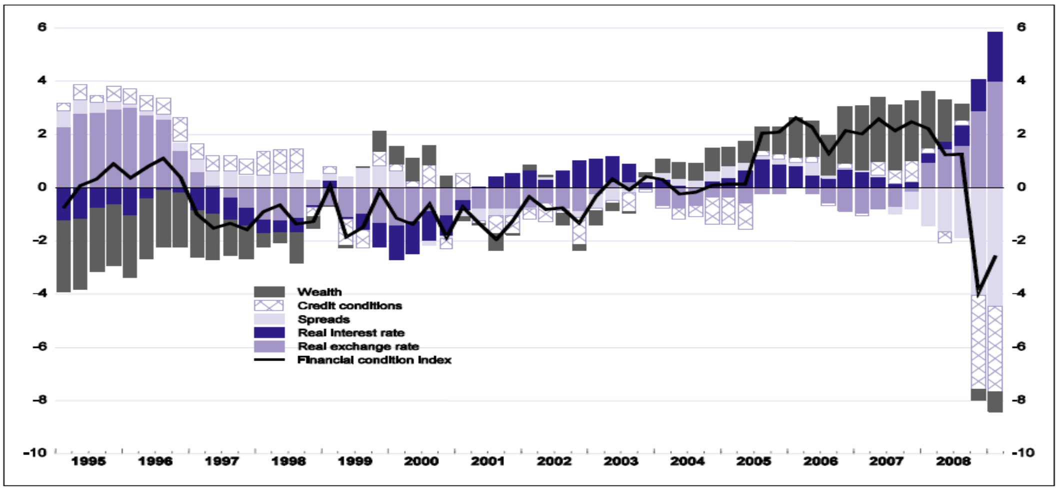
[141] With a similar approach, Gilchrist et al. (2009), Merola, (2015), and Gelein (2010) estimate the SW model, augmented with a financial accelerator mechanism extended to 2009:Q1 and 2012Q4. They include two financial shocks (namely, an external finance premium shock and a net-worth shock) and then they add to the set of observables two financial series, the logarithm of the leverage ratio and the credit Spread. They calibrate the leverage ratio to 1.7, which corresponds to the average leverage ratio in the U.S. non-financial corporate sector over the period of 1973 to 2009. Similarly, they conclude in favour of a financial accelerator mechanism. However, their conclusion is not supported by a high value of the elasticity of the external finance premium. Gilchrist, et al. (2009) estimate this parameter to be equal to 0.01, Merola estimates this parameter to be equal to 0.03 but this research estimates this parameter to be equal to 0.121.



Source: OECD (2010).

Figure 6.3 Comparison of Financial Conditions Indices (FCI)
G4 Countries (United States, Euro Area, Japan and the United Kingdom).

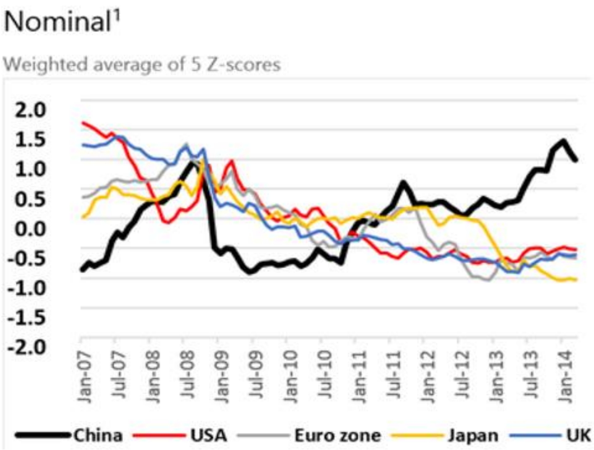
The UK financial condition index closely moves with the U.S. FCI rather than the E.A. and Japan indices from 1995 to 2008. The FCIs in Figure 6.3 is in close proximity to the findings of this study. Figure 6.4 reports the disaggregated FCIs wealth, credit, Spread, real interest rate and exchange rate. The chart (Figure 6.3) represents these components with financial condition index. It also shows that the Spread is a good proxy for the FCI. The EFP is positively correlated with the observed series of the corporate Spreads and is able to reproduce the tightening of credit conditions witnessed in late-2008 and early-2009. In comparison to the major industrial countries' FCIs such as the EEA, China, U.S., Japan, and the UK, the Chinese economy has not been affected severely by the GFC. During the post-crisis period (2007Q3 to 2014Q4), the nominal and real weighted average FCI movements of the three major economies is presented in Figure 6.5 and 6.6.



Source: OECD (2010)

Figure 6.4 The Financial Conditions Index for the United Kingdom

Figure 6.4, 6.5, and 6.6 show the degree of comovement that the UK FCI is closely correlated with the U.S. FCI. The intuition behind this is that the UK financial market and economy is influenced by the U.S. financial and economic dynamics. This has been witnessed during the recent GFC that the U.S. financial crisis quickly spilled over to the UK economy as compared to China and Japan. The real weighted average FCI also show that the UK and the U.S. financial conditions start recovering from July 2011. Similar trend is also observed in the Spread measures of this study.



Source: Datastream BIS, (Guonan Ma, 2015)

Figure 6.5 (Nominal) Financial Condition Indices (FCI) for Major Economies[142]

Figure 6.6 (Real) Financial Condition Indices (FCI) for Major Economics

6.6.4 The Impulse Response Analysis

The estimated impulse response analysis quantifies the reaction of single variable on an exogenous shock to the model. They are set to measure the response of a dynamic system to external changes in the form of a reaction of a system with respect to time. They are used to inspect the inter-relationship of the model variables. The study identified two special cases of shocks: the single equation shock and the joint equation shock. The eight shocks identified in the two DSGE models, with and without the FAM, mirror the residual covariance structure. The single equation IRFs investigates orthogonalised impulse response and the joint equation investigates the variance decomposition (VD). Furthermore, the historical cumulative effects are investigated using historical variance decomposition (HVD). The HVD accounts for not only the instantaneous response for a certain standard deviation but also the cumulative effects of these impacts in the given time horizon.

[142] As shown above, a rise suggests tightening and a positive movement indicates tighter than the period average. The official ceiling for the one-year deposit rate is taken as the policy rate of the Public Bank of China (PBC). The benchmark stock market indices are Shanghai Stock Exchange Composite Index for China, S&P 500 for the U.S., Nikkei 225 for Japan, FTSE 100 for the UK, and a market cap weighted average of CAC, 40, DAX 30, IBEX 35, FTSE Mid and AEX (Jan 2007 = 100) for the Euro Area. The real interest rate and exchange rate are nominal rates adjusted for current CPI inflation (Guonan Ma, 2015).

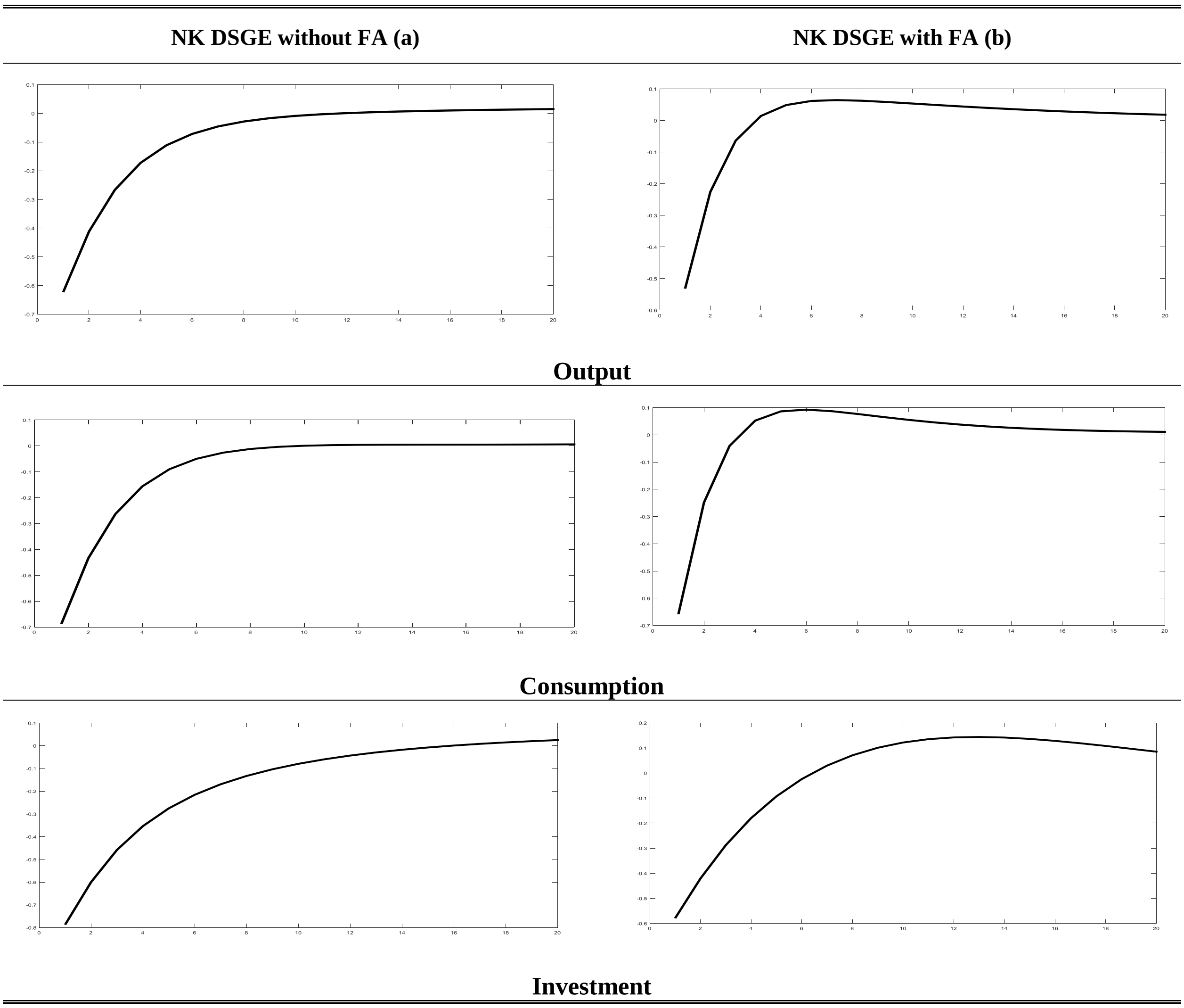


Figure 6.7 The Impulse Responses to Monetary Policy Shock
Source: author's analysis.

The reaction is measured for every variable a certain time after shocking the system. The selected IRFs underscore important aspects of the model(s). It highlights the premium, investment, government spending and monetary policy shocks that are relevant to the transmission mechanism. Figure 6.7 reports the response of observed variables to a monetary policy shock. The IRFs in the first column reports the responses to the monetary policy shock without the financial accelerator mechanism, while the second (right) column reports the responses to monetary policy shock with the financial accelerator mechanism. This model takes into account the sample period from 1955Q1 to the run up to the beginning of the global financial crisis 2007Q3. The IRFs represent the response of output and its components (consumption and investment). It measures the mean variables' responses to a one standard deviation of an orthogonalised monetary policy shock as a percentage deviation from the steady state in both accelerator mechanisms.

The monetary policy shock, a standard demand shock, has a negative impact on output (consumption and investment) and inflation. After a tightening of the monetary policy, investment starts declining more sharply after a while, when financial accelerator mechanism is in operation. The initial sign of increasing trend in investment response may refer to the adjustment period until the existing investment period ends. This suggests that investment does not show an immediate decline at the beginning, implying the expected effect of reducing the demand for capital followed by its price. In the financial accelerator framework, the reduction in price leads to a decrease of the net worth from investors' side, which makes the entrepreneur riskier to lenders. Therefore, lenders have to charge a higher premium and this further depresses investments, generating the extra response as displayed in Figure 6.8.

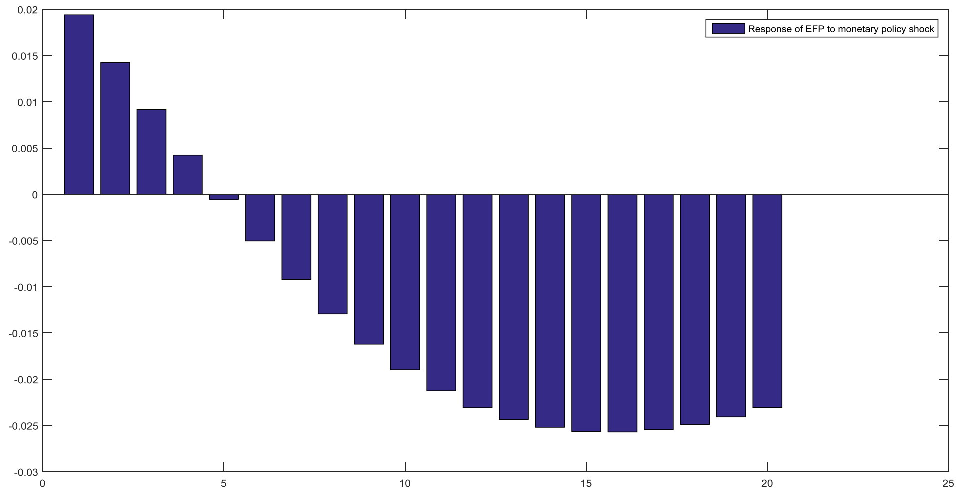


Figure 6.8 The Impulse Response of Spread to Monetary Policy Shock
(Model with FA Mechanism)
Source: author's analysis.

It is also important to note that, as in BGG and the empirical evidences based on the U.S. data, the accelerator effect is also transmitted to output and consumption. Strong response is recorded in output when the FA mechanism is in operation and this was owing to a stronger response of consumption with a hump shaped response, as in BGG (see Figure 6.7). This implies that consumption's dynamics is described solely by the Euler Equation, i.e. the real interest rate is the main determinant. This response may not be directly related to financial frictions, which actually operate through the investment channel (SW, 2007). The study also confirms that, as shown in Figure 6.8, the theoretical conclusions made by BGG (1999) and Walentin (2005) that the EFP turns out to be counter-cyclical when the monetary policy shock hits the economy. Unlike the response of output and its components, the Spread responded counter-cyclically to a one standard deviation move of a monetary policy tightening. When the FA mechanism is in operation, it has shown that Spread takes over the role of investment.

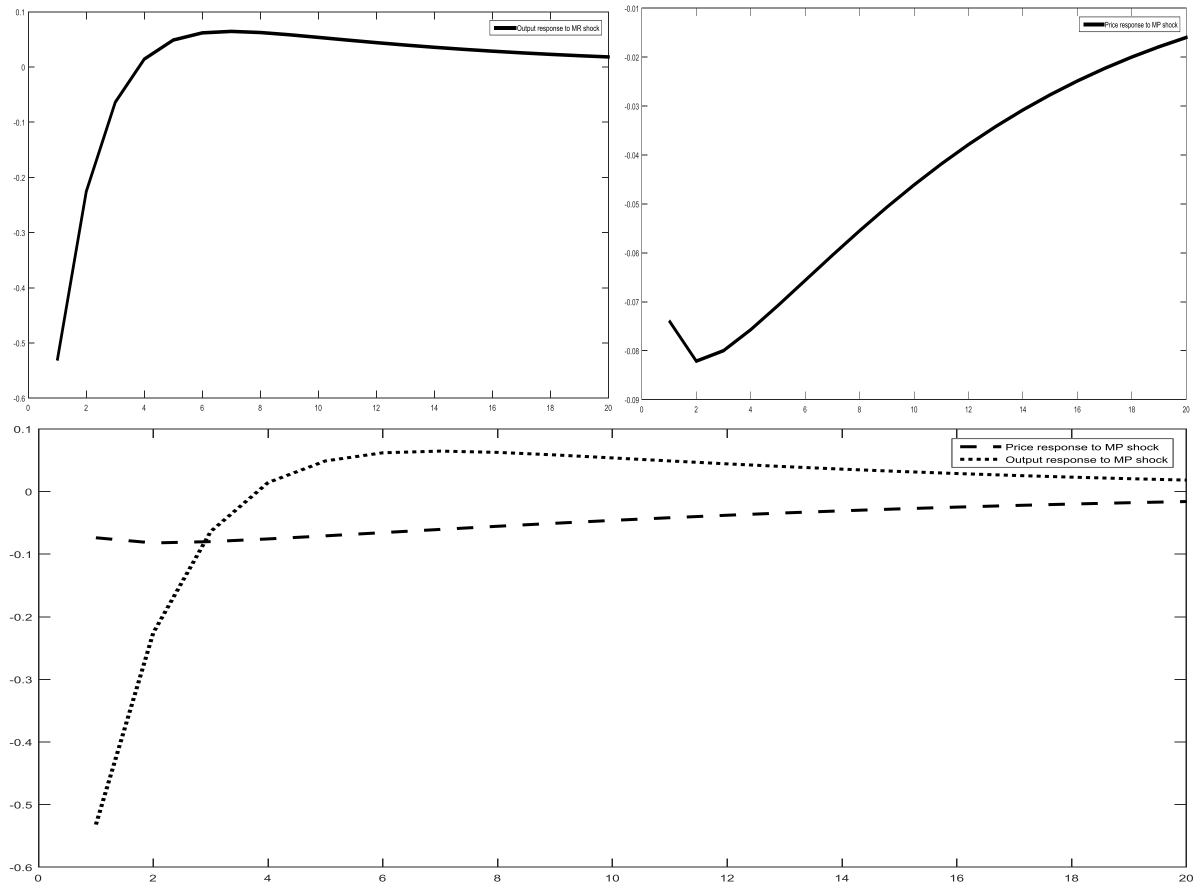


Figure 6.9 The Impulse Responses of Output and Inflation to MP Shock
The additional IRFs show output (left) and inflation (right) drawn to scale, where output is the dotted line and Inflation is the dashed line. Source: author's analysis.

The marginal differences between the responses when the FA mechanism is in operation and when it is switched off is mainly because only monetary policy shocks do not play a significant role in altering responses. There are two reasons for this. *First*, monetary policy shocks only account for a small fraction of inflation and output deviations. *Second*, as shown in Figure 6.9, the peak effect of the policy shock on inflation occurs before its peak effect on output. In the U.S. business cycle, Gali (1999), Francis and Ramey (2005), Gali and Rabanal (2004), and SW (2007) argue that due to the presence of nominal price rigidities, habit formation and adjustment costs to investment, positive productivity shocks lead to an immediate fall in hours worked. Given the strong positive correlation between output and hours worked over the business cycle, productivity shocks do not play an important role in business cycle, unlike what is expected in the RBC model. The comparison between the two samples reveals that the DSGE model without the FAM is not able to capture the movements of other structural shocks such as consumption, investment and output. The DSGE model with the FAM reveals some information that when the banking sector is taken into account as part of the DSGE model components, it shows variability in movements to a monetary policy shocks. This leads to a need for further analysis to investigate the response of other structural shocks to monetary demand shocks.

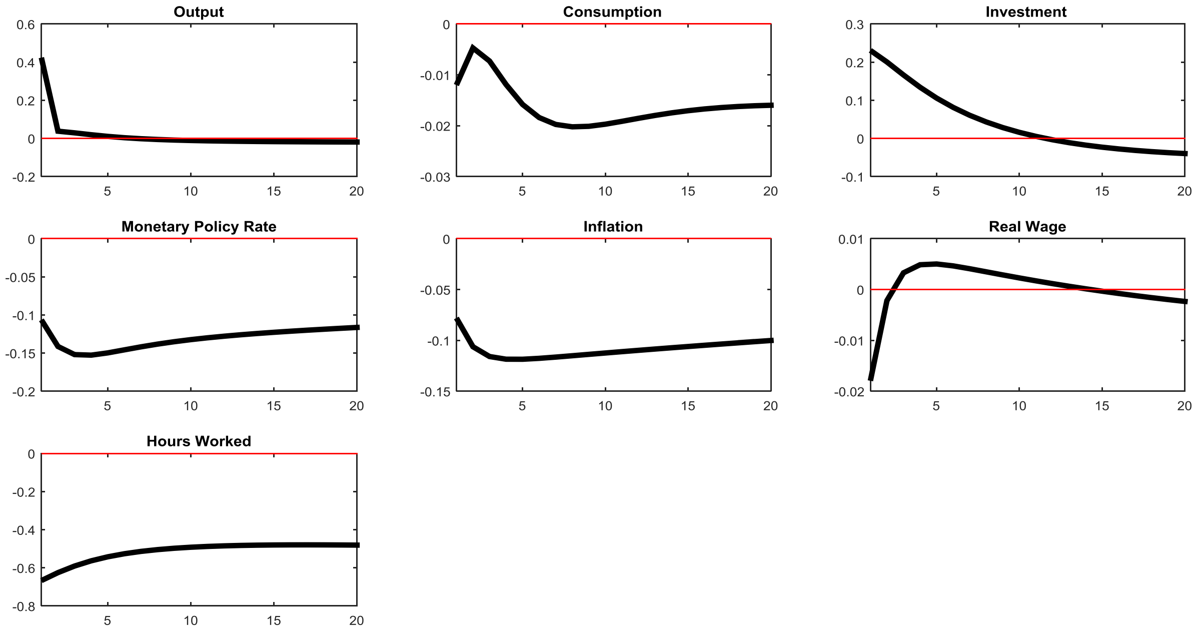


Figure 6.10 The Impulse Responses to Productivity Shock [without FAM]

Using a VAR approach, CEE (2005), Vigfusson (2004), Dedola and Neri (2004), and Peersman and Straub (2005) have argued that the empirical evidence on the effect of a productivity shock on hours worked is not very robust and could be consistent with a productivity impact on hours worked. Similarly, it is also found for the UK that the response of hours worked to productivity shock is not robust as stated by Dedola and Neri (2004). However, unlike the response to MP shocks, consumption and investment indicate robust reaction to productivity shock. Consumption reduces at the beginning but remains stable below the zero benchmark. This implies that an increase in productivity shock encourages households to withhold consumption in order to save. Investment on the other hand continuously declines for about 7 quarters. Price mark-up does not show robust reaction but wage mark-up shows strong reaction to productivity shocks.

Productivity shock is a standard supply shock that impacts output negatively but inflation positively. This is correctly confirmed on the responses to productivity shock, as shown in Figure 6.11 when the FA mechanism is in operation. The second DSGE model highlights the role of financial friction in the form of Spread. The differences are clearly observed in the two responses presented in Figure 6.10 and Figure 6.11. Generally, the NK DSGE model confirms that productivity shocks play a less dominant role (as in SW, 2007, U.S. business cycle) in driving output developments beyond the one-year horizon in the estimated model when the FA mechanism is not in operation. Unlike the Real Business Cycle hypothesis, the productivity shock impacted output slowly when the model is without the FA mechanism, as compared to the one with the FA mechanism.

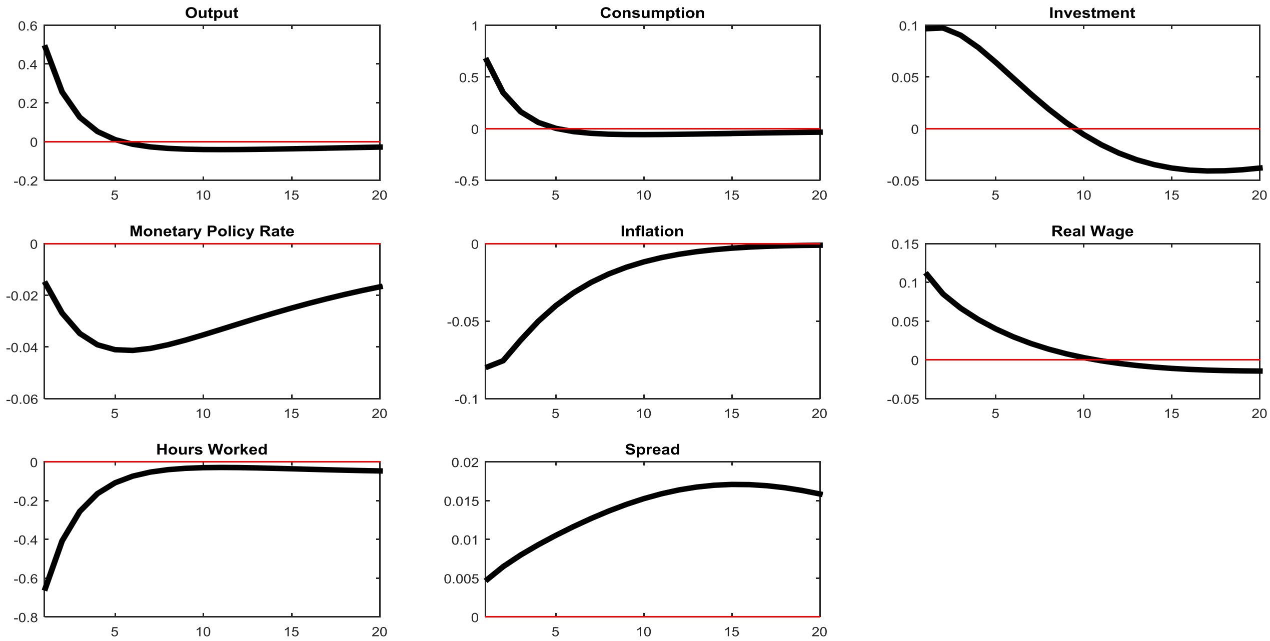


Figure 6.11 The Impulse Responses to Productivity Shock [FAM]
(With the FA Mechanism Operator)

The striking difference can be seen on price mark-up, having a pro-cyclical response when FA is not in operation and countercyclical response when FA is in operation. Hours worked remains far below zero when FA is not in operation but it declines towards the zero line when FA is in operation. In terms of business cycle frequencies, hours worked accounted for about 21.12% to productivity shock when the FA mechanism is in the model of the full data sample. On the other hand, hours worked accounted for 20.9% when the FA is not in the model of the data sample that excludes the post 2007Q4 period. The difference is very marginal but it confirms that (see Table 6.9 and 6.10) the presence of the FA mechanism in the DSGE model makes no significant difference on the level of innovation on hours worked. Similarly, the posterior estimates and IRFs confirm the work of Gali (1999), and Francis and Ramey (2005).

Moreover, shocks to the quantity of capital (due to decline in output) translates into a shock to banks' balance sheet. This is because of the identity between capital and assets (Villa and Yang, 2011). Financial frictions are always binding and depositors require that banks do not become overleveraged[143]. As a result, banks are forced to curtail their lending. This squeeze on credit means that firms are able to buy less capital for use in the following period. The shock to bank capital directly affects the banks' balance sheet, which results a decline in bank net worth that tightens the banks' borrowing constraint due to the fact that banks are leveraged. This could be the reason why

[143] Overleveraged banks carry too much debt as compared to their net worth. Banks with overleveraged status are not able to payments to clear its debt. Ultimately, savers will react negatively which exacerbate the credit worthiness of the bank, which may lead to the collapse of the financial institution. Too low leverage ratio is also not a good sigh as it may indicate inability to borrow due to its tight profit margins.

the model reflects the decline in output and the increase in inflation when the financial accelerator mechanism is in operation.

It is also worth commenting on two important factors to understand the financial accelerator effect in the transmission mechanism. These factors are the size of the Spread and the growth of bank profit. Following a sharp decline in banks' net worth, banks have to cut their lending because of the balance sheet constraint. This means, the more leveraged they are, the larger is the impact of capital losses on the reduction in lending. This cutback (also discussed in Villa and Yang, 2011) in lending leads to a fall in banks' profit. Banks, therefore, need to increase lending rate to balance and rebuild their profit and capital base. The Spread rises when banks increase lending rate (see Figure 6.11). This implies that as the financial cost increases, firms reduce demand for loan and cut back investment and increase own capital utilisation. This negative aggregate demand feeds back to the banking sector, which result in lower bank profits. This, in turn, causes banks to further tighten credit supply and raise lending Spread in order to satisfy their endogenous balance sheet constraint. This is what is known as a financial accelerator effect, which clearly mapped by the estimated Bayesian likelihood DSGE approach. The severity of the financial accelerator effect can be felt and it could take a long period for banks to rebuild their capital. The persistent slowdown in bank lending due to low demand, exacerbated by the reduction of the credit flow in the economy. The financial friction effect and its acceleration impact is clearly shown in the IRFs of the two DSGE models (see Figure 6.10 and 6.11).

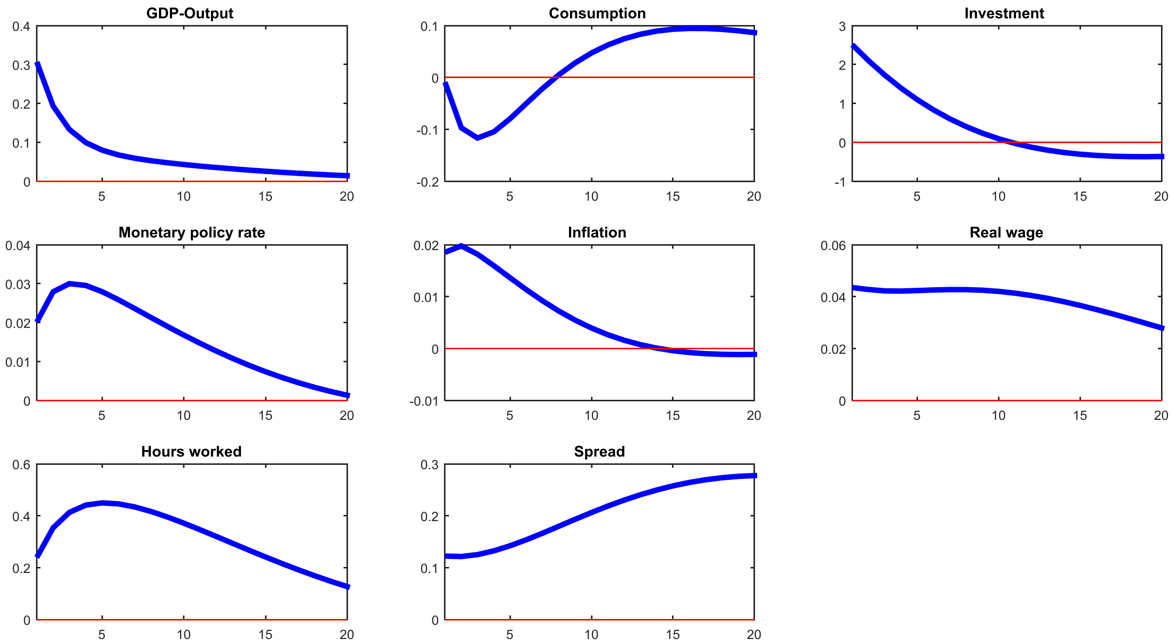


Figure 6.12a The Impulse Responses to Investment Shock [FAM]

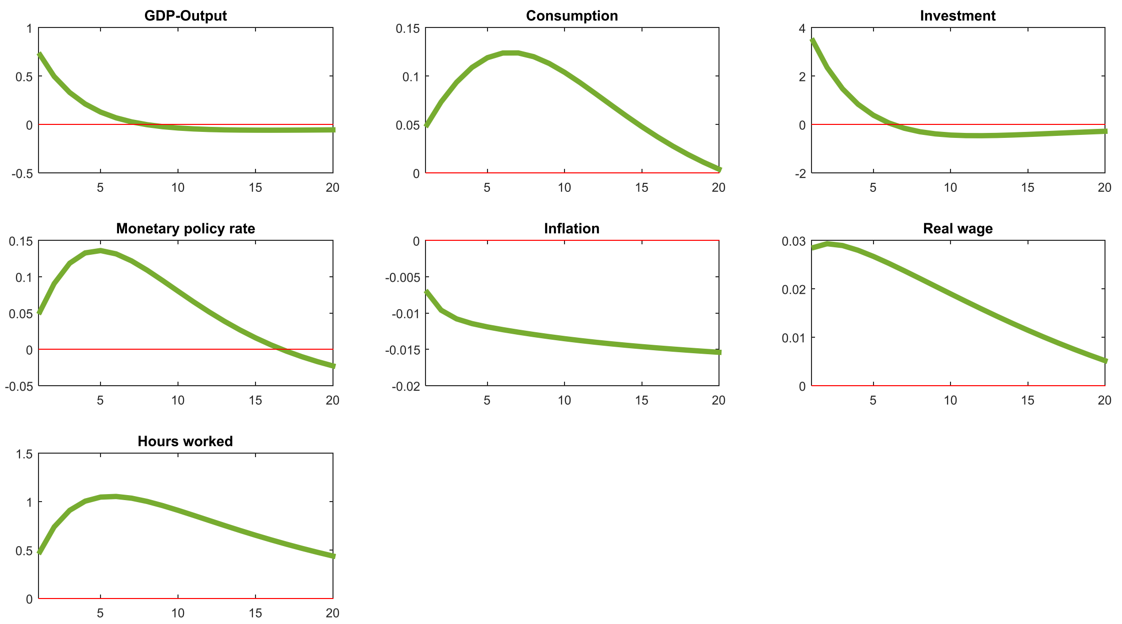


Figure 6.12b The Impulse Responses to Investment Shock [without FAM]

A positive productivity shock leads to an expansion of aggregate demand, output, and real wages, but causes an immediate and significant reduction in hours worked. This also substantiates that financial friction does work through investment rather than hours worked. Furthermore, the estimates also show that it is mainly the estimated degree of habit persistence and the importance of capital adjustment costs that explain the negative impact of productivity on hours worked. Similar result is also found by Francis and Ramey (2005). The analysis of the impulse response functions (IRFs) based on the estimated parameters reaches the same conclusions. Figures 6.12a and Figure 6.12b illustrate the IRFs to the investment shock for the two sample periods with and without the FA mechanism. Output and investment in sample period 1 (1955 to 2014), when the FA mechanism is not in operation, show similar declining tendencies but consumption remains nearly/below zero up to 8 quarters (2 years) then moves upward above the zero benchmark when the financial accelerator is in operation. On the other hand, in sample period 2 (1955 to 2007), when the FAM is not in operation, output, consumption and investment respond to the investment shock in a significantly different manner. This highlights that the role of financial frictions in the UK economy is not negligible or self-adjusting, as it has been thought during the inflation targeting and "Great Moderation" period.

Consumption responded positively to investment shock for about 8 quarters (2 years period) then responded negatively all the way to the end of the period. This can be interpreted as the slow household consumption (slow habit formation) adjustment behaviour. Investment, on the other hand, reaches to the zero base level faster than the case when the FA mechanism is in operation.

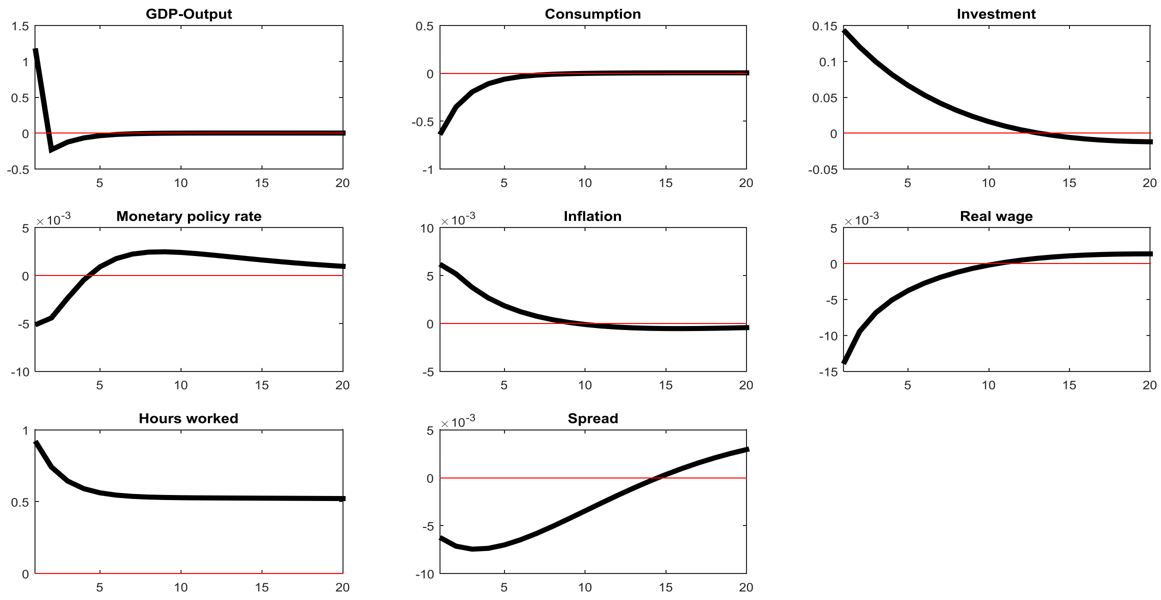


Figure 6.13a The Impulse Responses to Government Spending Shock [FAM]

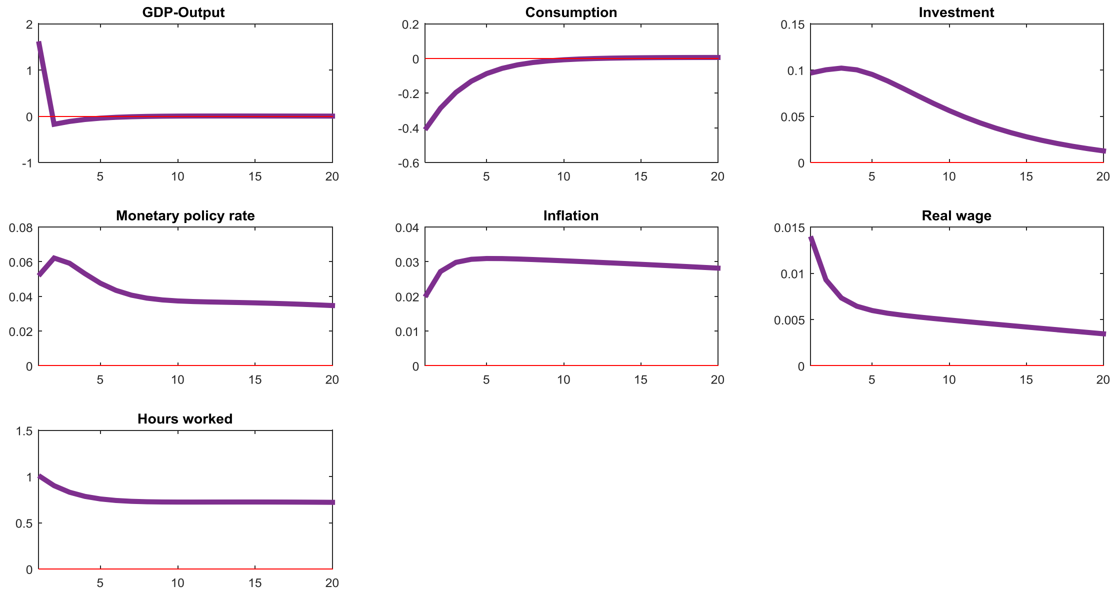


Figure 6.13b The Impulse Responses to Government Spending Shock [without FAM]

Furthermore, investment and output show persistent decline in response to the investment shock, while consumption remains above zero earlier when the FAM is not in the model. The persistence and less relevant response of investment to the investment shock is observed when the financial accelerator mechanism is in operation. This is because the response to investment shock was replaced by exogenous shocks, due to Spread. One can conclude that the financial accelerator mechanism reduces the impact of the investment shock when the FA mechanism is in operation. Additionally, the impulse response analysis highlights the effectiveness of the fiscal stimulus in the presence of financial frictions. Figure 6.13a and Figure 6.13b report the impulse responses to government spending shocks. The results show that the model of the “Great Moderation” period exhibits slow but persistence decline when FA is in operation as compared to the model without the FA mechanism. Consumption and output do not show significant difference both with and without the FA mechanism. On the other hand, when the crisis period is included, the difference is observed on the investment response whereby investment declines in a slower pace than the trend, when the FAM is in operation, which could be due to the financial stimulus. The stimulus reduces the EFP so encourages investment and the crowding-out effect becomes negligible. Additionally, this outcome underlines that the higher inflation resulting from the fiscal stimulus (when FA is in operation) reduces the real interest rate and hence the external financial risk premium. The stimulus put into place since 2008 in the UK supports investment and output growth as in the U.S. case (see Merola, 2015 and Carrillo and Poilly, 2013). In terms of the government interventions, Fernandez-Villaverde (2010) states that in the presence of financial frictions the fiscal stimulus becomes more effective but the assumption hinges on the state of nominal liabilities, which works through the debt-deflation effect. According to the estimates of the structural parameters in both sample periods, the model with the financial friction mechanism show that, during the period of global financial crisis, the monetary policy was less reactive to inflation.

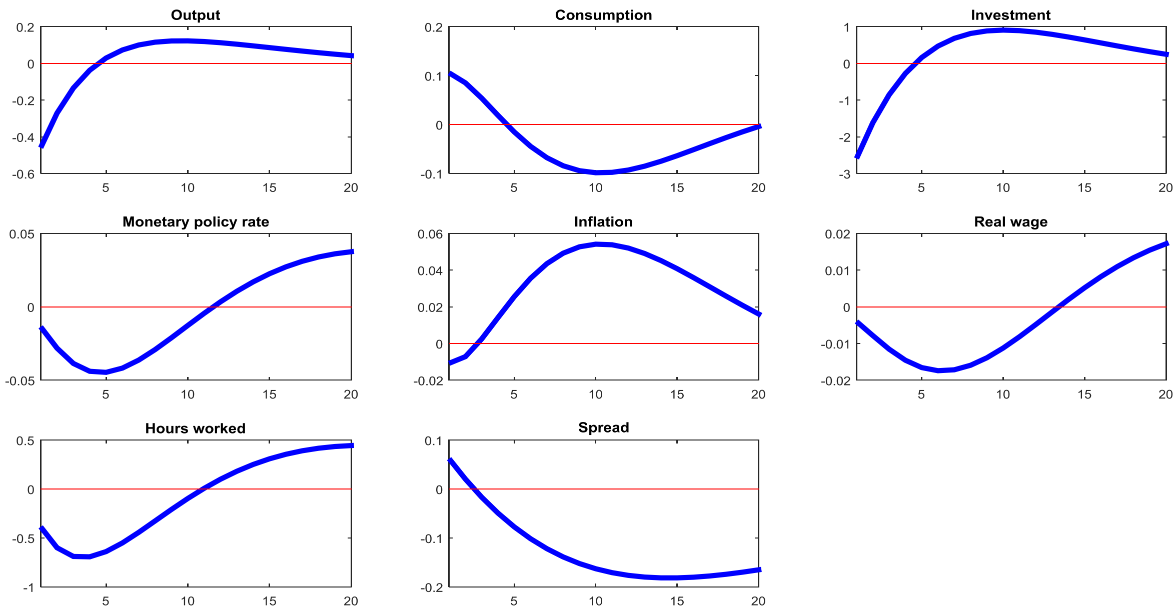


Figure 6.14 The Impulse Responses to a Spread Shock (2000 to 2014)

Furthermore, the posterior estimates shown in Table 6.7 and Table 6.8 of the two alternative Bayesian New Keynesian DSGE models and the impulse responses of the inflation shock confirm that the monetary policy rate was less reactive when FA mechanism is in operation as compared to the other alternative. This outcome is in direct contrast to the action taken by the BoE in 2008 and 2009 that the interest rate was cut to a lower 0.5% level but less aggressively as compared to (see Figure 6.14) the pre-crisis period. Policymakers, at different levels expressed this concern to cut the policy rate less aggressively not to exacerbate the worsening market conditions (Bini- Smaghi, 2008). This implies that when policymakers have a more pessimistic view of the economic performance than the market participants do, they are likely to take aggressive monetary policy decision (Merola, 2015)[144].

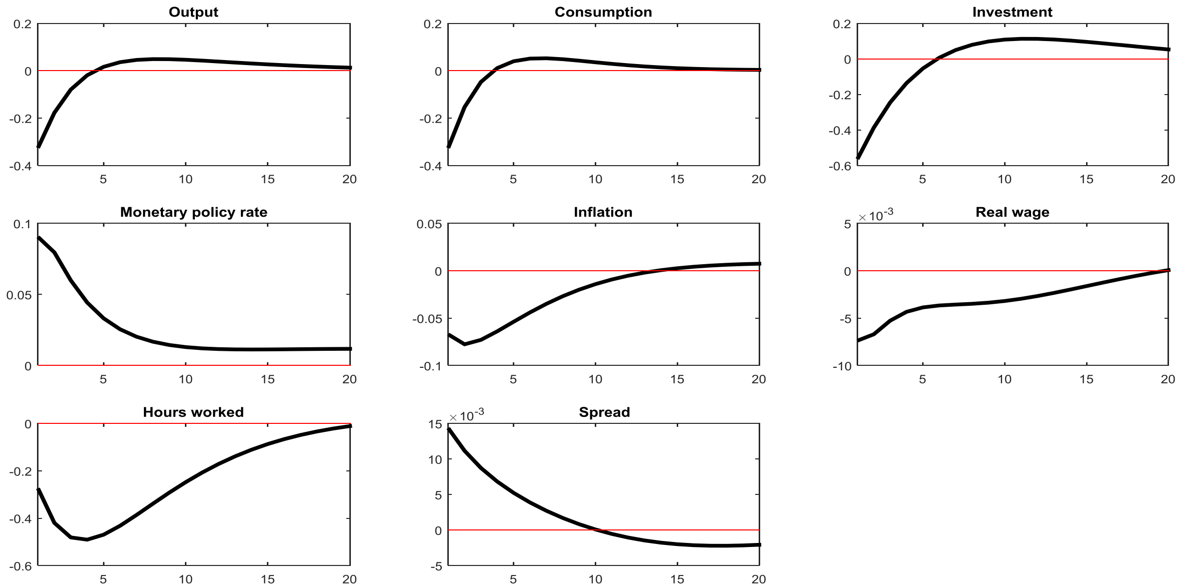


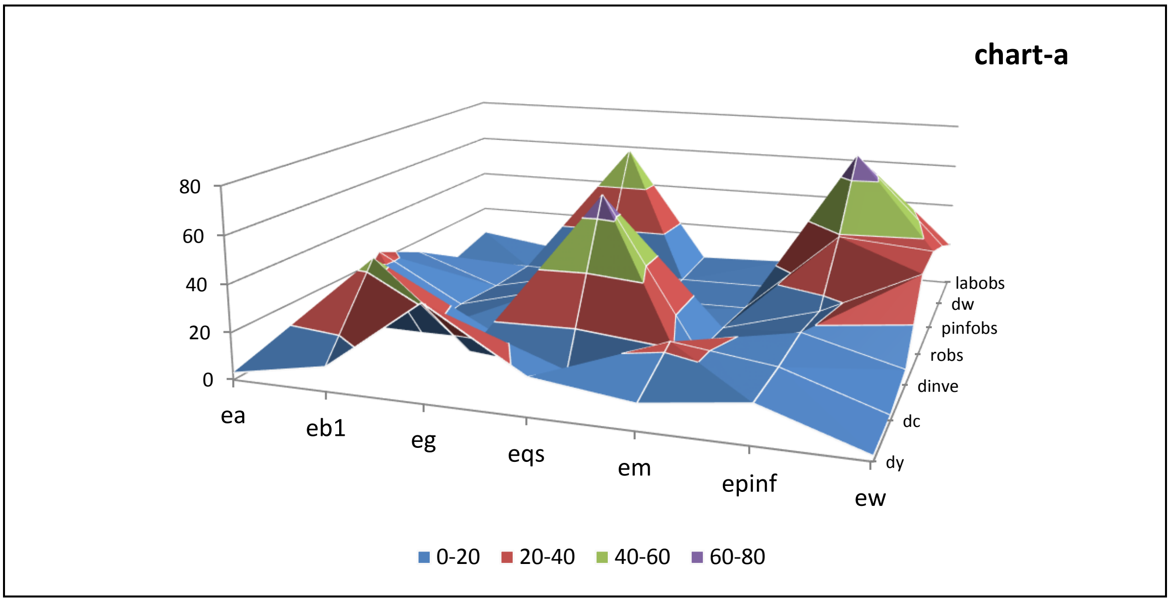
Figure 6.15 The Impulse Responses to MP Shocks (2000 to 2014)

First, in the context of the UK economy, the BoE would have cut the interest rate to a zero level. This shows that the central bank decided not to react more aggressively than what it has effectively done. The lender of the last resort did in fact cut the interest rate (mainly from 2009 onwards) but decided not to go below the effective interest rate, 0.5%. If the interest rate falls below the 0.5%, it would have been close to zero or negative during the post-crisis period and would have turned positive again because of rebounding economic activity. However, a zero level policy rate could limit central bank's further option in operating the monetary policy. Savings wold not have any value but might have encouraged more investment. Zero bound policy rate can also be used to encourage inflation and reduce the threat of deflation. *Second*, if the conditional forecast is carried on assuming that monetary shocks are zero from 2009 onwards, the model recommends the BoE to decrease the interest rate in the following years less aggressively than what it has actually done.

This result points out that the central bank decreased the interest rate pre-emptively, before the interest rate reaches to the 0.5% level. This finding is in line with the evidence for the Euro Area found in Gerlach and Lewis (2010) who argue that in early-2008, the ECB, in response to worsening economic conditions, cut interest rates more rapidly than the regular reaction function would have

[144] A contrasting recommendation is prescribed by a strand of literature on monetary policy in the vicinity of the zero bound. Among these authors, Orphanides and Wieland (2000) find that the policy rate becomes increasingly sensitive to inflation as it falls and the likelihood that the ZLB will be reached rises.

predicted. Figure 6.16 (chart-a, and chart-b) reports two surface charts with various heights that correspond with the level of shock it accounts for. For example, when the FA mechanism is not in operation, inflation, hours worked and real wage react more than the other variables to monetary policy and inflation shocks. On the other hand, when the FA mechanism is in operation, the Spread shock responds to a higher extent to shocks such as investment, government spending, and monetary policy.



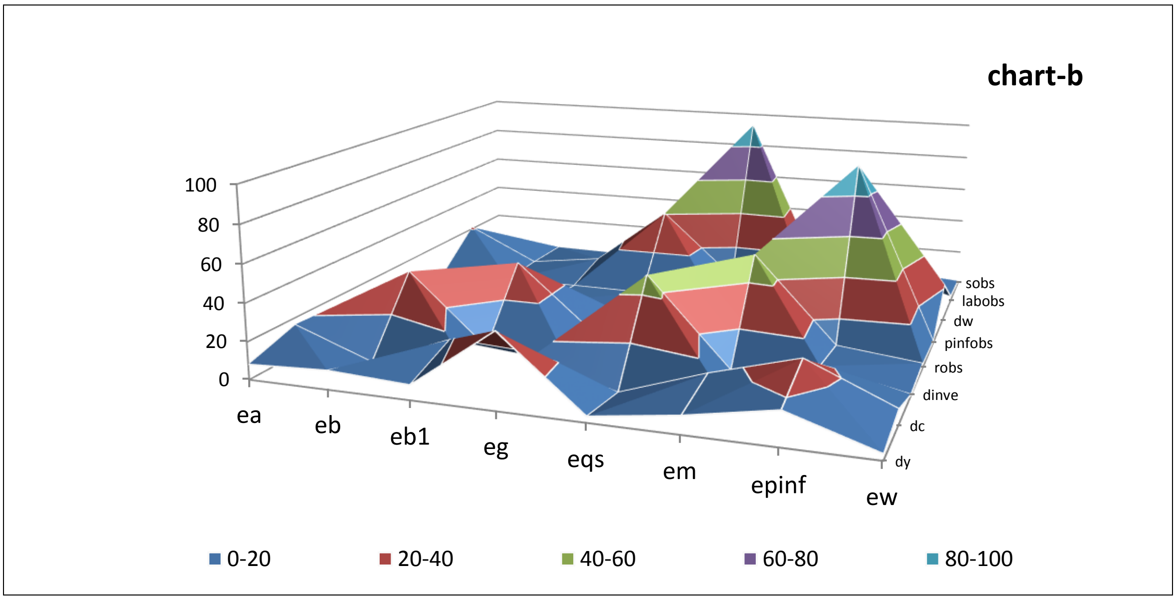


Figure 6.16 A Three Dimensional CVD with and without the FAM
ex's are shocks and dx's are the variables. The height and distribution of the graph represent the average contribution of each variable to the shock. (t = 10). CVD refers to Conditional Variance Decomposition. ea stands for productivity shock, eb is spread shock, eb1 is preference shock, eg is government spending shock, eqs is investment shock, em is monetary policy shock, epinf is price mark-up shock, and ew is wage mark-up shock.

The estimation results also help to shed some light on the interpretation of movements in the external finance premium (EFP). The movement of the EFP is interpreted in relation to shocks that drive the business cycle. The IRFs in Figure 6.17 plot the EFPs, based on the parameters estimated over the whole sample 1955-2014. The response functions, as in Merola (2015), De Graeve (2008), and Gelain (2010) show that the counter-cyclical behaviour of the EFP depends on the type of shock. Similarly, the estimates and the IRFs show that the EFP is not necessarily counter-cyclical. The IRFs in Figure 6.17 display a mixture of pro-cyclical and counter-cyclical movements. It shows that the productivity, wage mark-up and investment shocks lead to a pro-cyclical external finance premium after some periods. On the contrary, the EFPs respond counter-cyclically to the Spread shock. Similarly, the government and monetary policy shocks and to some extent the preference and price mark-up shocks respond countercyclically.

The shock known as 'the Spread shock' introduces as a proxy for external finance premium which is a wedge between the rate set by the central bank and the interest rate faced by enterprises. It can also be set as the difference between a riskless bond rate and risky interest rate. This wedge increases the premium charged by lenders, which consequently dampens investment and ultimately the economic activity. The response of investment shocks also leads to pro-cyclical external financial premium, which results in a reduction in net worth due to a decrease in the price of capital. This, thereby, leads to the external finance premium becoming pro-cyclical because of increased entrepreneurial borrowing needs. It also reduces net worth, which ultimately leads to low borrowing and low investment followed by low productivity in the economy. As to the government spending shocks, the EFP reacts counter-cyclically, implying that the higher aggregate demand increases the price of capital and hence borrowing needs. Nevertheless, in the context of the implications with respect to the financial frictions, the increase in the price of capital improves borrowers' collateral. Consequently, the EFP may start to look, slightly, like pro-cyclical. It confirms the intuition behind the IRFs reported in Figure 6.18.

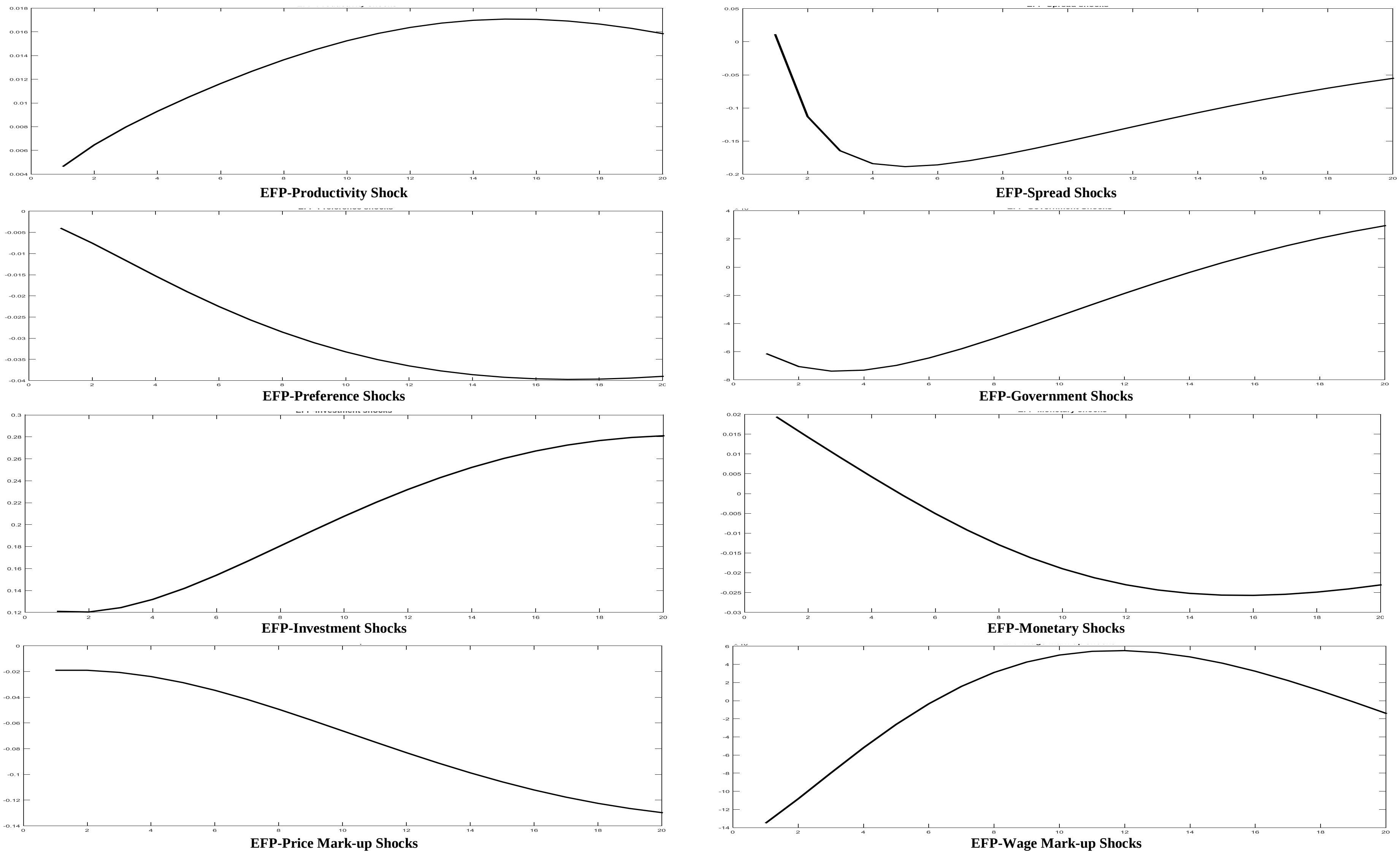
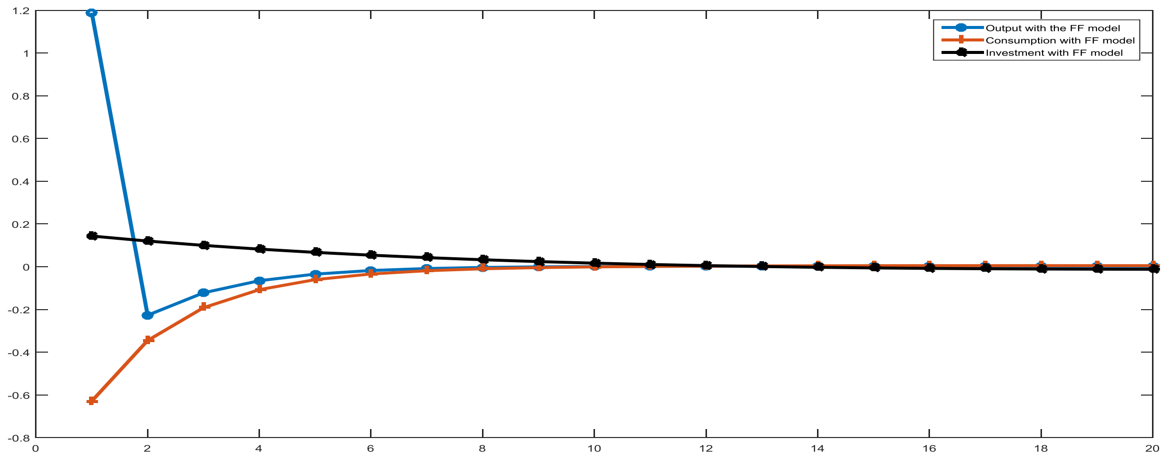
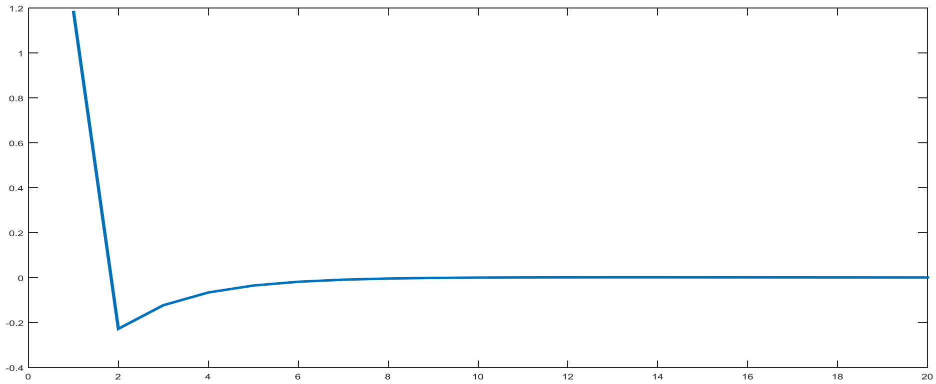


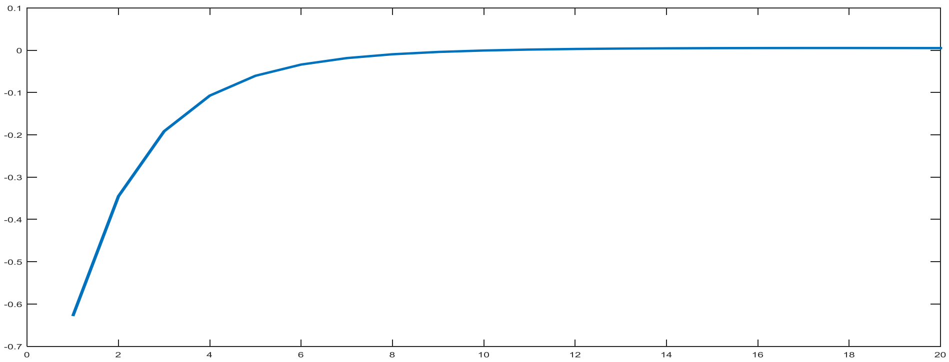
Figure 6.17 The Impulse Responses of the EFP to each Shock

The IRFs of the External Finance Risk Premium are shown as deviations from the steady-state expressed as percentage points. The IRFs are based on estimated parameters from the SW model with financial frictions over the full sample (1955-2014).

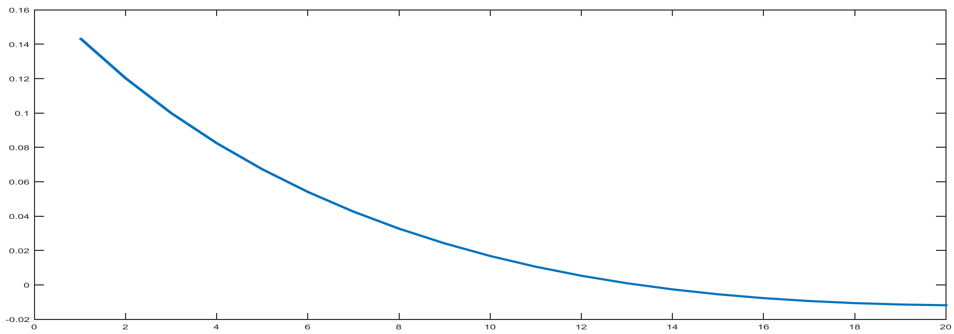




Output



Consumption



Investment

Figure 6.18 The Impulse Responses to the Government Spending Shock (full data)
Variables are percentage deviations from the steady-state. The IRFs are based on parameters estimated over the full sample (1955-2014).

The results also show that the increase in the EFP does not overturn the positive effect on output due to the productivity shock, the investment specific shock, monetary policy shock, price mark-up shock, and the government spending shocks. The IRFs confirm that economic expansions may have occurred because of the increasing trend of the EFP. A price mark-up shock is associated with lower production and thus lower external finance premium with higher market power. Firms, as a result, will have an incentive to reduce production and keep price high to maximise profits, implying more borrowing capacity due to high collateral capability. The EFP is counter-cyclical and conditional on a monetary policy shock so that an exogenous rise in the interest rate lowers asset prices and consequently net worth. Since firms are leveraged, net worth falls more than asset prices, which leads to an increase in firms' borrowing needs. The findings are in line with those of BGG (1999), De Graeve (2008), and Merola (2015). As shown in Figure 6.19, the output variability to productivity, government and investment shocks become neutral in the long-run (about 8 to 20 quarters). The same is true that the output variability to price mark-up and monetary shocks remains the same in the long-run. This highlights that variability of output is a short-run effect. There is also evidence that external finance premium and monetary policy shocks are counter-cyclical (Figure 6.20).

Output response

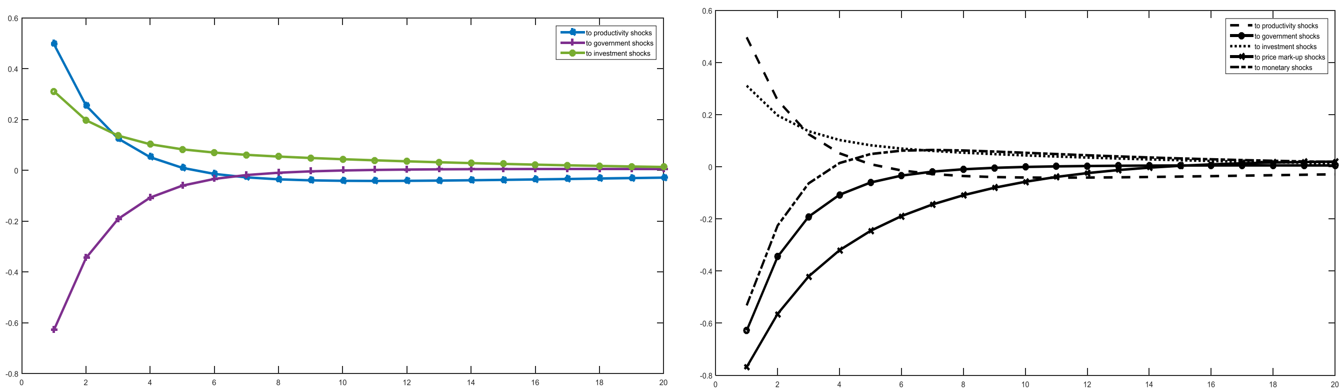


Figure 6.19 The Impulse Responses of Output to Various Shocks
Productivity, Government, Investment, Price mark-up and Monetary Shocks

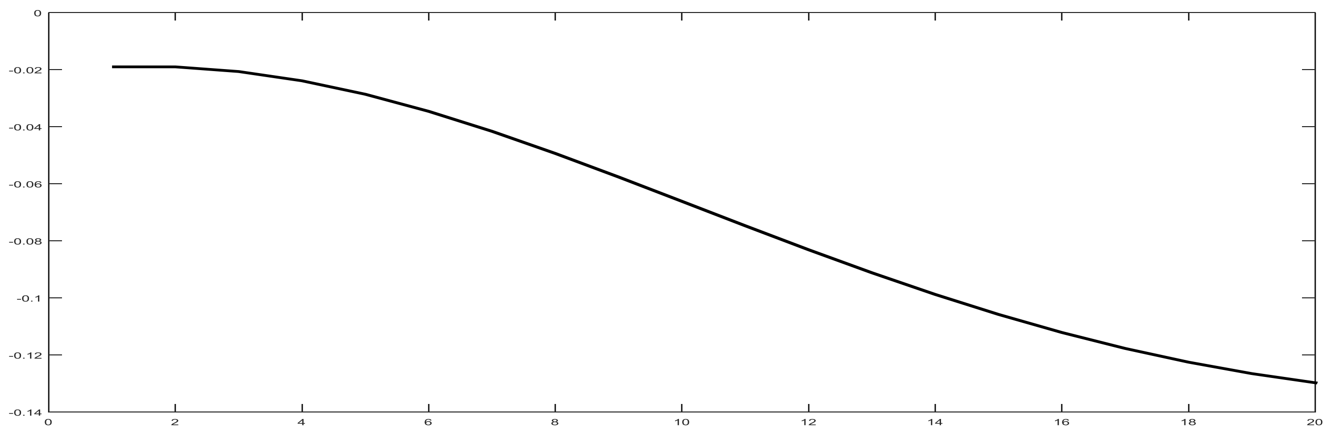


Figure 6.20 The Impulse Response of the EFP to Monetary Policy Shock

6.7 What Drives the Business Cycle?

6.7.1 Variance Decompositions

Variance decomposition (VD) is useful to provide insights into the main driving forces. It highlights the major contributing factors to output, price and investment shocks. The VD in the context of this study investigates the sources of business cycle fluctuations in the UK economy. This section discusses the VD in terms of individual plots and quantified contributions based on the two variants of the B-DSGE models. The analysis also determines the contributing factors to the macroeconomic and financial fluctuations. The contribution of each of the structural shock to the variance of the observed variables is reported as soon as the impact hits the economy. Table 6.9 and 6.10 report each shock of the observed macroeconomic variables obtained from the augmented DSGE model with and without the FAM. The VD analysis is disaggregated into two parts as full data (1955Q1 to 2014Q4) and partial data (1955Q1 to 2007Q3). As in SW (2007), the decomposition algorithm of each shock is reported at different time horizons (*t=1*, *t=10* and *t=40* basis-period). This refers to 2.5 and 10 years period equivalent to short and long-run impacts of the structural shocks.

The results indicated that the productivity shocks, the government spending shocks, the investment shocks, the Spread shocks and the preference shocks are the major driving forces behind short and long-run variations in output. Their impact, however, has reduced across the given time horizon, the government spending being the biggest force when the FA mechanism is in operation. The driving forces impact the output similarly in both sample periods with the FA mechanism. In the full sample, the government spending explains 40% (at $t = 1$) to 21% (at $t = 40$), while in the short sample, it explains 45% (at $t = 1$) to 35% (at $t = 40$) of the variations in output. The second and third most important driving forces to the output fluctuation, when the FA mechanism is in operation, are inflation, and Spread shocks, respectively. It is also worth highlighting that when the financial accelerator mechanism is not included in the model, the driving forces to output fluctuation have changed. In the full sample, preference shocks explain 68.4% at $t = 1$ and 72.07% at $t=40$, while in the short sample, government spending accounts for 56% at $t=1$ and 42% at $t=40$. Investment shock is the second most important driving force, followed by a productivity shock in the full sample, while preference and investment shocks are the second and third important forces for the variations in output in the short sample that does not include the post-crisis period. This shows that preference and investment shocks are the most prominent driving forces during the IT, GFC and post-crisis period without the FA mechanism, but government expenditure and inflation shocks are the most prominent factors to force output to fluctuate in the pre and post-GFC period. Unlike the studies for the U.S. and Euro Area (SW, 2003, 2007), price mark-up shock accounts for more output fluctuation than the wage mark-up shock. Furthermore, unlike the output fluctuations, the inflation developments tell a different story. Over 53% of variations in inflation is explained by price mark-up shocks in both cases of the FA mechanism and sample period. This phenomenon could be due to (a) degree of price stickiness as it requires high and persistent marginal cost changes to impact inflation, (b) the fact that the Bank of England reacts quickly to changes in inflation and output gap as in Taylor rule, and (c) due to consumer preferences and expecting the monetary policy to react for changes in inflation, which triggers consumption adjustments to the BoE expected policy reactions. This is also reflected in such a way that, in the short-term, the fluctuations in nominal interest rate is explained by monetary policy shocks but at medium to long time horizon preference shocks explained more than 67% of nominal interest fluctuation in the sample that includes the financial crisis than without the financial crisis. This is also true for both cases, with and without the FA mechanism.

The Spread shock gains relevance in the long-run and partially replaces the productivity and the preference shocks. When the FA mechanism is in operation, the relevance of the investment shocks is notably reduced as shown in Figure 6.12a and 6.12b. Regardless of the presence of endogenous financial frictions, the determinant of consumption at short and long time horizon, the major part of the variation is explained by the preference shock, especially before 2007. On the other hand, when the FA mechanism is in operation, the investment shock explains the largest part of its own movement at time horizons: 48.58% at *t=1*; 51.39% at *t=10*; and 51.89% at *t=40* (see Table 6.9). The contribution of investment to its own shock has shown to have not only a short-run but also a long-run effect with an increasing trend. Investment shocks are likely to have a progressive role in impacting on forthcoming outlay, as future investments are dependent on past investment activities. This is highly prominent during the financial crisis. On the other hand, when the crisis period is not included in the sample, the role of investment shock has slightly increased from 36.7% at *t=1* to 37.62% at *t=10,* and to 36.11% at *t=40.*

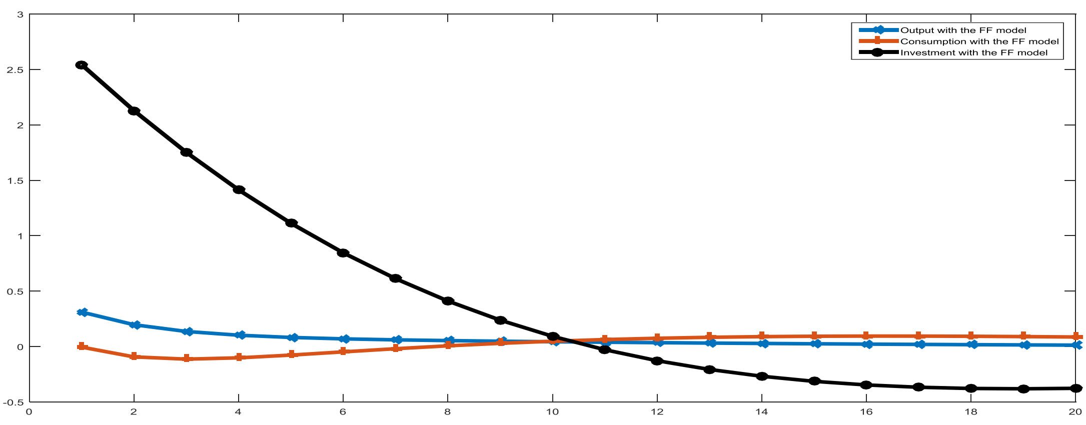


Figure 6.21 The Impulse Responses to Investment Shock (full data)
Percentage deviations from the steady-state. The IRF is based on parameters estimated over the period, 1955-2014.

Additionally, with respect to output, the role of the investment shocks, which accounts for the economic fluctuation, has shown significant difference in the two sample cases of the FA mechanism. When the FA mechanism is in operation, the role of investment shocks on output has only increases from 3.23% at *t=1* to 4.52% at *t=40* in the full sample. When the sample does not include the crisis period, the role of investment shocks on output has only increased from 1.97% to 2.71%. This is a wide-ranging evidence to show that the FA mechanism works as an accelerator mechanism more in the crisis period than the normal period. On the other hand, in the absence of the FA mechanism, the role of investment shocks on output increases from 12.16% to 23.13% in the full sample and marginally increases from 11.7% to 16.5% in the partial sample. This clearly shows that the role of investment shocks on output is lower, when the FA mechanism is in operation. This also implies that the role of investment is lower in a financial volatility periods as compared to the shocks in the financial sector.

The contribution of the Spread shock (FF) to output increases from 10.19% to 16.01%, so is the reduction in investment shock. When FA is in operation the role of the investment shocks is being gradually replaced by the impact of the Spread shock. The spread shock plays more significant role than the investment shock, particularly when the sample includes the crisis period. The DSGE model, with its strands of the accelerator mechanism, can help to shed some light to understand the source of the aggregate fluctuations in the External Finance Premium (EFP). The fluctuations of the EFP are mainly driven by the investment and Spread shocks. The results (see Table 6.9 and 6.10) confirm that investment shock accounts for 47% to 93% to the fluctuations in the EFP in the full sample, while the Spread shock contributes up to 48% to the EFP fluctuations in the full sample and, particularly at $t = 10$, in the DSGE model with the FA mechanism. The contribution of investment shock is both in the short and long time horizons, but the major impact of Spread shock is recorded from short to midterm, both in the long and short time horizon, reducing to 17% at *t=40*. Therefore, Investment shocks are short and long-run phenomena in the financial sector, while Spread is a short to medium term phenomena concerning the contribution to the EFP fluctuations.

Furthermore, the Spread shock becomes more prominent and persists during the crisis starting from its origin up to a period of 10 quarters (2.5 years), particularly, when the FA mechanism is in operation. Figures 6.22a and 6.22b present counterfactual analysis of the conditional variance decomposition across the three time horizons. The graphs represent the magnitude of the investment shock that accounts for EFP at *t=1, t=10*, and *t= 40.* Investment shock has been the *first* highest contributing factor to EFP in all time horizons, which increases in the short-run (red dotted line of Figure 6.22a) at *t = 1* and *t=40*, as compared with the investment shock that accounts for the EFP fluctuation before the global financial crisis (Figure 6.22b). The *second* highest contributing factor to EFP in the full sample is the Spread shock, which contributes more to EFP at *t =10*, but contributes less in the same time horizon when the crisis period is not included.

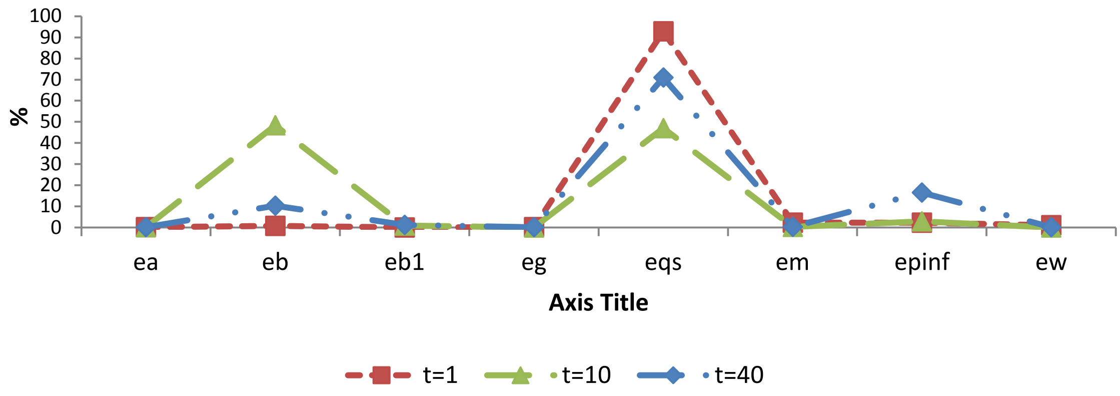


Figure 6.22a Aggregate EFP and the Contributing Factors (1955 to 2014)

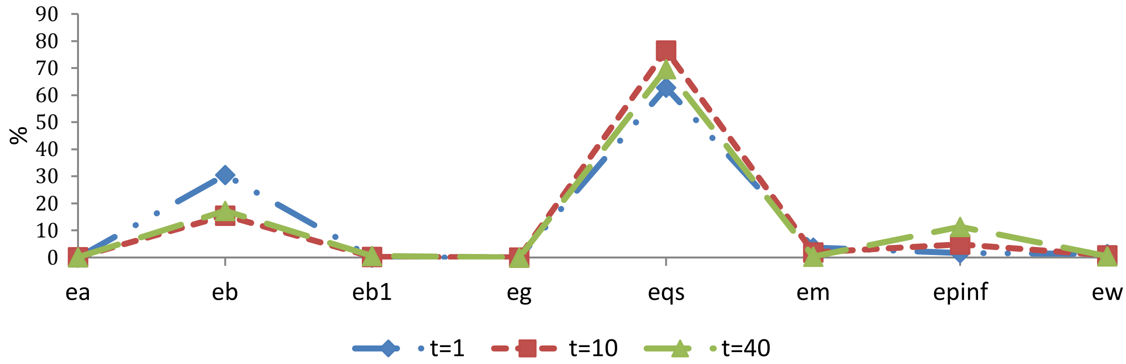


Figure 6.22b Aggregate EFP and the Contributing Factors[145] (1955 to 2007)

The *second* major contributor to EFP is the Spread shock followed by the price mark-up shock. In the same DSGE model, the Spread shock was the highest contributor at *t=1* in the partial sample and at *t=10* in the full sample. This is a clear evidence that EFP is a medium to long-term phenomena in the crisis period but a short term during normal economic conditions. The *third* major contributor is the price mark-up shock that contributes more at *t=40*, both with and without the crisis period, but at different magnitude. It can also be said that investment shock is a short-run contributor while Spread shock is a long-run contributor when the crisis period is included.

Identifying the major contributing factors to EFP across the time horizon is a useful exercise for a practical policy measures to limit and minimise the negative impact of the GFC. This outcome corresponds to the impact of the recent crisis on the UK economy. The cost of the financial crisis

[145] where ea refers to productivity shock, eb Spread shock, $eb1$ is preference shock, eg is government spending shock, eqs is investment shock, em is interest rate shock, $epinf$ is inflation (price mark-up) shock and ew is real wage (wage mark-up) shock.

is still being felt in all sectors of the economy. This justifies the medium to long-term behaviour of the Spread shock contrary to what was suggested in the RBC and DSGE models without a financial frictions component. The significance of the Spread shock is relevant not only in the short-run but also in the long time horizon. The investment shock on the other hand has a short-run impact on the economy during a period of financial crisis. It reaches at its peak at $t = 1$. The other interesting outcome of the conditional variance decomposition (CVD) of the EFP is the price mark-up shock, which is also known as inflation shock, becomes relevant as a policy target when the economy is not in a crisis. Its contribution to the EFP is negligible during the financial crisis as the shock is accounted for a short period, which is only prominent at $t =40$. Therefore, having inflation targeting monetary policy during the crisis and recession periods is not a sound policy strategy.

The productivity (21.12%) and government spending (40.59%) shocks impact not only output but also hours worked and are the main sources of short-run fluctuations. To a lesser extent, the preference shock (6.84%) and the price mark-up shocks (16.68%) are another important source of economic fluctuations in terms of hours worked in the short-run. However, the wage mark-up shock becomes the dominant factor behind movements in hours worked (11.10% and 22.96%) in the long-run. With respect to the determinants of inflation, variations of inflation in the given time horizon, is largely driven by the price mark-up shock (95.20%, 84.30% and 78.94%, respectively). The results of the conditional variance decomposition also show that, in both cases (with and without the crisis period), the price mark-up shock is evident in the short-run as well as in the long-run. The findings are more prominent when the FA mechanism is in operation. During the crisis period, the monetary policy shock accounts only for a small fraction of inflation volatility in the time horizons (0.55%, 1.87% and 2.09%, respectively). This implies the level of effectiveness of MP in the crisis period.

The next question is to investigate what determines inflation based on the two strands of the DSGE model. Price mark-up makes the most contribution to EFP in the short-run in the full sample, but it accounts for the highest contribution in the long-run of the shorter sample that does not include the crisis period. Variations in the short-term inflations are probably driven by price mark-up shock, accounting for 95% of the shock to inflation fluctuations. In the long-run, preference shock accounts for 13.4% of the shock to inflation. Similarly, price mark-up shock also dominates inflation and wage mark-up in the short time horizon of the shorter sample period (1955 to 2007). When the sample is extended to 2014, the recession emphasises the role played by the price mark-up shock, which remains to be the dominant source of fluctuation in inflation, wage and hours worked in all time horizons.

Table 6.9 Variance Decomposition with the FA Mechanism

Shocks / Var.		Model with FAM:1955Q1-2014Q4								Model with FAM: 1955Q1-2007Q3							
		ϵ_t^a	ϵ_t^b	ϵ_t^β	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w	ϵ_t^a	ϵ_t^b	ϵ_t^β	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w
t=1	Output	8.23	10.19	7.94	40.07	3.23	9.43	17.69	3.23	10.88	11.34	7.09	45.05	1.97	9.71	20.16	3.8
	Cons.	16.38	0.59	17.69	13.9	0	15.26	27.85	8.34	18.98	0.73	15.24	20.73	0.08	12.18	22.98	9.09
	Invest	0.07	38.34	0.03	0.15	48.58	2.52	9.96	0.34	0.24	44.02	0.33	0.16	36.07	5.02	13.6	0.55
	Int. Rate	0.39	0.05	36.38	0.04	0.76	52.67	7.32	2.39	0.2	0.08	35.12	0.13	0.25	52.99	8.85	2.38
	Inflation	0.64	0	2.26	0	0.03	0.55	95.2	1.32	0.83	0.03	2.47	0	0	0.59	94.55	1.52
	Wage	0.59	0	0.26	0.01	0.09	0.22	77.38	21.44	0.94	0	0.28	0.01	0.05	0.26	79.74	18.73
	Labour	21.12	1.02	6.84	40.59	2.78	8.12	16.68	2.85	15.87	1.27	6.71	42.79	1.87	9.2	18.54	3.74
	Premium	0.14	0.83	0.1	0.24	92.86	2.39	2.28	1.16	0.01	30.56	0	0.06	62.82	3.66	1.62	1.26
t=10	Output	5.91	12.28	6.86	30.98	4.42	8.45	26.28	4.82	10.55	14.3	6.2	35.77	2.64	8.69	29.64	5.2
	Cons.	14.53	1.07	14.34	13.11	1.01	12.39	33.03	10.51	17.1	2.29	12.77	19.45	1.36	10.45	25.58	11
	Invest	0.11	23.18	0.04	0.17	51.39	1.84	22.88	0.38	0.35	31.38	0.34	0.19	37.62	3.79	25.88	0.46
	Int. Rate	1.88	0.06	63.71	0.01	0.95	15.16	16.86	1.38	1.81	0.54	56.13	0.02	0.13	14.85	25.64	0.88
	Inflation	0.93	0.01	9.5	0	0.08	1.87	84.3	3.31	1.16	0.15	10.37	0	0.01	1.91	82.85	3.54
	Wage	0.75	0	0.35	0.01	0.46	0.25	86.6	11.59	1.2	0.01	0.33	0.01	0.27	0.27	87.13	10.78
	Labour	1.62	0.26	5.69	8.89	3.72	5.53	63.18	11.1	1.16	0.57	4.32	9.51	2.55	5.32	63.23	13.36
	Premium	0.24	48.33	0.92	0.07	47.08	0.3	2.97	0.09	0.1	15.47	0.22	0.06	76.55	1.87	4.87	0.87
t=40	Output	5.23	16.01	6.95	27.02	4.52	8.35	27.03	4.9	10.83	16.55	6.23	35.19	2.71	8.71	29.61	5.17
	Cons.	14.58	1.21	14.25	12.57	3.53	12.04	31.65	10.16	16.74	3.75	12.59	18.48	3.62	9.96	24.41	10.46
	Invest.	0.15	22.3	0.1	0.16	51.89	2.14	22.66	0.6	0.4	34.74	0.46	0.16	36.11	3.65	23.94	0.55
	Int. Rate	1.77	0.06	62.19	0.01	0.64	9.23	24.94	1.16	1.85	0.57	55.62	0.02	0.38	9.51	30.45	1.6
	Inflation	0.88	0.01	13.39	0	0.07	2.09	79.94	3.61	1.11	0.19	13.79	0	0.08	2.05	78.95	3.83
	Wage	0.82	0.01	0.37	0.01	0.85	0.27	86.35	11.33	1.29	0.07	0.37	0.01	0.47	0.28	86.88	10.63
	Labour	0.47	0.13	2.16	7.35	1.39	1.62	63.91	22.96	0.42	0.59	1.73	9.2	1.15	1.79	58.2	26.91
	Premium	0.2	12.35	1.3	0.03	71.37	0.35	14.29	0.12	0.14	17.32	0.63	0.01	69.71	0.36	11.3	0.53

Note: The contribution of each structural shock (columns) to variance of observed variables (rows) is reported on impact *(t=1)* and at various time horizons, (*t=10*= 2.5 years) and *(t=40 = 10 years).*
Source: author's analysis.

As shown in Table 6.9, when the FA mechanism is in operation in the short and long samples, the monetary policy shock accounts only for a small (0.55% to 0.59) fraction of inflation volatility. One can conclude that inflation is impacted by its own past (up to 80%) in the short-run and preference shock in the long-run (up to 14%). Price mark-up remains to be dominant even without the financial crisis in the short and long-run periods. Therefore, the impact of FF on inflation is not significantly high as compared with its impact on output. This reflects the economic case in the UK where inflation remains low in the post-crisis period. Finally, wage developments are explained by the wage mark-up shock both in the short and long-run time horizons. However, the major share of the wage fluctuation is due to the price mark-up shock (up to 87%). It is evident that wages are highly sticky so one needs quantitatively important shocks to account for the behaviour of wages (also found in Merola, 2015; Gali, 2007). Inflation accounts for 3%, 17% and 31% of the wage mark-up shocks in the short sample at *t=1, t=10* and *t=40*, respectively. The reaction of wage mark-up shock is less significant in the crisis period. This supports the New Keynesians' theory of price and wage movements that remains sticky for a certain time before they respond to macroeconomic and structural shocks. Unlike the New Classical advocates, the

New Keynesians use this theory to explain involuntary unemployment and the influence of monetary policy on economic activity. The results obtained in this study also highlight the validity of the New Keynesian theory of price and wage stickiness, which was the main disagreement between the two schools of thoughts. Overall, the conditional variance decomposition quantifies the disturbances originated in the Spread that have gained relevance and have partially replaced the role of traditional demand shocks in driving macroeconomic fluctuations during the recession period (post-2007/08). The major contributors of external finance premium are investment and spread shocks in the United Kingdom business cycle fluctuations in the presence of the financial accelerator mechanism.

Table 6.10 Variance Decomposition without the FA Mechanism

Shocks / Var.		Model without FAM:1955Q1-2014Q4								Model without FAM: 1955Q1-2007Q3							
		ϵ_t^a	ϵ_t^b	ϵ_t^β	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w	ϵ_t^a	ϵ_t^b	ϵ_t^β	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w
t=1	Output	11.39		68.36	8.86	12.16	10.99	0.05	0.19	3.83		13.61	56.1	11.69	8.27	5.54	0.95
	Cons.	7.69		72.69	8.54	0.22	10.69	0.01	0.15	0.01		66.07	7.63	0.1	21.34	4.81	0.04
	Invest	0.44		0	0.18	90.01	2.53	3.08	3.76	0.35		0.04	0.06	82.98	4.08	8.22	4.27
	Int. Rate	0.14		95.93	0.04	0.01	0.14	3.43	0.31	14.78		25.73	3.51	3.06	48.8	1.24	2.88
	Inflation	2.12		0.06	0	0	0.3	97.47	0.04	0.93		0.01	0.06	0.01	0.11	96.8	2.08
	Wage	1.73		0	0	0	0	63.91	34.36	0.03		0.02	0.02	0.07	0.18	48.41	51.28
	Labour	1.72		75.73	9.83	0.17	12.16	0	0.39	20.91		11.58	47.96	9.9	6.91	2.63	0.11
	Premium																
t=10	Output	9.57		72.45	7.17	18.13	8.75	1.7	0.24	3.16		11.87	46.41	16.84	11.76	8.85	1.11
	Cons.	6.46		76.83	6.92	0.22	8.45	0.83	0.28	0.08		52.11	10.38	3.6	24.84	8.26	0.73
	Invest	2.87		0.52	0.47	64.44	5.36	17.66	8.67	0.58		0.22	0.27	77.3	5.36	9.52	6.74
	Int. Rate	0.62		82.99	0.03	0.04	0.84	7.66	7.81	25.58		8.18	3	15.64	8.97	17	21.62
	Inflation	4.61		0.31	0	0.01	2.14	85.33	7.6	7.03		0.11	0.48	0.08	0.87	74.98	16.45
	Wage	4.27		0	0	0.01	0	64.84	30.87	0.02		0.05	0.03	0.34	0.57	65.03	33.96
	Labour	1.28		28.48	16.58	0.11	35.29	17.55	0.71	10.36		5.5	21.42	28.97	26.19	7.05	0.51
	Premium																
t=40	Output	9.57		72.07	7.13	23.13	8.76	1.73	0.61	3.05		10.85	42.4	16.5	10.9	14.81	1.5
	Cons.	6.48		76.64	6.91	0.23	8.45	0.84	0.46	0.31		47.61	9.49	4.68	22.79	14.09	1.04
	Invest.	3.3		0.56	0.45	58.25	5.61	19.31	12.52	0.64		0.22	0.26	71.32	4.69	16.61	6.26
	Int. Rate	0.61		67.75	0.03	0.04	2.51	8.2	20.85	29.78		3.44	2.81	9.23	4.46	15.1	35.18
	Inflation	3.89		0.55	0	0.01	4.01	68.87	22.66	13.28		0.17	1.02	0.3	1.37	52.83	31.02
	Wage	4.31		0	0	0.01	0.01	64.88	30.79	0.04		0.06	0.04	0.37	0.66	69.16	29.68
	Labour	1.4		9.98	17.91	0.06	22.64	27.98	20.04	9.73		2.92	20.32	13.02	23.39	25.88	4.74
	Premium																

Note: The contribution of each structural shocks (columns) to variance of observed variables (rows) is reported on impact *(t=1)* and at various horizons (*t=10=2.5 years)* and (*t=40= 10 years).*
Source: Author's calculations

The Variance Decomposition of the alternative DSGE model without the financial accelerator mechanism tells a different story. As shown in Table 6.10, the major contributing factor for output variability in the short, middle and long time horizon was the preference shock (68.36%, 72.45% and 72.07%, respectively) in the long sample. On the other hand, the government spending shock accounts for 40%, 31% and 27%, respectively, to the output variations from short to long time horizons, when the FA mechanism is in operation, but the contribution increases to 56%, 46%, and 42%, respectively when the mechanism is not in operation for the small sample. Only below

10% contribution is recorded, when the crisis period is included in the second DSGE model case. This clearly shows that the impact of government expenditure is highly prominent in a normal economic condition rather than the post-crisis period. The contribution of the monetary policy shock to output remains below 10% in most of the time horizons both in pre and in post-crisis period. The inflation shock accounts for output volatility more when FA mechanism is introduced in the DSGE model than without the mechanism. This is confirmed in both sample periods.

6.7.2 Historical Variance Decompositions

FEVD is an econometric tool that is used to assess the driving forces related one-to-one to business cycle fluctuations. Business cycle is a macroeconomic phenomenon that occurs in a time horizon of 2 to about 10 years. However, FEVD does not identify which macroeconomic shocks are the main driving force of the business fluctuations over the entire business cycle (Seymen, 2008). Historical Variance Decomposition (HVD), provides better information that covers the entire business horizon from historical perspective. This section uses HVD plots to identify the major driving force(s) based on the cumulative effects of historical movements of the complete business cycle. The estimated model and the observed propagation mechanism are used to quantify the relative importance of different shocks. It is possible to analyse what role the shock from financial sector has played in the degree of volatility of the main variables since the onset of the crisis. The HVD plots that are shown in the following section, report the historical decomposition for the main macro and financial variables. The parameters are kept fixed at the posterior mode level then the decomposition is obtained using Kalman smoother to acquire the innovations of each shock (SW, 2007; Villa and Yang, 2011). Figures 6.23 to 6.28 report the historical contribution of the various structural shocks to output, investment, Spread and price developments in the UK from 1955 to 2014 and with a particular focus from 2000 onwards. The post-2000 time horizon represents a period of boom and bust in the UK and other major industrial economies. This historical decomposition is based on the estimates of the various shocks in the DSGE model with the FA mechanism over the period 1955 to 2014. Interpreting historical decomposition requires careful quantification, although the results help to appreciate how the estimated model interprets specific movements in the observed data, particularly of the 2007/8 contraction period.

The historical decompositions for output show that the Spread shock has accounted for more than half of the fall in output since the start of the crisis. During stable economic periods (2000 to mid-2004), the bank capital shock drives up investment but pushes it down during the crisis. Besides, bank lending has been weak since the beginning of the crisis. Although it is difficult to identify the dynamics of credit demand versus supply shocks, the Bayesian DSGE model gives the prospect to study this dynamics. It is apparent that the financial sector is the source of the credit supply shock, which affects the banks' ability to extend credit. The credit demand shock encompasses a shock to productivity, interest rate, and government expenditure. This credit demand shock affects firms' demand for credit. Figure 6.23 and 6.24 report the sharp rise in Spread, while the crisis is mainly attributed to credit supply shocks, particularly, in the most recent quarters, which implies that weak demand starts to play in the system. The productivity and interest rate shocks explain the noticeable fraction of the total variation in inflation, whereas the price mark-up shock plays a minor role. Over the sample period, as shown in Figure 6.24, monetary policy and productivity shocks are dominant sources of movements that contribute to the fluctuations of inflation. However, the Spread shock still accounts for a large share of the inflation movements during the stable economic period. During this period, the estimates show that the monetary policy responds quite forcefully to inflation. This change in monetary policy was apparent from 2004 to mid-2007, where the monetary policy rate increased to 5.75% before its downward spiral to historical lower level of 0.5%.

In both sample periods, the Spread shock accounts for a significant portion of drop in output from 2007Q3 towards the recession and recovery periods. This result corresponds well with the sizeable damage that the global financial crisis has caused on the economy between the end of 2007 and early 2010. Prominently, a momentous tightening of credit dramatically slows down the economic activity. The historical decomposition for output growth clearly show (see Figure 6.23) this fact at about 140 base point (post-crisis period) and thereafter. The Spread and the preference shocks contribute the largest share to the slowdown of the economic activity from the end of 2007 to the mid-2009. The intuition behind this is that due to lack of confidence in the economy, households postponed consumption, but continue to save. The changing pattern in consumer preferences resulted in slowdown of investment and the real economy. This explains that the household preference shocks impacted output and contributed more to output decline, particularly in the pre-crisis period.

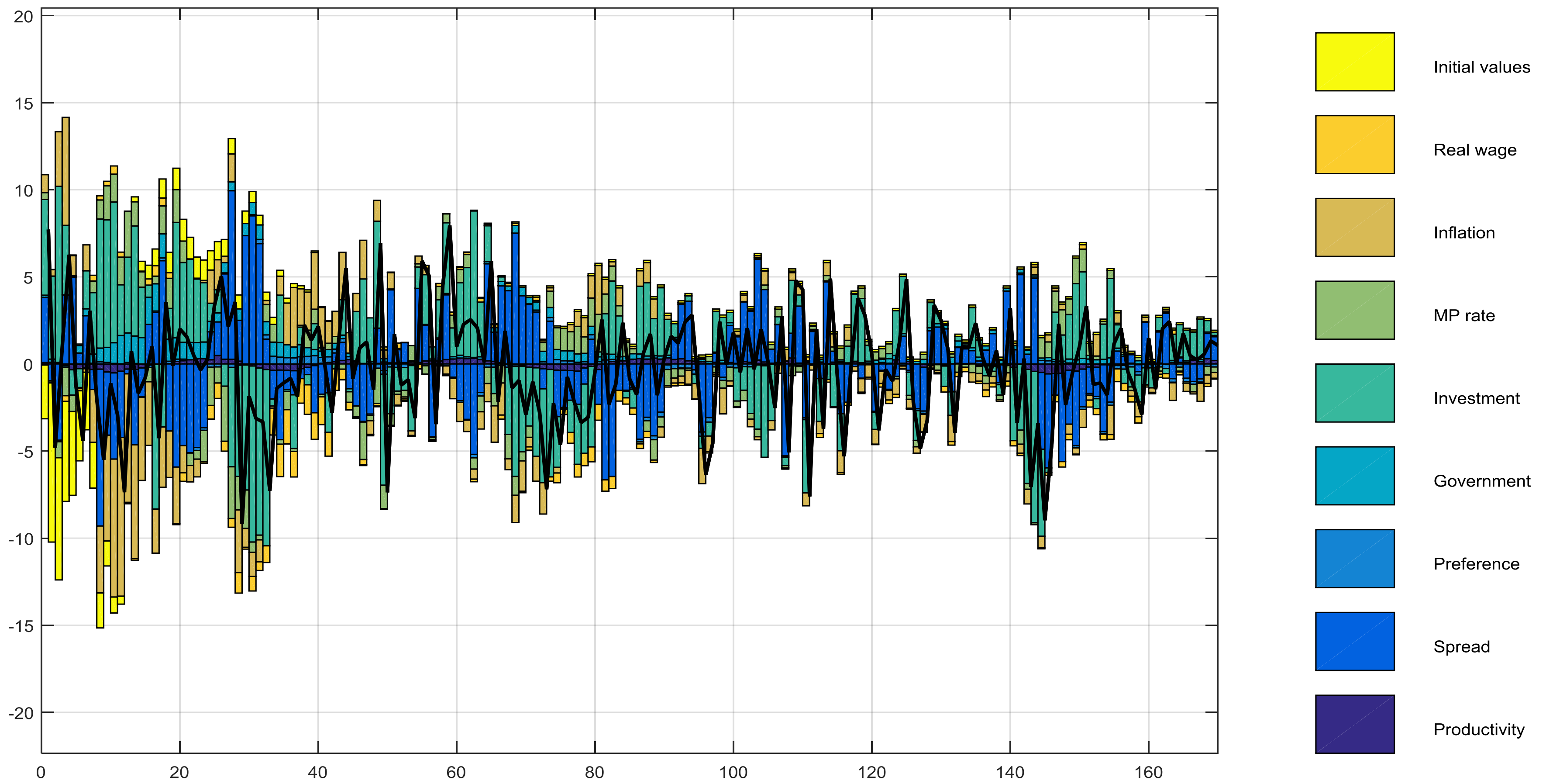


Figure 6.23 Historical Decomposition of Output Growth (1955 to 2014)

With Figures that show various shock contributions to the percentage deviations from steady-state of the real GDP growth (solid line) in the DSGE model with FA mechanism estimated over the period 1955Q1 to 2014Q4.

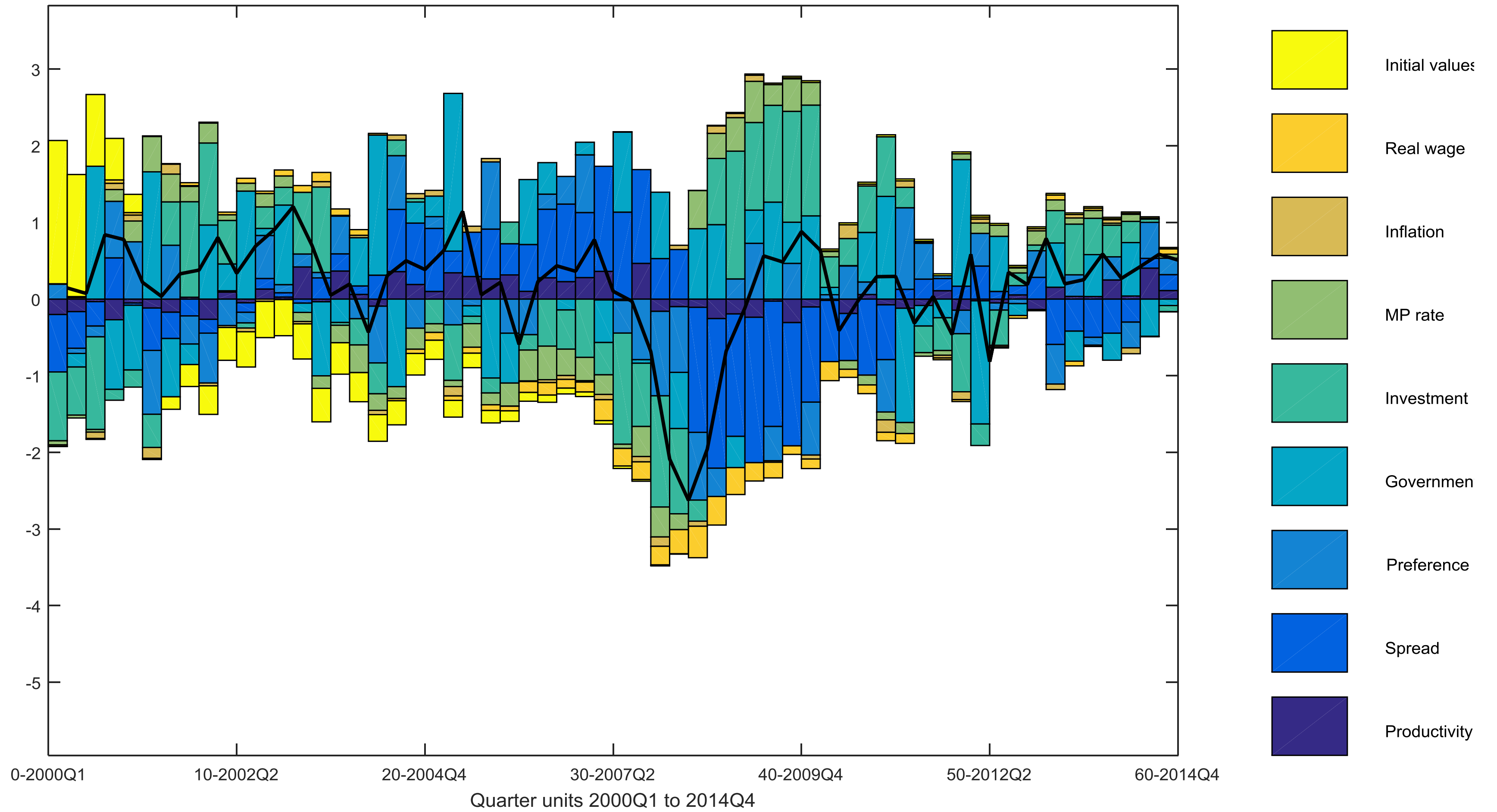


Figure 6.24 Historical Decomposition of Output Growth (2000 to 2014)
With Figures that show various shock contributions to the percentage deviations from steady-state of the real GDP growth (solid line) in the DSGE model with FA mechanism estimated over the period 2000Q1 to 2014Q4.

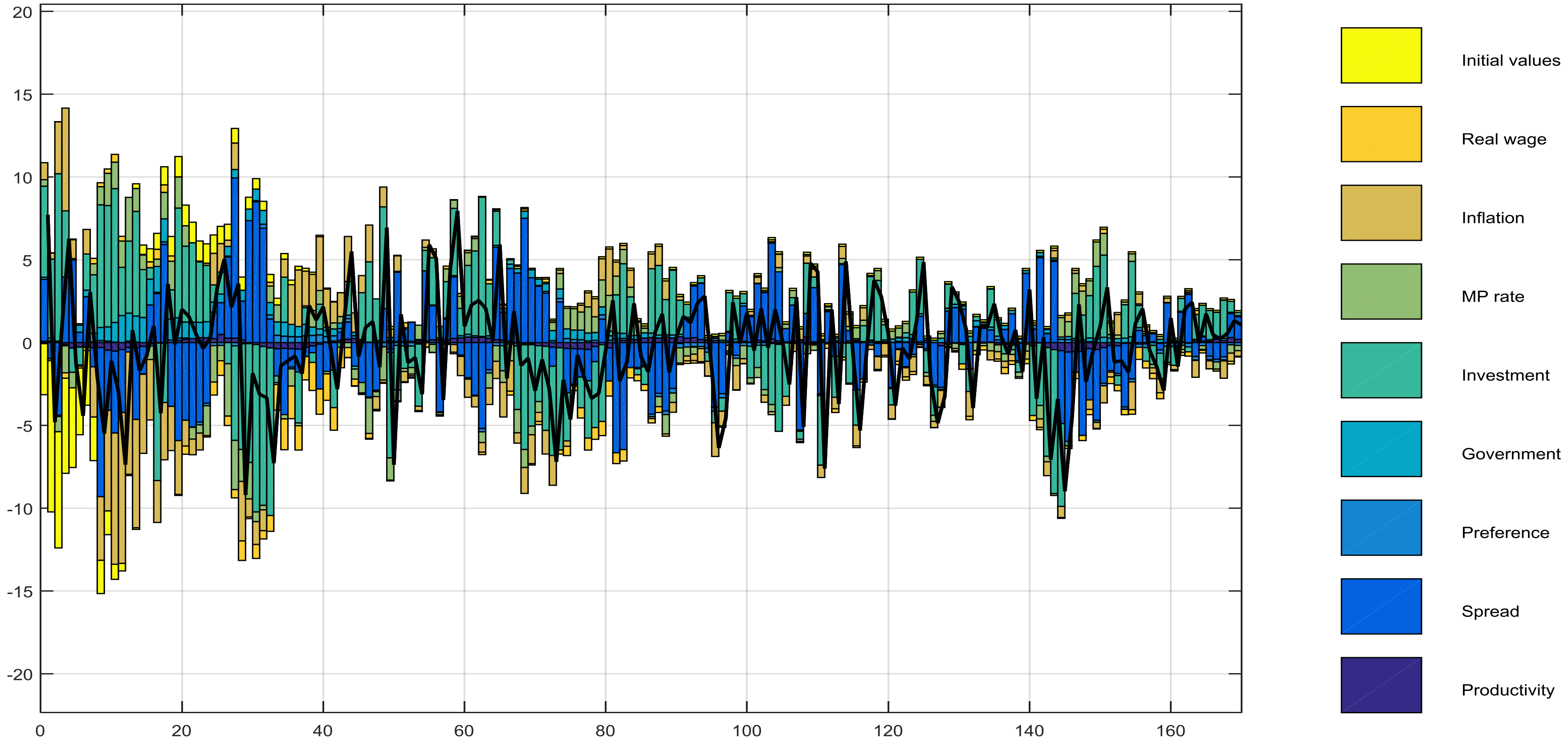


Figure 6.25 Historical Decomposition of Investment (1955 to 2014)
With Figures that show various shock contributions to the percentage deviations from steady-state of investment (solid line) in the DSGE model with FA mechanism estimated over the period 1955Q1 to 2014Q4.

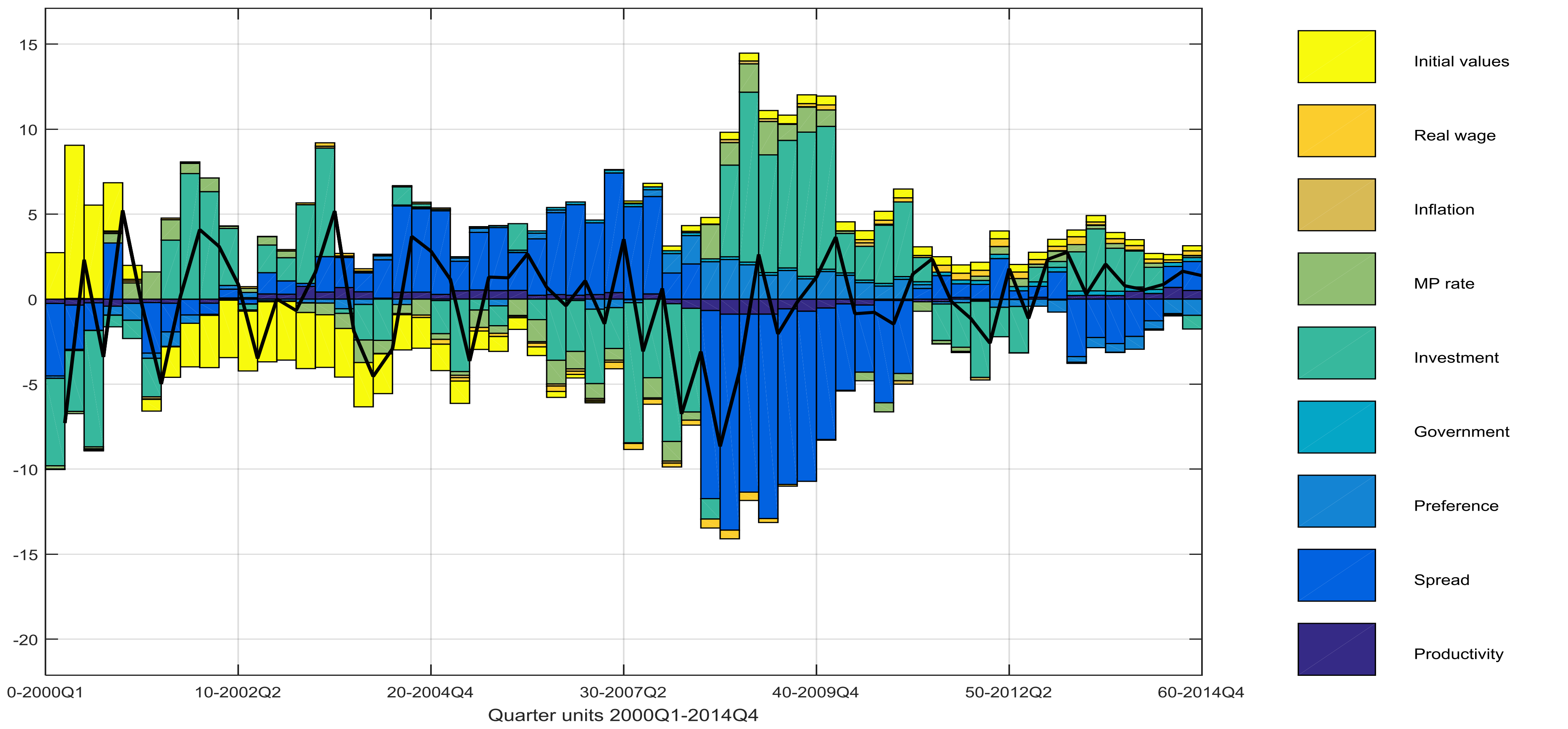


Figure 6.26 Historical Decomposition of Investment (2000 to 2014)
With Figures that show various shock contributions to the percentage deviations from steady-state of investment (solid line) in the DSGE model with FA mechanism estimated over the period 2000Q1 to 2014Q4.

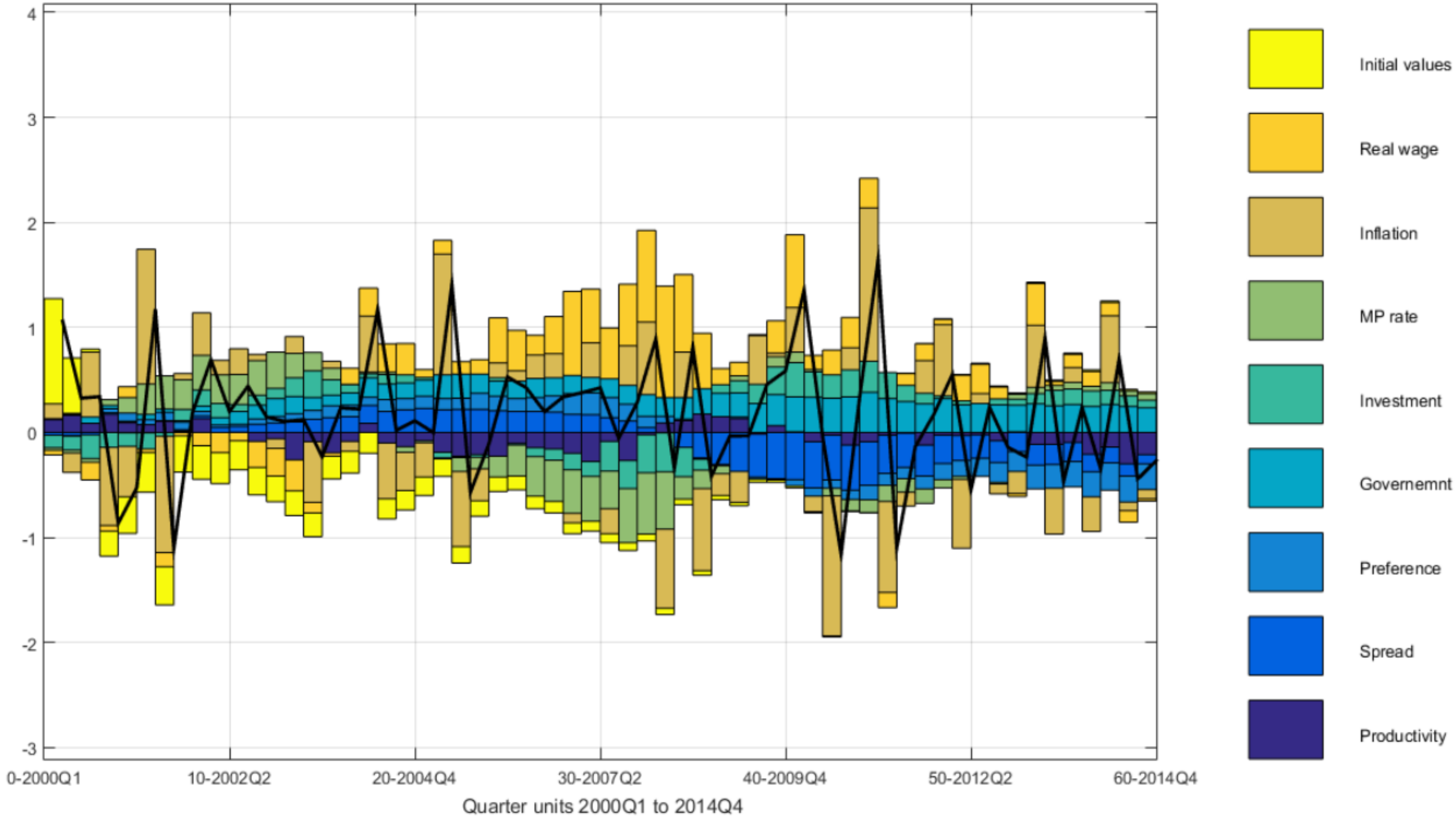


Figure 6.27 Historical Decomposition of Inflation (2000 to 2014)
With Figures that show various shock contributions to the percentage deviations from steady-state of inflation (solid line) in the DSGE model with FA mechanism estimated over the period 2000Q1 to 2014Q4.

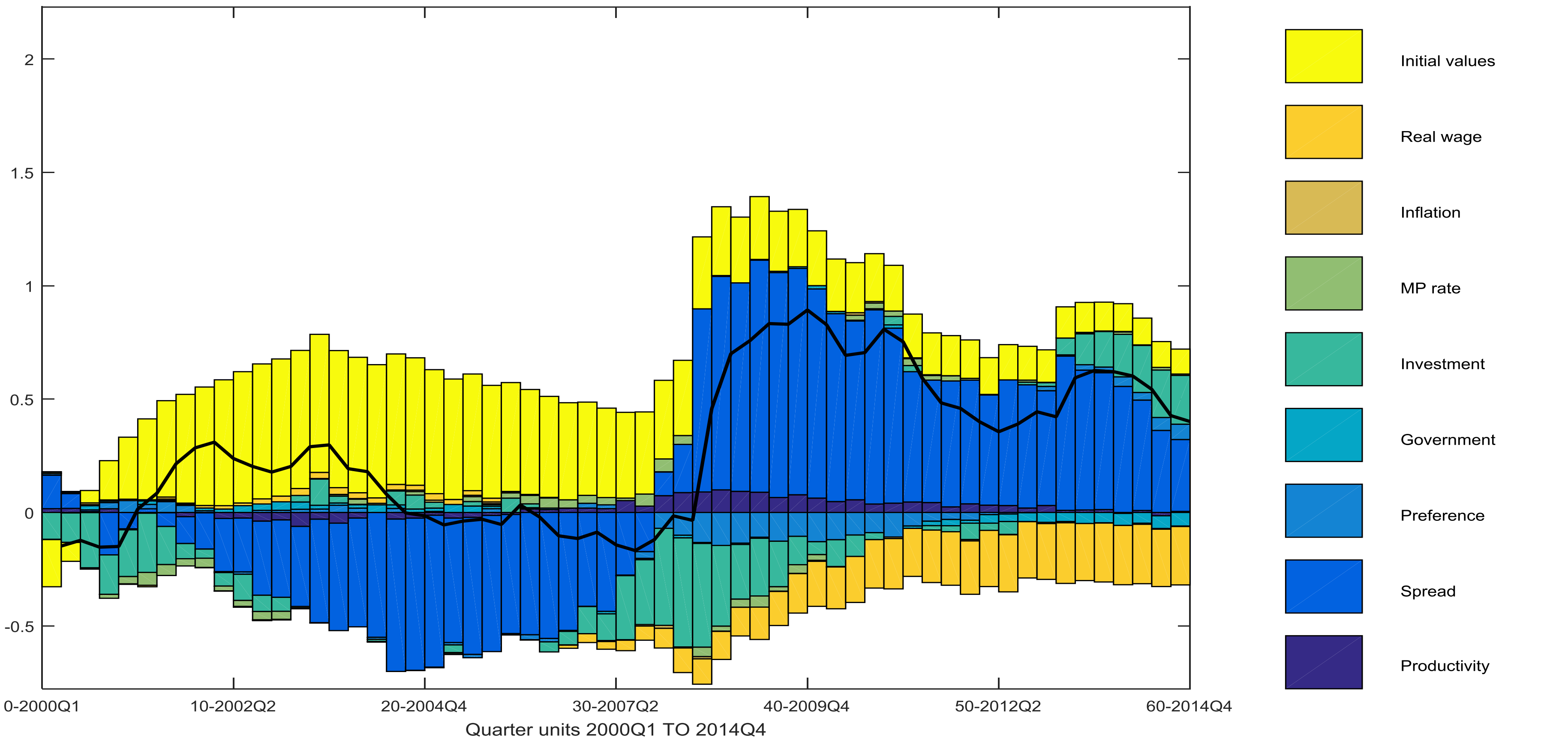


Figure 6.28 Historical Decomposition of Spread (2000 to 2014)
With Figures that shows various shock contributions to the percentage deviations from steady-state of investment (solid line) in the DSGE model with FA mechanism estimated over the sample 2000Q1 to 2014Q4.

Fiscal policy has contributed to the surge in output during the crisis. This finding captures the effect of the fiscal stimulus package passed in early-2009, as the government policy to support employment and output. Accordingly, to the ONS data, productivity has increased in the U.K during the recession at a lower rate, as compared with other industrial economies. Pertaining to the role of the monetary policy shock, the historical decomposition of output growth shows that monetary policy shock, price mark-up (to a lesser extent), investment shocks and fiscal stimulus account for a portion of output growth variation between mid-2000 and 2007. Figure 6.23 and 6.24 also show that output fluctuations before the crisis (early-2000s) are largely explained by the government stimulus and investment shocks, unlike the U.S., where output fluctuations are largely explained by monetary policy shocks (see SW, 2007; Merola, 2015).

The persistence increase in interest rate from 2001 to 2007 accounts for 3.5% to 6.3% to the portion of output increase to the run-up to the global financial crisis (see Figure 6.23 and 6.24). When the recent financial crisis was heightened, with the policy rates near to the lower bound, the BoE was forced to use unconventional monetary policy measures to support activities in capital markets and the impaired banking system. However, output has continued to decline from 2007Q3 to 2012Q4. The historical decomposition indicates that the investment and household preference shocks account for the major part of output decline in the post-crisis period. The DSGE model with financial accelerator mechanism clearly shows that the traditional transmission mechanism of the monetary policy through its traditional instrument of the nominal interest rate was less effective. The results also appear to imply that the co-ordination problem between the monetary and financial sectors has failed to provide prudential supervision and regulation to monitor the movement of shocks in the credit channel of the MTM. This has been one of the major policy mistakes that led to a weak safeguarding mechanism in the run up to the GFC. Although the monetary policy shock in the aftermath of the crisis seems to have contributed to the surge in output from end of 2012 onwards, it becomes a less relevant source of output fluctuation during the crisis (see Figure 6.23 and 6.24). The estimation of the DSGE model also points out that the Spread shock plays an important role in the business cycle fluctuation. One of the most interesting outcomes of the HVD is the direction of the Spread shock that has sharply reversed its course in the post-global financial crisis. It swings from having a significantly expansionary effect on output and investment (from 2002 to 2006) to having a negative impact, especially on investment spending after the GFC (see Figures 6.23 to 6.26). Additionally, the results in both cases reveal the link between the Spread shock and the real economy that is operating through the investment channel.

The historical decomposition of investment shocks reported in Figure 6.25 and Figure 6.26 confirms that the rise of investment from 2002 to 2006 and the sharp contraction in 2007/08 have, for the most part, caused by the Spread shock. The Spread shock, shown in Figure 6.23, 6.24, and 6.28 are suitable to account for the macroeconomic dynamics before and after the crisis. Similar conclusions are also reached by Merola (2015), Gerali et al. (2010), and Gelain (2010) in a larger-scale model with explicit banking sector. Although the SW models augmented with a financial accelerator mechanism and remains to be a medium-scale model without explicitly including the banking sector, it is able to yield results strikingly similar to those obtained in large-scale DSGE models.

The results of the DSGE model estimated based on the Bayesian likelihood approach also support the precept that financial crisis and recessions could go hand in hand with credit tightening. Spread shock, as also shown in this research, behaves as a close substitute of the financial shocks in the credit sector. To substantiate this intuition, Figure 6.3 and 6.4 show the presence of strong correlation between the Spread shock and the Financial Condition Index (FCI). The movement of the indices show a tightening of financial conditions in the UK starting from the second half of 2003 to 2006 with a relative lax then after. The central message from these FCIs is that the UK financial conditions have shown relative ‘laid-back’ among the major economies since the global financial crisis (see Figure 6.3). The peak in the Spread shock is associated with the break-out of the financial crisis and deterioration of financial conditions (Figure 6.28). The correlation between the Spread shock and financial conditions provides additional support to the insight that the Spread shocks, rising from the cost of loan, constrains firms' demand for investment and behaves similarly to financial type shocks in DSGE models with the banking sector.

6.8 Credit Policy

The NK DSGE model is estimated with and without the FA mechanism. It also includes conventional monetary policy such as the feedback parameter with the assumption that the Bank of England's implementation both conventional and unconventional monetary policy, i.e. the Taylor rule and the credit policy in the form of direct lending to financial institutions. Although the parameters are not directly represented as a credit policy, the response of output, investment and consumption to the External Finance Premium shock is a good proxy to assume the credit policy. In a provision of good profit, EFP is likely to reduce. On the contrary, EFP increases when enough credit is not available.

Banks collect credit from households and make loans to non-financial firms. This necessitates that in the presence of sufficient deposit level, a bank can lend frictionlessly to nonfinancial firms against their future profit. Hence, firms offer to banks a perfect state contingent security. The banks' activity can be summarised in two phases. In the *first* phase, banks raise deposits and equity from the households. In the *second* phase, banks use the deposits to make loans to firms. From the firms' side, EFP is a proxy for the wedge between the cost of generating money internally and externally. The level of loans issued to entrepreneurs' depends on the level of the deposits and the net worth of NW_t^B of the intermediary. This implies a banking sector's balance sheet of the form:

$$L_t = NW_t^B + D_t \tag{6.53}$$

where L_t is the level of the loan, D_t is the level of deposit and NW_t^B is banks net worth. The net worth of the bank accumulates according to:

$$NW_t^B = R_{l,t}\, L_{t-1} - R_t D_{t-1} \tag{6.54}$$

$$NW_t^B = \left(R_{l,t} - R_t\right) L_{t-1} + R_t NW_{t-1}^B \tag{6.55}$$

where R_t is banks' return on lending. The above equation states that it is profitable for the bank to accumulate assets until they remain active. Therefore, the banker's objective is to maximise expected discounted terminal wealth:

$$V_t^B = E_t \sum_{i=0}^{\infty} (1-\theta^B)\theta_i^B \Lambda_{t,t+i} NW_{t+1+i}^B \tag{6.56}$$

where $\Lambda_{t,t+i} = \beta^i \frac{MU_{t+i}^C / P_{t+i}}{MU_t^C / P_t}$ is the stochastic discount factor, subject to an incentive constraint for lenders (households) to be willing to supply funds to the banker and θ is the survival rate, the probability of remaining in business the next period. Therefore, the term $(1-\theta)\theta^{i-1}$ represents the probability for a bank to exist at the i^{th} period. The survival rate in this study is represented by the leverage ratio (see Table 6.7 and 6.8). As shown above, the response in the leverage ratio (also known as survival rate) is lower in both pre and post-crisis period than the assumed *a priori*. The survival rate is much lower than the assumed *a priori* in the full data sample. This indicates firms' capital shortage during the crisis period. The close proximity of the posterior for the survival rate to the prior implies a steady-state leverage ratio of about 10 which is a reasonable rate of FIs in the UK (see Figure 6.3 and 6.4; Table 6.7 and 6.8).

To improve liquidity provision, the central bank might offset the contraction (Figure 6.14 and 6.15) with the non-standard measure. Figure 6.15 shows the response of output, investment and consumption to the Spread shock. Although it is unlikely for the central bank to increase interest rate in a period of financial crisis, it injects credit to offset the recession. This intervention by central banks makes the crisis less severe. In the case of net worth shock[146], the contraction of output is lower in the presence of unconventional monetary policy, but it is slightly more persistent. Central bank intermediation reduces inflation and the contraction of lending.

Spread shock is significantly reduced when unconventional monetary policy is at work. Given the financial accelerator mechanism explained in the previous section, the moderate rise in Spread implies a lower contraction in lending. The highest Spread shock persisted from the early 2008 to the end of 2009, and then becomes moderate. However, it remains to be a significant factor to impact investment and output. The lower contraction in lending as of 2009 was due to unconventional monetary action. Credit policy is essential not only in terms of contraction of output, but also in terms of inflation, lending, and Spread. Particularly, the intervention by central banks is significantly important to reduce the tightening of lending. These results might be particular interest because in the SW model, the response to the Spread shock captures, to some extent, the dynamics of the sub-prime crisis. There is also some evidence that the intervention by the central bank aimed at reducing the Spread is likely to weaken the financial accelerator mechanism.

[146] To warrant that entrepreneurs' net worth will never be sufficient to fully finance the new capital acquisition. Entrepreneurs have a limited life span and the probability that entrepreneurs will survive until next period is ν. The entrepreneur's net worth is defined as:

$$\frac{1}{\nu f} n_{t+1} = (lev) f_t - \omega(lev-1)(p_{t-1}^k + k_t) - (lev-1)(r_{t-1} - \pi_t) + [\omega(lev-1) + 1] n_t$$

The magnitude of the EFP is positively correlated to leverage conditions of entrepreneurial BSs. The higher the size of the external premium, the higher is the leverage condition of entrepreneurial BSs. The presence of an EFP magnifies the effect of adverse shocks, as it raises the cost of borrowing and further worsens BS conditions. It is also important to note that high banks' net worth is directly related to lower EFP as banks' reduce cost of lending. On the other hand, lower net worth is related to higher EFP. To minimise risk of default in lending, banks' protect themselves by increasing cost of lending, hence high EFP (BGG, 1999).

6.9 Conclusions

The New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model is estimated using a Bayesian approach based on Smets and Wouters (2003, 2005, and 2007) model, augmented with the presence and absence of FA mechanism for the UK from 1955Q1 to 2014Q4. The study extended the model with eight types of structural shocks selected based on SW and estimated parameters on the UK data using the B-DSGE approach. The results with and without the financial accelerator mechanism are compared to assess the performance of the two DSGE models. The study assessed the fit of the model based on the Bayes Factor Decision Rule Criteria, Laplace Approximation and Harmonic Means. The tests confirmed that the DSGE model with the FA mechanism performed better than the one without the FAM. The two DSGE models are estimated based on Bayesian likelihood approach for two sample periods. The outcomes of the two DSGE models provide greater understanding of the role of financial frictions and its interaction with the rest of the economy.

The theme of this Chapter has been to study the role of financial frictions in the MTM and identify the influential shocks that contribute to output, price and other macroeconomic shocks as seen through the lens of the Bayesian DSGE model. The assessment of the fit of the model showed that the DSGE model with FAM is quite satisfactory with a close match to the relative standard deviations. The data strongly favoured the model with financial frictions as compared to the one without nominal and real financial frictions. The evaluation of the fit of the model showed that the B-DSGE model without the FAM poorly matches the dynamics of the UK data. The estimation process and the results highlighted that external finance premium (EFP) is driven mainly by four shocks from the supply side: *investment, government spending, price mark-up, labour supply shocks*, and to a lesser extent *monetary policy shocks* from the demand side. The four shocks have different level of impact up on the EFP. Considering all the shocks, *productivity shocks, labour supply shocks, government spending shocks, investment shocks, and real wage shocks* led to pro-cyclical premium, while *Spread, preference and monetary shocks* generate a counter-cyclical response.

The results also provided an insight into the role of financial factors for business cycle fluctuations in the UK economy. Based on the estimation of the Bayesian DSGE model with financial frictions, the first part of the results implied that the recent global financial crisis has enhanced the financial accelerator as a mechanism of propagation and amplification of business cycles in developed economy such as the U.S. and the UK. The study also highlighted that the Spread shocks have become more relevant during the crisis. There is a striking similarity with the U.S. case reported in SW (2007), and Merola (2015) that the direction of the Spread shock has sharply overturned its course at the end of 2007. These occurrences have a significantly expansionary effect on output during the period from 2002 to 2006 and then accounted for the economic slowdown, which starts at the end of 2007, and beginning of 2008. The Spread shock generated by the model shows a strong correlation with measures of financial conditions (see Figure 6.28). This supports the intuition that the Spread shock, by raising the cost of loan, constrains firms' demand for investment and behaves similarly to financial-type shocks in models with an explicit banking sector. The *Calvo* adjustment and the degree of indexation results indicated that there is high degree of stickiness in the period of financial crisis. In terms of nominal rigidities, the wage and price *Calvo* adjustments confirmed that price stickiness is more important than wage stickiness, both before and after the financial crisis.

Taken as a whole, the historical development in financial market that led to the episodes of the economic expansion in 2002 and the slowdown in 2007/08 are suitably captured by the model with financial accelerator mechanism. In shaping the business cycle and in particular, the intensity of recessions can be explained by the concomitance of the peak in the external finance premium and the deepening of the recession. This supports the argument that enterprises' balance sheets and financial factors have an important role to play. This research proxy the banking sector by the provision of loan to the non-financial private sector. Future research may address this issue by specifying two models concurrently – one with only Spread and the other with Spread and lending components. The Spread parameter, in this study, acted as a close proxy of the EFP and showed that it mimics the DSGE models that incorporates a defined banking sector. This is the first study of its kind that estimates a Bayesian DSGE model for the UK based on full sample period and a period that represents the financial crisis.

The credit policy with respect to the shock to output, inflation and investment showed persistence during the crisis period but the contraction reduced due to the intervention by the policymakers in the form of credit provision, which resulted in significant moderation of the contraction. The study confirmed that the policymakers set the short-term nominal interest rate according to a simple Taylor-type reaction function (as shown in Chapter 2). Given the changes in the UK monetary transmission mechanism (as shown in Chapter 3) and the number of regime shifts and structural breaks (as shown in Chapter 4) and also the prominence of the credit supply shocks (shown in Chapter 5), relying on a specific monetary policy reaction function of a conventional type has found to be futile. The results also confirmed that financial stress is a medium and long-run phenomena but investment and monetary policy shocks are short-term forces. More importantly, the study determined the need for Prudential Financial regulation as an integral part of the monetary policy rules with the aim to stabilise not only output and price but also the financial sector. For economies with high GDP share of the financial sector, such as the UK, it is important to integrate a Prudential

Financial regulation in the monetary policy decision-making process. The UK financial sector accounts for 10% of GDP, which is the highest of all G7 economies. The second highest was Canada at 6.7%, and the lowest was Germany at 3.9% (BoE, 2015). Despite a number of warnings, the UK financial sector grew rapidly between 2006 and 2008. This fast growth and deepening financial institutions led to economic and financial instability due to increased public debt. This may encourage (as also stated in the OECD report) greater risk taking and high leverage, if poorly regulated and unsupervised. Therefore, the UK monetary authority should take actions to limit the growing financial sector by implementing austerity measures in the sector. Having a growing financial sector deepens not only personal and housing debt, but also business debt that hinders investment and ultimately leads to low output and employment.

CHAPTER 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Introduction

The recent global financial crisis revealed several failings in both monetary and financial regulations. Contrary to what was believed by central banks and policy research, evidences show that price stability is not a sufficient condition for financial stability. Hence, micro-prudential regulation alone becomes insufficient to ensure the financial stability objective. The study employed Generalised Methods of Moments (GMM), Vector Autoregression (VAR), Vector Error Correction (VEC), the ZA & BP structural breaks DPA, Structural Vector Autoregression (SVAR), Bayesian VAR and the financial accelerator NK Dynamic Stochastic General Equilibrium (BVAR-DSGE) models. Using the theoretical and empirical models, the study investigated the UK monetary policy reaction functions, the role of structural changes, the monetary transmission mechanism, the role of aggregate demand and supply shocks and the financial frictions in the pre and post-crisis periods.

Since the highly innovative and fundamental contributions made by Kydland and Prescott (KP) to the macroeconomic research on the design of economic policy and the driving forces behind business cycles, macroeconomic research develops new approaches stemming from this innovative revolution. Their work has not only transformed economic research, but also profoundly influenced the practice of economic policy in general and monetary policy in particular. The noble contributions they have made set into two closely related areas of macroeconomic research. The *first* concerns the design of macroeconomic policy that uncovers inherent imperfections known as "credibility problems" that focused on the ability of governments to implement desirable economic policies. *Second,* they demonstrated how variations in technological development and the main source of long-run economic growth could lead to short-run fluctuations. This noble revolution that led KP to a *Nobel Prize* award offered a new paradigm in macroeconomic modelling. Their contributions have been a ground breaking achievement that transformed the understanding of macroeconomic and monetary policy framework from the 1970s to the culmination of the "Great Moderation" period.

From the mid-1930s to the mid-1970s, Keynesian view of '*aggregate demand*' has been accepted as a driving force of variation in output and employment which was followed by KP's advocacy of the variations in technological development in the post-1970s as the main source of long-run economic growth that leads to short-run fluctuations. Although these ground breaking theories and practices change the view and the understanding of macroeconomics, the early Keynesians, New Keynesians and KP have failed to account for the role of financial market frictions and the permanent macroeconomic shocks. This endeavour and the level of acknowledgement conveyed into practice since the 2007/8. Consequently, the recent financial crisis have brought a shift in paradigm and opened the door to a new debate. In the current search for new knowledge and understanding, embarking on a research of this kind provides not only some answers but also contributes to the knowledge that macroeconomists, financial practitioners and policymakers are still searching for. The attempt made in this research is to provide at least some convincing answers to the complex questions raised in the aftermath of the crisis and to recommend further research areas.

The financial crisis has stimulated various theoretical and empirical studies on the propagation mechanism underpinning business cycle. In the presence of weak and fragile banks, addressing this issue in the context of the UK economy is essential. Although, a growing theoretical and empirical literature have shown the relevance of financial frictions, the recent GFC provides further impetus to revisit the macroeconomic research approaches and assumptions made. It is important to investigate and examine both the build-up of risks during the "Great Moderation" period as well as the functioning of monetary policy in the pre and post-crisis periods. One of the most important lessons of the recent financial crisis is that financial and monetary stability cannot be targeted independent of each other and that MPTM very much depend not only on MP but also on the state of the banking system[147].

The precise workings of monetary policy, its impact and the role of financial frictions in the TM are becoming obvious interests to policymakers and academia. Yet, despite considerable research on the impact of monetary policy, there are still considerable disagreements about the impacts and the mechanisms through which monetary policy impulses and other macroeconomic shocks transmit to the real economy. The need to unlock these key issues has been intensified since the GFC. All research conducted in the post-crisis period have been attempting to contribute to the new and modern macroeconomic paradigm which this research has played a part. To assess the impact of monetary policy on the real economy, a range of empirical estimates have emerged in the literature and the effects on price and output of a 1 percentage point innovation to the policy rate tend to be 0.5% and 1% respectively. However, a notable issue in the empirical investigation is that the vast assumptions are made with regards to the functioning of the TM. The failure to account for the financial intermediaries and the propagation and accelerator mechanism of the credit sector call for a complete review of not only the mechanism of the transmission system but also how shocks pass through the channels before hitting the target of the real economy.

[147] A key statement that led to the motivation of this research.

Furthermore, previous macroeconomic and financial studies overlooked the presence of structural breaks in the monetary and financial series, which are known to reduce the power of the non-stationarity test algorithms. Disregarding the impact of structural changes in the macroeconomic and financial time series, potentially leads to model misspecifications when accounting all breaks as significant disturbances rather than identifying persistent shocks from the transitory ones. Taking all these research gaps and motivations into account, the research achieved the following objectives. *First*, it investigated the UK monetary policy rule reaction functions within the existing theoretical and empirical framework using a GMM model and determined if monetary policy rule can be different in pre-IT, post-IT, in a financial crisis and recession periods. *Second*, it examined the dynamics of the channels of MTM before and after the GFC and assessed whether the 2007/8 financial crisis has changed the course of the channels in the MPTM. Specifically, whether the role played by each channel in the transmission mechanism has weakened or strengthened. *Third*, it investigated the role of shocks in the UK economy using VAR, VEC and SVAR models and addressed if the issue of credit shocks has a plausible macroeconomic effects. *Fourth*, it addressed the issue of structural changes in relation to the UK economy based on the assumption that multiple structural breaks existed. Explicitly, the study examined the robustness of the Augmented Dickey-Fuller (ADF) unit root test to the presence of endogenously determined one to many structural breaks. *Fifth*, it explored whether credit supply shocks behave more like aggregate demand or aggregate supply shock and determined how monetary policy and credit supply shocks differ during the pre/post-IT and pre/post-crisis policy regimes. Furthermore, the role of balance sheet and bank lending channels are investigated to address their role in the credit market. *Finally, (sixth),* it determined the role and contribution of financial market frictions in the transmission mechanism using a Bayesian New Keynesian DSGE models.

7.2 Major Findings

The review work of the theoretical and empirical analyses covered a time horizon ranging from early 1950s to late 2014. Besides, much of the existing monetary policy empirical studies focus on the United States but there are far fewer investigations for other countries such as the United Kingdom. This study attempted to fill these gaps and provided wide-ranging research information, conveyed new macroeconomic knowledge and understanding to academia and policymakers. It also discovered and quantified the actual role of credit market in the UK economy with and without financial market frictions. Furthermore, the study provides a new benchmark for future macroeconomic research. The rigorous theoretical and empirical reviews identified five MPRFs and these RFs are empirically investigated for three policy regimes. The five monetary policy reaction functions are the *Taylor rule*, the *McCallum rule* and the hybrid rules such as *Taylor-McCallum* rule, *McCallum-Hull-Mankiw* rule and *McCallum-Dueker-Fischer* rule. Ten forward and backward-looking RFs are estimated using a GMM and OLS simulations. The empirical findings confirmed that the interest rate, monetary base and the implicit monetary target setting behaviour of MP makers have been pragmatic in the UK monetary environment from 1962 to 2014. There is clear evidence that the dominant time horizon in the post-IT period to the run up to the 2007 GFC, the UK monetary policy framework has been dominated by inflation targeting policy of the *Taylor rule* type. The monetary base and the implicit monetary and exchange rate targets have been the main features of the UK monetary policy during the pre-IT policy regime. What is unfolding is the complete disregard of the role of the financial sector in the monetary policy making process during the "Great Moderation" and more importantly in the run-up to and the onset of the GFC. The post-IT period exhibits a combination of conventional and unconventional monetary policy rather than a specific monetary policy rule. The empirical findings of the post-crisis period are particularly important to investigate the role of financial and macroeconomic shocks.

In the majority of the post-1992 period, the UK monetary policy was found to be an interest rate based monetary policy controlled by the CB. Previous studies focused on two types of monetary policy rules, namely, Taylor and McCallum rules. One of the novelties of this research is that it attempted to incorporate a further three monetary policy rules and investigated the relevance of the monetary policy reaction functions by simulating the policymakers' behaviour in the form of backward and forward-looking reaction functions. The information obtained from the investigation of the policy reaction functions is incorporated in the structure of the DSGE model to assess the role of financial market frictions. Briefly, *Chapter 2* highlighted the UK interest rate setting behaviour that can be described by a mix of various MP rules.

The study provided a rigorous quantitative assessment of the changes in the MTM. Understanding the TM through which the channels operate provides important feedback to monetary authority and policymakers to achieve policy objectives. Policymakers who understand the way the mechanism works are able to identify the right policy. The work presented in *Chapter 3* is motivated by the need to understand the MP transmission mechanism in the context of the new Macroeconomic paradigm. Reviewing the mechanism through which the monetary policy shocks pass through is an important step to understanding the policy making process. *Chapter 3* discussed the Keynesian and Monetarists views of the transmission mechanism. The Keynesians advocate the operation of the mechanism through the interest rates but monetarists believe that in the long-run money growth affects only nominal variables. Real variables, according to monetarists, are not affected by money growth in the long-run and instead are determined by factors such as labour mobility and the existence of minimum wages and technology progress. On the contrary, Keynesians believe that the changes in monetary growth affect not only the nominal variables but also the real variables. When there are unemployed resources in the economy, according to the Keynesians view, increased money growth will usually be associated with an increase in output and a fall in unemployment. Hence, output is demand driven and that unemployment is due to insufficient demand. However, this view is now being challenged by the post-crisis macroeconomic understanding.

Although there exists a vast body of knowledge on the MTM, there is less consensus on the mechanism of the channels in the interim stages of the process. After discussing the Neoclassical and Non-Neoclassical MT channels and highlighting the drawbacks of the New Keynesian models, the study employed Bayesian VAR and DSGE models to evaluate the impact of policy decisions and optimal policy options. The micro-founded theoretical model has proved that the credit channel propagate the monetary policy shock and is found to be the main transmission channel of the UK MTM. The Bayesian VAR approach is able to show the differences in the responses of price and output to monetary policy shocks. However, it is difficult to interpret the impulse responses and FEVDs estimated from the Choleski and structural approaches. The estimation of a more structured and micro-founded model can indicate if there have been offsetting forces that resulted in some changes in the MTM as elicited from the VAR or there could be a possibility that there have been no changes at all.

The estimated closed economy Bayesian DSGE model reveals that in the post-1992, the nominal rigidities become weaker and the coefficients of inflation in the monetary policy rule increased while output declined. The changes in the private sector parameters (non-target variables) are responsible for the stronger reaction of output and inflation to a monetary policy shock and the milder reaction of prices after a cost-push shock in the post-IT periods, while the modification of the monetary policy conduct influenced the responses of both output and prices to a technology shock. The results confirmed that the drop in macroeconomic volatility observed in the pre and post-crisis periods was only marginally attributable to a more favourable set of shocks in the IT sample. The drop in inflation was due mostly to changes in the monetary policy rule parameters while that on output was due to changes in the private sector behaviour.

Motivated by the BP recent studies who argued that the evidence of a unit root in many economic series might be attributed to a multiple structural breaks of macroeconomic and financial time series in a long time horizon, *Chapter 4* investigated the structural changes and the macroeconomic innovations. It highlighted - *first,* the implication of the low power non-stationarity test on MEFT series based on the ZA's approach; *second,* the long-run time-series properties of macroeconomic variables using the stationary test with MSB. This is the first and new approach to examine non-stationarity of the UK MEFT series using endogenously determined one-to-many multiple SBs based on ZA and BP dynamic programming algorithm (DPA). *Third*, the MEFT variable(s) with permanent significant structural breaks are categorised homogeneously. The Chapter begins by examining the MEFT series assuming consistency in the conventional ADF tests, followed by unknown one-time and endogenously determined MSBs over the period of 1960 to 2014. The study examined and characterised the property of the MEFT series. Unlike those from traditional ADF UR tests without structural breaks, the results corroborate that all MEFT series should not be characterised by a single nomenclature, i.e. nonstationary/stationary. When a single and multiple structural breaks are incorporated, the evidence favours that some of the MEFT series show constant or/and trend break stationarity. Based on the occurrence of structural breaks, the recent GFC, the oil price shock, CBI and government slow and abrupt policy reactions caused persistent shocks that have undoubtedly changed the course of the economy

Shocks that stay longer in the time horizon are likely to trigger significant impacts on the real economy and are known to be persistent. It is important to note that countering for transitory shocks is considered as unnecessary. This is because transitory shocks are expected to revert back to the equilibrium line or to the state where it was before the deviations. The study characterised the MEFT series and found that most of the financial sector variables have more persistent shocks than the macroeconomic and monetary variables. Considering the number of significant breaks found in the empirical analysis, one can conclude that the UK MEFT sectors are characterised by four major structural shifts or non-revertible breaks. *first break* is related to the 1970s oil price crash; the *second break* is related to the 1980s and early 2000s recession; the *third break* is related to the early 2000s Dot-Com bubble that created a massive fall in equity markets due to over speculation of technology shocks, and the *fourth break* is associated with the consequences of the 1997 Asian crisis. The fourth break is also related to the recent GFC that amounted over 7% decline of manufacturing output and 8.1% rise of unemployment, which triggered the 2011 and 2012 double dip recessions.

The main contributions of *Chapter 4* to the literature are threefold. *First,* the statistical properties of the methods for detecting and estimating one, two and multiple SBs are analysed when both regressors and errors are allowed to exhibit long range dependency. *Second,* valid algorithm methods of approximating the number of breaks in the MEFT series based on the limiting distribution of relevant estimators are developed under possible long range dependency. The novelty in relation to the SB analysis is the fact that it combined the ZA and BP SB DPA to the same data series and determined structural changes in the monetary, financial and macroeconomic sectors. *Third,* it discovered that the financial sector exhibits high concentration of persistent structural shocks that lasted longer than it was perceived. Having identified the financial sector with the most number of persistent breaks, the study estimated 16 Structural VAR models that accounted for the persistent SBs. *Chapter 5* examined the endogenous relationships between credit and other key macroeconomic variables, particularly, the monetary policy of the UK economy. The IRFs and FEVDs indicated that, at short time horizon, shocks to the interest rate, the exchange rate, and past shocks to credit are found to be more important to explain movements in the credit channel. Over longer time horizons, shocks to output, inflation and commodity prices played a greater role. For the domestic variables in general, the exogenous international variables are responsible for a large proportion of forecast errors in the long-run. The model revealed that a shock to the interest rate, increasing it by 20 months[148], resulted in the level of credit being almost half of a percentage point lower after 11 months (about a year). If monetary policy subsequently reacts in a manner consistent with its past behaviour, credit could have continued to decline for about 50 months (about four years) by almost 0.88% lower than the counterfactual level. The timing of the response of credit shock appeared to be similar to that of inflation. The response of output was more rapid that reached to a maximum response after about 5 months. The response of the other domestic variables accorded with the responses found elsewhere in the IRFs.

The IRFs also showed that prices and output move in somewhat opposite direction as a response to credit shocks. This implies that financial shocks appeared to be more like aggregate supply shocks so a positive aggregate supply shock will have permanent positive effects on output. A contraction in credit supply pushes down on output while moving inflation upwards. This is particularly highlighted in the robustness check of the IRFs identified based on sign restrictions. This could be due to an exchange rate effects on potential supply as financial services are one of the most important sources of exports for the UK economy. Evidences also show that the UK trade surplus

[148] Base points refer to the time measurement unit (months).

in insurance and financial services recorded nearly £60bn in 2013, which accounted for 3.5 percent of GDP. It is also pointed out that credit supply shocks are likely to have direct quantitative bearing over and above the impact on borrowing rates. This implies that more than the borrowing rates, credit supply shocks amplify the impact on lending through the cost of borrowing than the monetary policy shocks.

In the run-up to the financial crisis, credit supply shocks were more prominent to explain most of the sources of volatilities in the financial sector. The results confirmed that aggregate supply shocks are the most important source of disturbances than the aggregate demand shocks. Credit supply shocks impact output and prices in the same way as aggregate supply shocks. The intuition behind this is that the long-run effect of the monetary and credit shocks is likely to have forced credit supply shocks to contribute to the deviation of the risky rates from the riskless rates (also called Spread). This deviation is believed to be captured by the aggregate supply shocks in the economy. In the post-GFC period, more than a third of the fall of the UK output relative to the pre-crisis period could have been caused and explained by the credit supply shocks. The IRFs and FEVDs showed the range of impacts across the different identification schemes. The median and maximum oscillations of the specifications, which include quantity effects, would suggest that the most likely impact ranges between 2.5% to 5% of the 10% fall of the UK GDP relative to trend, depending on how much of the identified impact includes the response of monetary policy. The empirical results also suggested some avenues for further research to establish how these shocks transmit, accelerate and amplified in the MTM. It is also important to establish optimum monetary policy conduct based on the historical decomposition of the quantitative responses depend on agents' objective functions and constraints.

The study also investigated the presence of the credit channel in the form of *balance sheet* and *bank lending channels* based on the possible assumption of the short and long-run movements (cointegrations). To identify the presence of these conduits, the investigation estimated successive VAR and VEC models. The IRFs and FEVDs revealed that the UK credit channel works through both the balance sheet and the bank lending channels, which the bank lending channel is found to be the most prominent. This implies that both adverse economic conditions and contractionary monetary policy are likely to reduce not only the capacity of firms to borrow but also the supply of loan banks are able to provide. This confirmed that the identified models belong to the "credit view" rather than the "money view. The statement of the credit view that monetary tightening by the lender of last resort is able to reduce the supply of bank loans is satisfied for the UK. It also satisfied that the monetary induced decline in the supply of bank loans depresses aggregate spending due to the significance of the bank dependent borrowing. This was investigated based on how the movements in the monetary policy rate affect banks' lending using the MIX regression, Spread regression and Loan regression simulations within the VAR and VEC framework. The investigation has determined the two ways the credit channel can work in the UK financial sector. Having identified the credit supply shocks responsible for the majority of volatilities, the research has further investigated the role of financial market frictions in an estimated NK DSGE model using a Bayesian approach. The investigation established and contributed new understanding of how shocks spread in the transmission mechanism. The empirical investigation also determined the role played by financial market frictions in the run up to the financial crisis both in the financial market and in the real economy.

The theoretical and empirical evidence gathered in *Chapter* 6 indicated that the understanding surrounding the pass through mechanism of the monetary policy impulses are not conclusive. The existing literature uncovered the critical issue with respect to the degree and speed of the monetary policy impulses that amplified in the transmission mechanism and impact other rates faced by firms and households. The current literature is investigating the role of financial accelerator mechanism in a New Keynesian General Equilibrium model. However, there are few attempts made to determine the role of FF and quantify its impact on output and price. The study in this Chapter contributed to the existing literature by empirically exploring how the intermediate, endogenous and final variables behave in response to exogenous policy impulses in the presence and absence of the FA mechanism. The research stressed that financial intermediaries are not simply part of the propagation or amplification factors of the TM. In the post-crisis period, some studies presented DSGE models with financial frictions and credit policy calibrated for the US, Euro Area and the UK economies. Unlike the studies conducted in the pre-crisis period, the new approach incorporates financial intermediaries that face an agency problem and with endogenously constrained balance sheets. This shows that the financial frictions are directly originated in the financial sector.

With this background, the final Chapter examined the empirical property of the Smets and Wouters's DSGE model estimated for the UK data from the mid-1950s to late 2014. The fit of the model is satisfactory with a close match to the relative standard deviations. In the DSGE model, the study analysed the capability of the model to mimic the path of financial variables. It employed a Bayesian estimation procedure to estimate two DSGE models: one with a financial accelerator mechanism and the other without. This approach has become very popular both in academia and among central banks. The B-DSGE model employed four key sectors: households, businesses, the monetary policymakers and the financial sector.

To evaluate the model, the UK data on consumption, output, investment, total hours worked, real wages, the nominal interest rate, inflation and Spread are used with 18 shocks that includes the financial frictions. The study employed the large sample size in order to gather as much information as possible about the parameters, while recognising that there will be a trade-off against accuracy if, as is likely, their values change over time. The results showed that households become less willing to substitute consumption today for future consumption so their saving and consumption decision was less affected by changes in the real interest rate in the pre-crisis than the post-crisis period. There are also parameters that determine costliness to businesses preference to adjust the amount of labour and capital it employs in response to changes in the demand for its products, rather than changing the price that it charges. The investment adjustment cost for business in the UK remains more or less stable (7.40 to 7.30) in the pre-crisis period while it increases from 7.5 to 9.5 when the crisis period is included in the sample. This implies that the investment adjustment cost significantly increases during the crisis period than a non-crisis period.

As confirmed by the Laplace approximation, Harmonic mean and the Bayes factor, the data strongly favoured the DSGE model with financial frictions as compared with the models without nominal and real financial frictions. The estimation process and the results highlighted that External Financial Premium (EFP) is driven mainly by four shocks from the supply side: *investment*, *government spending*, *price mark-up*, and *labour supply shocks*, in order of importance. To a lesser extent *monetary policy shocks* from the demand side, impacts the EFP. Furthermore, the IRFs revealed that *productivity shocks*, *labour supply shocks*, *government spending shocks*, *investment* and *real wage shocks* lead to pro-cyclical premium, while *spread*, *preference* and *monetary policy shocks* generate a counter-cyclical reaction. The results also provided important insight into the role of financial factors for business cycle fluctuations in the UK economy. The outcome of the DSGE model with FFs implied that the recent GFC has enhanced the FA as a mechanism of propagation and amplification that spread shocks in the business cycles of developed economies such as the U.S. and the UK. The comparison of the DSGE models with and without the FAM provided enough evidence that the financial volatility has become more relevant during the crisis than the pre-crisis period. The striking similarity discovered with other studies on the U.S. data is that the direction of the reaction path of the Spread shock has sharply reversed its course at the end of 2007. These occurrences have substantial expansionary effect on output from 2002 to 2006, followed by the economic slowdown, which started at the end of 2007 and the beginning of 2008. The Spread shocks generated by the model[149] displayed a strong correlation with financial condition measures. This supports the intuition that the Spread shocks, by increasing the cost of loans, constrains firms' demand for investment and behaves similarly to financial-type shocks in models with an explicit banking sector.

[149] See Figure 6.28.

Taken as a whole, the historical development in financial markets that has led to the episodes of the economic expansion in 2002 and the slowdown in 2007/08, the high rate of growth of the financial sector from 2005/6 to the late 2009 are suitably captured by the DSGE model augmented by the FAM. The comparison between the model with and without the FAM also revealed that the integration of the FAM has improved the performance of the DSGE model. The impulses and reactions determined by the DSGE model with the FAM explained the rational behaviours of the various economic agents. In shaping the business cycle and, in particular, the intensity of recessions can be explained by the concomitance of the peak in the EFP and the deepening of the recession. This supports the argument that enterprises' balance sheets and financial factors have an important role to play. The credit policy with respect to the shock to output, inflation and investment showed persistence in the long time horizon during the crisis period but the contraction reduced due to the CB’s intervention. The study based on the Bayesian NK DSGE model also provided a quantitative assessment of the financial frictions on the UK business cycle and determined the role of financial channels in transmitting shocks from the financial market to the real economy. Furthermore, the results confirmed that a more aggressive monetary policy would have had little success in improving the response of the economy to the financial bubble, as the actions of the central bank would have remained limited by the use of a single instrument, the interest rate.

7.3 Policy Recommendations

It is impossible to conduct monetary policy without a complete understanding of how the economy works. Theoretical and econometric models are vital in this process. This study helps to understand not only the UK monetary policy, but also the role played by the financial market frictions. The issues in this research are simulated, estimated and analysed using not only the theoretical B-DSGE model but also through ZA and BP MSB dynamic programming algorithms, VAR, BVAR, VEC, SVAR and GMM approaches. In all approaches, the role of financial intermediaries and thus financial frictions is consistently highlighted and leads to the following six policy recommendations: (a) *Conduct monetary policy in both conventional rule based and unconventional manners:* the BoE independence paves the way to a better conduct of monetary policy and becomes more accountable for the decision of the monetary policy. However, the monetary policy fails to account for the extent of financial volatilities in the run-up to the financial crisis. Therefore, it is of paramount importance that the design of monetary policy should take into account the financial stability rather than a one-sided and rule-based traditional MP rule that accounts only for interest rate mechanism; (b) *Empirical analysis for a monetary policy should take into account structural shifts:* if the shifts in macroeconomic, financial and monetary series are not accounted, models could be misspecified and misinterpreted. Paying no attention to the presence of structural breaks potentially leads to a vastly different and erroneous conclusions and wrong policy recommendations. Any policy that seems to have relied upon accurate empirical forecasts without accurately accounting for structural changes could be misleading.

The MSB analysis with respect to the MEFT series implies that the appropriate specification of empirical models of macroeconomic phenomena should be in levels and must account for structural breaks; (c) *Monetary policy decision should take into account the credit supply shocks to play effective role in stabilising the economy:* the impact of the credit supply shocks on output cannot be completely offset by the response of the traditional monetary policy. Monetary policymakers should take into account not only the demand side but also the supply side of credits. Credit supply shocks have a larger impact on lending than monetary policy shocks. Most of the movements in the pre and post-crisis period appeared to be explained by the credit supply shocks. Credit supply shocks also happened to have permanent effect to cause a wedge between the risk free and risky lending rates; (d) *Credit supply shocks are aggregate supply shocks so monetary policy should react not only to monetary target shocks but also non-monetary policy shocks: m*onetary policy is tightened in response to positive non-monetary aggregate demand shocks and loosened in response to positive aggregate supply shocks. It is also important to *monitor the credit market.* Financial frictions contribute more to the decline of output than monetary policy shocks alone. The monetary policy authority, in cooperation with the financial regulation authority[150], should regulate and monitor the credit market. The contribution of the credit supply shocks need to be controlled before the shock negatively impacted the economy; *(e) Monetary policy shocks accounts for the financial market frictions to represent the rational behaviour of agents in the economy:* this entails that the financial sector policy in the form of prudent regulation is principally important to stabilise the economy. Spread shock is found to be the most important shock in the UK economy so the monetary and financial policies should take into account the role of financial frictions in the policy making process. A macroeconomic policy that fails to account for factors that causes financial frictions will addresses only part of the important issues; *(f) Austerity in the financial sector:* The share of the financial sector in the UK economy has been growing very fast. According to the OECD report, by 2009 the sector accounted for 10% of GDP, which is the highest of the G7 economies.

A rapidly growing financial sector is an indication of indebtedness as more and more people take credit to finance their housing needs, for example, in the form of mortgages. This potentially create an inflated housing bubble which contributes to the declining business investment, particularly, in the manufacturing sector. An economy which is not supported by a manufacturing sector is mostly at the verge of collapse when a financial sector crisis, or any link to it, arises. Further expansion in the financial sector is associated with slower long-term economic growth and greater economic inequality. An economy with a larger share of the financial sector pulls away more capital from other sectors and more and more professionals are likely to become bankers or involve in some financial sector investment. Based on the quantitative assessments and review of current literature, this research recommends reducing the share of the UK financial sector to 3% of GDP. This helps to reduce the potential and systemic risks and allows the manufacturing sector to grow and expand to account for major share of the real economy.

[150] Refers to Financial Conduct Authority and the Prudential Regulation Authority of the BoE.

7.4 Limitations and Future Research Directions

The research claims originality with respect to its link to the current research developments in the new (modern) macroeconomic epitomes and its novel contribution to existing knowledge. The conduct of monetary policy and the dynamics of the MTM are still under question due to its failure to capture the building-up of bubbles in the credit market. Persistence shocks that lead to structural changes are not well integrated in the macro theoretical and empirical analyses. There is a general assumption that all macroeconomic, financial and monetary shocks are important but it is essential to identify the transitory and persistent shocks in the MEF sectors and prioritise policy decisions. The current VAR model and the extension of it assume parameter consistency without accurately accounting for structural breaks. The highly controversial issue on how to introduce financial frictions in a DSGE model needs further investigation to account for both financial and non-financial frictions. Theoretical and empirical macroeconomic models have been silent on the issue of financial market frictions from the early 1900s to the run-up to the recent GFC. In the face of all these questions, new paradigm shifts and challenges, undertaking this vast area of research to convincingly provide some answers is a bold attempt in terms of the effort, academic excellence and the resources it has required.

Although research in the post-crisis period attempted to address the global systemic crisis of the "Great Moderation" capitalist system, static Neoclassical models are proved unsuitable. The recent global financial crisis highlighted the need for a new approach in line with the increasingly complex reality of a globalised and rapidly changing world. Therefore, in the context of dynamic modelling, this study recommends the following future research areas: *(a) A non-linear dynamic approach for MP rules reaction functions*- it is useful to attempt the monetary policy rules reaction function assuming non-linearity to capture the real and dynamic variable movements that leads to a better understanding of the MP reaction functions. Although, the linearity assumption is valid, the non-linearity approach may reduce the loss of information in the DGP; *(b) Accounting for financial and non-financial frictions separately*- as a future research, this study recommends to simulate a DSGE model augmented with the financial/corporate Spread, agents in the credit market and non-financial frictions that may arise due to households' unpredictable behaviour and the objective function of agents in the economy. This may help to separate the quantitative impulses of financial frictions and non-financial frictions on output, price and investment; *(c) Measuring the strength of monetary policy transmission channels in the presence of FAM:* although the role of credit and monetary policy channels is included in this research, no detailed attempt has been made to measure the strength of the other transmission channels due to the scope of this research. This is a possible extension for future research in the area of MPTM; *(d) Disentangling the role of the exchange rate* *channel*- the exchange rate channel shows a significant response to all monetary policy rule reaction functions. It is therefore, important to study the role and contribution of the exchange rate channel in a NK DSGE model in the presence and absence of the FAM; *(e) Taking into account cointegration*: the study employs VAR, SVAR and VEC models to study the credit channel. SVAR models are consistent with non-recursive structures and the attempts made in this model provides short-term restrictions. However, it is important to allow long-term restrictions and cointegration models with multiple instruments to permit interactions in both time horizons. This could also be a further extension to model the UK monetary policy using VEC model, assuming long-term non-neutrality; (*f) Marginal efficiency of investment shocks*: this research addresses the role of financial frictions and found that the *Spread* shock has taken over the role of investment shocks during the period of financial crisis. This is a remarkable outcome but requires further empirical investigation to disentangle the marginal efficiency of investment shocks in the pre and post-crisis period. This issue is partially addressed but it is essential to investigate its significance using a DSGE model through IRFs, Variance and Historical Decompositions and finally *(g) extend this research for emerging markets:* research in these areas are highly intensified in advanced economies in the post-crisis period. However, the attention given to the emerging markets is very limited. It is highly recommended to assess the role of monetary policy, the way the financial system works, the level of risk involved in the financial sector, how their central banks function in controlling credit volatilities and the integration of micro and macro prudential policies in the real economies of the emerging markets.

Bibliography

Abbassi, P. and T. Linzert, (2012). The Effectiveness of Monetary Policy in Steering Money Market Rates during the Financial Crisis, Journal of Macroeconomics, 34: 945–954.

Abildgren, K. (2012). Business Cycles and Shocks to Financial Stability: Empirical Evidence from a New Set of Danish Quarterly National Accounts 1948-2010, Scandinavian Economic History Review, 60: 50-78.

Adolfson, M., Laséen, S., Lindé, J. and M. Villani, (2007). Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-through, Journal of International Economics, 72: 481-511.

Afandi, A. (2005). Monetary Policy Transmission Mechanism and Structural Breaks in Indonesia. University of Wollongong, PhD thesis, School of Economics and Information Systems, University of Wollongong, unpublished.

Ahmad, A.H. and O.B. Aworinde, (2016). The Role of Structural Breaks, Nonlinearity and Asymmetric Adjustments in African Bilateral Real Exchange Rate. International Review of Economics and Finance, 45:144-159.

Aleem, A. (2010). Transmission Mechanism of Monetary Policy in India, Journal of Asian Economics, 21: 186–197.

Alesina, A. (1988). Macroeconomics and Politics. In NBER Macroeconomics Annual, Ed. by Stanley Fischer: Cambridge, Mass. MIT Press: 17-52.

Alesina, A. and L. Summers, (1993). Central Bank Independence and Macroeconomic Performance: Some Comparative Evidence, Journal of Money, Credit, and Banking, 25: 151-162.

Ali, S.Z. and S. Anwar, (2013). Inflation and Interest Rates in the Presence of a Cost Channel, Wealth Effect and Agent Heterogeneity, Economic Modelling, 31: 286-296.

Amisano, G. and C. Giannini, (1997). Topics in Structural VAR Econometrics, 2nd Edition, Springer.

An, S. and F. Schorfheide, (2006). Bayesian Analysis of DSGE Models, Econometric Reviews, 26: 113–172.

Anderson, S., Cavanagh, J. and J. Redman, (2008). Skewed Priorities: How the Bailout Dwarfs other Global Crisis Spending. Washington, DC: Institute for Policy Studies.

Ando, A. and F. Modigliani, (1963). The Life Cycle Hypothesis of Saving: Aggregate Implications and Tests. American Economic Review, 53: 55-84.

Angeloni, I. and E. Faia, (2009). A Tale of Two Policies: Prudential Regulation and Monetary Policy with Fragile Banks. Kiel Working Papers, No. 1569, Kiel Institute for the World Economy.

Angelini P., Enria, A., Neri, S., Panetta, F. and M. Quagliariello, (2010). Pro-cyclicality of Capital Regulation: Is it a problem? How to fix it?' WP 74, Bank of Italy, Economic Research and International Relations Area.

Ang, A. and G. Bekaert, (2002). Regime Switches in Interest Rates, Journal of Business and Economic Statistics, 20: 163-182.

Angeloni, I., Kashyap, A.K. and B. Mojon, (2003). Monetary Policy Transmission in the Euro Area. Cambridge: Cambridge University Press.

Aoki, K., Proudman, J. and G. Vlieghe, (2004). House Prices, Consumption, and Monetary Policy: A Financial Accelerator Approach. Journal of Financial Intermediation, 13: 414–435.

Artis, M.J. and M.K. Lewis, (1984). How Unstable is the Demand for Money in the United Kingdom? Economica, 51: 473-486.

Arend, M. (2010). Financial Shocks, Financial Frictions and Financial Intermediaries in DSGE Models: Comments on the Recent Literature. MPRA Paper No. 22957: 2-12.

Aristei, D., and M. Gallo, (2014). Interest Rate Pass-Through in the Euro Area During the Financial Crisis: A Multivariate Regime-Switching Approach, Journal of Policy Modelling, 36: 273-295.

Arnone, M., Laurens, B.J. and J.F. Segalotto, (2006). The Measurements of Central Bank Autonomy: Survey of Models, Indicators, and Empirical Evidence. IMF Working Paper, No. 06/227. Washington, D.C.

Arnone, M. and D. Romelli, (2013). Dynamic Central Bank Independence Indices and Inflation Rate: A New Empirical Exploration. Journal of Financial Stability, 3: 385-395.

Aslam, A. and E. Santoro, (2008). Bank Lending, Housing and Spreads. Discussion Papers 08-27, University of Copenhagen. Department of Economics.

Atta-Mensah, J. and A. Dib, (2008). Bank Lending, Credit Shocks, and the Transmission of Canadian Monetary Policy. International Review of Economics and Finance, 17:159-176.

Auel, M.C., and H.F. De Mendonca, (2011). Macroeconomic Relevance of Credit Channels: Evidence from an Emerging Economy under Inflation Targeting, Economic Modelling, 28: 965–979.

Aysun, A.U. and R. Hepp, (2011). Securitization and the Balance Sheet Channel of Monetary Transmission, Journal of Banking and Finance, 35: 2111–2122.

Aysun, A.U. and R. Hepp, (2013). Identifying the Balance Sheet and the Lending Channels of Monetary Transmission: A Loan-Level Analysis, Journal of Banking & Finance, 37: 2812–2822.

Bacchiocchi, E. and L. Fanelli, (2015). Identification in Structural Vector Autoregressive Models with Structural Changes, with an Application to U.S. Monetary Policy, Oxford Bulletin of Economics and Statistic, 77: 761–779.

Bade, R. and M. Parkin, (1982). Central Bank Laws and Monetary Policy. Department of economics, University of Western Ontario, London, Ontario, Canada, N6A 5C2.

Badarau, C. and G. Levieuge, (2011). Assessing the Effects of Financial Heterogeneity in a Monetary Union: A DSGE Approach, Economic Modelling, 28: 2451-2461.

Baele, L., Bekaert, G., Cho, S., Inghelbrecht, K. and A. Moreno, (2012). Macroeconomic Regimes. Journal of Monetary Economics, 70: 51 – 71.

Bai, J. (1997). Estimation Of A Change Point In Multiple Regression Models, The Review of Economics and Statistics, MIT Press, 79: 551-563.

Bai, J. and P. Perron, (1998). Estimating and Testing Linear Models with Multiple Structural Changes. Econometrica, 66: 47–78.

Bai, J. and P. Perron, (2003a). Computation and Analysis of Multiple Structural Change Models, Journal of Applied Econometrics, 18: 1-22.

Bai, J. and P. Perron, (2003b). Critical Values for Multiple Structural Changes Tests, Econometrics Journal, 6: 72-78.

Bai, J. and P. Perron, (2006). Multiple Structural Change Models: a Simulation Analysis. Econometric theory and practice: Frontiers of analysis and applied research: 212-237.

Bailliu, J., Meh, C. and Y. Zhang, (2015). Macroprudential Rules and Monetary Policy when Financial Frictions Matter, Economic Modelling, 50: 148 – 161.

Bain, K. and P. Howells, (2009). Monetary Economics: Policy and its Theoretical Basis, Palgrave Macmillan, Palgrave Macmillan; 2nd Edition, Great Britain.

Ball, L. (1993). The Dynamics of High Inflation, NBER Working Paper, N0. 4578.

Ball, L. and N. Sheridan, (2005). Does Inflation Targeting Matter? In The Inflation Targeting Debate, NBER Studies in Business Cycles, Vol. 32, ed. Ben S. Bernanke and Michael Woodford. Chicago: University of Chicago Press.

Ball, L. (2014). Long-term Damage from the Great Recession in OECD countries, European Journal of Economics and Economic Policies: Intervention, Edward Elgar, 11: 149-160.

Ball, L. (2010). The Performance of Alternative Monetary Regimes, Handbook of Monetary Economics, In: Benjamin M. Friedman and Michael Woodford (Eds.), Handbook of Monetary Economics, 3: 1303-1343.

Baum, C.F., Caglayan, M. and N. Ozkan, (2003). Re-examining the Transmission of Monetary Policy: What More do a Million Observations have to Say? Boston College WP 2003.

Banerjee, A., Lumsdaine, R. L. and J.H. Stock, (1992). Recursive and Sequential Tests of the Unit Root and Trend-Break Hypothesis: Theory and International Evidence, Journal of Business and Economic Statistics, 10: 271-287.

Banerjee, A., Lazarova, S. and G. Urga, (1998). Bootstrapping Sequential Tests for Multiple Structural Breaks, Discussion Paper No. 98/24, European University Institute, Florence.

Bank of England, (1999). The Transmission Mechanism of Monetary Policy, Quarterly, WP/5 Bank of England, London, United Kingdom.

Bank of England, (2000), Economic Models at the Bank of England. Quarterly, WP/XV Bank of England, London, United Kingdom.

Bank of England, (2011). The United Kingdom's Quantitative Easing Policy: Design, Operation and Impact, Quarterly Bulletin Q3. London, United Kingdom.

Bank of England, (2011). The Transmission Mechanism of Monetary Policy. Available at http://www.bankofengland.co.uk/publications, accessed on: 12.05.2013.

Bank of England, (2013). Inflation Targeting and Flexibility. Quarterly Bulletin Q4, Bank of England, London, United Kingdom.

Bank of England, (2014). Money in the Modern Economy. Quarterly Bulletin Q1, Bank of England, London, United Kingdom.

Bank of England, (2015). One Bank Research Agenda. BoE Discussion Paper, Bank of England, London, United Kingdom.

Bank of International Settlements, (1995). Financial Structure and the Monetary Policy Transmission Mechanism, BIS Paper, Basel.

Bank of International Settlements, (1998). The Transmission of Monetary Policy in Emerging Market Economies. BIS Policy Papers. No. 3.

Bank of International Settlements, (2008). Transmission Mechanisms for Monetary Policy In Emerging Market Economies. BIS Papers. No. 35.

Bank of Thailand, (2010). Monetary Transmission Mechanism, Working paper, No. 335, Thailand.

Bardsen, G. and J.T. Klovland, (2000). Shaken or Stirred? Financial Deregulation and the Monetary Transmission Mechanism in Norway. Scandinavian Journal of Economics, 102: 563–83.

Barnett, A. and R. Thomas, (2013). Has Weak Lending and Activity in the United Kingdom been Driven by Credit supply shocks? Bank of England Working Paper, No. 482, London, United Kingdom.

Barnea, E., Landskroner, Y. and M. Sokoler, (2015). Monetary Policy and Financial Stability in a Banking Economy: Transmission Mechanism and Policy Tradeoffs. Journal of Financial Stability, 18: 78-90.

Barro, R.J. and D.B. Gordon, (1983b), A Positive Theory of Monetary Policy in a Natural Rate Model, Journal of Political Economy, 91: 589-610.

Barth, M. and V. Ramey, (2002). The Cost Channel of Monetary Transmission, NBER Macroeconomics Annual, 16: 199-256.

Basci, E., Ozel, O. and C. Sarıkaya, (2007). The Monetary Transmission Mechanism in Turkey: New Developments, Research and Monetary Policy Department Working Paper, No. 07/04, CBT.

Barksy, R. and E. Sims, (2011). News Shocks and Business Cycles, Journal of Monetary Economics, 58: 273-289.

Batini, N., Breuer, P., Kochhar, K. and S. Roger, (2006). Inflation Targeting and the IMF. IMF Board Paper, SM/06/33.

Batini, N. and D. Laxton, (2007). Under what Conditions can Inflation Targeting be Adopted? The Experience of Emerging Markets. In: Schmidt-Hebbel, K., Mishkin, F. (Eds.), Monetary Policy under Inflation Targeting. Central Bank of Chile. Vol. 396.

Bauwens, L., Lubrano, M. and J. F. Richards, (2000). Bayesian Inference in Dynamic Econometric Models, OUP Catalogue, Oxford University Press.

Baumeister, C. and L. Benati, (2012). Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound. Working Papers, No. 12-21, Bank of Canada.

Bean, C. (2001). The Formulation of Monetary Policy at the Bank of England, Quarterly Bulletin, Bank of England, London, United Kingdom.

Beck G.B. and V. Weiland, (2008). Central Bank Misperceptions and the Role of Money in Interest Rate Rules. European Central Bank Working Paper, Series 967.

Beck, T., Colciago, A. and D. Pfajfar, (2014). The Role of Financial Intermediaries in Monetary Policy Transmission. Journal of Economics and Control, 43: 1-11.

Begg. I., (2009). Regulation and Supervision of Financial Intermediaries in the EU: The Aftermath of the Financial Crisis. JCMS, 7: 1107–28.

Bekker, P.A. and D. Pollock, (1986). Identification of Linear Stochastic Models with Covariance Restrictions, Journal of Econometrics, 31: 179 – 208.

Belke, A. and T. Polleit, (2009). Monetary Economics in Global Financial Markets, ISBN 978-3-540-71003-5, Springer, New York.

Ben-David, D. and D.H. Papell, (1998). Slowdowns and Meltdowns: Post-war Growth Evidence From 74 Countries, Review of Economics and Statistics, 80: 561-571.

Ben-David, D. and D.H. Papell, (1995). The Great Wars, the Great Crash and the Unit Root Hypothesis, Journal of Monetary Economics, 36: 453-475.

Ben-David, D., Lumsdaine, R. and D.H. Papell, (2003). Unit Root, Post-war Slowdowns and Long-Run Growth: Evidence from Two Structural Breaks, Empirical Economics, 28: 303-319.

Benati, L. (2008). Investigating Inflation Persistence across Monetary Regimes, Quarterly Journal of Economics, 123: 1005–1060.

Benati, L., (2009). Long-run Evidence on Money Growth and Inflation. ECB Working Paper, Series 1027. Frankfurt am Main: European Central Bank.

Benati, L. and P. Surico, (2009). VAR Analysis and the Great Moderation, American Economic Review, 99: 1636–1652.

Benati, L. and T.A. Lubik, (2012). The Time-Varying Beveridge Curve. Non-linear Economic Modelling, Dynamic Modelling and Econometrics in Economics and Finance, 17: 167-204.

Berger H., Haan, J.D., Sylvester C. and W. Eijffinger, (2000). Central Bank Independence. An Update of Theory and Evidence. CESifo Working Paper Series, WP No. 255: 255, 1–54.

Berkes, I., Horváth, L., Kokoszka, P. and Q. Shao, (2006). On Discriminating between Long-Range Dependence and Changes in Mean, The Annals of Statistics, 34: 1140–1165.

Bernanke, B.S. and A.S. Blinder, (1988). Credit, Money, and Aggregate Demand. American Economic Review, 78: 435–439.

Bernanke, B.S. and A.S. Blinder, (1992). The Federal Funds Rate and the Channels of Monetary Transmission, American Economic Review, 82: 901–921.

Bernanke, B.S., (1986). Alternative Explorations of the Money-Income Correlation. Econometric Research Program, Research Memorandum, No. 321, Carnegie-Rochester Series on Public Policy, 25: 49-99.

Bernanke, B.S., (1993). How Important is the Credit Channel in the Transmission of Monetary Policy? A comment," Carnegie-Rochester Conference Series on Public Policy, Elsevier, 39: 47-52.

Bernanke, B.S., (1995). The Macroeconomics of the Great Depression: A Comparative Approach, Journal of Money, Credit and Banking, 27:1-28.

Bernanke, B.S. (2007). The Recent Financial Turmoil and its Economic and Policy Consequences, Speech 326, at the Economic Club of New York, New York, 15 and Board of Governors of the Federal Reserve System (U.S.).

Bernanke, B.S. and I. Mihov, (1998). Measuring Monetary Policy, Quarterly Journal of Economics, 113: 869–902.

Bernanke, B.S., Gertler, M. and S. Gilchrist, (1996). The Financial Accelerator and the Flight to Quality. Review of Economics and Statistics, 78: 1–15.

Bernanke, B.S., Gertler, M. and S. Gilchrist, (1998). The Financial Accelerator in a Quantitative Business Cycle Framework, Working Papers, C.V. Starr Centre for Applied Economics, New York University 98-03.

Bernanke B.S., Reinhart V.R. and B.P. Sack, (2004). Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment, Brookings Papers on Economic Activity, 2: 1-78.

Bernanke, B.S. and M. Gertler, (1989). Agency Costs, Net Worth and Business Fluctuations, American Economic Review, 79: 14–31.

Bernanke, B.S. and M. Gertler, (1995). Inside the Black Box: The Credit Channel of Monetary Policy Transmission. Journal of Economic Perspectives, 9: 27-48.

Bernanke, B.S., Gertler, M. and S. Gilchrist, (1999). The Financial Accelerator in a Quantitative Business Cycle Framework. Handbook of Macroeconomics, 1: 1341-1393.

Bernanke, B.S., Laubach, T., Mishkin, F.S. and A.S. Posen, (1999). Inflation Targeting: Lessons from the International Experience, Princeton University Press.

Bernanke, B.S. and J. J. Rotemberg, (1997). NBER Macroeconomics Annual 1997, Volume 12, NBER Books, National Bureau of Economic Research, Inc, No. 97-1.

Bernanke, B.S. Boivin, J. and P. Eliasz (2005). Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach, Quarterly Journal of Economics, 120: 387-422.

Betancour, C., De Gregorio, J. and J.P. Medina, (2006). The Great Moderation and the Monetary Transmission Mechanism in Chile, Working Paper, No. 393, Central bank of Chile.

Bils, M. and P.J. Klenow, (2004). Some Evidence on the Importance of Sticky Prices, Journal of Political Economy, 112: 947-85.

Binning, A. (2014). Underidentified SVAR Models: A framework for Combining Short and Long-Run Restrictions with Sign-Restrictions, Working Paper, No. 14, Norges Bank.

Bini-Smaghi, L. (2008). Careful with (the D) Words!, Speech, European Central Bank, European Colloquia Series, Venice.

Bjørnland, H.C. and D.H Jacobsen, (2013). House Prices and Stock Prices: Different Roles in the US Monetary Transmission Mechanism, Scandinavian Journal of Economics, Wiley Blackwell, 115: 1084-1106.

Blackburn, K. and M. Christensen (1989). Monetary Policy and Policy Credibility, Theory and Evidence. Journal of Economic Literature, 27: 1-45.

Blanchard, O.J. and D. Quah, (1989). The Dynamic Effects of Aggregate Demand and Supply Disturbances, American Economic Review, 79: 655-673.

Blanchard, O.J. and D. Quah, (1993). The Dynamic Effects of Aggregate Demand and Supply Disturbances: Reply, American Economic Review, 83: 653-58.

Blanchard, O.J. and R. Perotti, (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output, Quarterly Journal of Economics, 117: 1329-1368.

Blanchard, O.J. and M.W. Watson, (1986). Are Business Cycles All Alike? The American Business Cycle: Continuity and Change. University of Chicago Press, Chicago, IL, pp. 123-180.

Blanchard, O. J. and P. Diamond, (1992). The flow Approach to Labor Markets. The American Economic Review 82: 354–359.

Blanchard, O. J. and P. Diamond, (1994). Ranking, Duration, Unemployment and Wages. The Review of Economics and Statistics 61: 417–434.

Blancheton, B., (2015). Central Bank Independence in a Historical Perspective. Myth, Lessons and a New Model, Economic Modelling, 52:101-107.

Blinder, A.S. and J.E. Stiglitz, (1983). Money, Credit Constraints, and Economic Activity, American Economic Review, 73: 297–302.

Boivin, J. and M. Giannoni, (2006). Has Monetary Policy become more Effective? Review of Economics and Statistics, 88: 445-462.

Boivin, J., Kiley, M.T. and F.S. Mishkin, (2010). How Has the Monetary Transmission Mechanism Evolved Over Time? NBER WP 15879.

Booth, G. G., Glascock, J.L., Martikainen, T. and T. Rothovius, (1994). The Financing of Residential Real Estate in Finland: An overview, Journal of Housing Research, 5, 205–226.

Borio, C. (2003). Towards a Macroprudential Framework for Financial Supervision and Regulation? BIS Working Papers, No. 128, Bank for International Settlements.

Boughton, J.M., (1993). The Demand for M1 in the United States: A Comment on Baba, Hendry and Starr, Economic Journal, 103: 1154-1167.

Bouis, R., Rawdanowicz, L., Renne, J.-P. Watanabe, S., and A. K. Christensen, (2013). The Effectiveness of Monetary Policy since the Onset of the Financial Crisis. In: Jannsen, N., Potjagailo, G. and M.H. Wolters (2015). The Monetary Policy during Financial Crises: Is the Transmission Mechanism Impaired. Kiel Working Paper, No. 2005. Kiel Institute for the World Economy, Kiellinie 66, 24105 Kiel, Germany.

Box, G. E. P. and G. M. Jenkins, (1976). Time Series Analysis: Forecasting and Control, Holden-Day, San Francisco.

Breitung, J., and S. Eickmeier, (2009). Testing for Structural Breaks in Dynamic Factor Models. Discussion Paper. Series 1: Economic Studies No. 05.

Brischetto, A. and G. Voss, (1999). A Structural Vector Autoregression Model of Monetary Policy in Australia, Reserve Bank of Australia Discussion Paper No 19.

Brito, R. D. and B. Bystedt, (2010). Inflation Targeting in Emerging Economies: Panel Evidence. Journal of Development Economics, 91: 198-210.

Brooks, S. P. and A. Gelman, (1998). Alternative Methods for Monitoring Convergence of Iterative Simulations, Journal of Computational and Graphical Statistics, 7: 434–455.

Brumberg R.E. and F. Modigliani, (1954). Utility Analysis and the Consumption Function: An Interpretation of Cross-section Data, K.K. Kurihara (Ed), Post-Keynesian Economics, Rutgers University Press, New Brunswick.

Bryant, R.C., Hooper, P. and C. L. Mann, (1993). Evaluating Policy Regimes, New Research in Empirical Macroeconomics, the Brookings Institution, Washington D.C.

Brzoza-Brzezina, M. and K. Makarski, (2011). Credit Crunch in a Small Open Economy. Journal of International Money and Finance, 30:1406–1428.

Brzoza-Brezezina, M., Kolasa, M. and K. Makarski, (2013). The Anatomy of Standard DSGE Models with Financial Frictions. Journal of Economic Dynamics and Control, 37: 32–51.

Brzoza-Brzezina, M., Kolasa, M. and K. Makarski, (2013). Bayesian Evaluation of DSGE Models with Financial Frictions, Journal of Money, Credit and Banking, Blackwell Publishing, 45: 1451-1476.

Bullard, J. (1999). Testing Long-Run Monetary Neutrality Propositions: Lessons from the Recent Research, Federal Reserve Bank of St. Louis Review, 57-77.

Cabrera, A. and L.F. Lagos, (2000). Monetary Policy in Chile: A Black Box? Working Paper, No. 88, Central bank of Chile.

Caglayan, M., Karoglou, M., Mouratidis, K. and E. Saeidinezhed, (2012). Monetary Policy Effects on Output and Exchange Rates: Results from US, UK and Japan, Department of Economics, University of Sheffield, unpublished.

Calza, A., Monacelli, T. and L. Stracca, (2009). Housing Finance and Monetary Policy. Working Paper, Series 1069, European Central Bank.

Calza, A., Monacelli, T. and L. Stracca, (2013). Housing Finance and Monetary Policy, Journal of the European Economic Association, 11: 101–122.

Calvo, G. (1983). Staggered Prices in a Utility Maximising Framework, Journal of Monetary Economics, 12: 383–398.

Canova, F. and De G. Nicolo, (2002). Monetary Disturbances Matter for Business Fluctuations in the G-7, Journal of Monetary Economics, 49: 1131-1159.

Canova, F. and J. Pina, (2005). What VAR Tells about DSGE Models? In Deibolt, C. and Krytsou. C. (Eds.) New Trends and Macroeconomics, Springer Verlag.

Canova, F. (2007a). Bayesian Time Series and DSGE Models, from Methods for Applied Macroeconomic Research. Methods for Applied Macroeconomic Research, Introductory Chapters, Princeton University Press.

Canova, F. (2007b). Methods for Applied Macroeconomic Research, Princeton University Press, Princeton, New Jersey.

Canova, F. and L. Sala, (2009a). Back to Square one: Identification Issues in DSGE Models. Journal of Monetary Economics, 56: 431-449.

Canova, F. and L. Gambetti, (2009b). Structural Changes in the US Economy: Is there a Role for Monetary Policy? Journal of Economic, Dynamics and Control, 33: 477–490.

Canova, F., Lopez-Salido, D. and C. Michelacci, (2010). The Effects of Technology Shocks on Hours and Output: a Robustness Analysis, Journal of Applied Econometrics, 25: 755-773.

Capie, F. and G. Wood, (2013). Central Bank Independence: A Victim of the Crisis? Economic Affair, 33: 379–385.

Carrillo, J.A. and C. Poilly, (2013). How Do Financial Frictions Affect the Spending Multiplier During a Liquidity Trap? Review of Economic Dynamics, 16: 296-311.

Carrion-i-Silvestre, J. L., Barrio-Castro T. D. and E. Lopez-Bazo, (2005). Breaking the panels: an Application to the GDP per capita, Econometrics Journal, 8: 159–75.

Carrion-i-Silvestre, J.L., Kim, D. and P. Perron, (2007). GLS-based Unit Root Tests with Multiple Structural Breaks both under the Null and the Alternative Hypotheses, Boston University - Department of Economics - Working Papers, Series, WP 2008-019.

Carlstrom, C., and T. Fuerst, (1997). Agency Costs, Net Worth, and Business Fluctuations: a Computable General Equilibrium Analysis, American Economic Review, 87: 893-10.

Carlstrom, C., Fuerst, T. and M. Paustian, (2009). Optimal Monetary Policy in a Model With Agency Costs. Journal of Money, Credit and Banking, 42: 4-5.

Carlstrom, C.T., Fuerst, T., Ortiz, A. and M. Paustian, (2013). Estimating Contract Indexation in a Financial Accelerator Model. Journal of Economic Dynamics and Control, Elsevier, 46: 130-149.

Castro, V. and R.M. Sousa, (2012). How Do Central Banks React to Wealth Composition and Asset Prices? Economic Modelling, 29: 641–653.

Casella, G. and R.L. Berger, (2001). Statistical Inference (2nd Ed.), ISBN 0-534-24312-6.

Catão, L. and A. Pagan, (2010). The Credit Channel and Monetary Transmission in Brazil and Chile: A Structural VAR Approach, Working Papers, Central Bank of Chile 579, Central Bank of Chile.

Catik, N. and C. Martin, (2012). Macroeconomic Transitions and the Transmission Mechanism: Evidence from Turkey Evidence from Turkey. Economic Modelling, 29: ISSN 0264-9993.

Cecchetti, S.G. (1995). Distinguishing Theories of the Monetary Transmission Mechanism. Federal Bank of St. Louis. Review, 77: 83–97.

Cecchetti, S.G. (1999). Legal Structure, Financial Structure, and the Monetary Policy Transmission Mechanism. Federal Reserve Bank of New York Economic Policy Review, 5: 9–28.

Cecchetti, S.G. (2011). Speech - Monetary Policy Lessons Learned from the Crisis and the Post-crisis Landscape. Bank for International Settlements: 1 – 10.

Cecchetti, S.G., and E. Kharroubi, (2015). Why Does Financial Sector Growth Crowd out Real Economic Growth? BIS Working Papers, No. 490, Bank for International Settlements.

Cecioni, M. and S. Neri, (2011). The Monetary Transmission Mechanism in the Euro Area: has it Changed and Why?, Temi Di Discussione, Economic Working Papers, No. 808, Bank of Italy, Economic Research and International Relations Area.

Cengiz, V. (2009). The Operation of Monetary Transmission Mechanism and Empirical Evidence, Journal of Erciyes, University Faculty of Economics and Administrative Sciences 33: 225-247.

Cespedes, L. F., Chang, R. and A. Velasco, (2004). Balance Sheets and Exchange policy. American Economic Review, 94: 1183-1193.

Cetorelli, N. and L.S. Goldberg, (2011). Global Banks and International Shock Transmission: Evidence from the Crisis. IMF Economic Review, 59: 41–76.

Chadha, J.S. and S. Holly (2011). Interest Rates, Prices and Liquidity: Lessons from the Financial Crisis (Macroeconomic Policy Making), Cambridge University Press.

Charoenseang, J. and P. Manakit, (2007). Thai Monetary Policy Transmission in an Inflation Targeting era, Journal of Asian Economics, 18: 144–157.

Chatzikonstanti, V. and I.A. Venetis, (2015). Long Memory in Log-Range Series: Do Structural Breaks Matter? Journal of Empirical Finance, 33: 104 – 113.

Chaudhuri, K. and Y. Wu, (2003). Random Walk Versus Breaking Trend in Stock Prices: Evidence from Emerging Markets, Journal of Banking and Finance, 27: 575-592.

Choi, W. and D. Cook, (2004). Liability Dollarization and the Bank Balance Sheet Channel, Journal of International Economics, 64: 247-275.

Chowla, S., Quaglietti, L. and R. Lukasz, (2014). How have World Shocks Affected the UK Economy? Bank of England Quarterly Bulletin, Bank of England, 54: 167-179.

Chowdhury, I., Hoffmann, M., and A. Schabert, (2006). Inflation Dynamics and the Cost Channel of Monetary Transmission, European Economic Review, 50: 995–1016.

Christensen, I. and A. Dib, (2005). Monetary Policy in an Estimated DSGE Model with a Financial Accelerator. Society for Computational Economics in its Series Computing in Economics and Finance, Series number 314.

Christensen, I. and A. Dib, (2008). The Financial Accelerator in an Estimated New Keynesian Model, Review of Economic Dynamics, 11: 155–178.

Christiano, L.J. (1992). Searching for a Break in GNP, Journal of Business and Economic Statistics, 10: 237-49.

Christiano, L., Eichenbaum, M. and C. Evans, (1996). The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds. Review of Economics and Statistics, 78: 16-34.

Christiano, L., Eichenbaum, M. and C. Evans, (1998). Modelling Money. NBER Working Paper, No. 6371.

Christiano, L., Eichenbaum, M. and C. Evans, (1999). Monetary Policy Shocks: what have we Learned and to what End? In: Woodford M. and J. Taylor, (2012), Handbook of Macroeconomics, (Eds), Economic Modelling, 29: 1440–1449.

Christiano, L.J., Eichenbaum, M. and C. Evans, (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy Journal of Political Economy, 113: 1-46.

Christiano, L.J., Motto, R. and M. Rostagno, (2003). The Great Depression and the Friedman-Schwartz Hypothesis, Journal of Money, Credit and Banking 35: 1119–1197.

Christiano, L.J., Motto, R. and M. Rostagno, (2007). Monetary Policy and Stock Market Boom-Bust Cycles, Manuscript, North-western University.

Christiano, L.J., Motto, R. and M. Rostagno, (2008). Shocks, Structures or Monetary Policies? The Euro Area and US after 2001, Journal of Economic Dynamics and Control, 32: 2476-2506.

Christiano L.J., Mathias, C. and T.K. Walentin, (2011). Introducing Financial Frictions and Unemployment into a Small Open Economy Model, Journal of Economic Dynamics and Control, 35: 1999–2041.

Christiano, L.J. Motto, R. and M. Rostagno, (2010). Financial Factors in Economic Fluctuations. European Central Bank Working Paper, Series 1192.

Christiano, L. and M. Eichenbaum, (1990). Unit Roots in Real GDP: Do we know, and do we Care? Carnegie Rochester Conference Series on Public Policy, 32: 7-62.

Christoffel, K., Coenen, G. and A. Warne, (2008). The New Area-Wide Model of the Euro Area - a Micro-Founded Open-Economy Model for Forecasting and Policy Analysis, Working Paper Series, No. 944, ECB.

Cicek, M. (2005). The Monetary Transmission Mechanism in Turkey: An Analysis with VAR (Vector Autoregression) Method, Journal of Economics, Business Administration and Finance, 233: 82-105.

Cihak, M., Schaeck, K. and S. Wolfe, (2009). Are Competitive Banking System More Stable? Journal of Money, Credit and Banking, 41: 711-734.

Clarida, R., Galì, J. and M. Gertler, (1998). Monetary Policy Rules in Practice: some International Evidence, European Economic Review, 42: 1033–1067.

Clarida, R., Gali, J. and M. Gertler, (1999). The Science of Monetary Policy: A New Keynesian Perspective, Journal of Economic Literature, 37: 1661-1707.

Clarida, R., Galí, J. and M. Gertler, (2000). Monetary Policy Rules and Macroeconomic Stability: Evidence and some Theory. Quarterly Journal of Economics, 115: 147–180.

Clarida, R.H., (2001). Comment on Optimal Central Bank Areas, Financial Intermediation, and Mexican Dollarization, Journal of Money, Credit and Banking, Blackwell Publishing, 33: 667-68.

Clarida, R.H., (2012). What has and has not been Learned about Monetary Policy in a Low-Inflation Environment? A Review of the 2000s, Journal of Money, Credit and Banking, Blackwell Publishing, 44: 123-140.

Clark T.E. (1994). Nominal GDP Targeting Rules: Can They Stabilize the Economy? Economic Review, Federal Reserve Bank of Kansas City, Quarter 3.

Claus, I., (2011). Inside the Black Box: How Important is the Credit Channel Relative to the Interest and Exchange Rate Channels? Economic Modelling, 28: 1–12.

Clements, M. P. and D.F. Hendry, (1998a). Forecasting Economic Time Series. Cambridge: Cambridge University Press.

Clements, M. P. and Hendry, D. F. (1998b). Some Methodological Implications of Forecast Failure. mimeo, Institute of Economics and Statistics, University of Oxford.

Clemente, J., Montanes, A. and M. Reyes, (1998). Testing for a Unit Root in Variables with a Double Change in the Mean, Economics Letters, 59: 175-182.

Cloyne, J. and P. Hurtgen, (2014). The Macroeconomic Effects of Monetary Policy: A New Measure for the United Kingdom, Bank of England working papers, No. 493, Bank of England.

Cochrane J.H. (1991a). A Critique of the Application of Unit Roots Tests, Journal of Economic Dynamics and Control, 15: 275-284.

Cochrane, J.H. (1991b). Univariate vs. Multivariate Forecasts of GNP Growth, and Stock Returns: Evidence and Implications for the Persistence of Shocks, Detrending Methods, NBER Working Papers, No. 3427, National Bureau of Economic Research, Inc.

Cochrane J.H. (2007). Identification with Taylor Rules: A Critical Review. NBER working paper, No. 13410.

Cooley, T. and M. Dwyer, (1998). Business Cycle Analysis without much Theory: A look at Structural VARs. Journal of Econometrics, 83: 57-88.

Cook, T.Q., (1978). Regulation Q and the Behaviour of Savings and Small Time Deposits at Commercial Banks and the Thrift Institutions, Economic Review, 64: 14–28.

Cooley, T.F. and V. Quadrini, (2004). Optimal Monetary Policy in a Phillips-curve world, Journal of Economic Theory, 118: 174–208.

Cover, P.J. and S.K. Mallick, (2012). Identifying Sources of Macroeconomic and Exchange Fluctuations in the UK. Journal of International Monetary and Finance, 31: 1627 – 1648.

Cukierman, A.S. Webb and B. Neyapti, (1992). Measuring the Independence of Central Banks and Its Effects on Policy Outcomes, World Bank Economic Review, 6: 353-398.

Cukierman, A.S., (2013). Monetary Policy and Institutions before, during, and after the Global Financial Crisis, Journal of Financial Stability 9: 373– 384.

Curdia, V. and M. Woodford, (2010). Credit Spreads and Monetary Policy. Journal of Money, Credit and Banking, Blackwell Publishing, 42: 3-35.

Curdia, V. and M. Woodford, (2009). Credit Frictions and Optimal Monetary Policy. BIS Working Papers, No. 278, Bank for International Settlements.

Curdia, V., Del Negro, M. and D.L. Greenwald, (2013). Rare Shocks, Great Recessions. FRB San Francisco, WP 2013-01.

Cuthbertson, K. and M.P.T. Taylor, (1987). The Demand for Money: A Dynamic Rational Expectations Model, Economic Journal, 97: 5-76.

Cuthbertson, K., (1988). The Demand for M1: A Forward-Looking Buffer Stock Model, Oxford Economic Papers, 40: 110-131.

Cuthbertson, K., Nitzsche, D. and N. O'Sullivan, (2008). UK Mutual Fund Performance: Skill or Luck? Journal of Empirical Finance, 15: 613–634.

Davoodi, H.R., Dixit, S. and G. Pinter, (2013). Monetary Transmission Mechanism in East African Community in East African Community. An Empirical Investigation. IMF, WP 13/39.

Debelle, G. and S. Fischer, (1995). How Independent Should a Central Bank Be? Federal Reserve Bank of San Francisco, Working Papers in Applied Economic Theory 94-05.

Dedola, L. and S. Neri, (2004). What does a Technology Shock Do? A VAR Analysis with Model based Sign Restrictions, CEPR Discussion Paper, No. 4537.

Delivorias, A. (2015). Monetary Policy of the European Central Bank. Strategy, Conduct and Trends. European Parliament, ISBN 978-92-823-6592-2.

Del Negro, M. Giannoni, M.P. and F. Schorfheide, (2013). Inflation in the Greater Recession and New Keynesian models. Staff Reports 618, Federal Reserve Bank of New York.

Del Negro, M. and F. Schorfheide, (2013). DSGE Model-Based Forecasting, Handbook of Economic Forecasting, Elsevier.

Dennis R. (2004a). Solving for Optimal Simple Rules in Rational Expectations Models, Journal of Economic Dynamics and Control, 28: 1635-1660.

Dennis R. (2004b). Inferring Policy Objectives from Economic Outcomes. Oxford Bulletin of Economics and Statistics, 66: 735 – 764.

Den Hann, W.J., Sumner, S.W. and G.M. Yamashiro, (2007). Bank Loan Portfolios and the Monetary Transmission Mechanism, Journal of Monetary Economics, 54: 904-924.

Diamond, D.B. and M.J. Lea, (1992). Housing Finance in Developed Countries: An international Comparison of Efficiency, Journal of Housing Research, 3: 1–271.

Dickey, D.A. and W.A. Fuller, (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root, Journal of the American Statistical Association, 74: 427-31.

Doan, T., Litterman, R. and C. Sims, (1984). Forecasting and Conditional Projection Using Realistic Prior Distributions, Econometric Reviews, 3: 1–100.

Dueker, M. and A.M. Fischer, (1996). Inflation Targeting in a Small Open Economy: Empirical Results for Switzerland, Journal of Monetary Economics, 37: 89-103.

Dueker, M. and A.M. Fischer, (1999). A Guide to Nominal Feedback Rules and their Use for Monetary Policy. Federal Reserve Bank of St. Louis Review, 80: 55-63.

Dueker, M. and A.M. Fischer, (2001). The Mechanics of a Successful Exchange Rate Peg: Lessons for Emerging Markets. Federal Reserve Bank of St. Louis Review.

De Graeve, F., (2008). The External Finance Premium and the Macroeconomy: U.S. post-WWII evidence, Journal of Economic Dynamics and Control, 32: 3415–3440.

De Fiore, F. and O. Tristani, (2009). Optimal Monetary Policy in a Model of the Credit Channel. Working Paper Series, No. 1043, European Central Bank.

Davig, T. and E. M. Leeper, (2007). Generalizing the Taylor Principle, American Economic Review, 97: 607–635.

Dhrymes, P. J., (1978), Introductory Econometrics, New York: Springer-Verlag.

Dhrymes, P. J., (1994), Topics in Advanced Econometrics, New York: Springer-Verlag.

Diebold, F. and A. Inoue, (2001). Long Memory and Regime Switching. Journal of Econometrics, 105: 59-131.

Dib, A., (2009). Banks, Credit Market Frictions and Business Cycles. Working paper, Bank of Canada.

DiCecio, R. and E. Nelson, (2007). An estimated DSGE Model for the United Kingdom, Federal Reserve Bank of St. Louis Review, 89: 215-32.

Dickey, D.A. and W.A. Fuller, (1981). Likelihood Ratio Tests for Autoregressive Time Series with a Unit Root, Econometrica, 49: 1057-72.

Doan, T., (2004). Rats Manual, Version 6. Estima, Evanston, H.

Dogan, E. (2016). Analysing the Linkage between Renewable and Non-renewable Energy Consumption and Economic Growth by Considering Structural break in Time Series Data. Renewable Energy, Vol.99, pp.1126-1136.

Dotsey, M., (1987). Open Market Operations in Australia: a US Perspective, Reserve Bank of Australia Discussion Paper No. 8702.

Dungey M. and A. Pagan, (2000). A Structural VAR Model of the Australian Economy. Economic Record, 76: 321–342.

Dynan, K., Elmendorf, D.W. and D.E. Sichel, (2006). Can Financial Innovation Help to Explain the Reduced Volatility of Economic Activity? Journal of Monetary Economics, 53: 123-50.

Engle, R. F. and C. W. J. Granger, (1987). Cointegration and Error-Correction Representation: Estimation and Testing, Econometrica, 55: 251-76.

ECB, (2009). Monetary Policy before and after the Financial Crisis of 2007. Speech by Jürgen Stark, Member of the Executive Board of the ECB. University Tübingen, Tübingen.

ECB, (2010). Monetary Policy Transmission in the Euro Area. ECB Monthly Bulletin Article. Available at: http://www.ecb.europa.eu/mopo/intro/transmission/html/index.en.html, Accessed on: 20.07.2014.

Edge, R.M., Michael, T. K. and J.P. Laforte, (2008). Natural Rate Measures in an Estimated DSGE Model of the U.S. Economy, Journal of Economic Dynamics and Control, 32: 2512-2535.

Eijffinger, S.C.W. and M. Hoeberichts, (1998a). The Trade Off between Central Bank Independence and Conservativeness, Oxford Economic Papers, 50: 397-411.

Eijffinger S.C.W. and M. Hoeberichts, (1998b). Central Bank Independence, A sensitivity Analysis, European Journal of Political Economy, 14: 73–88.

Eichenbaum, M., (1992). Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy: by Christopher Sims, Comment: European Economic Review, 36: 1001-1011.

Eichenbaum, M., (1997). Some Thoughts on Practical Stabilization Policy, American Economic Review, 87: 236 – 239.

Eksi, O., (2009). Lower Volatility, Higher Inequality: Are they Related? Universitat Pompeu Fabra. CREI Macroeconomics.

El-Shazly, A. (2016). Structural Breaks and Monetary Dynamics: A Time Series Analysis. Economic Modelling, 53: 133-143.

Elliott, G., Rothenborg, T.J. and J.H. Stock, (1996). Efficient Tests for an Autoregressive Unit Root. Econometrica, 64: 813-836.

English, W., Nelson, W.R., and B.P. Sack, (2003). Interpreting the Significance of the Lagged Interest Rate in Estimated Monetary Policy Rules. Board of Governors of the Federal Reserve System, Washington, DC 20551.

Elbourne, A., (2008). The UK Housing Market and the Monetary Policy Transmission Mechanism: An SVAR Approach, Journal of Housing Economics, 17: 65-87.

European Mortgage Federation, (2000). Funding of Mortgage Loans in the European Union and Norway. Working Paper.

European Commission, (1998). Euro 1999, Part 2: Report, 25 March 1998.

European Monetary Institute, (1997). Legal Convergence in the Member States of the European Union, Frankfurt, am Main, October.

Fair, R.C., (1976). A Model of Macroeconomic Activity. Vol.1. The Empirical Model. Ballinger, Cambridge, Massachusetts.

Faust, J., (1998). The Robustness of Identified VAR Conclusions about Money. Carnegie-Rochester Conference Series on Public Policy, 49: 207-244.

Faust, J., Swanson, E.T. and J.H. Wright, (2004). Identifying VARs based on High Frequency Futures Data. Journal of Monetary Economics, 51, 1107–1131.

Faust, J., Gilchrist, S., Wright, J.H. and E. Zakrajsek, (2012). Credit Spreads as Predictors of Real-time Economic Activity: a Bayesian Model-Averaging Approach. Finance and Economic Discussion Series 2012-77. Board of Governors of the Federal Reserve System.

Favero C.A., (2001). Applied Macroeconometrics, OUP Catalogue, University Press, Oxford.

Fernandez-Villaverde, J., (2010). Fiscal Policy in a Model with Financial Frictions. American Economic Review, Papers and Proceeding.

Ferreira, N., Menezes, R. and S. Bentes, (2014). Cointegration and Structural Breaks in the EU Sovereign Debt Crisis. International Journal of Latest Trends in Finance & Economic Sciences IJLTFES, E-ISSN: 2047-0916

Fiorentini, R. and R. Tamborini, (2001). The Monetary Transmission Mechanism in Italy: The Credit Channel and a Missing Ring, Giornale degli Economisti, GDE (Giornale degli Economisti e Annali di Economia), Bocconi University, 60: 1-42.

Fischer, S., (1977). Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule, Journal of Political Economy, 85: 191-205.

Fisher, P., (2012). Bernanke Risks Creating a Liquidity Trap, Financial Times, September 10.

Fleming, J.M., (1962). Domestic Financial Policies under Fixed and Floating Exchange Rates. Staff Papers, International Monetary Fund, 9: 369-380.

Francis, N., Owyang, M., Roush, J. and R. DiCecio, (2014). A Flexible Finite-Horizon Alternative to Long-run Restrictions with an Application to Technology Shocks, Review of Economic and Statistics, 96: 638–647.

Friedman, M., (1959). The Demand for Money: Some Theoretical and Empirical Results, Journal of Political Economy, 67: 327-338.

Friedman, M., (1968). The Role of Monetary Policy. The American Economic Review. Vol. LVIII, No. 1: 1-17.

Friedman, M., (1989). Changing Effects of Monetary Policy on Real Economic Activity, Federal Reserve Bank of Kansas City Symposium Proceedings.

Friedman, M., (1997). John Maynard Keynes, Economic Quarterly, 83:1-23.

Friedman, M., (2008). Theory of the Consumption Function, Princeton University Press, Princeton.

Friedman, M. and A.J. Schwartz, (1963). A Monetary History of the United States, 1867–1960, Princeton University Press, Princeton.

Fuller, W.A., (1976). Introduction to Statistical Time Series. New York: Wiley.

Gali, J. and P. Rabanal, (2004). Technology Shocks and Aggregate Fluctuations: How Well does the RBC Model Fit Postwar US Data? NBER Macroeconomics Annual.

Galí, J. and M. Gertler, (2007). Macroeconomic Modeling for Monetary Policy Evaluation, Journal of Economic Perspectives, 21: 25-45.

Gali, J., (1992). How Well Does the IS-LM Model to Post-War US data. Quarterly Journal of Economics, 107: 709-720.

Gali, J., (1999). Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations? American Economic Review, 89: 249-271.

Galí, J., (2007). Constant Interest Rate Projections Without the Curse of Indeterminacy, Economics Working Papers, No. 1057, Department of Economics and Business, Universitat Pompeu Fabra.

Gelain, P., (2010). The External Finance Premium in the Euro Area: a Dynamic Stochastic General Equilibrium Analysis. North America Journal of Economic and Finance 21: 49–71.

Gerali, A., Neri, S., Sessa, L. and F.M. Signoretti, (2010). Credit and Banking in a DSGE model of the Euro Area, Journal of Money, Credit and Banking, 42: 107–141.

Gertler, M. and P. Karadi, (2011). A Model of Unconventional Monetary Policy, Journal of Monetary Economics, 58: 17–34.

Gerke, R., Jonsson, M., Kliem, M., Kolasa, M., Lafourcade, P., Locarno, A., Makarski, K. and P. McAdam, (2012). Assessing Macro-Financial Linkages: a Model Comparison Exercise. Deutsche Bundesbank Discussion Paper No. 02.

Gerlach, F. and F. Smets, (1995). The Monetary Transmission Mechanism: Evidence from the G7 Countries. CEPR Discussion Paper, 1219.

Gerlach, S. and J. Lewis, (2010). The Zero Lower Bound, ECB Interest Rate Policy and the Financial Crisis, CEPR Discussion Papers 7933, C.E.P.R. Discussion Papers.

Gertler, M. and C. Lown, (2000). The Information in the High-Yield Bond Spread for the Business Cycle: Evidence and Some Implications, NBER Working Paper, No. 7549.

Gertler, M. and N. Kiyotaki, (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis, In: Friedman, Benjamin M., Woodford, Michael (Eds.), Handbook of Monetary Economics, 3: 547–599.

Gertler, M. and S. Gilchrist, (1993). The Role of Credit Market Imperfections in the Monetary Transmission Mechanism: Arguments and Evidence, Scandinavian Journal of Economics, 95: 43–64.

Gertler, M., and S. Gilchrist, (1994). Monetary Policy, Business Cycles and the Behaviour of Small Manufacturing Firms, Quarterly Journal of Economics, 109: 309–340,

Gertler, M., Sala, L. and A. Trigari, (2008). An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining, Journal of Money, Credit, and Banking, 40: 1,713 - 1764.

Gertler, M., Gilchrist, S. and F. Natalucci, (2007). External Constraints on Monetary Policy and the Financial Accelerator, Journal, Money Credit and Banking, 40: 243–271.

Ghatak, A., (1997). Unit Roots and Structural Breaks: The Case of India, 1900-1988, Journal of Applied Statistics, 24: 289-300.

Gilberto L. (2005). Unit Roots in Macroeconomic Time Series: Theory, Implications, and Evidence, Nova Economia, Economics Department, Universidade Federal de Minas Gerais (Brazil), 15: 145-176.

Gilchrist, S., Ortiz, A. and E. Zakrajsek, (2009). Credit Risk and the Macroeconomy: Evidence from an Estimated DSGE Model, (manuscript).

Gilchrist, S.G. and E. Zakrajsek, (1995). The Importance of Credit for Macroeconomic Activity: Identification through Heterogenity. In: Peek, J., and E.S. Rosengreen, (Eds.), Is Bank Lending Important for the Transmission of Monetary Policy? Federal Reserve Bank of Boston Conference Series, Boston, 39: 129–158.

Gilchrist, S. and E. Zakrajsek, (2012a). Bank Lending and Credit Supply Shocks. In Allen, F., Aoki, N., Kiyotaki, N., and R. Gordon, (Eds), The Global Macro Economy and Finance, International Economic Association, Palgrave Macmillan, 154–176.

Gilchrist, S. and E. Zakrajsek, (2012a). Credit Spreads and Business Cycle Fluctuations, American Economic Review, 102: 1692–1720.

Giordani, P. (2004). An Alternative Explanation of the Price Puzzle, Journal of Monetary Economics, 51: 1271-1296.

Glynn, J., Perera, N. and R. Verma, (2007). Unit Root Tests and Structural Breaks: A Survey With Applications, Journal of Quantitative Methods for Economics and Business Administration, 3:63-79.

Goodfriend, M. and B. T. McCallum, (2007). Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration, Journal of Monetary Economics, 54: 1480-1507.

Goodfriend, M., (2012). The Elusive Promise of Independent Central Banking. Bank Japan Monetary Economics Study, 30: 39–54.

Goodfriend, M. and R. King, (1997). The New Neoclassical Synthesis and the Role of Monetary Policy, NBER Chapters, in: NBER Macroeconomics, 12: 231-296.

Goodhart C.A.E., Sunirand, P. and D. Tsomocos, (2006). A Model to Analyse Financial Fragility, Economic Theory, 27: 107-142.

Gordon, D.B. and E.M. Leeper, (1994). The Dynamic Impacts of Monetary Policy: an Exercise in Tentative Identification, Journal of Political Economy, 102: 1228–1247.

Gordon, R.J., (1990). What is New Keynesian Economics? Journal of Economic Literature, 28: 1115–171.

Gottschalk, J., (2001). An Introduction into the SVAR Methodology: Identification, Interpretation and Limitations of SVAR Models, Kieler Arbeitspapier, No. 1072.

Granger, C.W.J., (1981). Some Properties of Time Series Data and use in Econometric Model Specification, Journal of Econometrics, 16: 121 - 130.

Granger, C.W.J. and N. Hyung, (2004). Occasional Structural Breaks and Long Memory with an Application to the S&P 500 Absolute Stock Returns. Journal of Empirical Finance, 11: 399–421.

Grenville, S., (1997). The Evolution of Monetary Policy: from Money Targets to Inflation Targets. In Lowe, P. (Ed.), Monetary Policy and Inflation Targeting, Proceedings, Reserve Bank of Australia, Sydney, 125–158.

Greasley, D. and L. Oxley, (2010). Cliometrics and Time Series Econometrics: Some Theory and Applications, Journal of Economic Surveys, 24: 755–774.

Griffin, A. and S. Wall, (2004). Applied Economics (10th Edn.), Pearson Education, Prentice Hall, Financial Times, London.

Grilli, V. and N. Roubini, (1995). Liquidity and Exchange Rates: Puzzling Evidence from the G-7 Countries, Salomon Brothers Working Paper, S/95/31, New York University.

Grilli, V., Masciandaro, D. and G. Tabellini, (1991). Political and Monetary Institutions and Public Financial Policies in the Industrial Countries, Economic Policy, 13: 341-392.

Gudmundsson, M., (2007). Financial Globalisation and the Transmission Mechanism of Monetary Policy in Small and Medium Size Countries, Workshop, Centre for Central Banking Studies, Bank of England, London: 16-18.

Gumata, N., Kabundi, A., and E. Ndoux, (2013). Important Channels of Transmission Monetary Policy Shock in South Africa, ERSA WP, 375: 1-30.
Guonan Ma, (2015). A Compelling Case for Chinese Monetary Easing, Policy Contributions 879, Bruegel.

Gurley, J. and E. Shaw, (1960). Money in a Theory of Finance, Washington, DC: Brookings Institutions.

Hall, A.R., (1994). Testing for a Unit Root in Time Series with Pre-test Data-based Model Selection, Journal of Business and Economic Statistics, 12:461-470.

Hall, P.A., (1993). Policy Paradigms, Social Learning, and the State: The Case of Economic Policymaking in Britain. Comparative Politics, 25: 275–296.

Hall, R.E., (1975). The Rigidity of Wages and the Persistence of Unemployment, Brookings Papers on Economic Activity, No. 2: 301-350.

Hall, R.E. and G.N. Mankiw, (1994). Nominal income targeting. In Mankiw, G.N. (Ed.), Monetary Policy. University of Chicago Press, Chicago.

Hall, R.E., (1995). Lost Jobs. Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution, 26: 221-274.

Hall, S., (2008). Credit Channel Effects in Monetary Transmission Mechanism. International Bank Division: 289-320.

Hall, T.E., (1990). McCallum's Base Growth Rule: Results for the United States, West Germany, Japan and Canada, Weltwirtschaftliches Archiv, 126: 630-642.

Hallsten, K., (1999). Bank Loans and the Transmission Mechanism of Monetary Policy, Sveriges Riksbank Working Paper, No. 73.

Halvorsen, J.I. and J. Dag Henning, (2009). Are Bank Lending Shocks Important for Economic Fluctuations? Norges Bank Working Paper, No. 27.

Halvorsen J.I. and J. Dag Henning, (2014). How Important can Bank Lending Shocks be for Economic Fluctuation? The North American Journal of Economic and Finance, 29: 104-123.

Harvey, A., (1989). Forecasting, Structural Time Series Models and the Kalman filter. Cambridge University Press, Cambridge.

Harrison, R. and O. Oomen, (2010). Evaluating and Estimating a DSGE Model for the United Kingdom, Bank of England Working Papers, No. 380, Bank of England.

Haslag, J.H. and S.E. Hein, (1995). Does it Matter How Monetary Policy is Implemented? Journal of Monetary Economics, 35: 359-386.

Haug A.A., Karagedikli, O. and S. Ranchhod, (2003). Monetary Policy Transmission Mechanisms and Currency Unions: a Vector Error Correction Approach to a Trans-Tasman Currency Union, Reserve Bank of New Zealand, Discussion Paper No. DP. 2003/04.

Hayashi, F., (1982). Tobin's Marginal q and Average q: a Neoclassical Interpretation, Econometrica, 50:213-224.

Hubbard, G., Kuttner, K. and D. Palia, (2002). Are there Bank Effects in Borrowers Costs of Funds? Evidence from a Matched Sample of Borrowers and Banks, Journal of Business, 75: 559-81.

Hubbard, R.G., (1995). Is there a "Credit Channel" for Monetary Policy? Federal Reserve Bank of Saint Louis Review, 77: 63-77.

Hamilton, J.D., (1994). Time Series Analysis. Princeton University Press.

Hansen, B.E., (2001). The New Econometrics of Structural Change: Dating Breaks in US Labour Productivity, Journal of Economic Perspectives, 15: 117-128.

Hansen, L.P., (1982). Large Sample Properties of Generalized Method of Moments Estimator, Econometrica, 50: 1029 – 1054.

Harimohan, R., (2012). How has the Risk to Inflation from Inflation Expectations Evolved? Bank of England Quarterly Bulletin, Q2: 52: 114 – 123.

Helbling, T., Huidrom R., Kose, M. and C. Otrok, (2011). Do Credit Shocks Matter? A Global Perspective, European Economic Review, 55: 340–353

Hendry, D.F. and N.R. Ericsson, (1991). Modelling the Demand for Narrow Money in the United Kingdom and the United States, European Economic Review, 35: 1131-1151.

Heracleous, M.S., Koutris, A. and A. Spanos (2006). Testing for Structural Breaks and other forms of Non-stationarity: a Misspecification Perspective, Society for Computational Economics, Computing in Economics and Finance, RePEc, No. 493.

Hodson, D., and D. Mabbett, (2009). UK Economic Policy and the Global Financial Crisis: Paradigm Lost? JCMS: Journal of Common Market Studies, 47: 1041–1061.

Holtemoller, O., (2002). Identifying a Credit Channel of Monetary Policy Transmission and Empirical Evidence for Germany. Humboldt-Universitat zu Berlin Sonderforschungsbereich, WP/373.

Iacoviello, M., (2005). House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle, American Economic Review, 95: 739-764.

Iacoviello, M. and S. Neri, (2010). Housing Market Spillovers: Evidence from an Estimated DSGE Model. American Economic Journal: Macroeconomics, American Economic Association, 2: 125-64.

Iacoviello, M., (2011). Housing Wealth and Consumption," International Finance Discussion Papers 1027, Board of Governors of the Federal Reserve System, U.S.

Iacoviello, M. and R. Minetti, (2008). The Credit Channel of Monetary Policy: Evidence from the Housing Market, Journal of Macroeconomics, 30: 69-96.

Iacoviello, M., (2015). Financial Business Cycles, Review of Economic Dynamics, 18: 140-164.

Im, K.S., Lee J. and M. Tieslau, (2005). Panel LM Unit Root Tests with Level Shifts, Oxford Bulletin of Economics and Statistics, 67: 393–419.

IMF, (2008). Global Financial Stability Report, October, Washington D C: IMF.

Ireland, P.N., (2005). Technology Shocks in the New Keynesian Model. Review of Economics and Statistics, 86: 923-936.

Ireland, P.N., (2006). The Monetary Transmission Mechanism, Working Paper Series, Federal Reserve Bank of Boston, NBER No. 06-1.

Issing, O., (2003). Monetary and Financial Stability: Is There a Trade-off? BIS Working Paper, No. 18.

Issing, O., (2012). The Mayekawa Lecture: Central Banks—Paradise Lost. Bank of Japan Monetary Economics Study, 30: 55–74.

Jang, K. and M. Ogaki, (2003). The Effects of Japanese Monetary Policy Shocks on Exchange Rates: A Structural Vector Error Correction Model Approach, Monetary and Economic Studies, 21: 1-34.

Jank, K., (2001). A Structural Vector Error Correction Model with Short-Run and Long-Run Restrictions, Manuscript, Ohio State University, Department of Economics.

Jefferys, H., (1961). Theory of Probability, 3rd Edn., Oxford University Press, Oxford.

Johansen, S., (1992). Determination of Cointegration Rank in the Presence of a Linear Trend, Oxford Bulletin of Economics and Statistics, 54: 383-399.

Johansen, S., (1991). Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian vector autoregressive models, Econometrica, 59: 1551-81.

Jorgenson, D., (1963). The American Economic Review. Papers and Proceedings, the American Economic Association. 53: 247-259.

Joyce, M., Tong, M. and R. Woods, (2011). The United Kingdom’s Quantitative Easing Policy: Design, Operation and Impact’, Bank of England Quarterly Bulletin, Q3: 200–212.

Jingyuan, L. and T. Guoqiang, (2008). Time Inconsistency and Reputation in Monetary Policy: A Strategic Model in Continuous Time. Acta Mathematica Csientia, 28: 697-710.

Judd, J.P. and G.D. Rudebusch, (1998). Taylor's Rule and the Fed: 1970-1997, Economic Review, Federal Reserve Bank of San Francisco, 3: 3-16.

Jeanne, O. and A. Korinek, (2010). Managing Credit Booms and Busts: A Pigouvian Taxation Approach. NBER Working Papers, No. 16377,

Jermann, U. and E. Quadrini, (2009). Macroeconomic Effects of Financial Shocks, NBER Working Paper, No. 15338.

Kapetanios, G., Mumtaz, H., Stevens, I., and K. Theodoridis, (2012). Assessing the Economy-wide Effects of Quantitative Easing’, Bank of England Working Paper, No. 443.
Kara, H. and F. Ogunc, (2005). Exchange Rate Pass-Through in Turkey: It is Slow, but is it

Really Low? The Central Bank of the Republic of Turkey, Research and Monetary Policy Department Working Papers, No. 05/10.

Karasoy, A., Kunter, K. and V. Us, (2005). Monetary Transmission Mechanism in Turkey under Free Float using a Small-Scale Macroeconomic Model, Economic Modelling, 22: 1064–1073.

Kashyap, A. K., and J.C. Stein, (2000). What do a Million Observations on Banks Say about the Transmission of Monetary Policy? American Economic Review, 90: 407–428.

Kashyap, A., Lamont, O. and J. Stein, (1994). Credit Conditions and the Cyclical Behaviour of Inventories, Quarterly Journal of Economics, 109: 565–592.

Kashyap, A., Stein, J. and W. Wilcox, (1993). Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance, American Economic Review, 83: 78–98.

Kashyap, A. K. and J. C. Stein, (1997). The Role of Banks in Monetary Policy: A Survey with Implications for the European Monetary Union. Economic Perspectives (FRB of Chicago) 21: 2–18.

Kass, R. and A. Raftery, (1995). Bayes Factors. Journal of the American Statistical Association, 90: 773–795.

Kedar-Levy, H., (2016). A Critical History of Financial Crisis. Why Would Politicians and Regulators Spoil Financial Giants? Imperial College Press.

Kejriwal, M. and P Perron (2010). Testing for Multiple Structural Changes in Cointegrated Regression Models, Journal of Business and Economic Statistics, American Statistical Association, 28: 503-522.

Keyenes, J.M. (1936). The General Theory of Employment, Interest, and Money, London, Macmillan and Co.

Kiley, M.T., (2013). Output gaps, Journal of Macroeconomics, 37: 1-18.

Kim S. and N. Roubini, (2000), Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach, Journal of Monetary Economics, 45: 561–586.

Kim, H.E., (1999). Was Credit Channel a Key Monetary Transmission Mechanism Following the Recent Financial Crisis in the Republic of Korea? The World Bank Policy Research Working Paper, No. 3003.

Kimball, M.S., (1995), The Quantitative Analytics of the Basic Neomonetarist Model, Journal of Money, Credit, and Banking, 27: 1241–1277.

King, R. G., Plosser, C.I. and S. Rebelo, (1988). Production, Growth, and Business Cycles: The Basic Neoclassical Model, Journal of Monetary Economics, 21: 195–232.

King, M., (1997). Rules and Discretion in Monetary Policy, Journal of Monetary Economics, 39: 81–97.

King, M., (2002). No Money, no Inflation: The Role of Money in the Economy. Bank of England Quarterly Bulletin, London.

King, R. G., Plosser, C.I. Stock, J.H. and M.W. Watson, (1991). Stochastic Trends and Economic Fluctuations, American Economic Review, 81: 819-840.

Kishan, R.P. and T.P. Opiela, (2000). Bank Size, Bank Capital, and the Bank Lending Channel, Journal of Money, Credit, and Banking, 32: 121–141.

Kiyotaki, N. and J. Moore, (1997). Credit Cycles, Journal of Political Economy, 2: 99- 105.

Klose, J., (2014). Determining Structural Breaks in Central Bank Reaction Functions of the Financial Crisis. The Journal of Economic Asymmetries, 11: 78-90.

Knotek, E., (2009). A Tale of Two Rigidities: Sticky Prices in a Sticky-Information Environment, Federal Reserve Bank of Kansas City, RWP, 05-15.

Kolasa, M. and G. Lombardo, (2014). Financial Frictions and Optimal Monetary Policy in an Open Economy. International Journal of Central Banking, 10: 43-94.

Koop, G. and S. Potter, (2007). Estimation and Forecasting in Models with Multiple Breaks. Review of Economic Studies, 74: 763-789.

Koop G.A., Leon-Gonzalez, R. and R.W. Strachan, (2009). On the Evolution of the Monetary Policy Transmission Mechanism, Journal of Economic Dynamics and Control, 33: 997–1017.

Kosfeld, R., (2002). Asset Price Channel and Financial Markets, Journal of Economics and Statistics (Jahrbuecher fuer Nationaloekonomie und Statistik), Justus-Liebig University Giessen, Department of Statistics and Economics, 222: 440-462.

Krainer, R.E., (2014). Monetary Policy and Bank Lending in the Euro Area: Is there a Stock Market Channel or an Interest Rate Channel. Journal of International Money and Finance, 49: 283-298.

Kremer, J., Giovanni Lombardo, G., Thadden, L. and T. Werner, (2006). Dynamic Stochastic General Equilibrium Models as a Tool for Policy Analysis, CESifo Economic Studies, 52: 640–665.

Kuttner K.N., and P.C. Mosser, (2002). Monetary Transmission Mechanism: Some Answer and Further Questions. FRBNY. Economic Policy Review, Staff Reports/Research Papers no. 111, Federal Reserve Bank of New York, NY.

Kydland, F. and E. Prescott, (1977). Rules Rather than Discretion: The Inconsistency of Optimal Plans, Journal of Political Economy, 85: 473-90.

Kydland, F.E. and E.C. Prescott, (1982). Time to Build and Aggregate Fluctuations, Econometrica, 50: 1345 –1370.

Laidler, D., (1984). The Buffer Stock Notion in Monetary Economics, Economic Journal, 94: 17-34.

Lanne, M. and H. Lutkepohl, (2008). Identifying Monetary Policy Shocks via Changes in Volatility, Journal of Money, Credit and Banking, 40: 1131 – 1149.

Lanne, M. and H. Lutkepohl, (2010). Structural Vector Autoregression with Non-normal Residuals, Journal of Business and Economics Statistics, 28: 159 – 168.

Lanne, M. and Lutkepohl, H. and K. Maciejowska, (2010). Structural Vector Autoregressions with Markov Switching, Journal of Economic Dynamics and Control, 34: 121 – 131.

Le, V.P.M., Meenagh, D., Minford, P. and M. Wickens, (2012a). Testing DSGE Models by Indirect Inference and other Methods: Some Monte Carlo Experiments, Cardiff Economics Working Paper, No. E2012/15.

Le, V.P.M., Meenagh, D. and P. Minford, (2012b). What Causes Banking Crises? An Empirical Investigation, Cardiff Economics Working Paper, No. E2012/14.

Lea, M.J., Welter, R. and A. Dubel, (1997). Study on Mortgage Credit in the European Economic Area, European Commission, Directorate General XXIV and Empirica.

Lea, R., (2015). UK Exports of Insurance and Financial Services are Crucially Important, but EU share is falling as growth disappoints, Economists for Britain (EfB) Perspective 4.

Lee, J. and M. Strazicich, (2001). Testing the Null Hypothesis of Stationarity in the Presence of Structural Breaks. Applied Economic Letters, 8: 377-382.

Lee, J. and M. Strazicich, (2001). Break Point Estimation and Spurious Rejections with Endogenous Unit Root Tests. Oxford Bulletin of Economics and Statistics, 63: 535-558

Lee, J. and M. Strazicich, (2003). Minimum Lagrange Multiplier Unit Root Tests with Two Structural Breaks. Review of Economics and Statistics, 81: 1082-1089.

Lee, C.C. and J.D. Lee, (2009). Energy Prices, Multiple Structural Breaks, and Efficient Market Hypothesis. Applied Energy 86: 466 – 479.

Leeper, E. M., Sims, C. A. and T. Zha, (1996). What Does Monetary Policy Do? Brookings Papers on Economic Activity, 2: 1-78.

Lensink, R. and E. Sterken, (2002). Monetary Transmission and Bank Competition in the EMU, Journal of Banking and Finance, 26: 2065–2075.

Leybourne, S. and P. Newbold, (2003). Spurious Rejections by Cointegration Tests Induced by Structural Breaks', Applied Economics, 35: 1117-1121.

Litterman, R. B., (1986). Forecasting with Bayesian Vector Autoregressions: 5 Years of Experience. Journal of Business and Economic Statistics, 4: 25–38.

Liu, P., Mumtaz, H., and A. Theophilopoulou, (2011). International Transmission of Shocks: a Time-Varying Factor-Augmented VAR Approach to the Open Economy. Bank of England WP 425, Bank of England.

Liu, J., Wu, S. and J.V. Zidek, (1997). On Segmented Multivariate Regression, Statistica Sinica, 7: 497–525.

Liu, M., (2000). Modelling Long Memory in Stock Market Volatility. Journal of Econometrics, 99: 139–171.

Lin, S., (2010). On the international effects of inflation targeting. Review of Economic Statistics. 92: 195–199.

Liu, C. and P. Minford, (2014). How Important is the Credit Channel? An Empirical Study of The US Banking Crisis, Journal of Banking and Finance, 41: 119–134.

Loayza, N. and K. Schmidt-Hebbel, (2002). Monetary Policy Functions and Transmission Mechanisms. An Overview, World Bank and Central Bank of Chile.

Lohmann, S., (1992). Optimal Commitment in Monetary Policy, American Economic Review, 82: 273-286.

Lombardo, G. and P. McAdam, (2010). Financial Market Frictions in a Small Open Economy for the Euro Area. Technical Report.

Lombardo, G. and P. McAdam, (2012). Financial Market Frictions in a Model of the Euro Area, Economic Modelling, Elsevier, 29: 2460-2485.

Lown, C., and S. Peristiani, (1996). The Behaviour of Consumer Loan Rates During the 1990 Credit Slowdown, Journal of Banking and Finance, 20: 1,673-94.

Lucas, R.E., (1972). Expectations and the Neutrality of Money, Journal of Economic Theory, 4: 103-124.

Lucas, R.E., (1973). Some International Evidence on Output Inflation Trade-offs. American Economic Review 63: 326–335.

Lucas, R.E., (1976). Econometric Policy Evaluation: A Critique, Carnegie-Rochester Conference Series on Public Policy, 1: 19-46.

Lucas, R.E., (1980). Methods and Problems in Business Cycle Theory, Journal of Money, Credit and Banking, 12: 696-715.

Ludvigson, S., Steindel, C., and M. Lettau, (2002). Monetary Policy Transmission through the Consumption-wealth Channel, Economic Policy Review, Federal Reserve Bank of New York, Issue May: 117-133.

Ludvigson, S., (1998). The Channel of Monetary Transmission to Demand: Evidence from the Market for Automobile Credit. Journal of Money, Credit and Banking, 30: 366–383.

Luetkepohl, H., (2005). Structural Vector Autoregressive Analysis for Cointegrated Variables, Economics Working Papers, No. ECO2005/02, European University Institute.

Lumsdaine, R.L. and D.H. Papell, (1997). Multiple Trend Breaks and the Unit Root Hypothesis. Review of Economics and Statistics, 79: 212-218.

Maddala, G. S. and I.M. Kim, (1998) Unit Roots, Cointegration and Time Series, Cambridge University Press.

Maddala, G.S. and I.M. Kim, (2003). Unit Root, Cointegration and Structural Change, Cambridge University Press, Fifth Edition, UK.

Mankiw, N.G., (1992). The Reincarnation of Keynesian Economics, European Economic Review, 36: 559–565.

Marotta, G., (2009). Structural Breaks in the Lending Interest Rate Pass-Through and the Euro, Economic Modelling, Elsevier, 26: 191-205.

Markovic, B., (2006). Bank Capital Channels in the Monetary Transmission Mechanism, Bank of England, Working Paper, No. 313.

Martin, C. and C. Milas, (2013). Financial Crises and Monetary Policy: Evidence from the UK, Journal of Financial Stability, 9: 654– 661.

Martin C. and C. Milas, (2004). Modelling Monetary Policy: Inflation Targeting in Practice, Economica, LSE and Political Science, 71: 209-221, 05.

Matsuki, T. and K. Sugimoto, (2013). Stationarity of Asian Real Exchange Rates: an Empirical Application of Multiple Testing to Non-Stationary Panels with a Structural Break, Economic Modelling, 34: 52-58.

Mauskopf, E., (1990). The Transmission Channels of Monetary Policy: How have they Changed? Federal Reserve Bulletin, 76: 961- 985.

Mehrotra, A. and J.R. Sanchez-Fung, (2011). Assessing McCallum and Taylor Rules in a Cross-Section of Emerging Market Economies. Journal of International Financial Markets, Institutions and Money, 21: 207-228.

McCafferty, I., (2013). Inflation Targeting and Flexibility. Speech at the Monetary Policy Committee, Bank of England, Hosted by the Wall Street Journal at Eight Member Club, London.

McCallum, B.T., (1979). The Current State of the Policy-Ineffectiveness Debate, American Economic Review, 69: 240–245.

McCallum, B.T., (1984). Credibility and Monetary Policy, NBER Working Papers, No. 1490, National Bureau of Economic Research, Inc.

McCallum, B.T., (1987). The Case for Rules in the Conduct of Monetary Policy: A Concrete Example," Federal Reserve Bank of Richmond Economic Review, 73: 10–18.

McCallum, B.T., (1988). Robustness Properties of a Rule for Monetary Policy, Carnegia-Rochester Conference Series on Public Policy, 29: 173-204.

McCallum, B.T., (1990), Targets, Indicators and Instruments of Monetary Policy, In: W. Haraf and W.Cagan (Eds.), Monetary Policy for a Changing Financial Environment, AEI Press, Washington DC: 44-70.

McCallum, B.T., (1993). Specification and Analysis of a Monetary Policy Rule for Japan, WP 4449, National Bureau of Economic Research.

McCallum, B.T., (1996). Crucial Issues Concerning Central Bank Independence, NBER Working Papers, No. 5597, National Bureau of Economic Research.

McCallum, B.T., (1999). Analysis of the Monetary Transmission Mechanism. Methodological Issues, NBER Working Paper, No. 7395, Cambridge, Massachusetts, National Bureau of Economic Research.

McCallum, B.T., (2000). Alternative Monetary Policy Rules: A Comparison with Historical Settings for the United States, the United Kingdom, and Japan. In: Taylor (Ed), Papers from the Riksbank-IIES Conference, June 1999 issue of the Journal of Monetary Economics. 49-79.

McCallum, B.T., (2002). Monetary Policy Rules and the Japanese Deflation, Conference Paper, Workshop, the Economic and Social Research Institute.

McCallum, B.T., (2002). Recent Developments in Monetary Analysis: The Roles of Theory and Evidence, Economic Quarterly, Winter Issue, Federal Reserve Bank of Richmond: 67-96.

McCallum B.T., (2006). Policy-Rule Retrospective on the Greenspan Era. Shadow Open Market Committee, Manuscript, May 8.

McCallum, B.T. and E. Nelson, (1999). Performance of Operational Policy Rules in an Estimated Semi classical Structural Model, in Monetary Policy Rules, ed. by John B. Taylor (Chicago: University of Chicago Press for NBER).

McCallum, B.T. and E. Nelson, (1999). Nominal Income Targeting in an Open-Economy Optimizing Model. Journal of Monetary Economics 43: 553–578.

Meier, A. and G.J. Mueller, (2006). Fleshing out the Monetary Transmission Mechanism: Output Composition and the Role of Financial Frictions. Journal of Money, Credit and Banking, 38: 2099–2134.

Meltzer A. H., (1995). Monetary, Credit and (Other) Transmission Process: A Monetarist Perspective, Journal of Economic Perspectives, 9: 40-72.

Merola, R., (2015). The Role of Financial Frictions During the Crisis: An Estimated DSGE model. Economic Modelling, 48: 70–82.

Metin, T., (2015). Sustainability of Social Security Policies in Turkey: Cointegration Analysis with Multiple Structural Breaks, Business and Economics Research Journal, 6: 1309-2448.

Mihailov, A., (2006). Operational Independence, Inflation Targeting and UK Monetary Policy, Economics Discussion Papers 602, University of Essex, Department of Economics.

Milani, F., (2012). The Modelling of Expectations in Empirical DSGE ModelS. A Survey: In Balke, N., Canova, F., Milani, F. and M.A. Wynne, (2012). DSGE Models in Macroeconomics: Estimation, Evaluation and New Developments. Emerald Group Publishing Limited, UK.

Milcheva, S., (2013). A Bank Lending Channel or a Credit Supply Shock? Journal of Macroeconomics 37: 314–332.

Minella, A. and N.F. Souza-Sobrinho, (2013). Monetary Policy Channels in Brazil through the Lens of a Semi-Structural Model, Journal of Economic Modelling, 30: 405–419.

Minea, A. and R. Topsoba, (2014). Does Inflation Targeting Improve Fiscal Discipline? Journal of International Money and Finance, 40: 185–203.

Mishkin, F. S., (1995). Symposium on the Monetary Transmission Mechanism, Journal of Economic Perspectives, 9: pp. 3-10.

Mishkin, F.S., (1996). The Channels of Monetary Transmission: Lesson for Monetary Policy. NBER, No. 27.

Mishkin, F.S., (2000). Inflation Targeting in Emerging-market Countries. American Economic Review, 90: 105–109.

Mishkin, F. and K. Schmidt-Hebbel, (2007a). Does Inflation Targeting Make a Difference? NBER. WP No. 12876.
Mishkin, F.S., (2001). The Transmission Mechanism and The Role of Asset Price in Monetary Policy, Working Paper, No. 8617, NBER.

Mishkin, F.S., (1997). The Causes and Propagation of Financial Instability: Lessons for Policy Makers, Proceedings - Economic Policy Symposium - Jackson Hole, Federal Reserve Bank of Kansas City, pages 55-96.

Mishkin, F.S., (2008). Global Financial Turmoil and the World Economy, Speech Given at the Caesarea Forum of the Israel Democracy Institute, Eliat, Israel.

Mishkin, F.S., (2011). Monetary Policy Strategy: Lessons from the Crisis, in: Monetary Policy Revisited. Presented at the ECB Central Banking Conference, The ECB Central Banking Conference, Frankfurt, 2–46.

Modigliani, F., (1971). Liquidity Preference and the Theory of Interest and Money. Econometrica, 12, No. 1:44-88.

Mojon B. and G. Peersman, (2001). A VAR Description of the Effects of Monetary Policy in the Individual Countries of the Euro Area, ECB Working Paper, No. 92.

Moron, E. and D. Winkelried, (2005). Monetary Policy Rules for Financially Vulnerable Economies. Journal of Development Economics, 76: 23–51.

Mountford, A. and H. Uhlig, (2009). What are the Effects of Fiscal Policy Shocks? Journal of Applied Econometrics, 24: 960 - 992.

Mundell, R. A., (1963). Capital Mobility and Stabilisation Policy under Fixed and Flexible Exchange Rates, Canadian, Journal of Economics, 29: 475-485.

Murchison, S. and A. Rennison, (2006) ToTEM: The Bank of Canada's New Quarterly Projection Model, Technical Reports 97, Bank of Canada.

Narayan, P.K. and R. Smyth, (2005). Electricity Consumption, Employment and Real Income in Australia, Evidence from Multivariate Granger Causality Tests. Energy Policy, 33: 1109-1116.

Narayan, P.K., (2006). Examining Structural Breaks and Growth Rates in International Health Expenditures, Journal of Health Economics, 25: 877-890.

Narayan, P.K., (2008). Is Asian Per Capita GDP Panel Stationary? Empirical Economics, 34: 439-449.

Narayan, P.K., (2010). Evidence on PPP for Selected Asian Countries from a Panel Cointegration Test with Structural Breaks, Applied Economics, Taylor and Francis Journals, 42: 325-332.

Narayan, P.K. and S. Popp, (2010). A New Unit Root Test with two Structural Breaks in Level and Slope at Unknown Time, Journal of Applied Statistics, 37: 1425-1438.

Narayan, P.K. and S. Popp, (2013). Size and Power Properties of Structural Break Unit Root Tests, Applied Economics, Taylor and Francis Journals, 45: 721-728.

Narayan, P.K. and R. Smyth, (2008). Are Oil Shocks Permanent or Temporary? Panel Data Evidence from Crude Oil and NGL Production in 60 Countries, Energy Economics, 30: 919-936.

Narayan, P. and A. Prasad, (2007). Mean Reversion in Stock Prices: New Evidence from Panel Unit Root Tests for Seventeen European Countries. Economics Bulletin, 3: 1-6.

Narayan, P.K. and R. Liu, (2013). New Evidence on the Weak-form Efficient Market Hypothesis. Working Paper, Centre for Financial Econometrics, Deakin University

Narayan, P.K. and P. Wong, (2009). A Panel Data Analysis of the Determinants of Oil Consumption: The Case of Australia, Applied Energy, 86: 2771–2775.

Nelson, C.R. and C.I. Plosser, (1982). Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications. Journal of Monetary Economics, 10: 139-162.

Nelson, C.R., and C.J. Murray, (2000). The Uncertainty Trend I U.S. GDP. Journal of Monetary Economics, 10: 139-162.

Neumann, M., (1991). Pre-commitment by Central Bank Independence. Open Economies Review, 2: 95-112.

Ng, S. and P. Perron, (1995). Unit Root Tests in ARMA Models with Data Dependent Methods for the Selection of the Truncation Lag, Journal of American Statistical Association, 90: 268-281.

Nikolsko-Rzhevskyy, A., Papell, D. and R. Prodan, (2014). Deviations from Rules-Based Policy and Their Effects, Journal of Economic Dynamics and Control, 49: 4-17.

Nordhaus, W., (1975). The Political Business Cycle. Review of Economic Studies 42: 169-90. In Alesina, A. and L. Summers, (1993). Central Bank Independence and Macroeconomic Performance: Some Comparative Evidence, Journal of Money, Credit, and Banking, 25: 151-162.

Noriega, A.E. and L.M. Soria, (2002). Structural Breaks, Orders of Integration, and the Neutrality Hypothesis: Further Evidence, Computing in Economics and Finance, 353. Society for Computational Economics.

Nunes, L., Newbold, P. and C. Kuan, (1997). Testing for Unit Roots with Breaks: Evidence on the Great Crash and the Unit Root Hypothesis Reconsidered. Oxford Bulletin of Economics and Statistics, 59: 435-448.

Office for the National Statistics (ONS), (2011/2015 & various).

Ohara, H.I., (1999). A Unit Root Test with Multiple Trend Breaks: A Theory and Application to US and Japanese Macroeconomic Time Series. The Japanese Economic Review, 50: 266-290.

Oliner, S.D. and G.D. Rudebusch, (1995). Is there a Bank Lending Channel for Monetary Policy? Federal Reserve Bank of San Francisco Economic Review 2: 3–20.

Oliner, S.D and G.D Rudebusch, (1996). Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance: Comment, American Economic Review, 87, 495–505.

Orphanides, A., (2003). Historical Monetary Policy Analysis and the Taylor Rule, Journal of Monetary Economics, 50: 983-1022.

Orphanides, A. and V. Wieland, (2000). Efficient Monetary Policy Design Near Price Stability, Journal of the Japanese and International Economies, 14: 327-365.

Pain, N., Lewis, C., Dang, T.T., Jin, Y. and P. Richardson, (2014). OECD forecasts during and after the financial crisis: A post mortem. In: Jannsen, N., Potjagailo, G. and M.H. Wolters, (2015). The Monetary Policy during Financial Crises: Is the Transmission Mechanism Impaired. Kiel Working Paper, No. 2005. Kiel Institute for the World Economy, Kiellinie 66, 24105 Kiel, Germany.

Paez-Farrell, J., (2009). Monetary Policy Rules in Theory and in Practice: Evidence from the UK and the US, Applied Economics, 41: 2037-2046

Palley, T.I., (1993). Milton Friedman and the Monetarist Counter-Revolution: A Re-appraisal, Eastern Economic Journal, Eastern Economic Association, 19: 71-81.

Papadamou, S., Sidiropoulos, M. and E. Spyromitros, (2014). Does Central Bank Transparency affect Stock Market Volatility? Journal of International Finance, 31: 362–377.

Patterson, K., (1987). The Specification and Stability of the Demand for Money in the United Kingdom, Economica, 54, 41-55.

Patra, M.D. and M. Kapur, (2012). Alternative Monetary Policy Rules for India, International Monetary Fund (IMF), WP/12/118.

Pauly, L., (2009). The Old and the New Politics of International Financial Stability. JCMS: Journal of Common Market Studies, 47: 955–75.

Peebles,P. Z., (2001). Probability, Random Variables and Random Signal Principles, McGraw-Hill Inc, Boston, ISBN 0-07-118181-4

Peek, J. and E. Rosengren, (2010). The Role of Banks in the Transmission of Monetary Policy, In The Oxford Handbook of Banking, Allen Berger, Philip Molyneux, and John Wilson, Eds. Oxford: Oxford University Press.

Peersman, G. and F. Smets, (2001). The Monetary Transmission Mechanism in the Euro Area: Evidence from VAR Analysis, ECB, WP No. 91

Peersman, G., (2010). Macroeconomic Consequences of Different Types of Credit Market Disturbances and Non-conventional Monetary Policy in the Euro Area. Mimeo, University of Ghent.

Peersman, G. and R. Straub, (2005). Technology Shocks and Robust Sign Restrictions in a Euro Area VAR, ECB Working Paper, No. 373.

Perron, P. and T. Vogelsang, (1992). Nonstationarity and level shifts with an application to purchasing power parity, Journal of Business and Economic Statistics, 10: 301-320.

Perron, P., (1989). The Great Crash, the Oil Price Shock and the Unit Root Hypothesis, Econometrica, 57: 1361-1401.

Perron, P., (1990). Testing for a Unit Root in a Time Series with a Changing Mean, Journal of Business and Economic Statistics, 8: 153-162.

Perron, P., (1994). Trend, Unit Root and Structural Change in Macroeconomic Time Series. In: Rao, B.B. (Ed.), Cointegration for the Applied Economist, MacMillan Press: Basingstoke, pp. 113-146.

Perron, P., (1997). Further Evidence on Breaking Trend Functions in Macroeconomic Variables, Journal of Econometrics, 80: 355-385.

Perron, P. and Z. Qu, (2006). Estimating Restricted Structural Change Models, Journal of Econometrics, 134: 373-399.

Perron, P. and Y. Yamamoto, (2014). A Note On Estimating And Testing For Multiple Structural Changes In Models With Endogenous Regressors Via 2sls, Econometric Theory, Cambridge University Press, 30: 491-507.

Pesaran, M. H., Pettenuzzo, D, and A. Timmermann, (2006). Forecasting Time Series Subject to Multiple Structural Breaks. Review of Economic Studies 73, 1057-1084.

Phelps, E.S. and J.B. Taylor, (1977). Stabilizing Powers of Monetary Policy under Rational Expectations, Journal of Political Economy, 85: 163-190.

Phillips, A. W. (1958). The Relationship between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957', Economica, 25: 283–299.

Phillips, P.C.B., (1986). Understanding Spurious Regression in Econometrics, Journal of Econometrics, 33: 311-40.

Phillips, P.C.B., (1987). Time Series Regressions with a Unit Root, Econometrica, 55: 227-301.

Phillips, P.C.B. and P. Perron, (1988). Testing for Unit Roots in Time Series Regression, Biometrika, 75: 335-346.

Phiromswad, P., (2015). Measuring Monetary Policy with Empirically Grounded Restrictions: and Application to Thailand. Journal of Asian Economics, 28: 104 – 113.

Plosser, C.I., (1989). Understanding Real Business Cycles, Journal of Economic Perspectives, American Economic Association, 3: 51-77.

Poddar, T, Goswami, M., Sole, J. and V.E. Ecaza, (2006). Interest Rate Determination in Lebanon, IMF WP, WP/06/94.

Polillo, S. and M.F. Guillén, (2005). Globalization Pressures and the State: the Worldwide Spread of Central Bank Independence. In: Arnone, M. and D. Romelli, (Eds), Dynamic Central Bank Independence Indices and Inflation Rate: A New Empirical Exploration, Journal of Financial Stability, 9: 385– 398.

Prescott, E.C. and R.M. Townsend, (1984). General Competitive Analysis in an Economy with Private Information. International Economic Review, 25: 1-20.

Queijo von Heideken, V., (2009). How Important are Financial Frictions in the U.S. and the Euro Area? Scandinavian Journal of Economics, 111: 567–596.

Qu, Z., (2011). A Test Against Spurious Long Memory. Journal of Business Economics and Statistics, 29: 423–438.

Raj, B., (1992). International Evidence on Persistence in Output in the Presence of an Episodic Change, Journal of Applied Econometrics, 7: 281-293.

Ramey, V. A., (1993). How Important is the Credit Channel in the Transmission of Monetary Policy? University of California.

Rapach, D. and M. Wohar, (2004). Testing the Monetary Model of Exchange Rate Determination: a Closer Look at Panels, Journal of International Money and Finance, 23: 867-895

Ravenna, F. and C.E. Walsh, (2006). Optimal Monetary Policy with the Cost Channel, Journal of Monetary Economics 53: 199 -216.

Rigbon, R., (2003), Identification through Hetrosekedasticity, Review of Economics and Statistics, 85: 777-792.

Rigobon, R. and B. Sack, (2003). Measuring the Reaction of Monetary Policy to the Stock Market, The Quarterly Journal of Economics, 118: 639-669.

Rogoff, K., (1985). The Optimal Degree of Commitment to an Intermediate Money Target. Oxford Journals - The Quarterly Journal of Economics, 100: 1169 – 1189.

Romer, C.D. and D.H. Romer, (1989). Does Monetary Policy Matter? A New Test in the Spririt of Friedman and Schwartz., In: Boivin, J., and M. Giannoni, (Eds), Has Monetary Policy Become More Effective? Review of Economics and Statistics, 88: 445–462.

Romer, C.D. and D.H. Romer, (1990). New Evidences on the Monetary Transmission Mechanism, Brookings Papers on Economic Activity, 1: 149-213.

Rose, A., (2007). A Stable International Monetary System Emerges: Inflation Targeting is BrettonWoods, Reversed, Journal of International Finance, 26: 663–681.

Rotemberg, J. and M. Woodford, (1997). An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy, NBER Macroeconomics Annual: 297-361.

Rothenberg, J., (1971). Identification in Parametric Models, Econometrica, 39: 577–591.

Rubio-Ramirez, J. F., Waggoner, D. F. and T. Zha, (2010). Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference. Review of Economic Studies, 77: 665-696.

Rudebusch, G.D., (1998). Do Measures of Policy in a VAR Make Sense? International Economic Review, 39: 907–931.

Rudebusch, G.D., (2002). Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty. Economic Journal, 112: 402–432.

Rudebusch, G.D. and L.E.O. Svensson, (1999). Policy rules for inflation targeting. In: Taylor, J.B. (Ed.), Monetary Policy Rules. University of Chicago Press, Chicago.

Said, S.E. and D.A. Dickey, (1984). Testing for Unit Roots in Autoregressive Moving Average Models of Unknown Order. Biometrika, 71: 599-607.

Salmon, C., (1995). Influences on Broad Money Growth', Bank of England Quarterly Bulletin, 46-53.

Samuelson, P.A. and R.M. Solow, (1960). Analytical Aspects of Anti-inflation Policy. American Economic Review, 50: 177–194.

Sargent, T.J. and N. Wallace, (1975). Rational Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule, Journal of Political Economy, 83: 241 – 254.

Sargent, T.J. and N. Wallace, (1985). Identification and Estimation of a Model of Hyperinflation with a Continuum of "sunspot" Equilibrium, Federal Reserve Bank of Minneapolis, Working Papers, No. 280.

Sbordone, A.M., Tambalotti, A., Krishna R. and K. Walsh, (2010). Policy Analysis Using DSGE Models: An Introduction, Economic Policy Review, 16: 23–43.

Schmidt, P., and P.C.B. Phillips, (1992). LM Tests for a Unit Root in the Presence of Deterministic Trends, Oxford Bulletin of Economics and Statistics, 54, 257-87

Schwartz, A., (1998). Why Financial Stability Depends on Price Stability, G. Wood (Ed.), Money Prices and the Real Economy, IEA: 34–41.

Sen, A., (2003). On Unit Root Tests When the Alternative is a Trend Break Stationary Process, Journal of Business and Economic Statistics, 21: 174-184.

Seymen, A., (2008). A Critical Note on the Forecast Error Variance Decomposition, ZEW Discussion Papers 08-065, ZEW - Zentrum für Europäische Wirtschaftsforschung, Center for European Economic Research.

Shabbir, A., (2008). Monetary Transmission Mechanism in Fiji and PNG. International Research, Journal of Finance and Economics, 15: 284–290.

Shao, X., (2011). A Simple Test of Changes in Mean in the Possible Presence of Long-Range Dependence, Journal of Time Series Analysis, 32: 598–606.

Shultz, G.P., (2014). The Importance of Rules Based Monetary Policy in Practice. Journal of Economic Dynamics and Control, 49:142-143.

Sims, C.A., (1980). Macroeconomics and Reality, Econometrica, 48: 1- 48.

Sims, C.A., (1986). Are Forecasting Models Usable for Policy Analysis? Minneapolis Federal Reserve Bank Quarterly Review, Winter, 2–16.

Sims C.A., (1990). Rational Expectations Modelling with Seasonally Adjusted Data, Discussion Paper. Institute for Empirical Macroeconomics No. 35, Federal Reserve Bank of Minneapolis.

Sims, C.A., (1992). Interpreting the Macroeconomic Time Series Facts: the Effects of Monetary Policy, European Economic Review, 36: 975-1011.

Sims, C.A., (1998). Comment on Glen Rudebusch's. Do Measures of Monetary Policy in a VAR Make Sense? International Economic Review, 39: 933 – 941.

Sims C.A., Stock, J.H. and M. Watson, (1990). Inference in Linear Time-Series Models with some Unit Roots, Econometrica, 58: 113-144.

Sims, C.A. and T. Zha, (2006a). Does Monetary Policy Generate Recessions? Macroeconomic Dynamics, 10, 231–272.

Sims, C. A. and T. Zha, (2006b). Were There Regime Switches in US Monetary Policy?, American Economic Review, 96, 54–81.

Sims, C.A. and T. Zha, (2005). Does Monetary Policy Generate Recessions? Research Paper, Federal Reserve Bank of Atlanta.

Smets, F., (1995). Central Bank Macroeconometric Models and the Monetary Policy Transmission Mechanism. In: BIS (Ed.), Financial Structure and the Monetary Policy Transmission Mechanism, C.B. 394.

Smets, F. and R. Wouters, (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area, Journal of The European Economic Association, 1: 1123-1175.

Smets, F. and R. Wouters, (2005). Comparing Shocks and Frictions in US and Euro Area Business Cycles: A Bayesian DSGE Approach. Journal of Applied Econometrics, 20: 161–183.

Smets, F. and R. Wouters, (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach, American Economic Review, 97: 586-606.

Smets, F., Christoffel, K., Coenen, G., Motto, R. and M. Rostagno, (2010). DSGE Models and Their Use at the ECB," SERIEs: Journal of the Spanish Economic Association, February, 1: 51–65.

Smets, F., (2014). Financial Stability and Monetary Policy: How Closely Interlinked? International Journal of Central Bank, 10: 263 – 300.

Smyth, R. and B. Inder, (2004). Is Chinese Provincial Real GDP per Capita Non-stationary? Evidence from Multiple Trend Break Unit Root Tests. China Economic Review, 15: 1–24.

Sorensen P.B. and H.J. Whitta-Jacobsen, (2010). Introducing Advanced Macroeconomics: Growth and Business Cycle, McGraw Hill Higher Educations, 2nd Education.

Stark T. and D. Croushore, (1996). Evaluating McCallum's Rule When Monetary Policy Matters, Federal Reserve Bank of Philadelphia WP, No. 96-3.

Stark, J., (2011). The Global Financial Crisis and the Role of Monetary Policy. Proceedings from the 13th Annual Emerging Markets Conference 2011. Washington.

Stock, J. H. and M.W. Watson, (1996). Evidence on Structural Instability in Macroeconomic Time Series Relations. Journal of Business and Economic Statistics, 14: 11–30.

Stock, J.H., (1999). A Class of Tests for Integration and Cointegration. In Cointegration, Causality, and Forecasting: A Festschrift for Clive W.J. Granger. Oxford: Oxford University Press, 135-167.

Strazicich, M.C., Lee J. and E. Day, (2004). Are Countries Converging Among OECD Countries? Time Series Evidence with two Structural Breaks, Journal of Macroeconomics, 26: 131-145.

Sun, L., (2010). Monetary Transmission Mechanisms and the Macroeconomy in China – VAR/VECM Approach and Bayesian DSGE Model Simulation, PhD thesis, University of Birmingham, Birmingham

Sun, S., Gan, C. and B. Hu, (2012). Evaluating McCallum Rule as Policy Guidelines for China, Joint Annual Conference of the New Zealand Association of Economics.

Surico, P. and E. Castelnuovo, (2009). Monetary Policy, Inflation Expectations and the Price Puzzle. Discussion Paper, 30. Bank of England.

Suzuki, T., (2004). Is the Lending Channel of Monetary Policy Dominant in Australia, Economic Record, 80: 145–156.

Svensson, L., (1997). Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets. European Economic Review, 41: 1111–1146.

Svensson, L.E.O., (2000). Open-Economy Inflation Targeting. Journal of International Economics, 50: 155-183.

Taglioni, D. and V. Zavacka, (2013). Innocent Bystanders: how Foreign Uncertainty Shocks Harm Exporters', ECB Working Paper, No. 1530.

Taylor, J.B., (1993). Discretion versus Policy Rules in Practice. Carnegie-Rochester Conference Series on Public Policy, 39: 195–214.

Taylor, J.B., (1995). The Monetary Transmission Mechanism. An Empirical Framework. Journal of Economic Perspectives, 9: 11-26.

Taylor, J.B., (1997). A Core of Practical Macroeconomics. American Economic Review, 87: 233-235.

Taylor J.B., (1998). Monetary Policy Guidelines for Employment and Inflation Stability, Inflation, Unemployment, and Monetary policy, The MIT Press, pp. 45.

Taylor J.B., (1999). A Historical Analysis of Monetary Policy Rules, In Monetary Policy Rules, University of Chicago Press.

Taylor, J.B., (2000a). Low Inflation, Pass-Through, and the Pricing Power of Firms. European Economic Review, 44: 1389-1408.

Taylor, J.B., (2000b). The Monetary Transmission Mechanism and the Evaluation of Monetary Policy Rules, Working Paper, No. 87, Central Bank of Chile.

Taylor, J.B., (2001). The Role of the Exchange Rate in Monetary Policy Rules. American Economic Review, 91: 263–267.

Taylor, J.B., (2013). Central Bank Independence: Reality or Myth? Discussion Paper, at the American Economic Association Annual Meeting, San Diego, California SIEPR Discussion Paper No. 12-009

Tobin, J., (1969). A General Equilibrium Approach To Monetary Theory, Journal of Money, Credit and Banking, Ohio State University Press, 1: 15-29. In: Boivin, J., Kiley, M.T. and F.S., Mishkin, (Eds). How has the Monetary Transmission Mechanism Evolved Over Time? NBER Working Paper, No. 15879.

Townsend, R.M., (1979). Optimal Contracts and Competitive Markets with Costly State Verification. Journal of Economic Theory, 21: 265–293.

Trifonova, S., (2012). The Role of Monetary Policy and Lessons from the Financial Crisis. Journal of US-China Public Administration, ISSN 1548-6591, 9: 1027-1038.

Uhlig, H., (2005), What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure. Journal of Monetary Economics, 52: 381-419.

Vigfusson, R.J., (2004). The Delayed Response to a Technology Shock: A Flexible Price Explanation, International Finance Discussion Paper Series 810. BG of the FR System, Washington.

Vilares, M.J., (1986). Structural Changes in Macroeconomic Models: Theory and Estimation. Martinus Nijhoff Publishers, the Netherlands.

Vosseler, A., (2014). Bayesian Model Selection for Unit Root Testing with Multiple Structural Breaks. Institute for Employment Research (IAB), Germany.

Villa, S. and J. Yang, (2011). Financial Intermediaries in an Estimated DSGE Model for the UK. Bank of England Working Paper, No. WP431.

Villa, S., (2013). Financial Frictions in the Euro Area: a Bayesian Assessment, Working Paper Series 1521, European Central Bank.

Vogelsang, T.J., (1997). Wald-type tests for Detecting Breaks in the Trend Function of a Dynamic Time Series, Econometric Theory, 13: 818-849.

Vogelsang, T.J., (2012). Heteroskedasticity, Autocorrelation, and Spatial Correlation Robust Inference in Linear Panel Models with Fixed-Effects, Journal of Econometrics, 166: 303-319.

Vogelsang, T.J. and P. Perron, (1998). Additional Tests for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time. International Economic Review 39: 1073-1100.

Volcker, P., (2010). How to Reform Our Financial System. The New York Times. Jan 20, 2010.

Weber, A., Gerke, R. and A. Worms, (2011). Changes in Euro Area Monetary Transmission? Applied Financial Economics, 21:131–145.

Walentin, K., (2005). Asset Pricing Implications of two Financial Accelerator Models. New York University.

Woodford, M., (2001). The Taylor Rule and Optimal Monetary Policy, in: Working Paper. Woodford Princeton University.

Woodford, M., (2003). Interest and Price: Foundation of a Theory of Monetary Policy, Princeton University Press.

Woodford, M., (2012). Inflation Targeting and Financial Stability, NBER Working Papers, No. 17967, National Bureau of Economic Research, Inc.

Wu, Y., (1999). More on Monetary Policy in a Small Open Economy, a Credit View, International Review of Economics and Finance, 8: 223–235.

Yamamoto, T. and P. Perron, (2013). Estimating and Testing Multiple Structural Changes in Linear Models using Band Spectral Regressions, Econometrics Journal, Royal Economic Society, 16: 400-429.

Wulandari, R., (2012). Do Credit Channel and Interest Rate Channel Play Important Role in Monetary Transmission Mechanism in Indonesia? A Structural Vector Autoregression Model, Procedia, Social and Behavioural Sciences, 65: 557 – 563.

Yiding, Y. and Z. Shuanghong, (2003). Empirical Analysis of the Monetary Policy Transmission through Interest Rate Channel in China. Working Paper.

Zha, T., (1999). Block Recursion and Structural Vector Autoregressions, Journal of Econometrics, 90: 291–316.

Zivot, E. and D.W.K. Andrews, (1992). Further Evidence on the Great Crash, the Oil Price Shock and the Unit Root Hypothesis. Journal of Business and Economic Statistics, 10: 251-270.

Zivot, E. and J. Wang, (1999). A Time Series Model of Multiple Structural Changes in Level, Trend and Variance, Econometrics, EconWPA.

APPENDIX

CHAPTER 2

2.1A Coefficients of the UK MPR Functions

Table 2.1A The Response of the MP Reaction Functions in Policy Regime I

RFs	BL/FL	$\beta_{((TR/DF))}$ Inf. gap	λ y-gap	$\delta_{((TR/\ MR/MT/HM/DF))}$ Exchange rate gap	$\varphi_{(TR/MT)}$ Lag p. rate	ρ NI gap	μ_{MR} Lag p inst	χ_h	ω	R^2	$Jstat$
Taylor	OLS-BL	+**	-**	-***	+***					0.90	0.24
Inst= r_t	GMM-FL	-*	-**	-*	+***					0.88	
McCallum	OLS-BL			-		-	+***			0.66	0.25
Inst=Δb_t	GMM-FL			+		-	+***			0.73	
Taylor-McCallum	OLS-BL			-**	+***	-**				0.88	0.24
Inst=r_t	GMM-FL			-	+***	+**				0.83	
M-H-M	OLS-BL			-			+***	-		0.56	0.19
Δb_t	GMM-FL			-			+***	-		0.55	
NFR	OLS-BL	+*		-					+***	0.55	0.25
Inst= $\Delta m_t - \Delta(m - p)_{\left(\frac{t}{t-1}\right)}$	GMM-FL	+		+					+***	0.66	

Source: author's analysis

Table 2.2A The Response of the MP Reaction Functions in Policy Regime II

RFs	**BL/FL**	$\boldsymbol{\beta_{((TR/DF))}}$ **Inf. gap**	$\boldsymbol{\lambda}$ **y-gap**	$\boldsymbol{\delta_{((TR/\ MR/MT/HM/DF))}}$ **Exchange rate gap**	$\boldsymbol{\varphi_{(TR/MT)}}$ **Lag p. rate**	$\boldsymbol{\rho}$ **NI gap**	$\boldsymbol{\mu_{MR}}$ **Lag p inst**	$\boldsymbol{\chi_h}$	$\boldsymbol{\omega}$	$\boldsymbol{R^2}$	$\boldsymbol{Jstat}$
Taylor	OLS-BL	+**	-**	+**	+***					0.91	0.27
Inst= r_t	GMM-FL	-*	+**	-	+***					0.88	
McCallum	OLS-BL			+		+	+***			0.53	0.19
Inst=Δb_t	GMM-FL			-		+	+***			0.65	
Taylor-McCallum	OLS-BL			+***	+***	+**				0.91	0.28
Inst=r_t	GMM-FL			+	+***	-**				0.87	
M-H-M	OLS-BL			+			+	+		0.54	0.29
Δb_t	GMM-FL			-			+***	+		0.58	
NFR	OLS-BL	-***		-					+***	0.61	0.23
Inst= $\Delta m_t - \Delta(m - p)_{\left(\frac{t}{t-1}\right)}$	GMM-FL	-***		+					+***	0.64	

Source: author's analysis

Table 2.3A The Response of the MP Reaction Functions in Policy Regime III

RFs	BL/FL	$\beta_{((TR/DF))}$ Inf. gap	λ y-gap	$\delta_{((TR/\ MR/MT/HM/DF))}$ Exchange rate gap	$\varphi_{(TR/MT)}$ Lag p. rate	ρ NI gap	$\mu(_{MR/MH)}$ Lag p inst	χ_h	ω	R^2	$Jstat$
Taylor	OLS-BL	+*	-**	+***	+***					0.92	0.26
Inst= r_t	GMM-FL	+*	+*	+	+***					0.78	
McCallum	OLS-BL			+*		-	+			0.62	0.32
Inst=Δb_t	GMM-FL			+*		+	+			0.68	
Taylor-McCallum	OLS-BL			+***	+***	-**				0.92	0.32
Inst=r_t	GMM-FL			-	+***	-**				0.91	
M-H-M	OLS-BL			+			+	+		0.52	0.22
Δb_t	GMM-FL			+			-	-		0.57	
NFR	OLS-BL	-**		+**					+	0.63	0.32
Inst= $\Delta m_t - \Delta(m - p)_{\left(\frac{t}{t-1}\right)}$	GMM-FL	-*		+*					-	0.74	

Source: author's analysis

2.2A Coefficients based on Various Policy Instruments

Table 2.4A Summary of Results based on Income, Output and Inflation Gap

MPR Function		UK MPR (1962-1992)		UK MPR (1993-2007)		UK MPR (2007-2014)	
		BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF
TMPRF	β/λ	**/***	**/***	**/**	**/**	*/**	*/*
MMPRF	θ	*	N	N	N	*	*
M-T MPRF	ρ	**	*	**	**	**	*
MHMMPRF	χ	N	N	N	N	N	**
NFR MPRF	β	*	N	***	***	**	*

Source: author's analysis (N=non significance)

Table 2.5A Summary of Results based on the D. Variables (Lagged Policy Instruments)

MPR Function		UK MPR (1962-1992)		UK MPR (1993-2007)		UK MPR (2007-2014)	
		BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF
TMPRF	φ	*	***	***	***	***	***
MMPRF	μ	***	***	***	***	N	N
M-T MPRF	γ	***	***	***	***	***	***
MHMMPRF	μ	***	***	N	***	N	N
NFR MPRF	ω	***	***	***	***	N	N

Source: author's analysis

2.6A Summary of Results based on Exchange Rate Component of the MPRFs

MPR Function		UK MPR (1962-1992)		UK MPR (1993 – 2007)		UK MPR (2007 – 2014)	
		BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF	BL-MPRF	FL-MPRF
TMPRF	δ_{TR}	***	**	**	N	***	N
MMPRF	δ_{MR}	*	N	N	N	*	*
M-T MPRF	δ_{MT}	**	N	***	N	***	N
MHMMPRF	δ_{MHM}	N	N	N	N	N	*
NFR MPRF	δ_{NFR}	N	N	N	N	**	*

Source: author's analysis

2.7A Summary of Results based on Significant Variables Reactions

MPR Function	UK MPR (1962-1992)	UK MPR (1993 – 2007)	UK MPR (2007 – 2014)
	Significant Variables of each MP Reaction Function		
TMPRF	SIG. POLICY INST., EXR, INFLATION & OUTPUT GAP REACTION		
MMPRF	SIG. POLICY INST. (PR-I & II), & EXR. (PR-I & III) REACTION		
M-T MPRF	SIG. POLICY INST., EXR (PR-I,II,III ONLY BL) & INCOME GAP REACTION		
MHMMPRF	SIG. POLICY INST. (PR-I, II), INF. GAP (PR-III) & EXR (PR-III) REACTION		
NFR MPRF	SIG. POLICY INST. (PR-III), NFR (PR-I,II,III) & EXR. (PR-III) REACTION		

Source: author's analysis

CHAPTER 3

3.1A FEVD Responses to Various Shocks

S-BVAR Sample 1 to MP Shock

Period	CP	Price	Output	Base R	Credit	Ex
1	3.68E-05	0.007870	0.246736	16.73425	0.109304	82.90181
2	0.001122	0.009948	0.184599	15.05142	0.107327	84.64558
3	0.001354	0.009529	0.200229	14.91533	0.107162	84.76640
4	0.010711	0.008443	0.359219	14.11764	0.105790	85.39819
5	0.011524	0.009065	0.412776	14.10792	0.105728	85.35298
6	0.014257	0.009010	0.414197	13.89057	0.105314	85.56665
7	0.024422	0.008743	0.481704	13.48624	0.104345	85.89455
8	0.026720	0.008715	0.489318	13.43913	0.104162	85.93196
9	0.026647	0.008682	0.493544	13.48681	0.104208	85.88011
10	0.026769	0.008701	0.488486	13.64086	0.104376	85.73081
11	0.028553	0.009239	0.481748	13.96434	0.104691	85.41143
12	0.027962	0.009388	0.465858	14.22922	0.105032	85.16254
13	0.026857	0.008994	0.480845	14.23414	0.105082	85.14408
14	0.026352	0.008653	0.501394	14.19005	0.105047	85.16850
15	0.025962	0.008627	0.498133	14.24313	0.105126	85.11902
16	0.026095	0.008634	0.497409	14.27269	0.105151	85.09002
17	0.026133	0.008665	0.497892	14.26901	0.105139	85.09316
18	0.026202	0.008728	0.497930	14.25556	0.105110	85.10647
19	0.027156	0.008723	0.500214	14.24808	0.105050	85.11078
20	0.028378	0.008799	0.503888	14.29451	0.105045	85.05938
21	0.028440	0.008824	0.501121	14.36217	0.105119	84.99433
22	0.028037	0.008725	0.503982	14.39187	0.105169	84.96222
23	0.027548	0.008643	0.503655	14.43065	0.105235	84.92427
24	0.027156	0.008620	0.500264	14.48493	0.105316	84.87371
25	0.026878	0.008572	0.500086	14.51244	0.105359	84.84666

S-BVAR Sample 2 to Credit Shocks

Period	CP	Price	Output	Base R	Credit	Ex
1	38.66340	0.396667	24.92229	7.852741	27.13462	1.030289
2	17.90827	0.019545	3.080940	8.713878	0.208647	70.06872
3	18.00678	0.135084	2.683694	23.95687	0.201720	55.01586
4	18.24123	0.120246	2.764898	22.35385	0.190419	56.32936
5	17.33035	0.110948	2.875948	23.31172	0.174479	56.19655
6	14.28855	0.088237	3.132265	27.16597	0.143652	55.18133
7	11.02067	0.063603	3.380365	30.81833	0.107812	54.60922
8	9.377359	0.048994	3.529537	32.22548	0.084058	54.73458
9	8.740367	0.041308	3.608448	32.44507	0.070205	55.09460
10	8.455808	0.037039	3.649803	32.36674	0.062305	55.42831
11	8.433522	0.034782	3.672662	32.07855	0.057687	55.72280
12	8.482043	0.033600	3.685959	31.82177	0.054999	55.92163
13	8.563512	0.033034	3.693952	31.60537	0.053391	56.05074
14	8.657142	0.032871	3.698776	31.43268	0.052450	56.12608
15	8.745460	0.032924	3.701652	31.30229	0.051904	56.16577
16	8.822369	0.033080	3.703360	31.20541	0.051585	56.18420
17	8.886527	0.033272	3.704426	31.13356	0.051387	56.19083
18	8.937148	0.033451	3.705222	31.08112	0.051242	56.19181
19	8.976465	0.033600	3.705940	31.04232	0.051118	56.19056
20	9.006587	0.033712	3.706668	31.01333	0.050999	56.18871

21	9.029471	0.033790	3.707433	30.99141	0.050881	56.18702
22	9.046843	0.033838	3.708223	30.97454	0.050762	56.18580
23	9.060057	0.033864	3.709017	30.96126	0.050644	56.18516
24	9.070182	0.033874	3.709790	30.95051	0.050529	56.18512
25	9.078083	0.033873	3.710521	30.94148	0.050420	56.18563

Sample-2 FEVD to MP shocks

Period	CP	P	Output	Base R	Credit	Ex
1	11.88079	0.230630	2.394007	56.90765	0.242916	28.34401
2	5.113633	0.126244	2.997431	57.98019	0.207489	33.57501
3	3.652880	0.085595	3.304675	53.35080	0.148523	39.45752
4	3.170501	0.075282	3.373938	51.72856	0.129608	41.52211
5	2.949945	0.070515	3.399022	50.42001	0.118372	43.04214
6	2.984082	0.067062	3.413830	49.29525	0.112797	44.12697
7	2.969107	0.065561	3.419570	48.78559	0.110083	44.65009
8	2.981433	0.064798	3.421737	48.50136	0.108977	44.92169
9	2.999282	0.064614	3.421497	48.40805	0.108967	44.99758
10	3.002524	0.064609	3.421107	48.40889	0.109196	44.99367
11	2.997334	0.064508	3.422004	48.42042	0.109237	44.98650
12	2.988659	0.064226	3.424538	48.40346	0.108908	45.01021
13	2.984489	0.063827	3.428048	48.34933	0.108306	45.06600
14	2.986400	0.063418	3.431539	48.27508	0.107640	45.13592
15	2.994297	0.063067	3.434467	48.19597	0.107044	45.20516
16	3.005836	0.062805	3.436638	48.12490	0.106588	45.26323
17	3.018182	0.062630	3.438102	48.06838	0.106275	45.30643
18	3.029716	0.062525	3.439014	48.02699	0.106080	45.33568
19	3.039476	0.062470	3.439540	47.99873	0.105968	45.35381
20	3.047150	0.062447	3.439820	47.98048	0.105909	45.36419
21	3.052910	0.062442	3.439959	47.96908	0.105880	45.36973
22	3.057098	0.062445	3.440024	47.96202	0.105865	45.37254
23	3.060105	0.062450	3.440056	47.95756	0.105858	45.37397
24	3.062284	0.062456	3.440078	47.95456	0.105852	45.37477
25	3.063905	0.062461	3.440100	47.95237	0.105847	45.37531

3.2 A Calibration and Volatility

Table 3.1A Calibrated Parameters

Parameter	Value	Descriptions
β	0.995	Discount factor
δ	0.025	Capital depreciation rate
g_y	0.15	Steady state share of gov't spending on output
α	0.25	Capital share in production function
i_y	0.22	Share of investment
ϕ_w	1.5	Steady state mark-up of wage setters
σ_l	1.5	Inverse of the labour supply elasticity
ψ	0.1	Adjustment cost of capital utilisation

Table 3.2A The Volatility of Output, Inflation and the Nominal Interest Rate
Panel A. Data

	$Stdev(\Delta Y)$	$Stdev(P)$	$Stdev(Inv)$
Pre INF	0.47	0.38	0.67
Post INF	0.34	0.20	0.22

Panel B. DSGE

		$Stdev(\Delta Y)$	$Stdev(\pi)$	$Stdev(r)$	$Stdev(\Delta Y)$	$Stdev(\pi)$	$Stdev(r)$
MP	**PS**	**Pre 2007Q3**			**Post 2007Q3**		
pre	pre	0.73	0.46	0.62	0.56	0.35	0.53
post	pre	0.99	0.37	0.66	0.77	0.32	0.58
Pre	post	0.62	1.43	1.23	0.43	0.90	0.81
post	post	0.75	0.43	0.59	0.50	0.34	0.46

3.3A Plots of Historical Decompositions

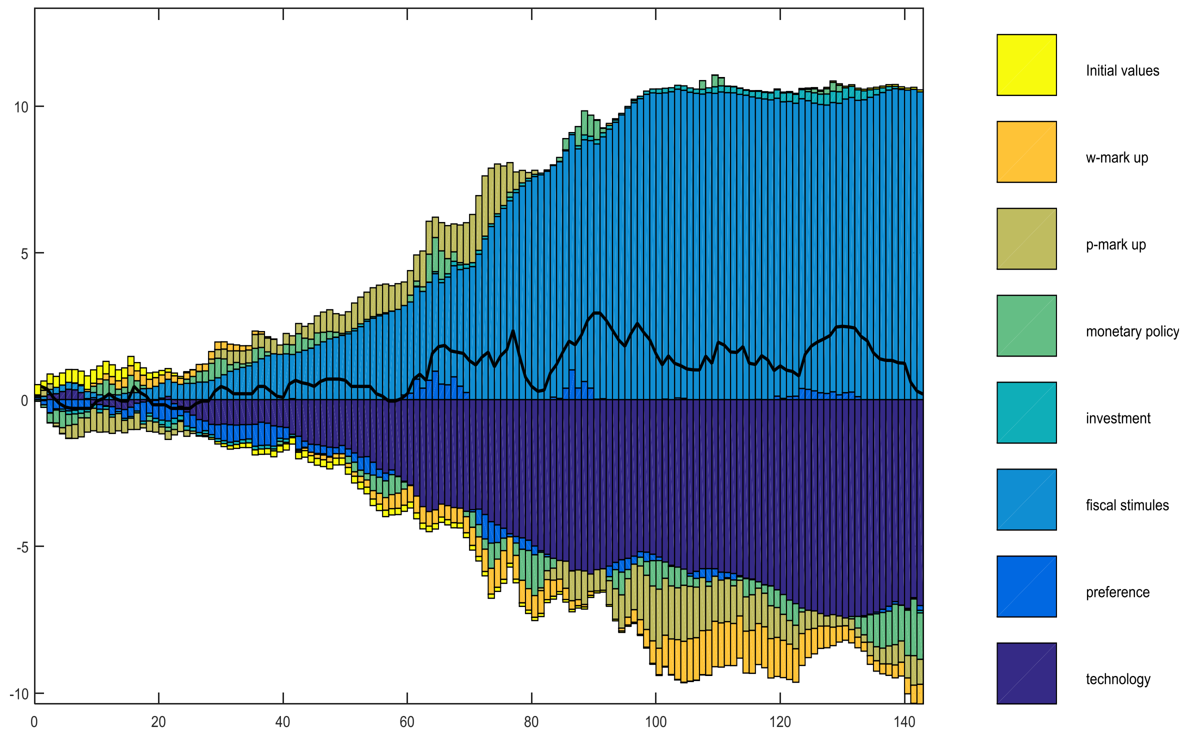


Figure 3.1A Pre-IT Historical Decomposition for Monetary Policy Shock

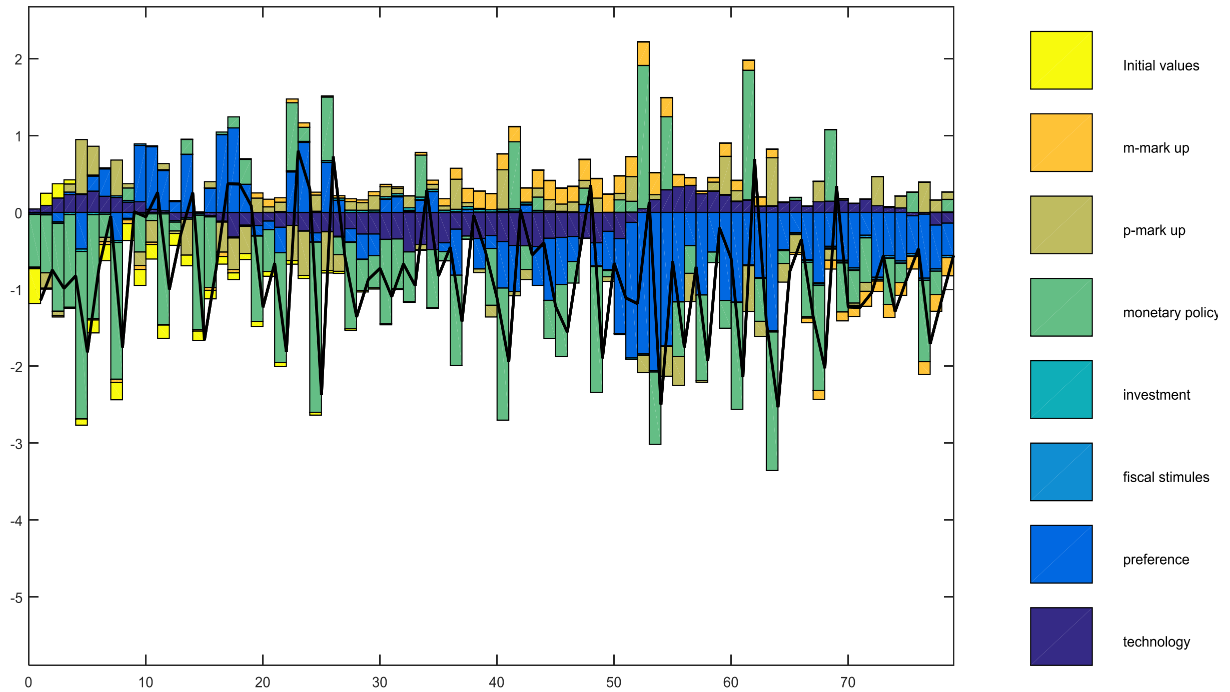


Figure 3.2A Post-IT Historical Decomposition for Monetary Policy Shock

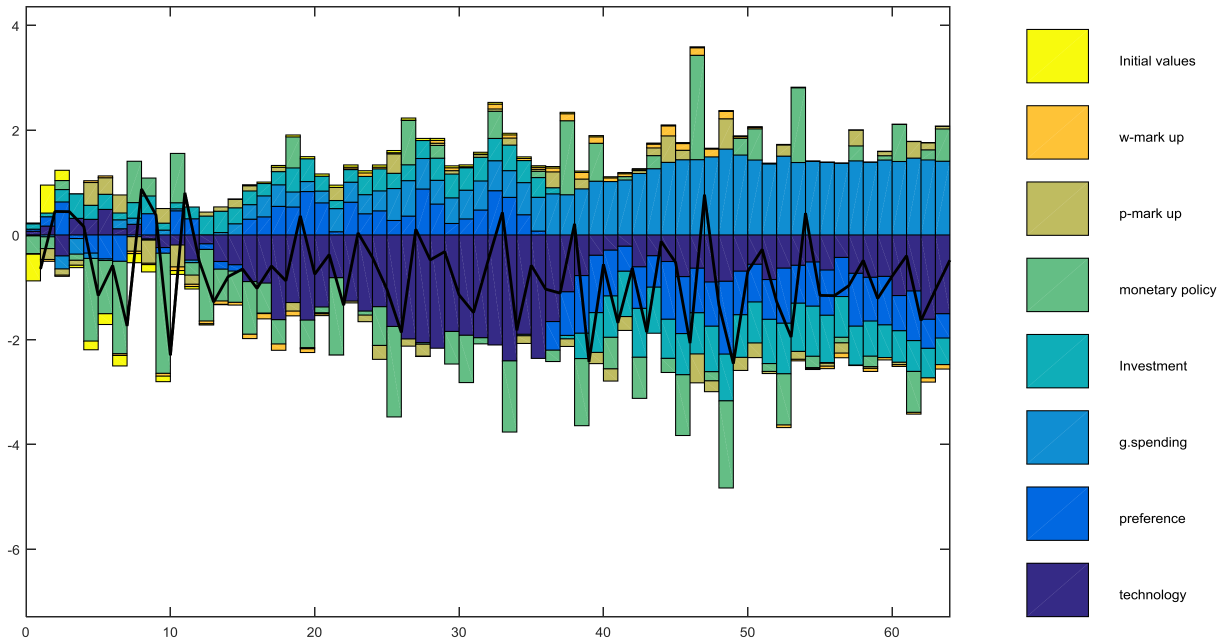


Figure 3.3A Pre-Crisis Historical Decomposition for Monetary Policy Shock

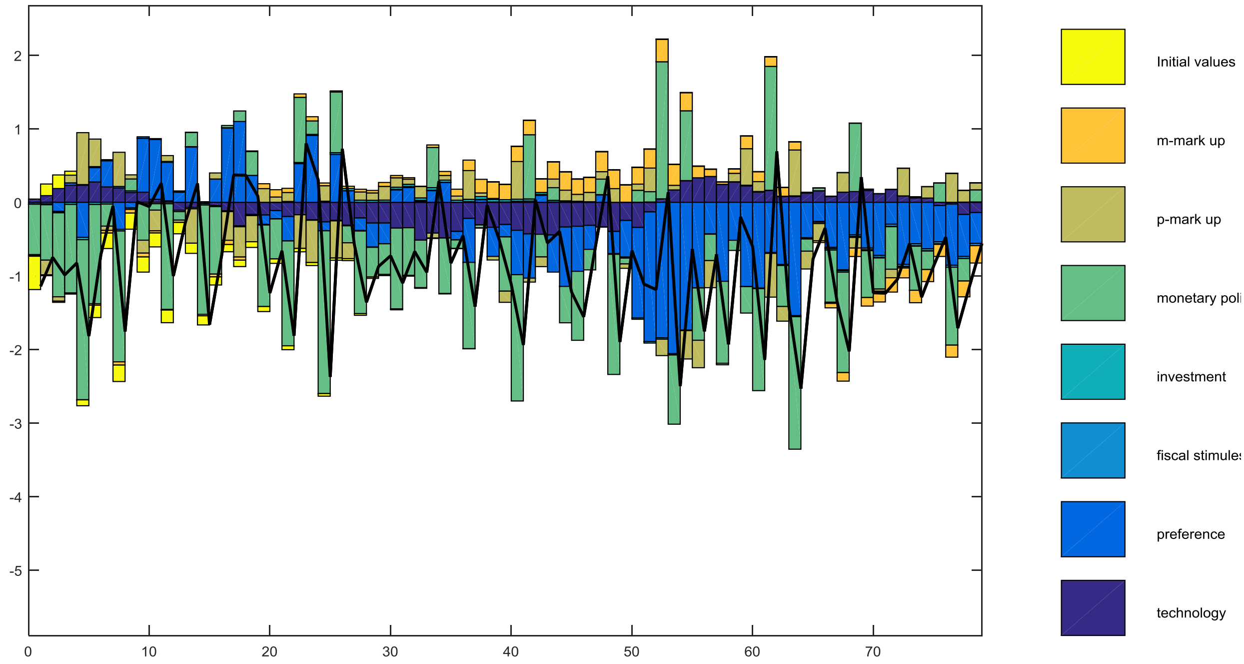


Figure 3.4A Post-Crisis Historical Decomposition for Monetary Policy Shock

CHAPTER 4

4.1A Data, Levels and Differenced Stationarity based on Kernel Density

Table 4.1A The Macroeconomic and Finance Series and Sample Periods

	Variables	**Sample Period**	**Observations**
1	Nominal GDP (LGDP)	1960:q1 – 2013:q4	216
2	Real GDP (LRGDP)	1960:q1 – 2013:q4	216
3	Real GNP (LGNP)	1960:q1 – 2013:q4	216
4	Nominal GNP (LGNP)	1960:q1 – 2013:q4	216
5	Net Investment (LINV)	1960:q1 – 2013:q4	216
6	Real Investment (LRINV)	1960:q1 – 2013:q4	216
7	CPI (LCPI)	1960:01 – 2014:02	637
8	Share prices (LSPR)	1960:01 – 2014:02	637
9	Exchange rate (LEXR)	1960:01 – 2014:02	637
10	Narrow Money (M1=LM1)	1980:01 – 2014:01	408
11	Broad Money (M3/M4=LM4)	1960:01 – 2014:01	636
12	Manufacturing stocks	1960:q1 – 2013:q4	216
13	Index of industrial production (LIIP)	1960:01 – 2014:02	637
14	Manufacturing employment (LME)	1978:q2 – 2013:q4	139
15	Total Employment (workforce) (LNTEM)	1960:q1 – 2013:q4	216
16	Manufacturing hourly earnings (LMHE)	1963:q1 – 2014:01	204
17	Unemployment rate (LUKUE)	1960:q1 – 2013:q4	216
18	House price (LHPQ)	1960:q1 – 2013:q4	216
19	House price (LHPM)	1960:q1 – 2014:q4	276
20	Short-term interest rate: UK: 90-day banks-accepted bill(LSTIR)	1960:01 – 2014:02	637
21	Interbank rate (LIBR)	1978:01 – 2014:02	432
22	90 days Treasury bill rate (LST90R)	1960:q1 – 2013:q4	216
23	Long-term interest rates: UK: 10 year Treasury bonds (LTIR)	1960 :01–2014 :02	631
24	Long-term interest rates (LLTIR)	1960:01 – 2014:02	637
25	Net Lending to private sector (LNLPS)	1982:07– 2014:02	504

Source: Data are extracted from the EUROSTAT, OECD Main Economic Indicators, the ONS, and the Bank of England.

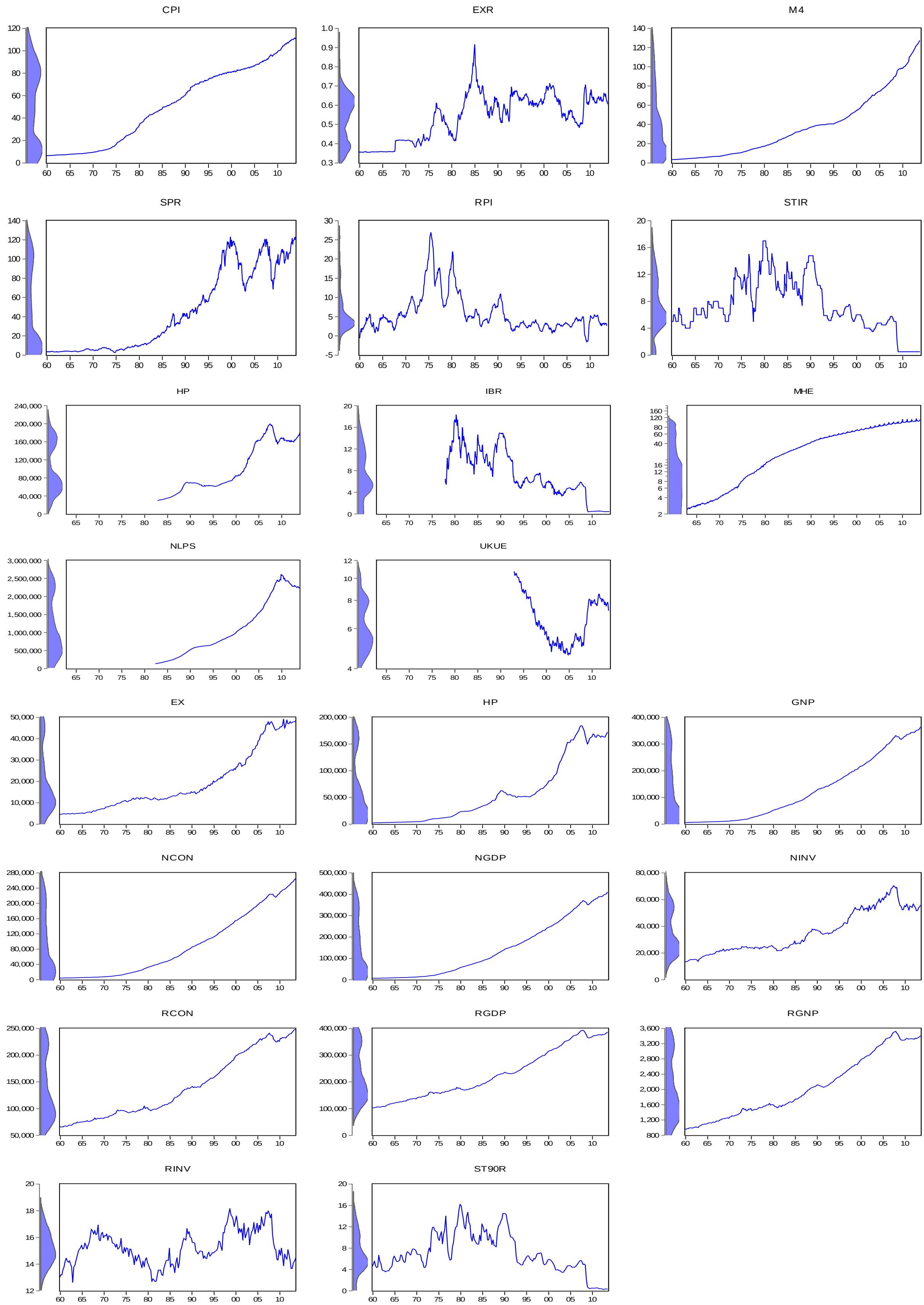


Figure 4.1A Quarterly Data Diagnosis in Levels with Kernel Density

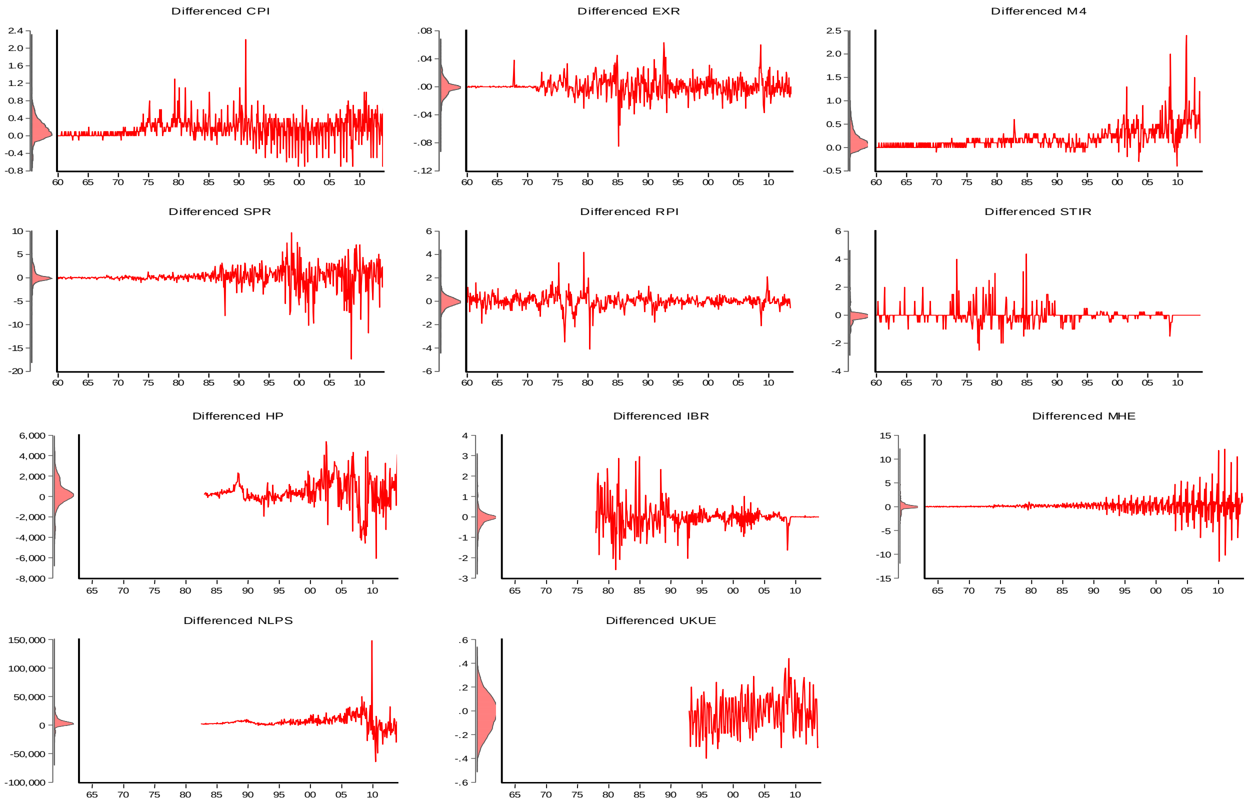


Figure 4.2A Differenced Monthly Data Diagnosis with Kernel Density

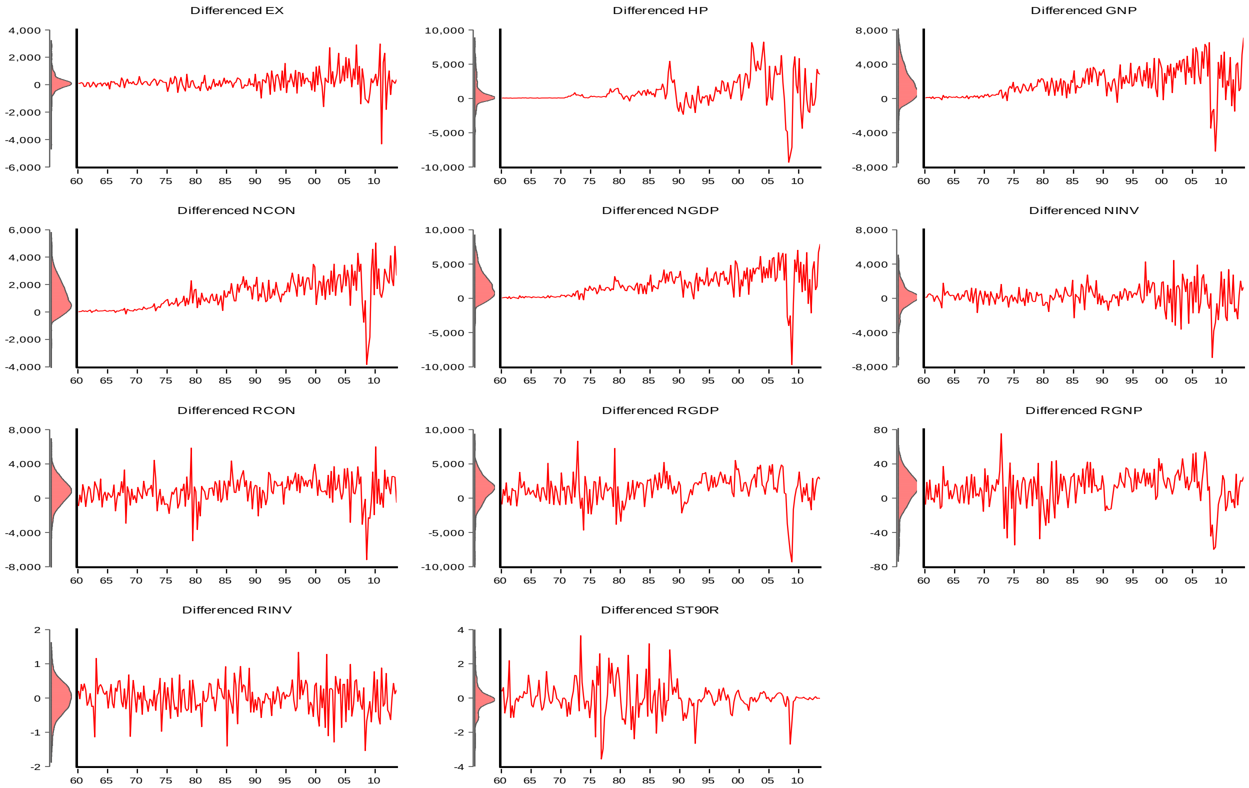


Figure 4.3A Differenced Quarterly Data Diagnosis with Kernel Density

Table 4.2A The Primary and Secondary Moments for Diagnosis of the MEFT

	Mean	Std. Dev.	CV	Skewness	Kurtosis	Jarque-Bera
LCPI	3.5801	0.9675	3.7005	-0.5950	1.761193	79.90967
LEXR	-0.6426	0.2308	-2.7847	-0.4020	1.959584	46.82811
LIIP	4.4790	0.1983	22.5868	-0.5198	2.194145	46.86367
LLTIR	1.7737	0.4370	4.0588	-0.3516	3.201864	14.49466
LM4	3.1887	1.0484	3.0415	-0.2850	1.858938	44.06392
LSPR	3.1284	1.3061	2.3952	-0.1561	1.408515	71.23739
STIR	6.4525	0.8743	7.3801	-1.8108	5.829038	571.9787
LTIR	1.7432	2.7327	0.6379	0.836177	3.537240	83.56270
HP	11.3700	0.5547	20.4968	-0.0806	1.850637	20.99067
LIBR	1.6288	1.0549	1.5440	-1.4188	3.934656	161.3953
LM1	3.6189	0.7703	4.6980	-0.1523	1.751844	22.62805
LMHE	3.2254	1.2206	2.6426	-0.5756	1.905086	64.57398
LNLPS	13.6308	0.8281	16.4599	-0.4411	2.249515	21.23782
LUKUE	1.8802	0.2397	7.8432	0.247068	1.784775	17.92649
LGNP	11.0923	1.3610	8.1498	-0.4308	1.732559	21.13995
LHP	10.2249	1.4018	7.2944	-0.3550	1.828325	16.89278
LIM	9.2381	0.7228	12.7812	0.240028	1.701507	17.24883
LNCON	10.6941	1.3811	7.7430	-0.3841	1.682502	20.93231
LNGDP	11.1918	1.3755	8.1366	-0.4289	1.730654	21.12496
LNINV	10.3745	0.4506	23.0247	0.049400	1.822130	12.57425
LNRGDP	12.2596	0.4110	29.8273	-0.0066	1.759600	13.84890
LNST90R	1.6836	0.9147	1.8405	-1.9348	6.366235	236.7538
LRCON	11.7619	0.4215	27.9046	0.123614	1.616924	17.76617
LRGNP	7.5550	0.3967	19.0434	0.009404	1.761998	13.79702
LRINV	2.7200	0.0818	33.2587	0.025115	2.408365	3.173000

Source: author’s analysis

Table 4.3A Augmented Dickey-Fuller test for a Unit Root without Structural Break

MEFT series/variables	$y_t = \mu + \beta t + \omega y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t$			
	k	$\boldsymbol{\mu}$	$\boldsymbol{\beta}$	$\boldsymbol{\omega}$
LCPI	12	0.0032(2.113)	0.027(0.669)	-0.0009(-1.269)
LMSE_Q	3	0.2918(2.896)	-0.001(-2.702)	-0.033(-2.924)
LMSE_M	9	0.1045(2.885)	-0.002(-2.701)	-0.011(-2.921)
LEXR	3	-0.0121(-2.239)	0.002(1.6309)	-0.0141(-2.604)
LIIP	1	0.0298(1.155)	0.001(0.0940)	-0.0065(-1.047)
LM4	10	0.0064(2.792)	0.002(1.0266)	-0.0020(-1.304)
LSPR	3	0.0144(2.485)	0.001(1.850)	-0.0101(-2.002)
LSTIR (t)	1	0.0173(1.576)	0.001(-2.148)	-0.0044(-1.186)
LLTIR	2	0.0178(1.926)	0.002(-1.958)	-0.0068(-1.623)
LHPM	5	0.0788(2.592)	0.003(2.284)	-0.00742(-2.547)
LIBR	7	0.0538(2.609)	-0.001(-2.804)	-0.0157(-2.566)
LMHE	12	0.009(3.124)*	-0.001(-0.9849)	0.0311(0.172)
LSNLPS (T)	0	0.3286(1.4798)	0.002(1.3611)	-0.0252(-1.452)
LUKUE	5	0.0228(2.3737)	0.000 (0.002)	-0.0031(-2.322)
LUSNL(T)	0	-0.0136(-0.452)	-0.001(-4.994)	0.0023(0.885)
LEX	2	0.2090(1.4633)	0.001(1.3163)	-0.0232(-1.360)
LGNP(T)	3	0.0067(0.2237)	-0.001(-0.647)	0.0007 (0.166)
LHPQ (T)	3	0.0705(1.8448)	0.001(1.3849)	-0.0080(-1.639)
LIM	2	0.2389(1.5201)	0.003(1.4009)	-0.0282(-1.432)
LNGDP (T)	3	0.0067(0.2237)	-0.001(-0.646)	0.0006 (0.165)
LNINV	4	0.4735(2.3604)	0.013(2.068)	-0.0484(-2.318)
LNRGDP(t)	3	0.4056(2.1313)	0.012 (1.987)	-0.0347(-2.102)
LNST90R(T)	1	0.0573(1.5935)	-0.001(-2.025)	-0.0158(-1.281)
LRGNP(T)	3	0.2325(1.8864)	0.002 (1.720)	-0.0330(-1.837)
LRINV(T)	1	0.1702(2.3820)	-0.001 (-0.125)	-0.0622(-2.330)

Note: The figures in parenthesis are t' statistics. The ADF critical values range from 3.12 (10%, >500^T) to 3.99 (1%, >200^T). The significance test is based on $\omega = 1$ at "***"1%,"**" 5% and "*"10% at different sample size. K= optimal number of augmented lags selected by *Akaike Information Criteria (AIC).* The maximum number of observation varies from 250 to 650 as advised by BP (2003) for trimming purpose.

ADF based on Model III (equation 4.2) (constant, trend)			
T	**1%**	**5%**	**10%**
25	-4.38	-3.60	-3.24
50	-4.15	-3.50	-3.18
100	-4.04	-3.45	-3.15
250	-3.99	-3.43	-3.13
500	-3.98	-3.42	-3.13
>500	-3.96	-3.41	-3.12

Critical Values for Table 4.1 (Chapter 4)

Table of some critical values at 5%

Model\ $\lambda = \frac{t_b}{T}$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$Model\ A^{ZA}$	-3.68	3.77	3.76	-3.72	-3.76	-3.76	-3.80	-3.75	-3.69
$Model\ B^{ZA}$	-3.65	-3.80	-3.87	-3.94	-3.96	-3.95	-3.85	-3.82	-3.68
$Model\ C^{ZA}$	-3.75	-3.99	-4.17	-4.22	-4.24	-4.24	-4.18	-4.04	-3.80

Table of Zivot-Andrews test statistics (T=214 to 650)

Level of Sig./Model	1%	5%	10%
$Model\ A^{ZA}$	-5.34	-4.93	-4.58
$Model\ B^{ZA}$	-4.80	-4.42	-4.11
$Model\ C^{ZA}$	-5.57	-5.08	-4.82

4.2A Structural Break Models According to Perron

Perron's notation of exogenous change and the unit-root null hypotheses

$$Model\ (A): y_t = \mu + dD(T_B)_t + y_{t-1} + e_t \quad (4.1A)$$

$$Model\ (B): y_t = \mu_1 + y_{t-1} + (\mu_2 - \mu_1)DU_t + e_t, \quad (4.2A)$$

$$Model\ (C): y_t = \mu_1 + y_{t-1} + dD(T_B)_t + (\mu_2 - \mu_1)DU_t + e_t, \quad (4.3A)$$

where $D(T_B)_t = 1$ if $t = T_B + 1, 0$ otherwise; $DU_t = 1$ if $t > T_B, 0$ otherwise; $A(L)e_t = B(L)v_t, v_t = iid(0, \sigma^2)$, with $A(L)$ and $B(L)pth$ and qth are order polynomials in the lag operator. As discussed above, *Model (A)* permits an exogenous change in the level of the series, *Model (B)* allows an exogenous change in the rate of growth while *Model (C)* allows both changes. The trend-stationary alternative hypotheses considered are:

$$Model\ (A): y_t = \mu + \beta t + (\mu_2 - \mu_1)DU_t + e_t, \quad (4.4A)$$

$$Model\ (B): y_t = \mu_1 + \beta_1 t + (\beta_2 - \beta_1)DT_t^* + e_t, \quad (4.5A)$$

$$Model\ (C): y_t = \mu + \beta t + (\mu_2 - \mu_1)DU_t + (\beta_2 - \beta_1)DT_t^* + e_t, \quad (4.6A)$$

where $DT_t^* = t - T_B$ if $t > T_B$ and 0 otherwise[151].

4.3A Structural Break Models based on ZA

$Model\ A^{ZA}$ [tests for one change in level (intercept)]

$$y_{it} = \mu_i + \alpha_i y_{it-1} + \beta_i t + \theta_i DU_t + \sum_{j=1}^{k} c_{ij}\,\Delta y_{it-j} + \varepsilon_{it} \quad (4.7A)$$

Given the date TB of structural changes, one can check if the data (y_t) behaves as process with only changes in level (the intercept of the trend) without altering the slope. The main question here is that – is it a change in the level (mean shift) of unit root process or in a level of a trend stationary process (slope or growth level change)? Model *A* tests the following null and alternative hypotheses:

$$H_0: y_t = \mu_0 + y_{t-1} + \mu_1 Dp + \varepsilon_t$$
$$H_1: y_t = \mu_0 + \gamma t + \mu_2 D_L + \varepsilon_t$$

$Model\ B^{ZA}$ [tests for one change in slope (trend)]

$$y_{it} = \mu_i + \alpha_i y_{it-1} + \beta_i t + \gamma_i DT_t + \sum_{j=1}^{k} c_{ij}\,\Delta y_{it-j} + \varepsilon_{it} \quad (4.8A)$$

Tests the following null and alternative hypotheses:

$$H_0:\ y_t = \mu_0 + y_{t-1} + \mu_2 D_L + \varepsilon_t$$
$$H_1:\ y_t = \mu_0 + \gamma t + \mu_3 D_T + \varepsilon_t$$

and

[151]As with the unit-root hypotheses, *Model (A)* allows for a one-time change in the level of the series, and, appropriately, Perron called this the "crash" model. The difference $\mu_2 - \mu_1$ represents the magnitude of the change in the intercept of the trend function occurring at time T_B. Perron labelled *Model (B)* the "changing growth" model, and the difference $\beta_2 - \beta_1$ repreesnts the magnitude of the change in the slope of the trend function occurring at the T_B. *Model (C)* combines changes in the level and the slope of the trend function of the series.

$Model\ C^{ZA}$[tests for changes in both level and slope]

$$y_{it} = \mu_i + \alpha_i y_{it-1} + \beta_i t + \theta_i DU_t + \gamma_i DT_t + \sum_{j=1}^{k} c_{ij} \Delta y_{it-j} + \varepsilon_{it} \qquad (4.9A)$$

The model tests the following hypotheses:

$$H_0: y_t = \mu_0 + y_{t-1} + \mu_1 Dp + \mu_2 D_L + \varepsilon_t$$
$$H_1: y_t = \mu_0 + \gamma t + \mu_2 D_L + \mu_3 D_T + \varepsilon_t$$

DUt is a pulse or an indicator dummy variable for a mean shift occurring at time TB, and DT is the corresponding trend shift variable, where $DUt = 1\ ift > TB,$ 0 otherwise; $DTt = t - TB\ if\ t > TB,$ 0 otherwise. It shows that DT_t changes the slope of the deterministic trend line in both stationary and unit root process. The break point in this case is searched for over the range of the sample. The break points are selected by choosing the value of TB for which the $ADF\ t-$ statistics (the absolute value of the t statistics for (α) is maximised. The null hypothesis that the series (y_t) is an integrated process without a structural break is tested against the alternative hypothesis that y_t is trend stationary with structural breaks in the trend function, which occur at an unknown time[152].

[152] See Ben-David and Papell, (1995).

4.4A One Break Point Results based on ZA

Table 4.4A ZA's one Break Point Tests Based on $Model\ A^{ZA}$, B^{ZA} and C^{ZA}[153]

Variables	$Model\ A^{ZA}$ α ≠ 0 ; β = 0 α=1,β=0,θ=0 Intercept [K]	$Model\ B^{ZA}$ α = 0 ; β ≠ 0 α=0,β=1,γ=0 Slope [K]	$Model\ C^{ZA}$ α ≠ 0 ; β ≠ 0 α=1,β=1,γ=0,θ=0 Intercept & Slope [K]	Significant Break Dates
		Macro-Economic Sector		
LUKUE-M	(-3.1501) [12]	-3.2778 [12]	-3.4533 [12]	
	1979M05	1980M07	1997M05	
LIIP	(-2.6112) [2]	(-3.6986) [2]	(-3.6693) [2]	
	2006M01	1999M09	1999M05	
LGNP	(-4.2939) [3]	(-3.9555) [3]	(-5.5860)*** [3]	1974Q2 (C)
	1974Q2	1980Q1	1974Q2	
LMEM	(-3.8873) [3]	(-3.7590) [3]	(-4.0105) [3]	
	2003Q2	1998Q1	1993Q1	
LNRGDP	(-2.5628) [3]	(-3.0383) [3]	(-3.3019) [3]	
	1994Q1	2005Q4	19999Q3	
LRGNP	(-2.307) [3]	(-2.7481) [3]	(-2.9829) [3]	
	1994Q1	2005Q4	2002Q2	
LNGDP	(-4.5897)* [3]	(-3.8569) [3]	(-5.7915)*** [3]	1974Q2 (A)
	1974Q2	1979Q4	1974Q2	1974Q2 (C)
		Financial Sector		
LMHE	(-4.6836)* [12]	(-4.3389)* [2]	(-4.3857) [2]	1974M03 (A)
	1974M03	1982M04	1974M03	1982M04 (B)
LEXR	(-4.0209) [3]	(-4.1860)*[3]	(-4.8793)*[3]	1984M06 (B)
	1975M01	1984M06	1981M02	1981M02 (C)
LHP_M	(-3.2378) [12]	(-2.2194) [12]	(-2.2194) [12]	
	2001M11	2006M01	2006M01	
LCPI	(-4.7142)*[12]	(-3.8470) [12]	(-5.7586)*** [12]	1973M03 (A)
	1973M09	1979M08	1974M01	1974M01 (C)
LIBR	(-8.9404)*** [7]	(-4.6498)** [7]	(-8.0750)*** [7]	2006M06 (B)
	2008M10	2006M06	2008M10	2008M10 (AC)
LSPR	(-3.7712) [9]	(-3.5254) [9]	(-3.6250) [9]	
	1981M11	1998M02	1981M11	
LNINV	(-2.8888) [4]	(-2.8444) [4]	(-3.5729) [4]	
	1987Q2	2005Q4	1997Q2	
LRINV	(-2.3079) [3]	(-2.7488) [1]	(-3.7247) [1]	
	1994Q1	2005Q1	1997Q2	
LNST90R	(-2.6437) [1]	(-3.8638) [1]	(-3.8524) [1]	
	2005Q4	2004Q3	2003Q4	
		Monetary Sector		
LM4	(-3.5309) [10]	(-3.0899) [10]	(-3.8252) [10]	
	1970M05	1981M12	1975M02	
LM1	(-3.6894) [12]	(-3.6697) [12]	(-3.7733) [12]	
	2010Q03	2008M02	2007M05	
LSTIR	(-3.0682) [4]	(-3.6393) [4]	(-3.6990) [4]	
	2006M01	1997M12	1988M06	
LLTIR	(-3.0147) [12]	(-5.8939)*** [12]	(-5.8939)*** [12]	1980M07 (B)
	1972M06	1980M07	1980M07	1980M07 (C)

Note: Figures in parenthesis are t statistics; *, **, and *** denote level of significance of the test of $\alpha^i = 1\ (i = A, B, C)$ at 10%, 5% and 1% levels, respectively. ZA's critical values are used to reject the false hypothesis.

Table of some critical values at 5%

Model\ $\lambda = \frac{t_b}{T}$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$Model\ A^{ZA}$	-3.68	3.77	3.76	-3.72	-3.76	-3.76	-3.80	-3.75	-3.69
$Model\ B^{ZA}$	-3.65	-3.80	-3.87	-3.94	-3.96	-3.95	-3.85	-3.82	-3.68
$Model\ C^{ZA}$	-3.75	-3.99	-4.17	-4.22	-4.24	-4.24	-4.18	-4.04	-3.80

Table of Zivot-Andrews test statistics (T=214 to 650)

Level of Sig./Model	1%	5%	10%
$Model\ A^{ZA}$	-5.34	-4.93	-4.58
$Model\ B^{ZA}$	-4.80	-4.42	-4.11
$Model\ C^{ZA}$	-5.57	-5.08	-4.82

[153] As the main objective of this part of the analysis is to identify the sig. Break dates, the table shows only the coefficients of the crash, growth and crash and growth terms.

4.5A Multiple Structural Break Critical Values

Table 4.5A Critical Values for BP Global Tests

Critical Values for BP Global Tests (Table 4.2 and 4.3)

Asymptotic Critical Values of the Multiple Break test for $\epsilon = 0.20$. The entries are Quantiles x such that $P\left(supF_{k,q} \leq \frac{x}{q}\right) = \alpha$.

$e = 0.20$	Number of Breaks, k				
α	1	2	3	$UDmax$	$WDmax$
0.900	6.72	5.59	4.37	6.96	7.67
0.950	8.22	6.53	5.08	8.43	9.27
0.975	9.77	7.49	5.73	9.94	10.93
0.990	11.94	8.77	6.58	12.02	13.16

Critical Values for BP Global Tests (Table 4.4)

Asymptotic Critical Values of the Sequential Test $FT(0\ vs\ l)$ for $\epsilon = 0.20$

$\epsilon = 0.20$	Number of Breaks, l			
α	0	1	2	3
0.900	6.72	8.13	9.07	9.66
0.950	8.22	9.71	10.66	11.34
0.975	9.77	11.34	12.31	12.99
0.990	11.94	13.61	14.31	14.80

Critical Values for BP Global Tests (Table 4.5)

Asymptotic Critical Values of the Sequential Test $FT(l+1\ vs\ l) = FT(2 \,|\, 1) =$ for $\epsilon = 0.20$

$\epsilon = 0.20$	Number of Breaks, l			
α	0	1	2	3
0.900	6.72	8.13	9.07	9.66
0.950	8.22	9.71	10.66	11.34
0.975	9.77	11.34	12.31	12.99
0.990	11.94	13.61	14.31	14.80

Critical Values for BP Global Tests (Table 4.6)

Asymptotic Critical Values of the Sequential Test $FT(l+1\ vs\ l) = FT(3 \,|\, 2) =$ for $\epsilon = 0.20$

$\epsilon = 0.20$	Number of Breaks, l			
α	0	1	2	3
0.900	6.72	8.13	9.07	9.66
0.950	8.22	9.71	10.66	11.34
0.975	9.77	11.34	12.31	12.99
0.990	11.94	13.61	14.31	14.80

Critical Values for BP Global Tests (Table 4.7)

Asymptotic Critical Values of the Sequential Test $FT(l+1\ vs\ l) = FT(4|3)$, for $\epsilon = 0.15$

$\epsilon = 0.20$	Number of Breaks, l					
α	0	1	2	3	4	5
0.900	7.04	8.51	9.14	10.04	10.58	11.03
0.950	8.58	10.13	11.14	11.83	12.25	12.66
0.975	10.18	11.86	12.66	13.40	13.89	14.32
0.990	12.29	13.89	14.80	15.76	15.76	16.27

Critical Values for BP Global Tests (Table 4.8)

Asymptotic Critical Values of the Sequential Test $FT(l+1|l) = FT(4|3)$, for $\epsilon = 0.15$

$\epsilon = 0.20$	Number of Breaks, l					
α	0	1	2	3	4	5
0.900	7.04	8.51	9.14	10.04	10.58	11.03
0.950	8.58	10.13	11.14	11.83	12.25	12.66
0.975	10.18	11.86	12.66	13.40	13.89	14.32
0.990	12.29	13.89	14.80	15.76	15.76	16.27

4.6A Assumptions of the Statistical Properties of the MSB

It is important to clearly state the underlying set of assumptions for the statistical properties of the resulting estimators[154].

ASSUMPTION A1: Let $w_t = (x_t', z_t')' W = (w_1, \ldots, w_T)'$, and $\overline{W^0}$ be the diagonal partition of W at $(T_1^0, \ldots, T_m^0)$ such that $\overline{W^0} = diag(W_1^0, \ldots, W_{m+1}^0)$. One assumes that for each $i = 1, \ldots, m+1$, with $T_0^0 = 1$ and $T_{m+1}^0 = T$, that $W_i^{0'} W_i^0/(T_i^0 - T_{i-1}^0)$ converges in probability to some non-random positive definite matrix not necessarily the same for all i.

ASSUMPTION A2: There exists an $l_0 > 0$ $such\ that\ for\ all\ l > l_0$, the minimum eigenvalues of$A_{it} = (\frac{1}{l}) \sum_{T_i^0+1}^{T_i^0+l} w_t w_t'\ and\ of\ A_{il}^* = (\frac{1}{l}) \sum_{T_i^0-l}^{T_i^0} w_t w_t'$are bounded away from zero $(i = 1, \ldots, m + 1)$.

ASSUMPTION A3: The matrix $B_{kl} = \sum_k^l z_t z_t'$ is invertible for $l - k \geq q$, the dimension of z_t.The sequence of error $\{Ut\}$ satisfies one of the following two sets of conditions:

ASSUMPTION A4(i): With $\{\mathfrak{F}_i : i = 1,2, \ldots\}$ a sequence of increasing δ-fields, assume that $\{u_t, \mathfrak{F}_i\}$ forms a L^r-martingale sequence with $r = 4 + \delta$ for some $\delta > 0$ (McLeish, 1975) and Andrews (1988). That is, there exist nonnegative constants $\{c_i : i \geq 1\}$ and $\{\psi : j \geq 0\}$ such that $\psi_i \downarrow 0$ as $j \to \infty$ and for all $i \geq 1$ and $j \geq 0$, implies: (a) $E\backslash E\big(u_t \backslash \mathfrak{F}_{i-j}\big)\backslash^r \leq c_i^r \psi_i^r$, $(b)\ E\backslash u_t - E(u_t \backslash \psi_{i+1})\backslash^r \leq c_i^r \psi_i^r$, $(c) \max_i c_i \leq K < \infty$,(d) $\sum_{j=0}^{\infty} j^{1+k} \psi_j < \infty$ for some $k > 0$. One also assumes (e) that the disturbances u_t are independent of the regressors w_s for all t and s.

ASSUMPTION A4(ii): Let $\mathfrak{F}_t^* = \sigma - field\ \{\ldots, w_{t-1}, w_t, \ldots, u_{t-2}, u_{t-1}\}.$ Assume (a) that $\{ut\}$ is a martingale difference sequence relative to $\{\mathfrak{F}_t^*\}$ and $\sup_t E|u_t|^{4+c} < \infty$ for some $c > 0$; (b) $T^{-1} \sum_{t=1}^{[T\,v]} z_t z_t' \xrightarrow{p} Q(v)$uniformly in $v \epsilon [0, 1]$, where $Q(v)$ is positive definite for $v > 0$; (c) If the disturbances u_t are not independent of the regressors $\{z_s\}$ for all t and s, the minimisation problem defined by (A3) is taken over all possible partitions such that $T_i - T_{i-1} > \epsilon T (i = 1, \ldots, m + 1)$ for some $\epsilon > 0$.

ASSUMPTION A5: $T_i^0 = [T\lambda_i^0]$, where $0 < \lambda_1^0 < \cdots < \lambda_m^0 < 1$.

Following assumption $A1 - A4$ the following propositions can be stated.

---

[154] As a matter of notation, BP let " $\xrightarrow{p}$ " denote convergence in probability, " $\xrightarrow{d}$ " convergence in distribution, and " $\Longrightarrow$ " weak convergence in the space D[0, 1] under the Skorohold metric (e.g., Pollard (1984, in BP, 1998)).

$\boldsymbol{PROPOSITION}$ **4.1**: Under Assumptions $A1 - A4$,

$$\hat{\tau} - \tau_1^0 = O_p\left(T^{-\frac{1}{2}}\right).$$

That is, the estimated break point is consistent for τ_1^0.

$\boldsymbol{LEMMA}$ **4.1**: Under Assumptions $A1 - A4$, for every $\epsilon > 0$, there exists an $M < \infty$ such that

$$P(\min_{k\epsilon D_{T,M}} S_T(k) - S_T(k_1^0) \leq 0) < \epsilon.$$

$\boldsymbol{PROPOSITION}$ **4.2**: under Assumptions A1-A4, for every $\epsilon > 0$, there exists a finite M independent of T such that, for all large T,

$$P(T|\hat{\tau} - \tau_1^0| > M) < \epsilon.$$

That is, the break point estimator is $T - consistent$[155].

When $U(\tau_1^0) = U(\tau_2^0)$, one can show that the function $U(\tau)$ has local minimum at τ_1^0 and τ_2^0. This leads to the conjecture that the estimated break point $\hat{\tau}$ may converge in distribution to a random variable with mass at τ_1^0 and τ_2^0 only. This leads to the following propositions:

$\boldsymbol{PROPOSITION}$ **4.3**: If Assumptions $A1 – A3$ hold and $U(\tau_1^0) = U(\tau_2^0)$, the estimator $\hat{\tau}$ converges in distribution to a random variable with equal mass at τ_1^0 and τ_2^0. Furthermore, $\hat{\tau}$ converges either to τ_1^0 or to τ_2^0 at rate T in the sense that for every $\epsilon > 0$ there exists a finite M, which is independent of T, such that, for all large T,

$P(|T(\hat{\tau} - \tau_1^0)| > M$ and $|\ T(\hat{\tau} - \tau_2^0)| > M) < \epsilon$.

$\boldsymbol{LEMMA}$ **4.3**: Under the assumptions of Proposition 4.3, for every $\epsilon > 0$, there exists an $M\ >\ 0$ such that

$P\left(\min_{K\epsilon D_{T,M}^i} S_T(k) - S_T(k_i^0) \leq 0\right) < \epsilon$, for $i = 1,2$,

Let R be the conventional matrix such that $(R\delta)' = (\delta_1' - \delta_2', \ldots, \delta_m' - \delta_{m+1}')$. Define

$$F_T(\lambda_1, \ldots \lambda_m; q) = \frac{1}{T}\left(\frac{T - (m+1)q}{mq}\right)\delta' R'(RV(\delta)R')^{-1}R\delta' (4.21)$$

where R is a matrix such that

$$(R\delta)' = (\delta_1 - \delta_2, \ldots, \delta_m - \delta_{m-1}), \qquad (4.10A)$$

and

$$V(\delta) = p\lim T(Z_{max}Z)^{-1}Z_{max}\Omega_{\max}Z(Z_{max}Z)^{-1} \qquad (4.11A)$$

$V(\delta)$ is a constant estimate of the variance covariance matrix of δ that is robust to serial correlation and heteroscedasticity.

[155] See Bai (1997) for Proof.

The statistic F_T^* is the conventional $F-statistic$ for testing $\delta_1=\cdots=\delta_{m+1}$ against $\delta_i\neq\delta_{i+1}$for some i given the partition $(T_1,\ldots,T_m)$. The $SupF$ type test statistic is then defined as

$$SupF_T^*(m;q)=\sup_{(\lambda_1,\ldots,\lambda_m)\epsilon\Lambda,} F_T^*(\lambda_1,\ldots,\lambda_m;q),$$

where

$$\Lambda_\epsilon=\{(\lambda_1,\ldots,\lambda_m);|\lambda_{i+1}-\lambda_i|\geq\epsilon,\lambda_m\geq\epsilon,\lambda_m\leq1-\epsilon\}$$

for some arbitrary positive number ϵ. In this general case, allowing for serial correlation in the errors, according to BP, the $supF_T^*(m;q)$ is rather cumbersome to compute. They suggest an alternative but asymptotically equivalent version by using the estimates of the break dates obtained from the global minimisation of the sum of square residuals (BP, 2002). The estimates are denoted by $\lambda_i=\frac{T_i}{T}$ for $i=1,\ldots,k,$ the test is then

$$supF_T(m;q)=\ F_T^*(\lambda_1,\ldots,\lambda_k;q)$$

The estimates $\lambda_1,\ldots,\lambda_m$ are equivalent to the argument that maximises the following F −statistic:

$$F_T(\lambda_1,\ldots\lambda_m;q)=\left(\frac{T-(m+1)q}{mq}\right)\delta'R'(RV(\delta)R')^{-1}R\delta' \qquad (4.12A)$$

$$V(\delta)=\left(\frac{ZZ}{T}\right)^{-1},$$

The covariance matrix of δ assumes spherical errors. This procedure is asymptotically equivalent since the break dates are consistent even in the presence of serial correlation. The asymptotic distribution still depends on the specification of the set Λ_ϵ via the imposition of the minimal length h of a segment. Hence, $\epsilon=\frac{h}{T}$.

$\boldsymbol{Proposition\,4.4}$. Let $Wq(.)$ be a $q-vector$ of independent *Wiener* processes[156] on $[0,1]$. Under $A4$ and $A8$[157] of BP and $m=0$,

$supFT(k;p)\Rightarrow supF_k,q=\sup_{(\lambda1,\ldots,\lambda k)\epsilon\Lambda_\epsilon} F(\lambda_1,\ldots,\lambda_k;q)$, with

$$F(\lambda_1,\ldots,\lambda_k;q)=\frac{1}{kq}\sum_{i=1}^{k}\frac{[\lambda_iW_q(\lambda_{i+1})-\lambda_{i+1}W_q(\lambda_i)]'[(\lambda_iW_q(\lambda_{i+1})-\lambda_{i+1}W_q(\lambda_i)]}{\lambda_i\lambda_{i+1}(\lambda_{i+1}-\lambda_i)}. \quad (4.13A)$$

There are various versions of the tests depending on the assumptions made with respect to the distribution of the data and the errors across segments. These variations relates to different

---

[156]The Wiener process $W_q(\lambda)$ are approximated by the partial sum $n^{-\frac{1}{2}}\sum_{i=1}^{[n\lambda]}$ eiwith $e\sim i,i,d.N(0,I_q)$ and. The number of replications is 10,000. For e+ach replication, the supremum of $F(\lambda_1,\ldots,\lambda_k;q)$ with respect to $(\lambda_1,\ldots,\lambda_k)$over the set Λ_ϵ is obtained via a dynamic programming algorithm (see BP, 2003).

[157] See BP for A4 and A8

specifications in the construction of the estimate of the limiting covariance matrix $V(\delta)$ given by (4.11)[158].

ASSUMPTION A6: The process $\{X_t\}$ is strictly stationary. This assumption allows one to express the limiting distribution free from the change point (k_1^0).

PROPOSITION 4.5: If Assumptions A1-A6 hold and X_t has a continuous distribution,

$$\hat{k} - k_1^0 \xrightarrow{d} argmin_l W^{(1)}(l, \lambda_1),$$

where

$$\lambda_1 = \frac{1 - \tau_2^0}{1 - \tau_1^0}\left(\frac{\mu_3 - \mu_2}{\mu_2 - \mu_1}\right).$$

Note that Assumption A4 (or, equivalent, (A6) guarantees that $|\lambda_1| < 1$.

[158] See Appendix for the various versions of the tests and the assumptions made with respect to the distribution of the data and the errors across segments.

CHAPTER 5

5.1A Summary Statistics and Diagnostics in Levels

Table 5.1A Summary Statistics of Log Transformed Statistics

	LCPI	LEXR	LFFR	LGDP	LIIP	IR	LM4	LCRED	LRPI	LSPI	BLR
Mean	2.97	-0.75	1.84	12.11	3.85	2.16	2.49	11.92	1.85	2.20	2.24
Median	2.97	-0.83	1.88	12.13	3.91	2.20	2.47	12.10	1.77	1.92	3.60
Maximum	4.23	-0.09	2.95	12.49	4.24	2.83	3.67	13.31	3.29	3.87	2.95
Minimum	1.87	-1.04	0.16	11.67	3.19	1.39	1.25	6.78	-0.36	0.88	1.44
Std. Dev.	0.82	0.24	0.50	0.23	0.29	0.38	0.76	1.13	0.69	0.85	0.55
Skewness	0.08	0.45	-0.32	-0.11	-0.62	-0.25	0.00	-1.32	-0.19	0.60	-0.30
Kurtosis	1.38	2.12	3.01	2.07	2.44	2.03	1.65	5.55	2.98	2.00	2.05
Jarque-Bera	42.16	25.48	6.58	14.47	29.98	19.20	29.00	102.84	2.23	38.74	22.00
Lag	12	3	1	4	7	3	0	4	12	1	2
Prob.	(0.04)	(0.04)	(0.06)	(0.19)	(0.05)	(0.15)	(0.99)	(0.00)	(0.05)	(0.04)	(0.14)
Observations	384	384	384	384	384	384	384	183.00	381	384	384

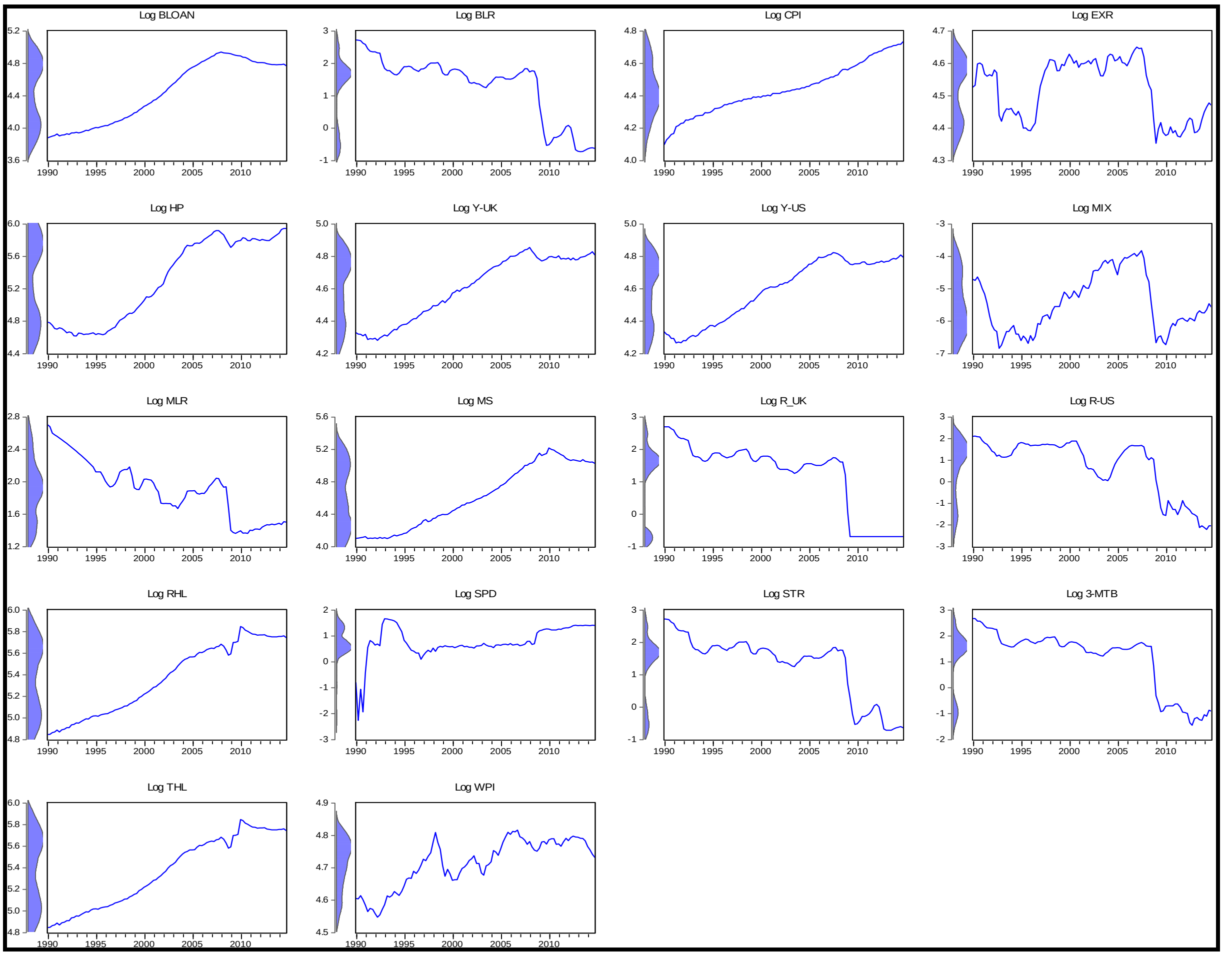


Figure 5.1A Diagnostics of Preliminary Data Plots in Levels

Note: The data used are BLOAN: log of real bank loan; HP: log of real house prices; Y: log of GDP; STR: short-term interest rate, percentage. SPD: Spread between mortgage rate and a safe rate (3-months Treasury bill), percentage. THL (RHL): log real total housing loan from banks; BL: log of real loans from banks for all other purposes. MIX: ratio between housing loans from State and non-depository institutions versus total housing loans. MLR: bank mortgage lending rate. MS: log money supply (M4); R (STR): real short term interest rate, percentage; MTB: real 3 month Treasury bill; WPI: world price index.

Data Generating Process - Non-Stationarity [Regime-1]

IIP, FFR, RGDP, IR, RPI, SPI, M4 and EXR

Data Series (1960M1 to 1991M12)

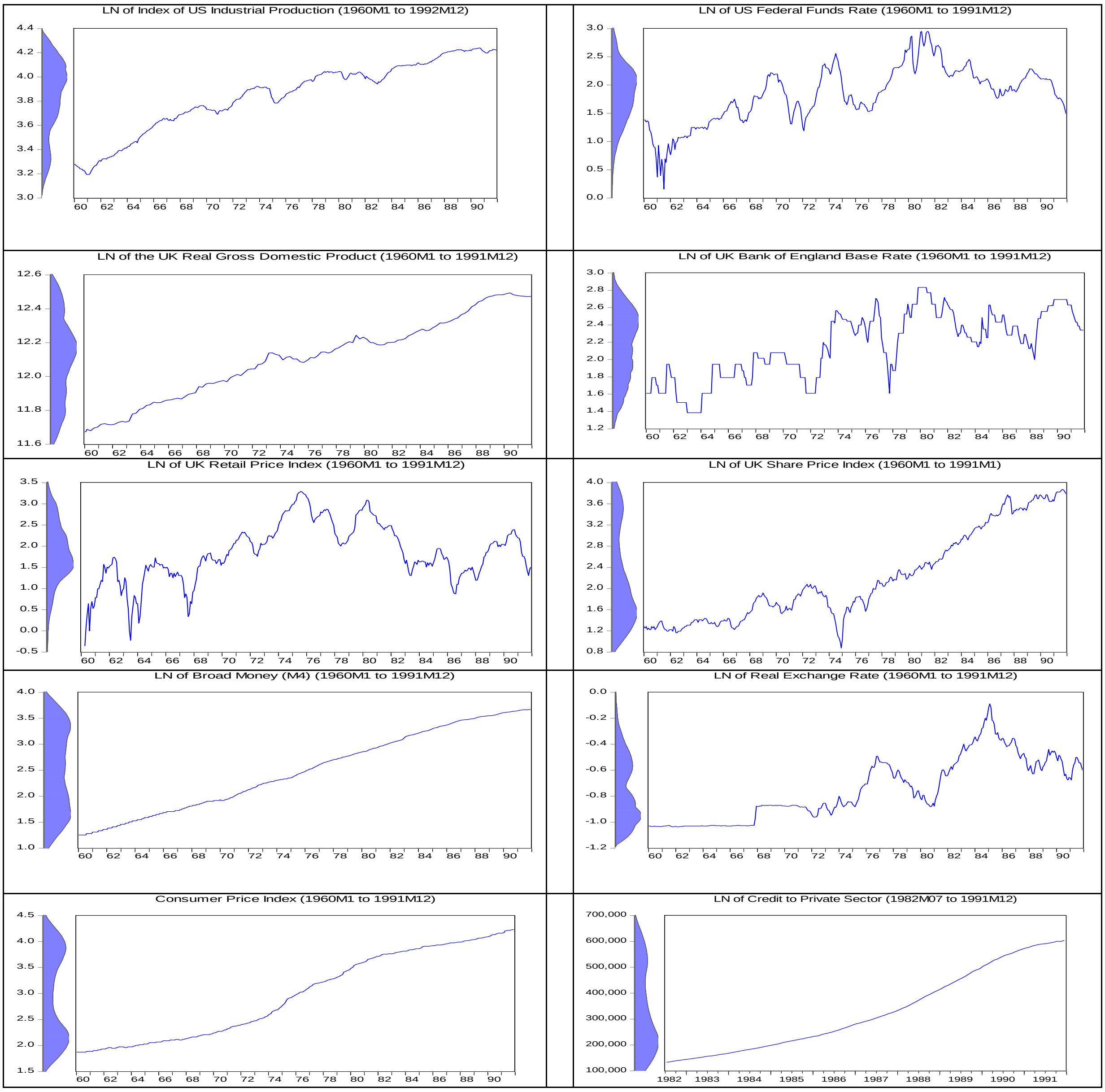


Figure 5.2A Regime-1 (Non-Inflation Targeting Regime) LEVELS

DGP –Stationarity [Regime-1]

IIP, FFR, RGDP, IR, RPI, SPI, M4 and EXR

Data Series (1960M1 to 1991M12)

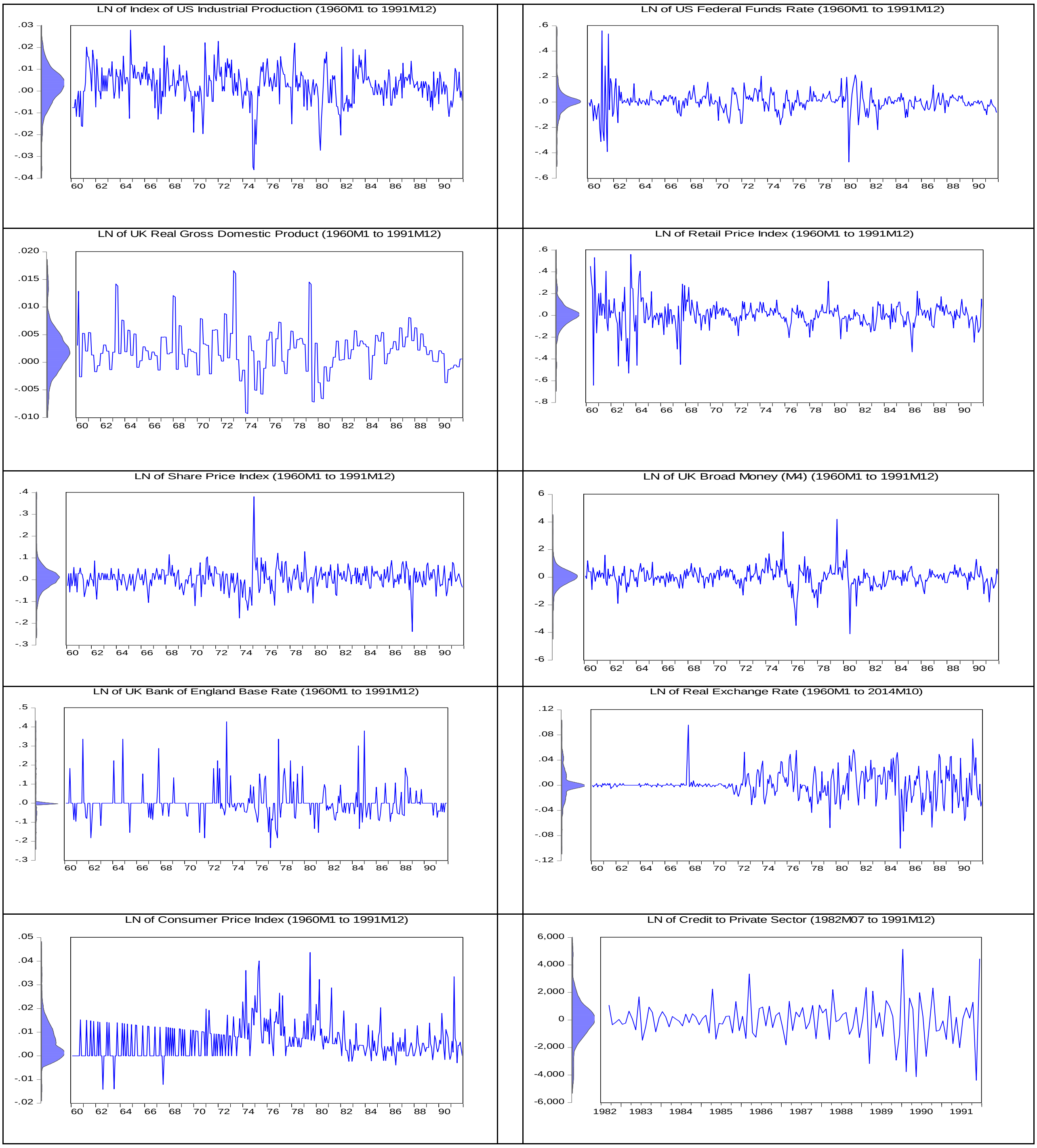


Figure 5.3A Regime-1 (Non-Inflation Targeting Regime) DIFCD

DGP - Nonstationarity [Regime 2]

IIP, FFR, RGDP, IR, CPI, CRED, M4 and EXR

Data Series (1992M1 to 2014M10)

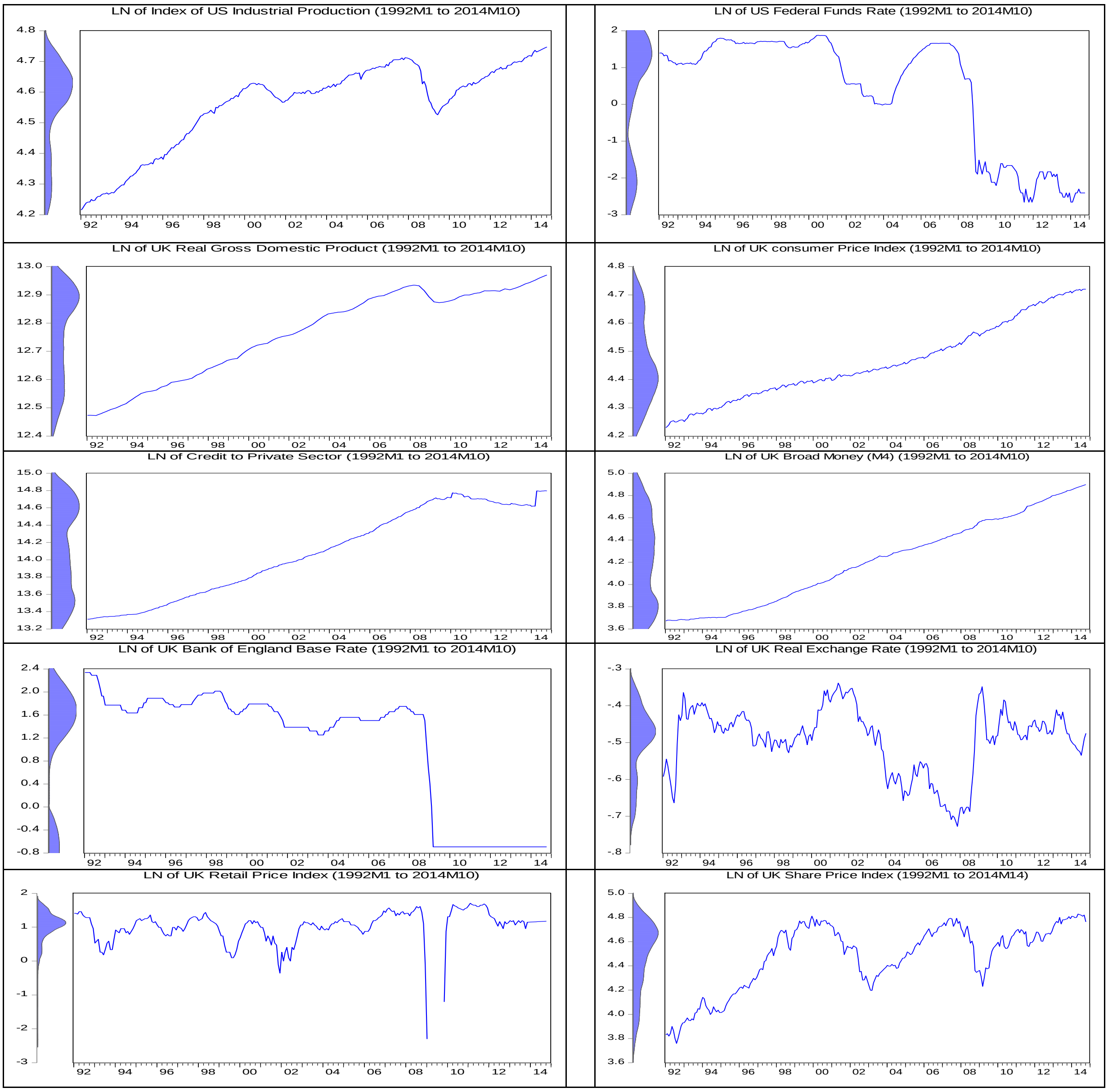


Figure 5.4A Regime-2 (Inflation Targeting Regime) LEVELS

DGP - Stationarity [Regime-2]

IIP, FFR, RGDP, IR, CPI, CRED, M4, EXR, RPI and SPI
Data Series (1992M1 to 2014M10)

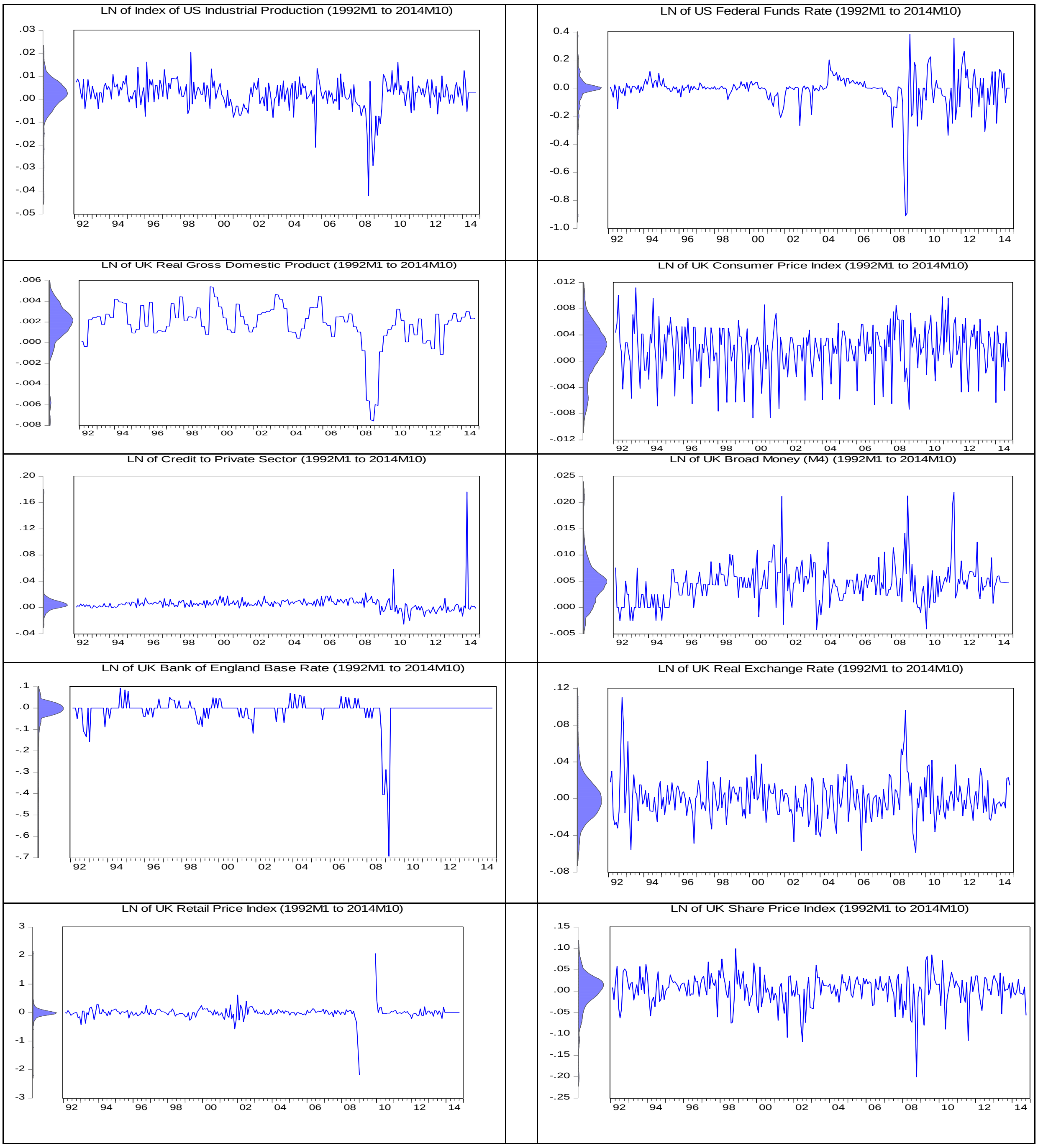


Figure 5.5A Regime-1 (Inflation Targeting Regime) DIFFERENCED

5.2A Stationarity and Lag Selection Tests

Table 5.2A ADF Test of Stationarity [lag] Regime-1

Variables	ADF				
	AIC	SIC	HQC	t-stat	PP Bandwidth
IIP	0.4429[5] 0.0000[4]	0.4553[3] 0.0000[0]	0.4553[3] 0.0000[4]	0.1633[9] 0.0000[11]	0.7155[11] 0.0000[7]
FFR	0.4498[11] 0.0013[12]	0.5524[4] 0.0000[3]	0.5524[4] 0.0000[10]	0.4498[11] 0.0013[12]	0.5690[4] 0.0000[10]
Y	0.1777[10] 0.0032[9]	0.9942[4] 0.0006[6]	0.1881[7] 0.0006[6]	0.1777[10] 0.0032[9]	0.5688[9] 0.0000[16]
CPI	0.5350[12] 0.4722[11]	0.5350[12] 0.4722[11]	0.5350[12] 0.4722[11]	0.5350[12] 0.4722[11]	0.7278[12] 0.0000[10]
RPI	0.5556[12] 0.0000[12]	0.5556[12] 0.0000[11]	0.5556[12] 0.0000[11]	0.5556[12] 0.0000[11]	0.1405[4] 0.0000[4]
SPI	0.5014[5] 0.0000[4]	0.3675[1] 0.0000[1]	0.3675[1] 0.0000[2]	0.3578[9] 0.0000[12]	0.4474[4] 0.0000[4]
CRED	0.1900[4] 0.9973[3]	0.1900[4] 0.9887[2]	0.1900[4] 0.9973[3]	0.1262[9] 0.9973[3]	0.5318[8] 0.0019[7]
M4	0.9942[4] 0.0000[3]	0.9942[4] 0.0000[3]	0.9942[4] 0.0000[3]	0.9909[6] 0.0000[5]	0.9838[10] 0.0000[11]
IR	0.0624[1] 0.0000[0]	0.1457[0] 0.0000[0]	0.1457[0] 0.0000[0]	0.043[12] 0.0000[7]	0.0612[6] 0.0000[1]
EXR	0.4022[3] 0.0000[2]	0.4248[1] 0.0000[0]	0.4248[1] 0.0000[2]	0.292[11] 0.0000[2]	0.5382[7] 0.0000[5]
BLR	0.0514[2] 0.0000[0	0.0847[3] 0.0000[0]	0.1358[0] 0.0000[0]	0.040[10] 0.0000[7]	0.0602[5] 0.0000[1]

Table 5.3A KPSS Test of Stationarity Regime-1

Variables	ADF	PP	KPSS (lm-stat)	ADF	PP	KPSS
IIP	-2.280967 0.4429	-1.774335 0.7155	0.396321	-7.165854 0.0000	-13.60364 0.0000	0.035631
FFR	-2.551113 0.3033	-2.054458 0.5690	0.293669	-4.567165 0.0013	-17.69605 0.0000	0.050364
Y	-2.871305 0.1732	-2.054954 0.5688	0.232753	-4.326173 0.0032	-8.726723 0.0000	0.060237
CPI	-2.115354 0.5350	-1.748142 0.7278	0.301663	-2.227754 0.4722	-16.33614 0.0000	0.461322
RPI	-2.078557 0.5556	-2.975499 0.1405	0.441927	-6.271236 0.0000	-16.37402 0.0000	0.044784
SPI	-2.175441 0.5014	-2.272784 0.4474	0.474867	-8.822429 0.0000	-14.26109 0.0000	0.035209
CRED	-2.829723 0.1900	-2.114727 0.5318	0.298682	0.138242 0.9973	-4.557029 0.0019	0.210400
M4	-0.133770 0.9942	-0.488924 0.9838	0.245874	-7.233168 0.0000	-22.70281 0.0000	0.302733
IR	-3.334017 0.0624	-3.348155 0.0602	0.198597	-17.69094 0.0000	-17.69190 0.0000	0.023383
EXR	-2.355962 0.4022	-2.109721 0.5382	0.105872	-9.056378 0.0000	-12.76695 0.0000	0.067416

Table 5.4A ADF Test of Stationarity [lag] Regime-2

Variables	ADF				
	AIC	SIC	HQC	t-stat	PP Bandwidth
IIP	0.3641[7] 0.0075[6]	0.4634 [1] 0.0054[3]	0.4634 [4] 0.0054[3]	0.3641 [7] 0.0075[6]	0.5748 [12] 0.0000[10]
FFR	0.6760[1] 0.0000[0]	0.6760 [1] 0.0000[0]	0.6760 [1] 0.0000[0]	0.3257 [8] 0.0000[0]	0.7033 [8] 0.0000[2]
Y	0.8441 [10] 0.0288[9]	0.7193 [1] 0.0047[0]	0.7193 [1] 0.0047[0]	0.8441 [10] 0.0288[9]	0.9494 [13] 0.0034[1]
CPI	0.7398 [12] 0.2378[12]	0.7398 [12] 0.4019[11]	0.7398 [12] 0.4019[11]	0.7398 [12] 0.4019[11]	0.8976 [46] 0.0000[6]
RPI	0.7191 [5] 0.8679[12]	0.6411 [3] 0.9108[2]	0.6220 [4] 0.9772[3]	0.6411 [3] 0.8679[12]	0.0001 [6] 0.0000[3]
SPI	0.5067 [1] 0.0000[0]	0.3675[1] 0.0000[0]	0.5067 [1] 0.0000[0]	0.5067 [1] 0.0000[0]	0.4979 [8] 0.0000[3]
CRED	0.9626 [0] 0.0000[0]	0.9626 [0] 0.0000[0]	0.9626 [0] 0.0000[0]	0.4643 [8] 0.0846[7]	0.9366 [7] 0.0000[6]
M4	0.0449 [6] 0.0000[4]	0.0035 [1] 0.0000[2]	0.0343 [4] 0.0000[0]	0.0343 [4] 0.0000[3]	0.0214 [8] 0.0000[4]
IR	0.4639 [8] 0.0000[4]	0.6857 [5] 0.0000[2]	0.6857 [5] 0.0000[4]	0.4639 [8] 0.0020[7]	0.6924 [10] 0.0000[9]
EXR	0.1651 [7] 0.0000[4]	0.1402 [1] 0.0000[0]	0.1349 [3] 0.0000[0]	0.1349 [8] 0.0000[5]	0.1963 [5] 0.0000[4]

Table 5.5A KPSS Test of Stationarity of Regime-2

Variables	ADF	PP	KPSS (lm-stat)	ADF	PP	KPSS
IIP	-2.428076 0.3641	-2.042814 0.5748	0.365876	-4.084840 0.0075	-15.74394 0.0000	0.096018
FFR	--1.852924 0.6760	-1.797919 0.7033	0.268836	-10.40583 0.0000	-10.36157 0.0000	0.059476
Y	-0.935209 0.9494	-2.054954 0.5688	0.417944	-3.634322 0.0288	-4.320230 0.0034	0.088967
CPI	-1.248590 0.9271	-1.748142 0.8976	0.396621	-2.699463 0.2378	-17.84092 0.0000	0.110735
RPI	-1.764686 0.7191	-5.160776 0.0001	0.109327	-1.367889 0.8679	-10.48662 0.0000	0.010988
SPI	-2.164964 0.5067	-2.180930 0.4979	0.213544	-13.96852 0.0000	-13.91633 0.0000	0.073460
CRED	-3.991878 0.0101	-1.032210 0.9366	0.209267	-15.93401 0.0000	-16.04610 0.0000	0.203702
M4	-3.571270 0.0342	-0.426921 0.9862	0.429234	-5.709025 0.0000	-12.73531 0.0000	0.202921
IR	-2.241933 0.4639	-1.820304 0.6924	0.295850	-6.405957 0.0000	-8.549077 0.0000	0.058253
EXR	-2.978478 0.1402	-2.806375 0.1963	0.149147	-7.288681 0.0000	-11.88204 0.0000	0.054987

Table 5.6A Lag Order Selection for Endogenous and Exogenous Variables (Regime 1)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	2150.638	NA	1.09e-17	-16.35601	-16.24706	-16.31222
1	6683.354	8754.024	1.67e-32	-50.46835	-49.48773	-50.07422
2	6881.156	369.9356	6.01e-33	-51.48974*	-49.63747*	-50.74527*
3	6947.457	119.9493	5.93e-33	-51.50731	-48.78338	-50.41250
4	7034.519	152.1920	5.00e-33*	-51.68335*	-48.08777	-50.23821
5	7093.961	100.2810	5.23e-33	-51.64856	-47.18132	-49.85308
6	7162.328	111.1603	5.13e-33	-51.68189	-46.34299	-49.53607
7	7219.001	88.68696	5.54e-33	-51.62596	-45.41541	-49.12980
8	7267.211	72.49968	6.43e-33	-51.50543	-44.42322	-48.65893
9	7317.643	72.76056	7.40e-33	-51.40186	-43.44799	-48.20502
10	7362.063	61.37379	9.00e-33	-51.25239	-42.42686	-47.70522
11	7420.378	77.01140	9.96e-33	-51.20899	-41.51181	-47.31148
12	7511.317	114.5413*	8.70e-33	-51.41463	-40.84579	-47.16678

Sample: 1992M01 to 2014M10, includes 262 observations.
* indicates lag order selected by the criterion

Table 5.7A Lag Order Selection for Endogenous and Exogenous Variables (Regime 2)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1682.038	NA	9.32e-16	-9.067959	-8.972574	-9.030068
1	8280.017	12838.34	4.26e-31	-44.39034	-43.43648	-44.01142
2	8495.462	408.7025	2.06e-31	-45.11903*	-43.30671*	-44.39909*
3	8565.437	129.3314	2.19e-31	-45.05928	-42.38849	-43.99831
4	8660.607	171.2549	2.03e-31	-45.13608	-41.60683	-43.73409
5	8758.967	172.1960	1.86e-31	-45.23017*	-40.84245	-43.48715
6	8790.779	54.13999	2.45e-31	-44.96357	-39.71738	-42.87952
7	8849.048	96.32606	2.80e-31	-44.84037	-38.73571	-42.41530
8	8925.601	122.8173	2.92e-31	-44.81627	-37.85314	-42.05017
9	8987.543	96.35443	3.30e-31	-44.71297	-36.89138	-41.60585
10	9063.099	113.8446	3.49e-31	-44.68346	-36.00340	-41.23531
11	9135.461	105.5037	3.77e-31	-44.63664	-35.09812	-40.84747
12	9210.528	105.7853*	4.05e-31	-44.60449	-34.20749	-40.47429

Table 5.8A Lag Exclusion Wald Chi-Squared Test for Joint lag Effect Numbers in [ ] are p-values. (Regime 1)

	LFFR	**LIIP**	LEXR	**LGDP**	LIR	**LM4**	LRPI	**LSPI**	Joint
Lag 1	415.3936	662.6757	794.3633	1505.034	413.8159	256.44	442.5604	633.64	5008.40
	[0.0000]	[0.0000]	[0.000000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Lag 2	21.537	41.657	73.867	225.4325	13.57371	39.929	15.159	40.749	453.48
	[0.0058]	[1.5e-06]	[8.3e-13]	[0.0000]	[0.0935]	[3.3e-06]	[0.0561]	[2.3e-06]	[0.0000]
df	8	8	8	8	8	8	8	8	64

Table 5.9A Lag Exclusion Wald Chi-Squared Test for Joint lag Effect Numbers in [ ] are p-values. (Regime 2)

	LCPI	**LEXR**	**LFFR**	**LGDP**	**LIIP**	**LIR**	**LM4**	**LNCRED**	**Joint**
Lag 1	216.64	441.61	**466.74**	**2052.04**	**254.04**	**511.9206**	**329.03**	**235.196**	**4451.11**
	[0.0000]	[0.0000]	**[0.0000]**	**[0.0000]**	**[0.0000]**	**[0.0000]**	**[0.0000]**	**[0.0000]**	**[0.0000]**
Lag 2	7.6953	34.062	**26.538**	**399.2242**	**33.847**	**65.189**	**12.39836**	**4.93719**	**573.57**
	[0.4638]	[3.9e-05]	**[0.0008]**	**[0.0000]**	**[4.3e-05]**	**[4.4e-11]**	**[0.1342]**	**[0.764]**	**[0.0000]**
df	8	8	**8**	**8**	**8**	**8**	**8**	**8**	**64**

5.3A Cointegration Test

Table 5.10A Unrestricted Cointegration Rank Test (Trace) for all variables in R-1

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.336204	820.4363	159.5297	0.0000
At most 1 *	0.304260	665.9490	125.6154	0.0001
At most 2 *	0.283535	529.1813	95.75366	0.0001
At most 3 *	0.247946	403.4798	69.81889	0.0001
At most 4 *	0.231772	296.0547	47.85613	0.0001
At most 5 *	0.195265	196.6518	29.79707	0.0001
At most 6 *	0.145989	114.7514	15.49471	0.0001
At most 7 *	0.136334	55.25666	3.841466	0.0000

Trace test indicates 8 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values.

Table 5.11A Unrestricted Cointegration Rank Test (Max-eigenvalue test) for R-1

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.336204	154.4873	52.36261	0.0000
At most 1 *	0.304260	136.7677	46.23142	0.0000
At most 2 *	0.283535	125.7015	40.07757	0.0000
At most 3 *	0.247946	107.4251	33.87687	0.0000
At most 4 *	0.231772	99.40287	27.58434	0.0000
At most 5 *	0.195265	81.90046	21.13162	0.0000
At most 6 *	0.145989	59.49469	14.26460	0.0000
At most 7 *	0.136334	55.25666	3.841466	0.0000

Max-eigenvalue test indicates 8 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values

Table 5.12A Unrestricted Cointegration Rank Test (Trace) for R-2

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.480856	688.4608	159.5297	0.0000
At most 1 *	0.416754	511.4559	125.6154	0.0001
At most 2 *	0.362714	365.8867	95.75366	0.0000
At most 3 *	0.256219	244.2418	69.81889	0.0000
At most 4 *	0.214053	164.3196	47.85613	0.0000
At most 5 *	0.144840	99.28575	29.79707	0.0000
At most 6 *	0.134673	57.03973	15.49471	0.0000
At most 7 *	0.064440	17.98472	3.841466	0.0000

Trace test indicates 8 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values

Table 5.13A Unrestricted Cointegration Rank Test (Max-eigenvalue test) for R-2

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.480856	177.0049	52.36261	0.0000
At most 1 *	0.416754	145.5693	46.23142	0.0000
At most 2 *	0.362714	121.6449	40.07757	0.0000
At most 3 *	0.256219	79.92217	33.87687	0.0000
At most 4 *	0.214053	65.03387	27.58434	0.0000
At most 5 *	0.144840	42.24603	21.13162	0.0000
At most 6 *	0.134673	39.05501	14.26460	0.0000
At most 7 *	0.064440	17.98472	3.841466	0.0000

Max-eigenvalue test indicates 8 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values

5.4A Impulse Response Functions

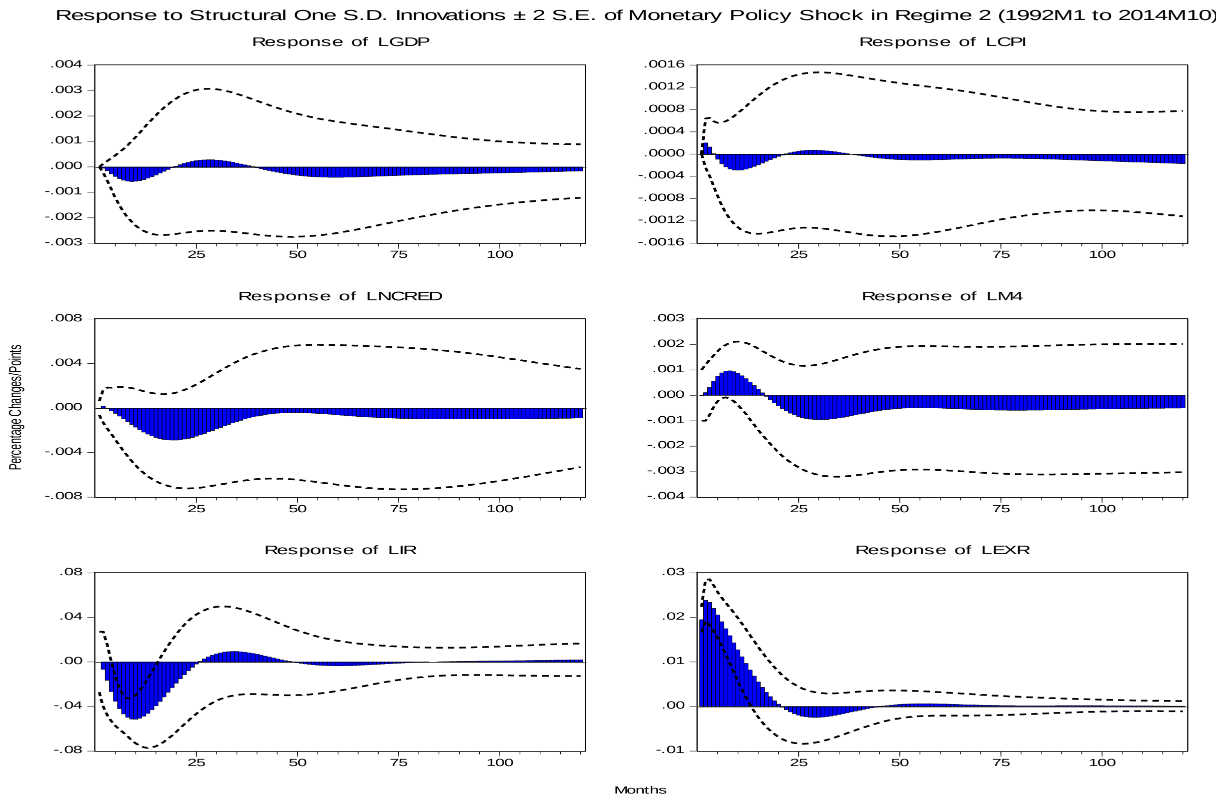


Figure 5.6A Response to a Monetary Policy Shock

GDP (%), Inflation (percentage points), Credit (%), Money Supply (%), Interest Rate (percentage points), and Exchange Rate (percentage points). 95% confidence interval.

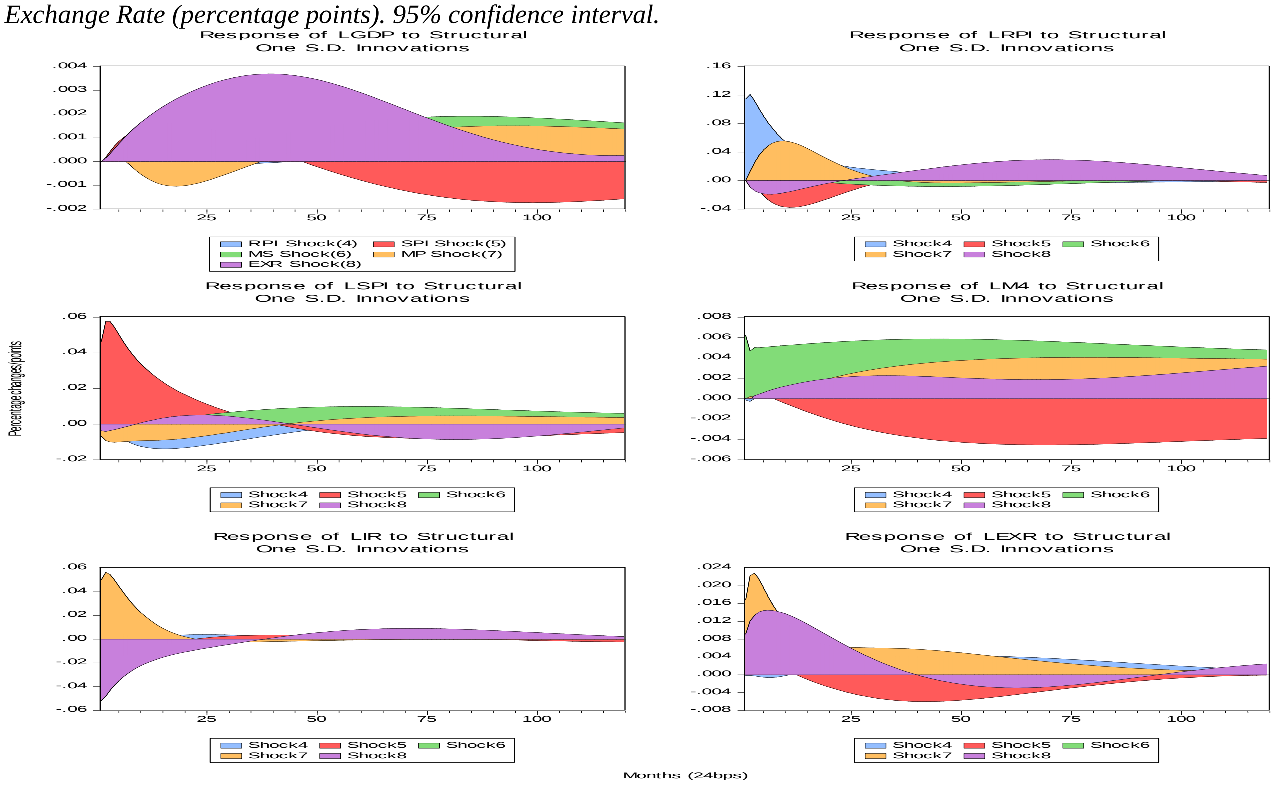


Figure 5.7A Combined Response of GDP, RPI, SPI, M4, IR, and EXR

To Structural one Standard Deviation Innovations of Monetary Shock (pre 1992)[159]*. 95% confidence interval.*

159 Two types of graphs are presented here. The coloured graph shows the magnitude of the response to the shock and the first graph shows more of the direction of the responses.

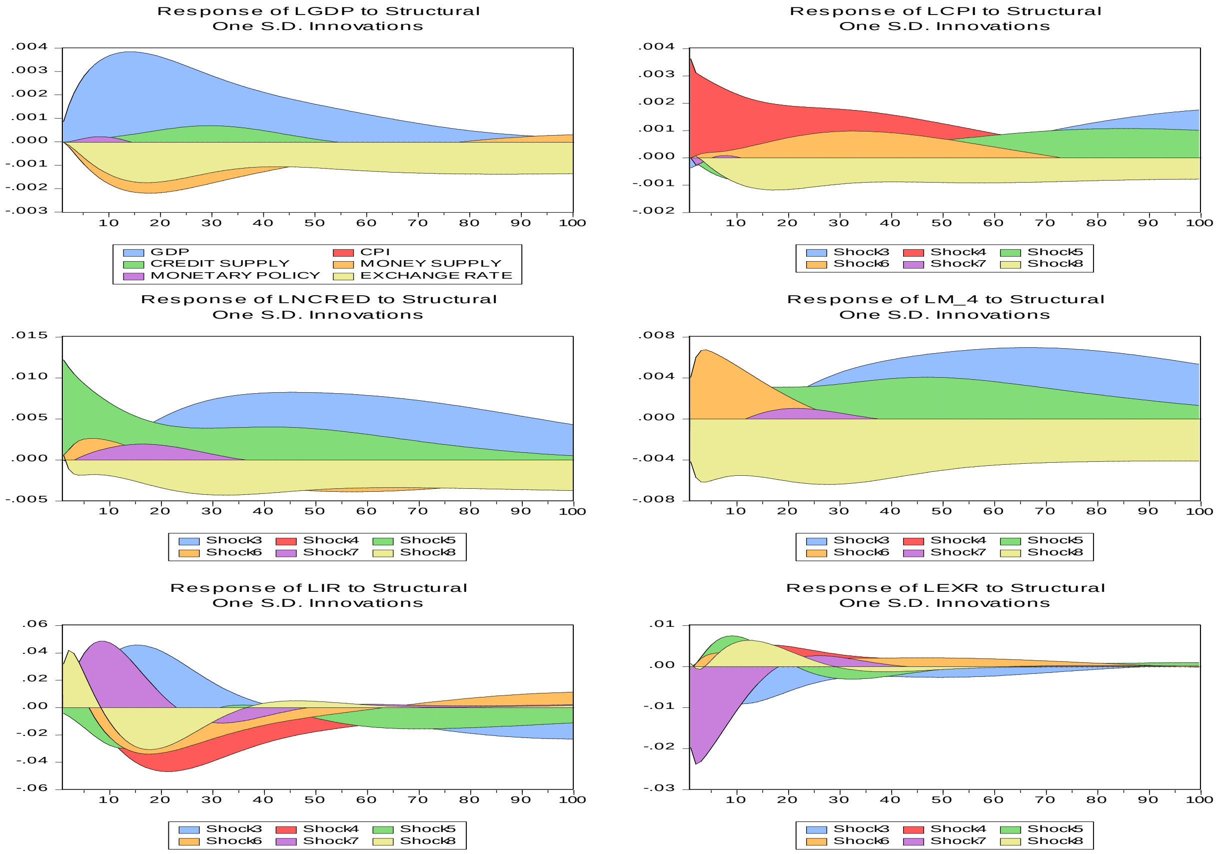


Figure 5.8A Combined Response of GDP, CPI, CRED, M4, IR, and EXR

To Structural one Standard Deviation Innovations of Monetary Shock (post 1992)[160] *. 95% confidence interval.*

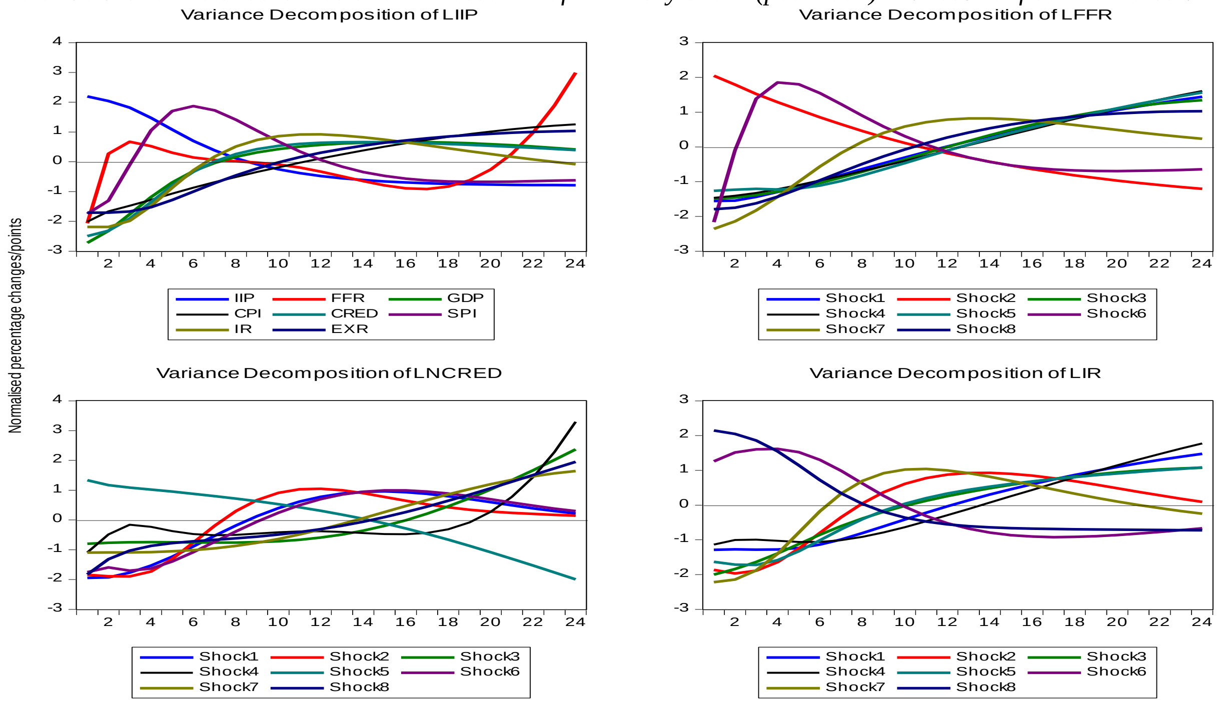


Figure 5.9A FEV Decomposition Responses to Monetary Policy and Credit Supply Shock

GDP (%), inflation (percentage points), credit (%), money supply (%), interest rate (percentage points), and exchange rate (percentage points). 95% confidence interval.

---

160 Two types of graphs are presented to show the combined responses in terms of direction of the responses (first graphs) and the magnitude of the response (second graphs) to the monetary policy shock.

5.5A Monetary Policy and Credit Supply Channels

Benchmark VECM with Rev-STR

(a) Monetary policy loosening (b) Credit supply easing

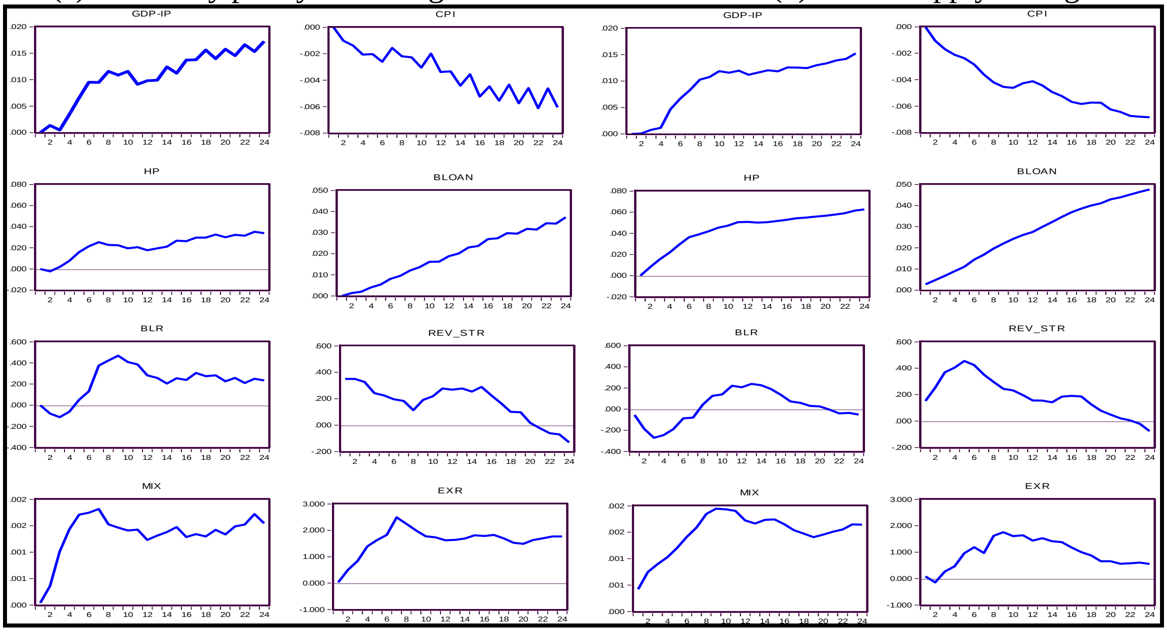


Figure 5.10A Baseline model: Cointegrated IRs to a Loose MP[161] and Credit Supply Easing [a].

Note: Two standard error confidence bands (asymptotic, Monte Carlo and bootstrap methods of obtaining confidence intervals yield similar results). VAR estimation from 1990q1 to 2014q4, including log-index of production (GDP-IP), inflation (CPI), reverse of short term interest rate (REV_STR), a mix between bank and sum of bank and market-based mortgages (MIXa). The reverse of the Fed rate is used to account for a positive shock, decreasing interest rates.

(a) Monetary policy Shock (b) Credit supply Shock

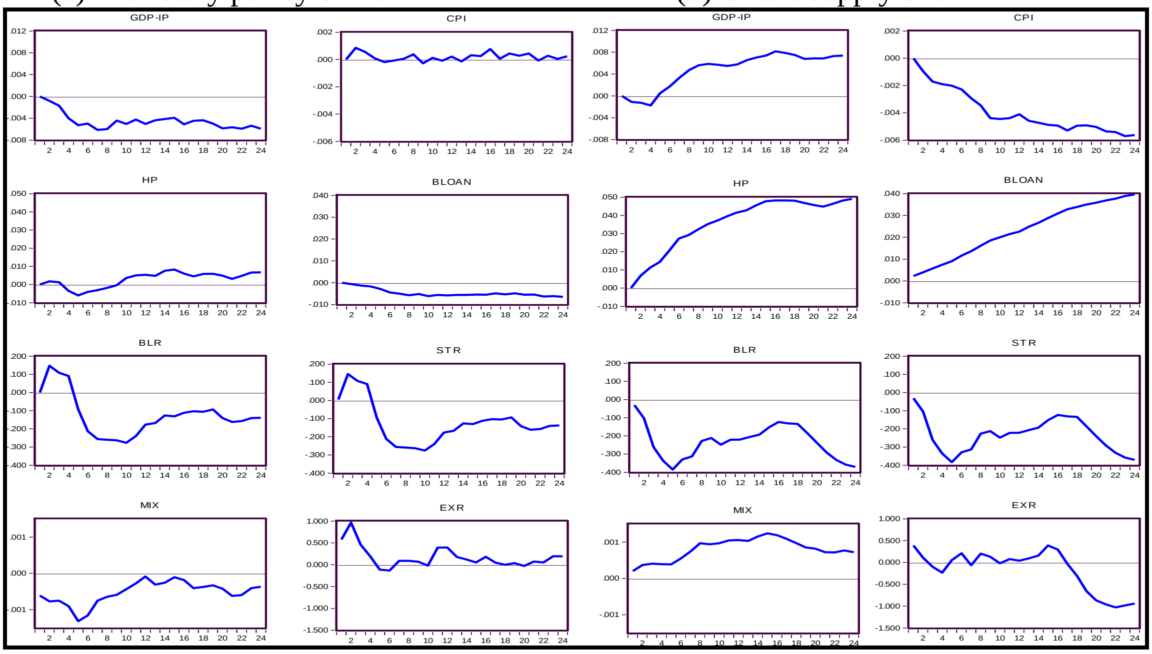


Figure 5.11A Baseline Model: Impulse Responses to Tight MP[162] and Credit Supply Shocks [b].

Note: Two standard error confidence bands (asymptotic, Monte Carlo and bootstrap methods of obtaining confidence intervals yield similar results). VAR estimation from 1990q1 to 2014q4, including log-index of production (GDP-IP), inflation (CPI), reverse of short term interest rate (REV_STR), a mix between bank and sum of bank and market-based mortgages (MIXa). The reverse of the Fed rate is used to account for a positive shock, decreasing interest rates.

---

[161] To encourage economic growth, a loose monetary policy makes money supply to expand and is easily accessible.

[162] Central banks constrict spending in an economy when it is growing too quickly, or to curb inflation when it is rising too fast. The CB "make money tight" by raising short-term interest rates (also known as the Fed funds, or discount rate), which increases the cost of borrowing and effectively reduces its attractiveness.

(a) Credit Supply Shock (b) Bank Lending Rate Shock

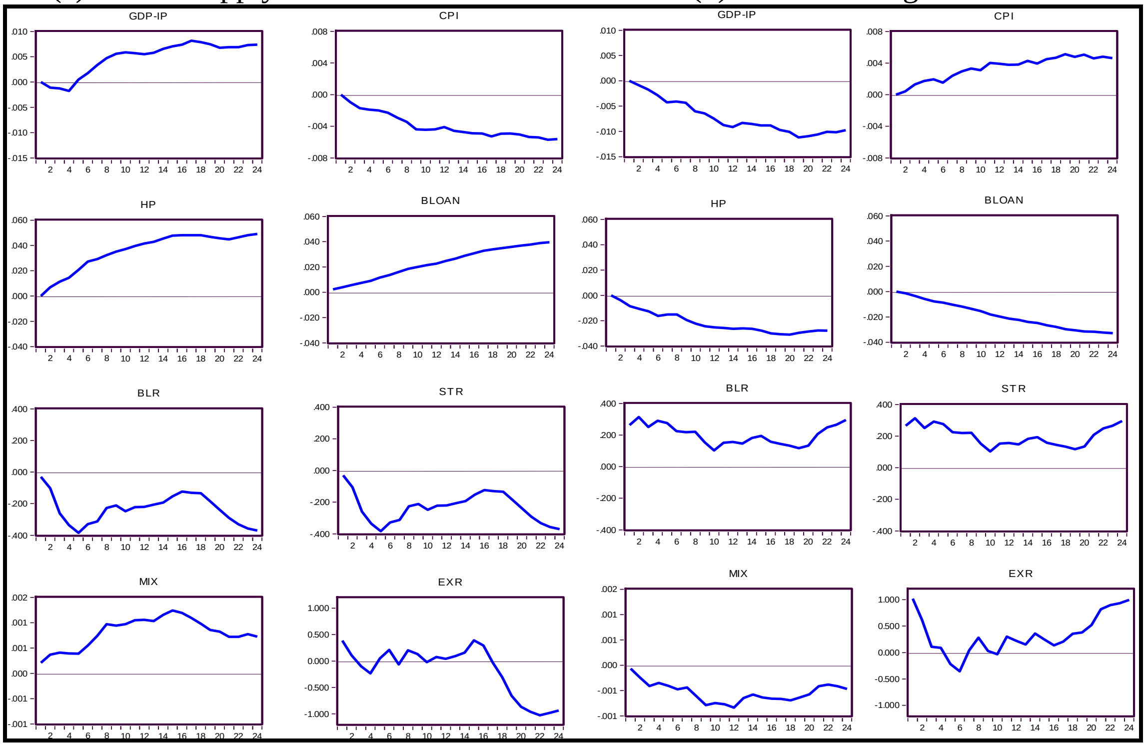


Figure 5.12A Baseline Model: Impulse Responses to Credit Supply and BLR Shocks [c].

Note: Two standard error confidence bands (asymptotic, Monte Carlo and bootstrap methods of obtaining confidence intervals yield similar results). VAR estimation from 1990q1 to 2014q4, including log-index of production (GDP-IP), inflation (CPI), reverse of short-term interest rate (REV_STR), a mix between bank and sum of bank and market-based mortgages (MIXa). The reverse of the STR is used to account for a positive shock, decreasing interest rates.

(a) SPREAD Shocks (b) Monetary Policy Shock

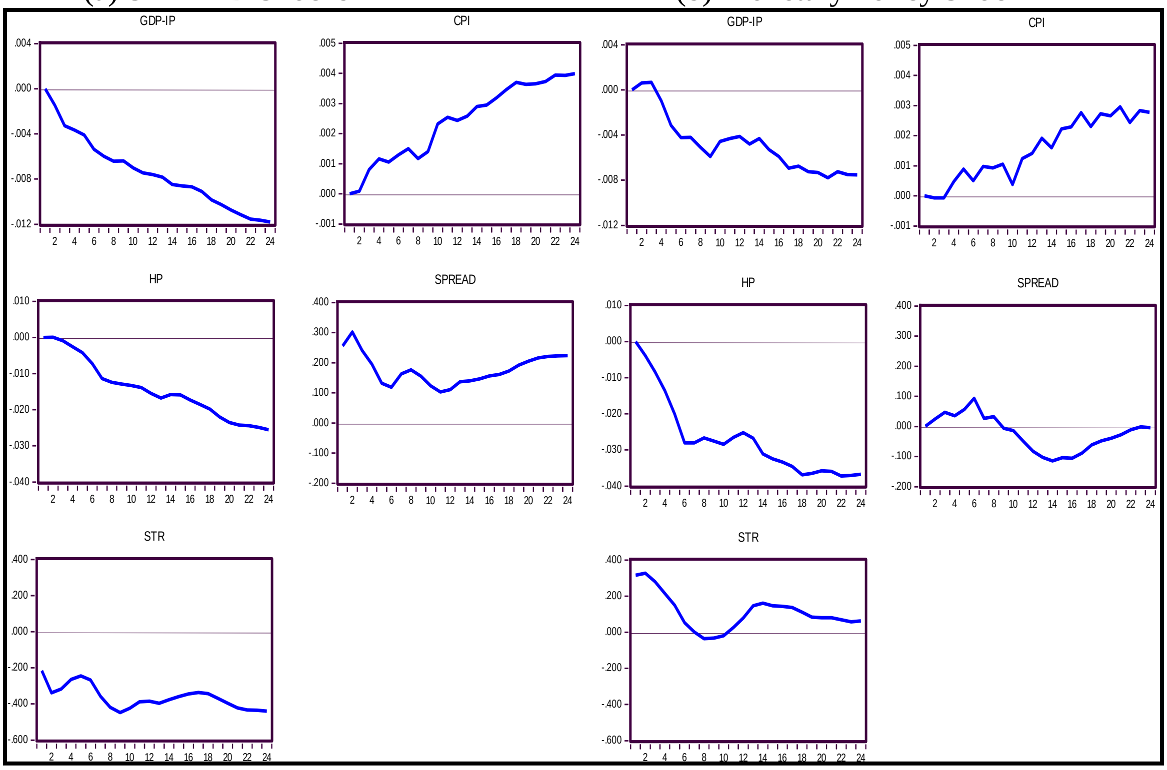


Figure 5.13A Baseline Model: Impulse Responses to Spread and MP Shocks [a].

Note: Two standard error confidence bands (asymptotic, Monte Carlo and bootstrap methods of obtaining confidence intervals yield similar results). VECM estimation from 1990q1 to 2014q4, including log-index of production (GDP-IP), inflation (CPI), reverse of short-term interest rate (REV_STR), a mix between bank and sum of bank and market-based mortgages (MIXa). The reverse of the STR is used to account for a positive shock, decreasing interest rates.

(a) Credit Supply Shock (b) Bank Lending Rate Shock

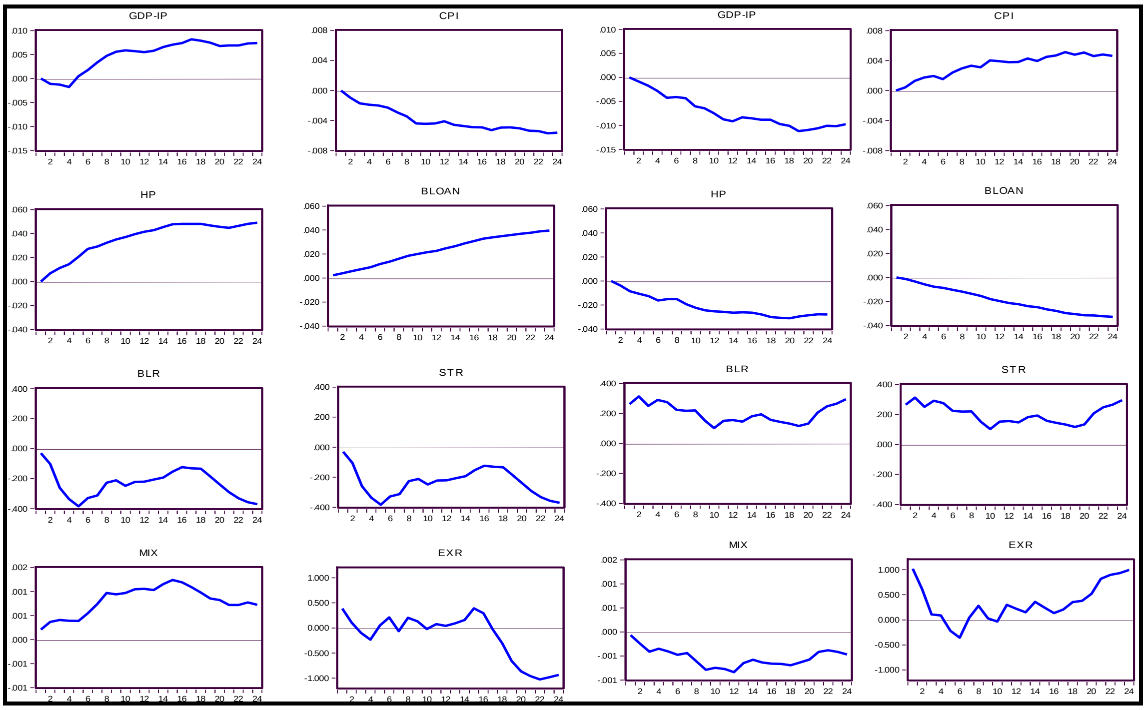


Figure 5.14A Baseline Model: Impulse Responses to Credit Supply and BLR Shocks [c].
Note: Two standard error confidence bands (asymptotic, Monte Carlo and bootstrap methods of obtaining confidence intervals yield similar results). VAR estimation from 1990q1 to 2014q4, including log-index of production (GDP-IP), inflation (CPI), reverse of short-term interest rate (REV_STR), a mix between bank and sum of bank and market-based mortgages (MIXa). The reverse of the STR is used to account for a positive shock, decreasing interest rates.

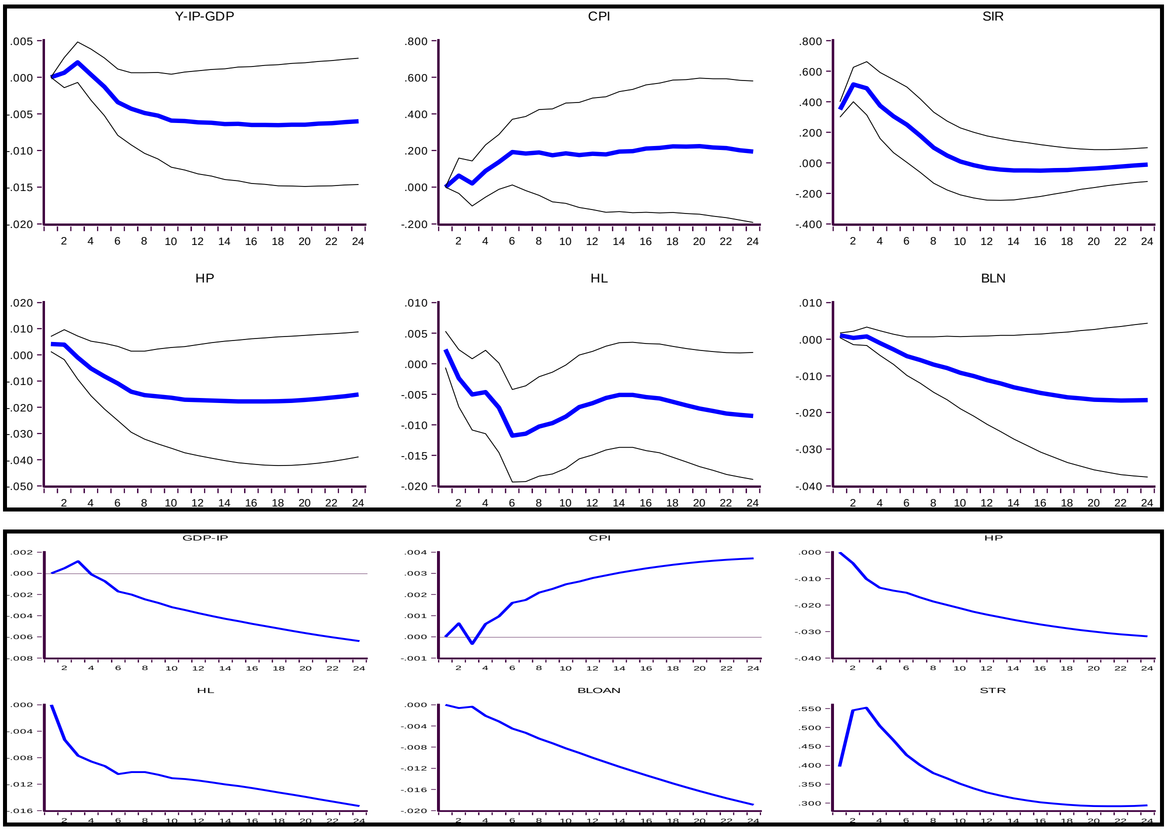


Figure 5.15A (2A) VECM IRs of ±1 S.E. Bands to a Monetary Shocks, Loans Regression.

Table 5.14A Forecast Error Variance Decomposition for the Baseline Model

Variance Decomposition of STR:

Period	S.E.	LOG(IP_UK)	LOG(CPI)	LOG(HP)	LOG(BLOAN)	BLR	STR	MIX	EXR
1	0.0084	21.995	1.9141	11.997	0.8817	63.196	0.0164	0.0000	0.0000
2	0.0110	26.437	4.6359	10.964	3.4667	48.194	6.0404	0.0915	0.1710
3	0.0148	30.585	4.8204	9.5469	12.273	35.321	4.9996	1.8563	0.5970
4	0.0204	26.541	4.2819	7.6287	18.873	30.854	3.9800	7.4365	0.4035
5	0.0272	19.648	4.8741	6.4672	20.754	23.912	3.0123	20.427	0.9045
10	0.0571	5.1859	8.6032	5.9098	10.597	8.6124	5.5934	51.885	3.6121
15	0.0837	3.2861	9.5238	5.1901	8.5726	6.7442	4.9309	55.927	5.8250
20	0.1124	2.6957	9.6817	5.3577	7.7829	5.9958	4.3341	57.022	7.1294
24	0.1339	2.1506	10.000	5.0239	8.9066	6.3200	3.9757	56.697	6.9250

Variance Decomposition of LOG(BLOAN):

Period	S.E.	LOG(IP_UK)	LOG(CPI)	LOG(HP)	LOG(BLOAN)	BLR	STR	MIX	EXR
1	0.0033	48.049	26.921	3.5005	21.527	0.0000	0.0000	0.0000	0.0000
2	0.0048	37.077	13.352	7.5968	31.099	2.4837	0.6399	2.9729	4.7763
3	0.0064	30.556	5.4182	6.7014	31.785	8.3293	1.3521	6.6027	9.2539
4	0.0076	29.207	3.1220	4.7462	30.466	13.494	1.4626	7.4046	10.0965
5	0.0092	29.702	1.7511	3.0254	28.023	16.056	1.9911	8.2480	11.2029
15	0.0292	36.598	1.1697	2.0175	22.684	15.102	1.5370	7.9239	12.9661
20	0.0403	39.158	1.1560	2.1847	21.340	14.477	0.9328	6.8265	13.9230
24	0.0485	40.091	1.3039	2.1762	20.371	14.013	0.7570	6.7723	14.5140

Variance Decomposition of REV_STR:

Period	S.E.	LOG(IP_UK)	LOG(CPI)	LOG(HP)	LOG(BLOAN)	BLR	REV_STR	MIX	EXR
1	0.0083	0.0051	3.6520	2.3183	14.297	4.1470	75.580	0.0000	0.0000
2	0.0110	12.012	3.6198	1.0827	20.493	1.6749	57.475	0.4831	3.1576
3	0.0141	19.696	2.3025	0.6190	27.277	1.7030	42.903	0.2547	5.2426
4	0.0173	22.534	9.6755	0.3981	27.976	5.2643	29.669	0.1719	4.3100
5	0.0227	17.757	22.136	1.6124	27.907	5.7091	21.666	0.4053	2.8044
10	0.0555	6.4592	34.773	26.802	15.106	2.0770	8.6733	4.3243	1.7839
15	0.0820	4.9009	37.291	26.746	11.808	1.5195	9.5750	6.7227	1.4345
20	0.1112	4.5477	36.705	29.977	10.462	1.6063	8.6469	6.2278	1.8265
24	0.1340	4.7955	34.333	32.674	8.7846	2.0746	7.3979	5.2576	4.6822

Variance Decomposition of LOG(BLOAN):

Period	S.E.	LOG(IP_UK)	LOG(CPI)	LOG(HP)	LOG(BLOAN)	BLR	REV_STR	MIX	EXR
1	0.0033	30.846	33.488	2.6645	33.001	0.0000	0.0000	0.0000	0.0000
2	0.0051	16.262	18.787	12.696	40.770	6.8626	2.5233	0.0410	2.0557
3	0.0065	12.107	9.5136	13.009	45.285	12.712	3.5427	0.0901	3.7399
4	0.0080	8.8442	4.5031	13.226	43.996	19.013	6.1702	0.0547	4.1912
5	0.0100	7.9601	2.6495	12.040	41.920	21.648	7.7464	0.0637	5.9702
10	0.0201	9.3844	0.3223	9.5196	38.008	16.540	13.620	0.2557	12.349
15	0.0297	11.081	0.2409	10.100	32.956	15.164	14.108	0.1666	16.181
20	0.0411	12.456	0.3048	10.477	30.085	14.375	14.545	0.0854	17.669
24	0.0497	13.503	0.2674	10.201	28.760	13.921	14.737	0.0721	18.535

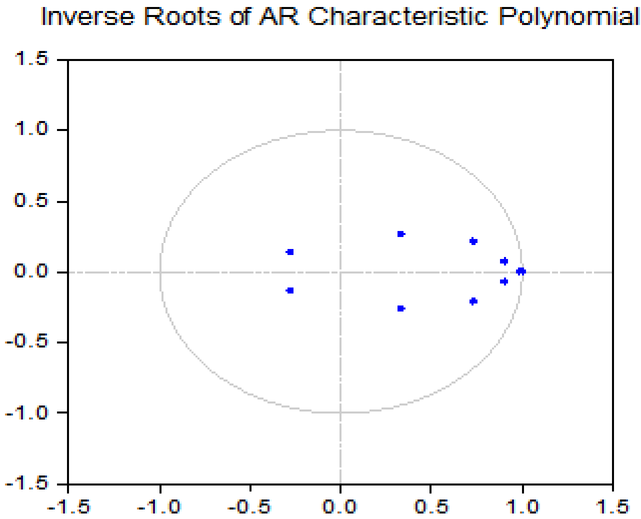


Figure 5.16A The VAR Stability Condition based on AR Characteristic Polynomial

Without a Credit Channel **With a Credit Channel**

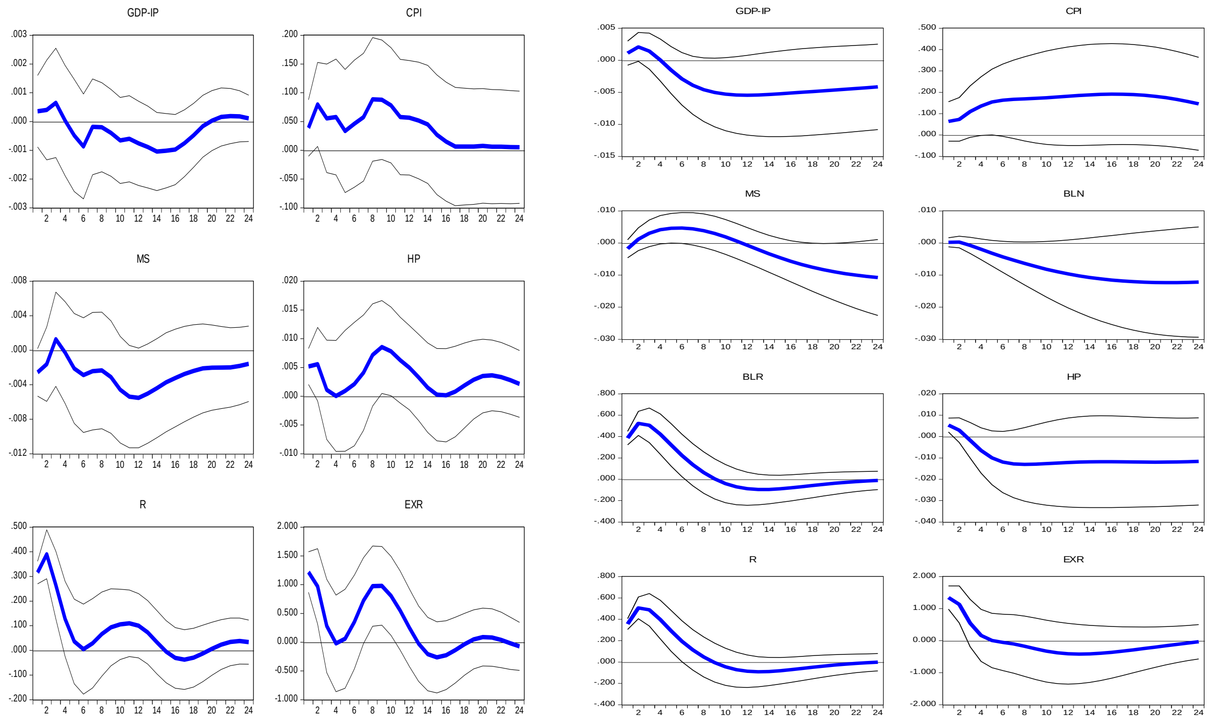


Figure 5.17A Monetary Policy Shock with and without a Credit Channel
IRFs are made with 95% CI**.**

Without Financial Frictions **With Financial Frictions**

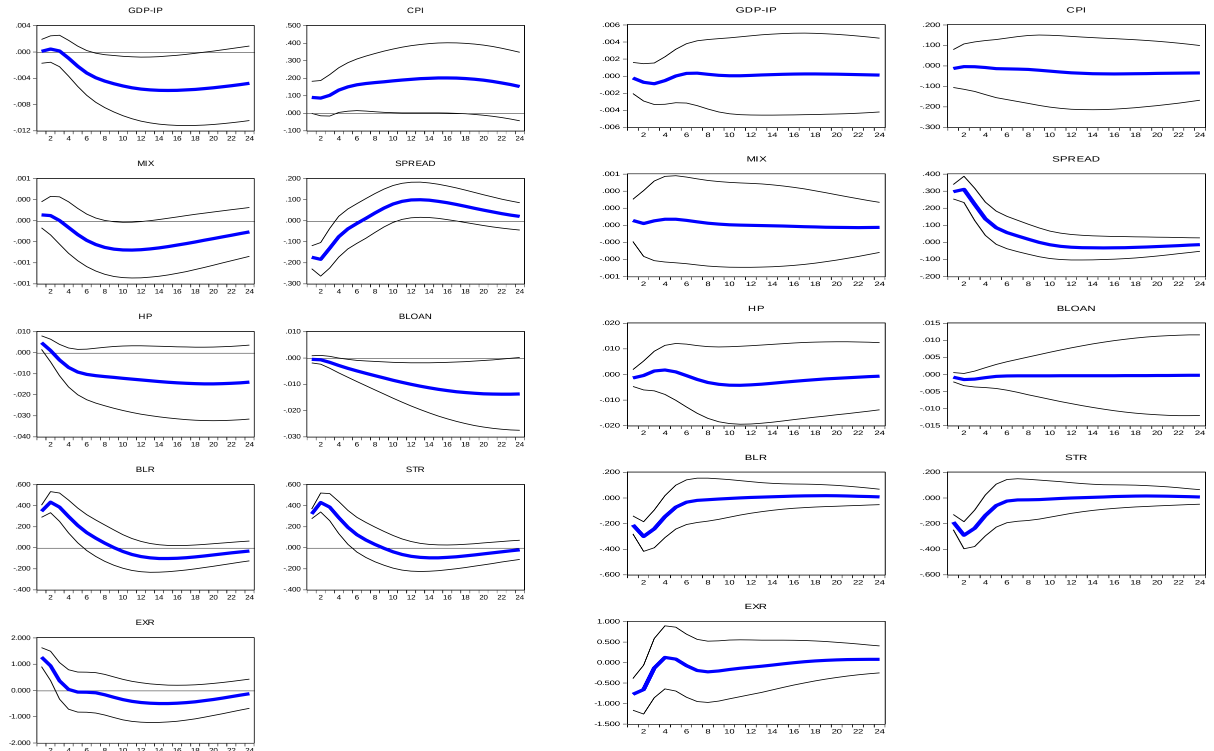
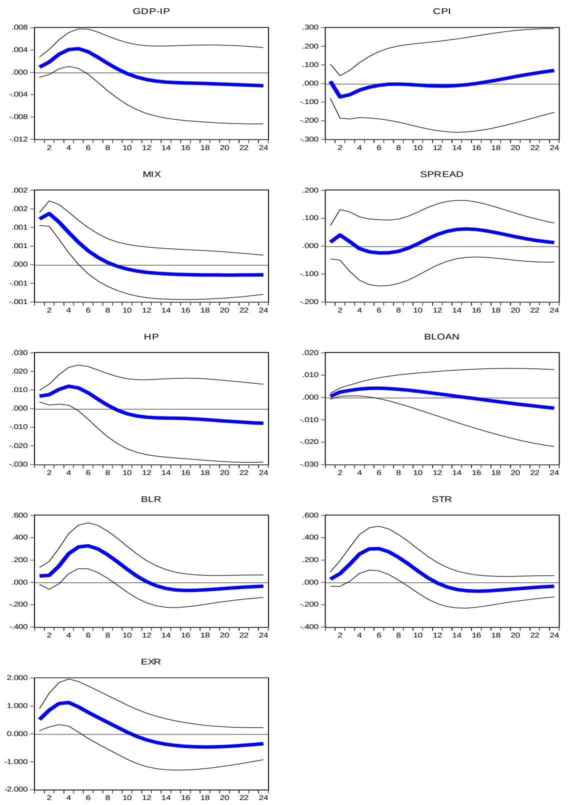


Figure 5.18A Monetary Policy Shock with and without Financial Frictions



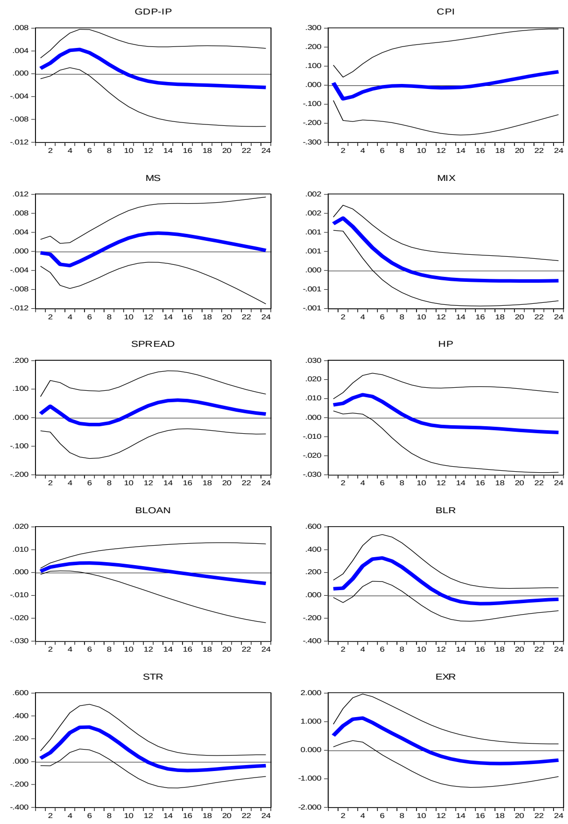


Figure 5.19A Responses to Mix (Credit Supply) Impulses

Figure 5.20A Responses when MS is included

IRFs are made with 95% CI**.**

CHAPTER 6

6.1A Data Description and Sources

Table 6.1 Data used for Dynamic Stochastic General Equilibrium Model

Output	Real Gross Domestic Product (GDP): Billions of Chained 2010=100, Seasonally Adjusted Annual Rate.
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Gross Domestic Product Deflator (GDPDEF)	Implicit Price Deflator - 2010=100, Seasonally Adjusted.
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Consumer Price Index (CPI)	Seasonally adjusted in terms of quarterly annualised inflation rate.
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Household Final Consumption Expenditure (CONS):	Seasonally Adjusted Annual Rate
Source:	*Office of the National Statistics (ONS), OECD and IFS.*
Fixed Private Investment (INV):	Seasonally Adjusted Annual Rate
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Labour Force	Sixteen Years & Over, Thousands, Seasonally Adjusted.
Source	*OECD, IFS and the Office of the National Statistics (ONS)*
Monetary Policy Rate: Bank of England Base Rate:	Averages of Quarterly Figures - Percent.
Source	*Bank of England (BoE), OECD and IFS.*
Hours Worked (HRW)	All Persons, Average Weekly Hours Duration: index, 2000=100, Seasonally Adjusted.
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Hourly Pay (HP)	All Persons, Hourly Compensation Duration: index, 2000=100, Seasonally Adjusted.
Source	*Office of the National Statistics (ONS), OECD and IFS.*
Spread (Proxy for FF)	Calculated as the yield on BAA rated corporate bonds over maturity-equivalent risk-free rates. Data is demeaned and then divided by 100 to make the units comparable with the other data. Source: Bank of England (BoE)

6.2A DGP – Variable Definitions

Table 6.2 Definition of Data and Variables used for Model Estimation

Consumption	$= logn(\ (CONS/DEF\ )/WFindex\ ) * 100$
Investment	$= logn(\ (FPI/DEF\ )/WFindex\ ) * 100$
Output	$= logn(\ GDP/WFindex) * 100$
Hours	$= logn(\ (HRW\ *\ WKF\ /\ 100\ )\ /\ WFindex\ ) * 100$
Inflation	$= logn(\ GDPDEF\ /\ GDPDEF(-1)\ ) * 100$
Real wage	$= logn(\ HWG\ /\ GDPDEF\ ) * 100$
Interest rate	$= BoE\ rate\ /\ 4$
External finance premium	$= BAA - AAA\ corporate\ spread\ /\ 4$. Alternatives as per BoE.

6.3A The Log-linearised Version of the DSGE Model and Parameter Definitions

All of the variables are log-linearised around their steady state. Variables that are not indexed by time represent steady-state values. To begin with, output (y_t) is composed by:

$$y_t = \frac{c}{y}c_t + \frac{i}{y} + i_t + \varepsilon_t^g + r^k\left(\frac{k}{y}\right)z_t^k + \left(\frac{k}{y}\right)f\left(1-\frac{r}{f}\right)\left(1-\frac{1}{lev}\right)\left(f_t + p_{t-1}^k + k_t\right) \quad (6.1A)$$

where c_t stands for consumption, i_t for investment and g_t is exogenously determined public spending. As in SW (2007) the steady state ratios $\frac{c}{y}$ and $\frac{i}{y}$ are defined as:

$$\frac{c}{y} = 1 - \frac{g}{y} - \frac{i}{y}, \text{ and } \frac{i}{y} = [\gamma - (1-\delta)]\frac{k}{y}, \quad (6.2A)$$

The cost associated with capital utilisation is measured by the $\boldsymbol{r^k\left(\frac{k}{y}\right)z_t^k}$ term. The term $\boldsymbol{\left(\frac{k}{y}\right)f\left(1-\frac{r}{f}\right)\left(1-\frac{1}{lev}\right)\left(f_t + p_{t-1}^k + k_t\right)}$ measures the bankruptcy costs. As in SW it is assumed that public spending follows an $AR(1)$ process with an iid $-$Normal error term and is also affected by the productivity shock[163] as follows:

$$\varepsilon_t^g = \rho_g\varepsilon_{t-1}^g + \eta_t^g + \rho_{ga}\eta_t^a$$

The model specification assumes that the economy is populated by three types of agents: *Households*, *firms,* and *financial intermediaries*. Besides, the economy consists of a large number of identical households. Each household chooses consumption, labour supply and capital holdings for the next period. Aggregate consumption evolves, according to:

$$c_t = c_1c_{t-1} + c_2E_tc_{t+1} + c_3(l_t - E_tl_{t+1}) - c_4\left(r_t - E_t\pi_{t+1} + \varepsilon_t^\beta\right) \quad (6.3A)$$

$$c_1 = \left(\frac{\frac{h}{\gamma}}{1+\frac{h}{\gamma}}\right); c_2 = \left(\frac{1}{1+\frac{h}{\gamma}}\right); c_3 = \frac{\sigma-1}{\sigma\left(1+\frac{h}{\gamma}\right)}\frac{W^hL}{C}; c_4 = \left[\frac{1+\frac{h}{\gamma}}{\sigma\left(1+\frac{h}{\gamma}\right)}\right] \quad (6.4A)$$

[163] The latter is empirically motivated. Estimation of the exogenous spending includes net exports, which is likely to be affected by domestic productivity developments.

where the parameter h introduces habit in consumption, σ represents the inverse of elasticity of intertemporal substitution and $\frac{W^{h}L}{C}$ is the steady-state ratio of labour income to consumption. Equation (6.48 and 6.49) represent that current consumption (c_t) depends on a weighted average of past and expected future consumption and on expected growth in hours worked $(l_t - E_t l_{t+1})$, the ex-ante real interest rate $(r_t - E_t\pi_{t+1})$, and a preference shock ε_t^{β} which is assumed to follow an AR(1) process with an iid-Normal error term: $\varepsilon_t^{\beta} = \rho\beta\varepsilon_{t-1}^{\beta} + \eta_t^{\beta}$. Investment dynamics are:

$$i_t = \frac{1}{1+\beta\gamma}\left[i_{t-1} + \beta\gamma E_t i_{t+1} + \frac{1}{\gamma^2\varphi}p_t^k\right] + \varepsilon_t^i \qquad (6.5A)$$

where φ is the steady-state elasticity of the capital adjustment cost function and β is the discount factor applied by households. The disturbance to the investment-specific technology process is assumed to follow an $AR(1)$ process with an IID-Normal error term: $\varepsilon_t^i = \rho_i\varepsilon_{t-1}^i + \eta_t^i$. The corresponding arbitrage equation for the value of capital is given by:

$$p_t^k = -\left(f_t + \varepsilon_t^b\right) + \frac{r^k}{r^k + (1-\delta)}r_{t+1}^k + \frac{(1-\delta)}{r^k + (1-\delta)}p_{t+1}^k \qquad (6.6A)$$

where f_t is the external cost of funding and r_t^k is the rental cost of capital. This current value of capital stock depends positively on its expected future value and the expected real rental rate on capital, and negatively on the ex-ante cost of external funding. The term $\varepsilon_t^b = \rho_b\varepsilon_{t-1}^b + \eta_t^b$ represents an exogenous disturbance to the external cost of funding. According to BGG (1999, the demand for capital should satisfy the following optimality condition based on the fact that the real expected return on capital is equal to the real cost on external funds:

$$E_t f_{t+1} = (r_t - E_t\pi_{t+1}) + \omega\left(p_t^k + k_{t+1} - n_{t+1}\right) \qquad (6.7A)$$

The gross external finance premium $(prem_t)$ depends on the borrowers' leverage ratio $(p_t^k + k_{t+1} - n_{t+1})$ and the parameter ω capturing the elasticity of the external finance premium with respect to the leverage ratio is represented as:

$$prem_t = E_t f_{t+1} - (r_t - E_t\pi_{t+1}) = \omega\left(p_t^k + k_{t+1} - n_{t+1}\right) \qquad (6.8A)$$

To warrant that entrepreneurs' net worth will never be sufficient to fully finance the new capital acquisition. Entrepreneurs have a limited life span and the probability that entrepreneurs will survive until next period is ν. The entrepreneur's net worth is defined as:

$$\frac{1}{\nu f}n_{t+1} = (lev)f_t - \omega(lev-1)\left(p_{t-1}^k + k_t\right) - (lev-1)(r_{t-1} - \pi_t) + [\omega(lev-1)+1]n_t \quad (6.9A)$$

The higher the size of the external premium, the higher is the leverage condition of entrepreneurial balance sheets. The presence of an external finance premium magnifies the effect of adverse shocks, as it raises the cost of borrowing and further worsens balance sheet conditions. Output is produced using capital (k_t) and labour services (l_t):

$$y_t = \Phi_P[\alpha k_t + (1-\alpha)l_t + \varepsilon_t^a] \qquad (6.10A)$$

where α is a parameter that captures the share of capital in production and the parameter Φ_P reflects the presence of fixed costs in production. Disturbances in total factors productivity are captured by the term $\varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a$ which follows an $AR(1)$ process with an iid −Normal error term. The current capital services depend on capital installed in the previous period (k_{t-1}^p) and the degree of capital utilization (z_t):

$$k_t = k_{t-1}^p + z_t \tag{6.11A}$$

where the accumulation of installed capital (k_t^p) is a function of the flow of investment and of the relative efficiency of these investment expenditures, as captured by the investment specific technology disturbance:

$$k_t^p = \frac{(1-\delta)}{\gamma} k_{t-1}^p + \frac{\delta}{\gamma} i_t + \delta\gamma^2\varphi\varepsilon_t^i \tag{6.12A}$$

the degree of capital utilisation is a positive function of the rental rate of capital:

$$z_t = \frac{1-z^k}{z^k} r_t^k \tag{6.13A}$$

where z^k determines the elasticity of utilization costs with respect to capital inputs. The rental rate of capital is derived by cost minimization:

$$r_t^k = w_t + l_t - k_t \tag{6.14A}$$

As in BGG and SW, price and wage setting follow a *Calvo-price* adjustment mechanism with partial indexation. Price mark-up (μ_t^p) is determined, under monopolistic competition, as the difference between the marginal product of labour (mpl_t) and the real wage (w_t):

$$\mu_t^p = mpl_t - w_t = \alpha r_t^k + (1-\alpha) w_t + \varepsilon_t^a \tag{6.15A}$$

In the same way, the wage mark-up is determined as the difference between the real wage and the marginal rate of substitution between working and consuming (mrs_t):

$$\mu_t^w = w_t - mrs_t = w_t - \left[w_t \sigma_l l_t + \frac{1}{1-\frac{h}{\gamma}} c_t + \frac{\frac{h}{\gamma}}{1-\frac{h}{\gamma}} c_{t-1} \right] \tag{6.16A}$$

where σ_l is the elasticity in terms of labour supply with respect to the real wage. Profit maximisation by price-setting firms give rise to the following New-Keynesian Philips Curve:

$$\pi_t = \frac{1}{1+\beta\gamma\iota_p} \{ \beta\gamma E_t \pi_{t+1} + \iota_p \pi_{t-1} - \pi_{mk} \mu_t^p \} + \varepsilon_t^p \tag{6.17A}$$

Equation (6.62) states that inflation (π_t) depends positively on past and expected future inflation, negatively on the current price mark-up, and positively on a price mark-up disturbance (ε_t^p). The price mark-up disturbance is assumed to follow an $ARMA(1,1)$ process with an iid-Normal error term: $\varepsilon_t^p = \rho_p \varepsilon_{t-1}^p + \eta_t^p - \mu_p \eta_{t-1}^p$, where the inclusion of the Moving Average (MA) term is designed to capture the high-frequency fluctuations in inflation. The speed of adjustment is measured by the term $\pi_{mk} = \frac{(1-\xi_p)(1-\beta\xi_p)}{\xi_p[(\Phi_P-1)\aleph_p+1]}$ to the desired mark-up and it depends on the degree of price stickiness (ξ_p), the degree of indexation to past inflation (ι_p), the curvature of the Kimball goods market aggregator $(\aleph_p)$, and the steady-state mark-up, which in equilibrium is itself related to the share of fixed costs in production (Φ_P) through a zero-profit condition. The Calvo-style wage setting implies

$$w_t = \frac{1}{1+\beta\gamma}\{w_{t-1} + \iota_w\pi_{t-1} - (1+\beta\gamma\iota_w)\pi_t + \beta\gamma E_t\pi_{t+1} - w_{mk}\mu_t^w\} + \varepsilon_t^w \qquad (6.18A)$$

Equation (6.63) states that the real wage is a function of expected and past real wages, expected, current, and past inflation, the wage mark-up, and a wage mark-up disturbance (ε_t^w). The wage mark-up disturbance is assumed to follow an $ARMA(1,1)$ process with an iid-Normal error term: $\varepsilon_t^w = \rho_w\varepsilon_{t-1}^w + \eta_t^w - \mu_w\eta_{t-1}^w$. As in the case of the price mark-up shock, the inclusion of a MA term permits to pick up some of the high-frequency fluctuations in wages. The term $w_{mk} = \frac{(1-\xi_w)(1-\beta\gamma\xi_w)}{\xi_w[(\Phi_w-1)\aleph_w+1]}$ measures the speed of adjustment to the desired wage mark-up, and it depends on the degree of wage stickiness (ξ_w), the degree of wage indexation (ι_w) and the demand elasticity for labour, which itself is a function of the steady-state labour market mark-up $(\Phi_w - 1)$ and the curvature of the Kimball labour market aggregator $(\aleph_w)$. The Taylor type rule in setting the short-term interest rate (r_t) and an exogenous disturbance term is assumed to follow an $AR(1)$ process with an iid-Normal error term $\varepsilon_t^r = \rho_r\varepsilon_{t-1}^r + \eta_t^r$: As a benchmark rule, the empirical-rate rule of SW model is added:

$$r_t = \rho r_{t-1}\rho_\pi(1-\rho)\pi_t + \rho_y(1-\rho)(y_t - y_t^P) + \rho_{dy}[(y_t - y_{t-1}) - (y_t^P - y_{t-1}^P)] + \varepsilon_t^r \qquad (6.19A)$$

where y_t^p is the flexible-price level of output and $\varepsilon_t^r \sim N(0, \sigma_r^2)$ is the monetary policy shock. The government fiscal policy is exogenous and is described by $g_t = \rho_g g_{t-1} + \varepsilon_t^g$, where $\varepsilon_t^g \sim N(0, \sigma_g^2)$. In addition there is the equilibrium condition that $G_t = T_t$. Finally, the aggregation for the resource constraint is represented as:

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}I_t + \frac{G}{Y}g_t + \frac{K}{Y}\psi Re^k re_t^k + \frac{K}{Y}S\left(1 - \frac{NW}{K}\right)(r_t^k + q_{t-1} + k_t) \qquad (6.20A)$$

To obtain the original model without financial frictions, it is sufficient to set the elasticity of the external finance premium to the leverage ratio $\omega = 0$ and the steady-state of the leverage ratio $lev = 1$. The model without financial frictions does not involve the spread shock.

6.4A Some Empirical Results of the DSGE Model

Table 6.1A Original and Model Moments for the Data Series

	Data(2000)		Data(2007)		Data(2014)	
	Original Moments					
Variable(t)	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev.**
Output	-0.038	0.835	-0.822	1.956	-0.792	1.867
Consumption	0.185	3.141	0.646	3.273	0.552	3.225
Investment	0.481	0.407	0.531	1.023	0.469	1.018
M. policy rate	0.220	0.699	0.439	0.574	0.396	0.620
Inflation	0.628	0.551	1.423	1.433	1.315	1.393
Wage mark-up	0.324	0.780	0.376	1.629	0.334	1.555
Hours mark-up	1.197	0.204	1.976	0.838	1.775	0.964
Spread	0.045	0.159	0.260	0.422	0.293	0.415
	Model Moments					
Output	0.1717	1.3585	0.4335	2.0753	0.417	2.0814
Consumption	0.1717	1.217	0.4335	2.193	0.417	2.1322
Investment	0.1717	5.34	0.4335	7.994	0.417	6.2963
M. policy rate	1.0348	0.6213	1.0201	1.1678	1.0832	1.132
Inflation	0.6359	0.7786	0.4767	1.6609	0.5124	1.6191
Wage mark-up	0.1717	0.8563	0.4335	2.0958	0.417	2.0605
Hours mark-up	-3.5303	5.2687	1.7925	0.7015	2.3436	1.0710
Spread	0.041	1.0682	0.032	1.6893	0.031	1.8868

Source: Author’s calculations

Table 6.2A Matrix of Correlation (MC) Estimated by the DSGE model *[MC1]*

MATRIX OF CORRELATIONS [Model with no FAM (Data2007)]							
Variables	dy	dc	$dinve$	$robs$	$pinfobs$	dw	$labobs$
Output	1	0.4559	0.6089	0.0272	-0.1718	0.3385	0.0735
Consumption	0.4559	1	0.2655	0.0467	-0.1648	0.2635	0.0919
Investment	0.6089	0.2655	1	0.0664	-0.1108	0.34	0.0766
MP rate	0.0272	0.0467	0.0664	1	0.7938	-0.0678	0.3076
Inflation	-0.1718	-0.1648	-0.1108	0.7938	1	-0.4498	0.2052
Wage	0.3385	0.2635	0.34	-0.0678	-0.4498	1	0.0292
Hours w	0.0735	0.0919	0.0766	0.3076	0.2052	0.0292	1
Spread							

Source: Author’s calculations

[MC2]

MATRIX OF CORRELATIONS [Model with FAM (Data20014)]

Variables	dy	dc	$dinve$	$robs$	$pinfobs$	dw	$labobs$
Output	1	0.8579	0.1506	0.328	-0.1471	0.0949	0.0531
Consumption	0.8579	1	0.0238	0.3681	-0.0988	0.0484	0.0431
Investment	0.1506	0.0238	1	-0.1592	-0.3294	0.2488	0.0453
MP rate	0.328	0.3681	-0.1592	1	0.53	-0.1898	0.1205
Inflation	-0.1471	-0.0988	-0.3294	0.53	1	-0.6531	0.0485
Wage	0.0949	0.0484	0.2488	-0.1898	-0.6531	1	0.0024
Hours w	0.0531	0.0431	0.0453	0.1205	0.0485	0.0024	1
Spread							

Source: Author's calculations

[MC3]

MATRIX OF CORRELATIONS [Model with FAM (Data2007)]

Variables	dy	dc	$dinve$	$robs$	$pinfobs$	dw	$labobs$	$sobs$
Output	1	0.4369	0.4332	-0.1134	-0.503	0.5099	0.0509	0.0034
Consumption	0.4369	1	-0.0173	-0.0823	-0.4672	0.4295	-0.0005	0.1022
Investment	0.4332	-0.0173	1	-0.1051	-0.3501	0.4391	0.0647	-0.164
MP rate	-0.1134	-0.0823	-0.1051	1	0.5199	-0.2437	-0.3299	-0.2279
Inflation	-0.503	-0.4672	-0.3501	0.5199	1	-0.7844	-0.1874	-0.1266
Wage	0.5099	0.4295	0.4391	-0.2437	-0.7844	1	0.1006	0.0494
Hours w	0.0509	-0.0005	0.0647	-0.3299	-0.1874	0.1006	1	0.122
Spread	0.0034	0.1022	-0.164	-0.2279	-0.1266	0.0494	0.122	1

Source: Author's calculations

[MC4]

MATRIX OF CORRELATIONS [Model with FAM (Data2014)]

Variables	dy	dc	$dinve$	$robs$	$pinfobs$	dw	$labobs$	$sobs$
Output	1	0.5311	0.4708	-0.0928	-0.5051	0.522	0.0505	0.0537
Consumption	0.5311	1	0.1093	-0.0905	-0.5255	0.4961	0.0137	0.1325
Investment	0.4708	0.1093	1	-0.0658	-0.3463	0.4526	0.0657	-0.0988
MP rate	-0.0928	-0.0905	-0.0658	1	0.4924	-0.21	-0.2843	-0.2061
Inflation	-0.5051	-0.5255	-0.3463	0.4924	1	-0.7849	-0.1657	-0.1044
Wage	0.522	0.4961	0.4526	-0.21	-0.7849	1	0.0927	0.1103
Hours w	0.0505	0.0137	0.0657	-0.2843	-0.1657	0.0927	1	0.1039
Spread	0.0537	0.1325	-0.0988	-0.2061	-0.1044	0.1103	0.1039	1

Source: Author's calculations

[MC5]

MATRIX OF CORRELATIONS [Model with FAM (Data2000)]

Variables	dy	dc	$dinve$	$robs$	$pinfobs$	dw	$labobs$	$sobs$
Output	1	0.1764	0.6273	-0.0813	0.0007	0.145	0.1252	-0.1676
Consumption	0.1764	1	-0.3145	-0.1349	-0.1883	0.1868	-0.0225	0.136
Investment	0.6273	-0.3145	1	0.0077	0.1401	0.0233	0.1383	-0.3161
MP rate	-0.0813	-0.1349	0.0077	1	0.3211	-0.0001	0.4717	-0.2084
Inflation	0.0007	-0.1883	0.1401	0.3211	1	-0.4799	0.2312	-0.1457
Wage	0.145	0.1868	0.0233	-0.0001	-0.4799	1	0.0538	-0.0021
Hours w	0.1252	-0.0225	0.1383	0.4717	0.2312	0.0538	1	-0.1468
Spread	-0.1676	0.136	-0.3161	-0.2084	-0.1457	-0.0021	-0.1468	1

Source: Author's calculations