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Examining the Effectiveness of Monetary Policy

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ABSTRACT

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and Professor Suyong Song

The main objective of my dissertation is to examine the causal effect of monetary policy. The first two chapters focus on the effectiveness of inflation targeting considering the role of preconditions such as institutional independence of central banks and a healthy financial system. It also analyzes the time-varying behavior of the inflation gap in all explicit inflation targeting countries and captures the gradual transition of actual inflation to its target over time. The last chapter examines monetary unification impact on bond markets before and after the European crisis.

Chapter 2 estimates the treatment effect of inflation targeting for 27 explicit inflation targeting countries. Our approach takes into account the problem of model misspecification and inconsistent estimation of parametric propensity scores by using a nonparametric series estimator and semiparametric single index method. In addition, this chapter also examines the impact of inflation targeting regime on a wider set of macroeconomic outcomes. The findings suggest that the results are sensitive to the choice of propensity score estimates based on different methods, and the semiparametric single-index model of propensity score provides the most economically meaningful results. The findings illustrate that the inflation targeting framework lowers inflation variability and improves

fiscal discipline. We find that this monetary policy regime reduces the real exchange rate volatility in developing countries but increases it in developed economies.

Chapter 3 analyzes the performance of the central banks by examining their success in achieving their explicit inflation targets. For this purpose, we decompose the inflation gap into predictable and unpredictable components. We argue that the central banks are successful if the predictable component in the inflation gap diminishes over time. The predictable component of inflation gap is measured by the conditional mean of a parsimonious time-varying autoregressive model. Our results find considerable heterogeneity in the success of these IT countries in achieving their targets at the start of this policy regime. Our findings also suggest that the central banks of inflation targeting countries started targeting inflation implicitly before becoming an explicit inflation targeter. The panel data analysis suggests that the relative success of these countries in reducing the gap is influenced by their institutional characteristics.

Chapter 4 determines the behavior of bond yields in Eurozone by examining the antithetic role of monetary unification before and after the European Debt Crisis. We study the causal effect of monetary unification on the European bond markets. We capture the causal effect by estimating treatment effects of European union. The findings illustrate that the treatment effects on bond yields varies before and after the European crisis. The results indicate that monetary unification reduces the level and volatility of long-term and short-term sovereign bond yields for the period before the crisis, 1993–2008. However, after the banking crisis, we witnessed a rise in yield spreads due to higher degree of debt-GDP ratios and higher risk of default in sovereign bonds.

To Arezoo

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1

Introduction

"If central banks continue to focus on price stability and keep inflation low and stable, there is every expectation that the current degree of macroeconomic stability will continue."

– John Taylor (2005)

"Inflation targeting is being put to the test and it will almost certainly fail."

– Joseph Stiglitz (2008)

Central banks use different tools to steer the economy. Monetary policy is characterized by central banks actions influencing money supply by a nominal anchor, such as the inflation rate, to attain their medium and long term goals. The issue of the effectiveness of monetary policy is a time-honored question in the literature of monetary economics and central banking. At first, the perspective on the effectiveness of monetary policy was defined as targeting high employment and growth without inflation. This perspective on the role of monetary policy had changed to a more comprehensive view of affecting both inflation and output.

This dissertation analyzes the effectiveness of monetary policy in steering the economy. *First*, we examine the role of inflation targeting (IT hereafter). Inflation targeting is a monetary policy strategy that control actual inflation. Under the IT regime, a central bank makes public a projected inflation rate and then attempts to steer actual inflation toward the target through different monetary policy tools. *Second*, we determine monetary unification impact. European Monetary System established in March 1979 to link members' currencies and prevent fluctuations in the exchange rate. After its success, the

European Community agreed to sign the Maastricht Treaty in 1992 to create a common Economic and Monetary Union. For Eurozone Monetary Union, a single monetary policy is set by the European Central Bank. One main reason to form a monetary union is that this offers a route to low and stable inflation.

The amount of work on the effectiveness of inflation targeting has considerably increased in the last two decades. On the one hand, researchers examine a significant effect of inflation targeting on macroeconomic performance (Neumann and von Hagen (2002), Wu (2004), Vega and Winkelried (2005), Mishkin and Schmidt-Hebbel (2007), Rose (2007), Creel and Hubert (2010), and Lin (2010)). On the other hand, scholars argue that the impact of the IT regime has been mostly insignificant (Johnson (2002), Angeriz and Arestis (2007), and Lin and Ye (2007)). In Chapter 2, we examine the effectiveness of inflation targeting by applying micro-econometric techniques. Our econometric methodology improves on the existing "treatment effect" literature on the impact of inflation targeting that has been proposed to reduce the selection bias. Self-selection problem may arise because a central banks' decision to adopt inflation targeting is related to the benefits from the adoption of IT. This may lead to a biased causal effect. The literature have attempted to overcome the selection bias problem by estimating propensity score and match treated and control units to mimic a randomized experiment; however, their parametric approach to estimate the average treatment effect of inflation targeting suffers from the model misspecification problem and may also provide us inconsistent estimates of the propensity scores. To take into account these econometric problems, we estimate the propensity scores by a nonparametric series estimator and a semiparametric index model. In order to capture inflation targeting effectiveness, we estimate its causal effect on inflation, inflation volatility, interest rate volatility, exchange rate volatility, fiscal discipline, and sacrifice ratio by considering the role of preconditions, such as central banks soundness and developed financial

infrastructure.

Most of the existing studies on the IT regime examine its efficacy by analyzing the behavior of inflation after the adoption of this regime. In Chapter 3, within a time series framework, we analyze the dynamic behavior of the gap between level of inflation and inflation target in all inflation targeters. We examine whether the success in achieving their explicit inflation targets is associated with the institutional strength of these countries. We test the effectiveness of the IT countries in meeting their target by decomposing the gap between actual inflation and the target into predictable and unpredictable components. We argue that a successful IT regime should bring down the predictable component of the inflation gap to zero over the medium-horizon if they are successful in bridging the gap that was predictable in advance. Our approach is motivated by Friedman's stabilization policy hypothesis (1953) where he argued that a successful central banker should make inflation perfectly stable. One consequence of a perfectly stable inflation is that it becomes unpredictable in a sense that a constant inflation forecast model can't be improved upon. It should be noted that unpredictability is a consequence of superior monetary policy in this context. We define the predictable component as the conditional expectation of the time varying parameter autoregressive model. Our approach is able to capture the gradual transition of actual inflation to its target over time.

In the last chapter, Chapter 4, we examine the role of European Monetary Union in the behavior of bond yields. After forming the European Monetary Union researchers have attempted to find whether this unification in Europe has been successful (McKinnon (2008), Rogers (2007), Beetsma and Giuliodori (2010), Rogers (2007), Ehrmann et al. (2011), Faini, Duranton and Hau (2006), and Gomez-Puig (2009)). The need to evaluate the performance of monetary unification has been steadily rising over the past decade.

We examine the causal effect of monetary unification on bond yields and bond spreads by answering the question of whether the reduction in the level and volatility of bond yields is due to monetary unification. The differences between the sovereign bond yields after forming monetary union reveal the true unification impact. Therefore, we link the average treatment effect literature to monetary unification context and estimate this causal effect. We also take into account country specific factors along with the difference among members and non-members. Country specific factors are one of the main determinants of sovereign bond yield spreads in European Monetary Union. We capture country specific factors and the selection problem. It is important to note that the behavior of bond yields and sovereign spreads changed after the European Sovereign Debt Crisis. Banking crises led to higher debt and a rapid rise in yield spreads. Higher risk of default in sovereign bonds is considered as the main reason of widening government bond yield differentials across Eurozone countries.

2

On the Effectiveness of Inflation Targeting

2.1 Introduction

Explicit inflation targeting has been increasingly adopted as a monetary policy strategy to curb actual inflation over the medium-to-long horizon. Under the IT regime, a central bank makes public a projected, or "target," inflation rate and then attempts to steer actual inflation toward the target through different monetary policy tools.[1] One of the impressive features of this monetary policy strategy is that no country has given up this regime after its adoption. Reserve Bank of New Zealand became the first central bank to adopt the IT regime in 1990. The ever-increasing popularity of the IT regime has led several other central banks to follow implicit inflation targeting.

The increasing popularity of the IT regime has naturally spawned a great deal of academic interest in its effectiveness. Even though the amount of work on the effectiveness of inflation targeting has increased manifold in the last two decades, there is no consensus on the overall impact of this regime on the macroeconomy. One view suggests a significant effect of inflation targeting on macroeconomic performance, whereas another strand of literature suggests that the impact of the IT regime has been mostly insignificant. Several researchers find that inflation targeting is successful in reducing inflation and inflation variability (Neumann and von Hagen (2002), Wu (2004), Vega and Winkelried (2005), Mishkin and Schmidt-Hebbel (2007) and Creel and Hubert

[1] Countries operating a fully fledged inflation targeting regime are: Armenia, Australia, Brazil, Canada, Chile, Colombia, the Czech Republic, Ghana, Guatemala, Hungary, Iceland, Indonesia, Israel, Mexico, New Zealand, Norway, Peru, Philippines, Poland, Romania, Serbia, South Africa, South Korea, Sweden, Thailand, Turkey and the United Kingdom (Hammond (2012)).

(2010)). Among them, Mishkin and Schmidt-Hebbel (2001) argue that the IT regime not only causes a reduction in inflation and inflation variability, but also lessens the sacrifice ratio, output volatility, and inflation expectations. The literature also identifies inflation targeting with lowering other economic variables such as exchange rate volatility (Rose (2007) and Lin (2010)),[2] interest rates (Filho (2011)), fiscal indiscipline (Minea and Tapsoba (2014) and Lucotte (2012)) and actual dollarization (Lin and Ye (2013)). However, Johnson (2002) and Angeriz and Arestis (2007) find that the IT regime did not reduce the variability of expected inflation. They suggest that targeters and non-targeters have experienced an unexpected reduction in inflation. Similar viewpoints have been expressed by Ball and Sheridan (2003), who argue that there is no evidence that IT reduces inflation variability, output volatility, and output growth. Lin and Ye (2007) also find that IT has no significant effects on either inflation or inflation variability.

Our study improves on the effectiveness of inflation targeting literature in three important ways. First, our econometric methodology improves on the existing "treatment effect" literature on the impact of inflation targeting that has been proposed to take into account the self-selection problem. Self-selection problem may arise because a central banks' decision to adopt inflation targeting is related to the benefits from the adoption of IT. This may lead to a biased causal effect. Previous studies (e.g. Lin and Ye (2013) and de Mendonca and de Guimaraes (2012)) have attempted to overcome the selection bias problem by estimating propensity score and match treated and control units to mimic a randomized experiment. The parametric approach to estimate the average treatment effect of inflation targeting suffers from model misspecification problem and provides inconsistent estimates of the propensity scores. To take into account these econometric problems, we estimate the propensity scores by a nonparametric series estimator and a semiparametric index model. In particular, we use the nonparametric

[2] Lin (2010) finds that inflation targeting lowers real and nominal exchange rate volatility only in industrial economies, but increases them in developing countries.

series estimator proposed by Hirano, Imbens and Ridder (2003) to estimate a consistent propensity score. This estimator can be used when the functional form of the propensity score and the distribution of the error terms are unknown. Even though nonparametric series estimator solves the model misspecification problem, it suffers from the "curse of dimensionality," as the dimension of the variable space increases at the higher power of the logit series estimation. To avoid the curse of dimensionality and to relax the parametric distributional assumption on the error terms, we estimate propensity scores using the semiparametric single index method suggested by Klein and Spady (1993) and Song (2014).

Most of the research on the treatment effect of inflation targeting has examined its impact on the level of inflation and inflation volatility. One of the proposed benefits of having a monetary policy regime with a nominal anchor is that it enhances the credibility of central banks. As a consequence the volatility of important macroeconomic variables such as the exchange rate and interest rate may be affected. The adoption of IT may also nudge the fiscal policymakers to adopt fiscally responsible policies. Moreover, inflation targeting can be able to bring inflation down at less cost. The second contribution of our paper is to examine the effectiveness of the IT regime by not only investigating its impact on inflation and inflation volatility, but also important macroeconomic variables such as interest rate volatility, exchange rate volatility, fiscal discipline, and sacrifice ratio.

The propensity score analysis for the IT regime involves estimating the probability of conducting IT in the first stage. The extant literature has ignored the role of financial market development in the probability of adopting inflation targeting. This is in contrast to the literature that talks about the preconditions for the IT regime, where researchers have strongly opined that financial market development is one of the most important criteria for adoption and the success of the IT regime. Therefore, in addition to the

variables like GDP growth, money growth, lagged inflation and openness that have been used in the literature, we also use bank assets-GDP ratio and private credit-GDP ratio as proxies for financial market development in the first step to estimate the probability of adopting IT.

Our findings suggest that the results of propensity score matching using the single index model in the first stage provides a more accurate estimation. We show that the effectiveness of IT and its significance vary among different country groups. In the first stage estimation, we find that institutional characteristics and financial market features, such as private credits and central banks' balance sheets, are crucial to determining the likelihood of the IT adoption. Our results illustrate that the inflation targeting framework lowers inflation variability for all country groups. However, the impact of IT is less in industrial economies than developing countries, implying that developing countries benefit more from adopting inflation targeting. We find that the IT regime improves fiscal discipline for both developing and developed economies and its impact is significantly larger in developing countries. In addition to the significant impact of IT on inflation variability and fiscal discipline, this monetary policy framework reduces the interest rate volatility and exchange rate variability in the full sample. However, inflation targeting has an asymmetric effect on the variability of exchange rate among developing and developed economies. Inflation targeting lowers the real exchange rate volatility in developing countries but increases it in industrial economies. A comparison between parametric and semiparametric propensity scores indicates that the semiparametric single index model provides the most meaningful results.

2.2 Background

2.2.1 Theoretical Context

Since the adoption of explicit inflation targeting by the Reserve Bank of New Zealand in 1990, there has been an explosion of interest in the theoretical and empirical work on the effect of inflation targeting. Most of the theoretical work has focused on examining whether inflation targeting is an optimal monetary policy strategy. Central banks adopt explicit inflation targeting by setting an instrument such that the inflation forecast and inflation target become identical. Svensson (1996) interprets inflation targeting as a targeting rule that specifies a target variable and target level to minimize a loss function. Central banks' objective in period t is to choose a sequence of interest rates to minimize the loss function:

$$\mathbb{E}_t \sum_{\tau=t}^{\infty} \delta^{\tau-t} L(\pi_\tau), \tag{2.1}$$

where π denotes inflation, $\mathbb{E}_t$ is expectations conditional on information in year t, δ is the discount factor, and $L(\pi_\tau)$ is the loss function which can be written as the following:

$$L_t = \frac{1}{2}[(\pi_t - \hat{\pi})^2 + \lambda y_t^2], \tag{2.2}$$

where $\hat{\pi}$ denotes the inflation target level, $\lambda \geq 0$ is the relative weight and y_t is the output gap. Thus, the inflation targeting framework is considered as the minimization of a loss function over inflation and output gaps. The first-order condition can be written as follows:

$$\pi_{t+\tau|t} = \hat{\pi},$$

for $\tau \geq T$, where $\pi_{t+\tau|t}$ denotes a conditional forecast of $\pi_{t+\tau}$ and $T \geq 0$ is the shortest horizon at which the instrument has an effect on inflation. In an explicit inflation targeting regime, the central bank commits to minimizing a loss function, so that the target would be equal to the τ-step ahead forecast. The effectiveness of this monetary policy framework can be considered through two channels of aggregate demand and expectations. In the aggregate demand channel, monetary policy affects aggregate demand, then it affects inflation via the Phillips curve. In the expectations channel, monetary policy affects inflation by anchoring inflation expectations. According to this view, the inflation forecast as a target provides better information about central bank actions and influences expectations. This transparency increases the effectiveness of monetary policy (Svensson (1999)). As in Woodford (2005) and Svensson (2005*a*), a higher degree of transparency improves the conduct of monetary policy. The consequences of the transparency of central banks are a reduction in uncertainty about future policy actions and anchoring actual inflation and inflation volatility.

In a theoretical framework, Demertzis and Hallett (2007) show that the transparency of central banks has no effect on the level of inflation and output, but it decreases the volatility of inflation and the output gap. Morris and Shin (2002) address this issue through the lens of welfare effects. They argue that greater transparency does not necessarily improve social welfare. In an economy with high volatile inflation, the central bank is unlikely to have more information than the private sector, and private information may crowd out the central bank's disclosed information, which leads to a greater volatility. However, Svensson (2005*b*) argues that the results of Morris and Shin

(2002) are misinterpreted as an "anti-transparency." He shows that the higher degree of transparency increases the social welfare. Recently there has been a surge of interest in the theoretical framework of inflation targeting effectiveness through the channels of expectations, transparency, and the accountability of central banks. Nevertheless, many researchers attempt to test this monetary policy effectiveness using different econometric methods. This study attempts to link the theoretical context and empirical frameworks and addresses issues that occur when estimating the effect of inflation targeting.

2.2.2 Empirical Background

The empirical research on the effectiveness of inflation targeting has primarily attempted to examine its impact on the level of inflation and inflation volatility. Initially most of the work focused on examining the effectiveness of the IT regime by performing some form of an event study analysis. This strand of literature compared the behavior of inflation and its volatility before and after the adoption of the IT regime. The event study approach was criticized on the grounds that this methodology does not take into account the changes in the behavior of inflation that would have taken place anyway in the absence of the IT regime. The criticism was based on the global fall in inflation and the inflation volatility that took place during the time this regime was in place in different countries. Studies in this strand of literature have borrowed the econometric technique from applied microeconomics to estimate the impact of inflation targeting. However, the existing empirical literature on the effectiveness of inflation targeting suffers from three problems. First issue is the estimation methodology. Second, the variables used to find the likelihood of adopting inflation targeting ignores the conventional wisdom and extant literature that suggests the role of preconditions in the effectiveness of inflation targeting such as a healthy financial system. Third, most of the work on inflation targeting using the treatment effect methodology has estimated the impact of this regime on the level of

inflation and inflation volatility. The literature lacks a comprehensive study on a variety of outcome variables.

Referring to the first issue, the estimation methodology, Ball and Sheridan (2003) find the effect of IT by comparing improvements in targeters to improvements in non-targeters. They use a differences-in-differences approach. In their framework, the average of outcome variables before and after the adoption of IT is regressed on a targeting dummy. The coefficient of the targeting dummy measures the effect of targeting on the outcome variables. To reduce the bias from the correlation of the outcome before the adoption of IT and the targeting dummy, they add the initial value of the outcome to the differences regression.[3] They find that this method produces an unbiased estimate of the dummy coefficient. In their study, the sample includes seven inflation targeters and 13 non-targeters; outcome variables are inflation, inflation variability, output growth, output volatility, and interest rates. They find no evidence that inflation targeting improves countries' economic performance. After this study, researchers have attempted to find the causal effect of the IT adoption on macroeconomic performance using the same methodology. Among them, Wu (2004) uses a differences-in-differences approach to compare the average change in inflation. He includes the first lag of the outcome variable to consider the persistence of the outcome. He finds that inflation targeters experienced a decrease in the average inflation rates after the adoption of IT.[4]

Mishkin and Schmidt-Hebbel (2001) address the question of whether there is a causal effect of the adoption of inflation targeting on the macroeconomic outcomes. They argue that the adoption of IT is an endogenous choice, and the empirical findings

[3] Ball and Sheridan (2003) argue that by including the initial value of the outcome to the differences regression, they control for regression to the mean.

[4] One main issue with differences-in-differences method is the serial correlation problem. The response in the differences-in-differences estimation, which is the outcome variable such as inflation and inflation variability, is highly serially correlated.

may not imply the causal effect of inflation targeting on the economic performance. So the OLS results may be biased because of endogeneity of the IT regime to inflation. They control for endogeneity using an instrument set including lagged values of inflation, inflation deviation from the target, inflation targeting dummy, nominal exchange rate depreciation, output gap, and Federal funds rate as well as making use of a panel data IV estimation. Their sample includes 21 developed and developing inflation targeting countries and 13 industrial non-targeters. The results of panel vector autoregressive model indicate that inflation targeting reduces inflation and output volatilities and adopting IT improves the efficiency of monetary policy.

Another problem that arises in estimating the average treatment effect of inflation is the selection problem. Inflation targeting selection is a process that permits central banks to adopt inflation targeting in countries that meet some economic and institutional preconditions. The preconditions include institutional independence of the central bank, a well-developed technical infrastructure in terms of forecasting, minimal dollarization, a healthy financial system, and well-developed capital markets. Thus, our observational data lack the randomized assignment of countries into the adoption of IT. Researchers must employ statistical procedures to balance the data before assessing treatment effects.

To address the self-selection problem of the IT adoption, Lin and Ye (2007) estimate average treatment effects using propensity score matching methods. They utilize a variety of matching methods to use a control group to mimic a randomized experiment. Propensity score analysis allows us to reduce the dimensionality to a one-dimensional score and to balance the differences between targeters and non-targeters. Their study employs seven industrial targeters and 15 non-targeters from the period of 1985 to 1999. They use outcome variables such as inflation, inflation variability, interest rates, and the income velocity of money to show that inflation targeting has no significant

effects on economic performance. Recently, other studies examine the effectiveness of inflation targeting using the average treatment effect literature (Lin (2010), Lucotte (2012), de Mendonca and de Guimaraes (2012), Lin and Ye (2013) and Minea and Tapsoba (2014)).

One important problem that has been neglected in the literature is the misspecification of propensity score. Zhao (2008) finds that the results of average treatment effects are sensitive to the specifications of propensity scores. Misspecified propensity scores lead us to a biased estimation of average treatment effects. To overcome this problem, we use a nonparametric series estimator, proposed by Hirano, Imbens and Ridder (2003). This estimator can be used when the functional form of the propensity score and the distribution of the error terms are unknown. Nonetheless, a nonparametric series estimator suffers from the "curse of dimensionality" problem due to the fact that the dimension of the variable space increases at the higher power of the logit series estimation.[5] To avoid the curse of dimensionality and relax the parametric distributional assumption, we estimate propensity scores using a semiparametric method. This method is useful when a nonparametric series estimator does not perform well because of the high dimension of variable space (Li and Racine (2011)). We consider the single index model suggested by Klein and Spady (1993). They introduce this semiparametric model where the response is a binary variable.

The second problem in the inflation targeting effectiveness literature is associated with finding the likelihood of adopting inflation targeting. Most of studies have focused on finding the effect of the macroeconomic variables on the likelihood of the IT adoption. However, a set of preconditions plays a vital role in the probability of adopting inflation targeting, especially in emerging market economies. These preconditions, which are

[5]The curse of dimensionality refers to the problem where the convergence rate is inversely related to the number of covariates (Li and Racine (2011)).

necessary for a monetary policy to be successful, fall into four categories: institutional independence, a well-developed technical infrastructure, economic structure, and a healthy financial system. The most important precondition discussed in the literature that has a huge impact on inflation targeting is a healthy financial system. The banking system should be sound and capital markets well developed to guarantee an effective monetary policy transmission. To examine the role of a healthy financial system for the adoption of inflation targeting, we choose central bank assets-GDP ratio and private credit-GDP ratio along with GDP growth, money growth, lagged inflation and openness. Central bank assets-GDP measures the size of the central bank, while private credit-GDP ratio is used to measure the financial depth.

The third problem in finding the effectiveness of inflation targeting is that most of the work on inflation targeting using the treatment effect methodology has estimated the impact of this regime on the level of inflation and inflation volatility. One of the proposed benefits of having a monetary policy regime with nominal anchor such as inflation targeting is that it enhances the credibility of central banks. Higher degree of credibility may influence the volatility of important macroeconomic variables. Moreover, one of the requirements of a successful adoption of the IT regime is the absence of fiscal dominance. Only a few papers (Lucotte (2012) and Minea and Tapsoba (2014)) have looked at the role of the IT regime in disciplining the fiscal behavior of the IT-adopting countries. Additionally, inflation targeters may experience less output losses during disinflations. There are two contrary views on the effect of inflation targeting on sacrifice ratios (Goncalves and Carvalho (2009) and Brito (2010)). However, the existing studies using the treatment effect methodology have not examined the impact of IT on fiscal discipline and sacrifice ratios. Therefore, in addition to the level and volatility of inflation, we examine the effectiveness of the IT regime by examining important macroeconomic variables such as interest rate volatility, exchange rate volatility, fiscal discipline, and

sacrifice ratio.

2.3 Data Description

The data set for this study consists of 98 countries for the period from 1990 to 2013 on an annual basis. Data are obtained from the International Monetary Fund's World Development Indicators and International Financial Statistics. Among our full sample, 27 countries are inflation targeters (treated group) and 71 countries are non-targeters (control group). Table A1 in Appendix A presents the list of inflation targeting countries along with the adoption dates, target levels at the adoption date, and the ir country groups. The lowest target rate at the date of the IT adoption belongs to Sweden and Thailand, two percent, and the highest rate is 15 percent for Israel. Seven countries are described as industrial inflation targeters; other 20 targeters are developing countries.[6] Table A2 shows the list of countries used as the control group. We impute incomplete multivariate data. There are two approaches for the imputation of multivariate data: joint modeling (JM) and Fully Conditional Specification (FCS), also known as Multivariate Imputation by Chained Equations (MICE). We use the MICE method because using the MICE algorithm preserves the relationships in the data and retains the uncertainty about these relations (Buuren and Groothuis-Oudshoorn (2011)).[7]

To examine the effectiveness of inflation targeting in emerging market and industrial economies, we divide the sample into developing (DCS) and developed (IND) countries. Table 2.1 indicates the sample sizes in the propensity score analysis for the full sample, industrial economies and developing countries. The full sample contains all 98 countries. The sample size is 2352, of which 1704 are control and 648 are treated units. After

[6] IT industrial countries are: Australia, Canada, Iceland, New Zealand, Norway, Sweden and the United Kingdom.

[7] For details, see Buuren and Groothuis-Oudshoorn (2011).

matching, 647 observations are left for the outcome analysis. In the subsample of industrial economies, there are 26 countries (10 inflation targeters and 16 non-targeters), and the total number of observations is 624. The subsample of developing countries includes 17 targeters and 55 non-targeters with 1848 observations.

Table 2.1: Sample sizes in propensity score analysis for all samples

	FULL		IND		DCS	
	Control	Treated	Control	Treated	Control	Treated
All	1704	648	384	240	1440	408
Matched	648	648	240	240	408	408
Unmatched	1056	0	144	0	1032	0
Discarded	0	0	0	0	0	0

FULL: full sample, IND: industrial economies, DCS: developing countries.

The dependent variable used in the first stage estimation is the inflation targeting dummy, which has the value 1 if the country adopts inflation targeting. We choose the following covariates for the propensity score analysis and the estimation of average treatment effects: the lagged inflation rate; real money growth; GDP growth; openness which is measured as exports plus imports divided by GDP, indicating the total trade as a percentage of GDP; central bank assets-GDP ratio as a measure of financial sophistication; and credit deposit to real sector by deposit money bank, which is the proxy of financial development. In the second stage estimation, the outcome variables include inflation, fiscal discipline, sacrifice ratio, inflation variability, interest rate volatility, and real exchange rate volatility. Following Lin and Ye (2007), we measure inflation variability by the standard deviation of a three-year moving average of inflation. Real exchange volatility defined as the standard deviation of a three-year moving average of real exchange rates and interest rate volatility defined as the standard deviation of a three-year moving average of 10-year government bond interest rates. We consider government debt-GDP ratio as an inverse proxy of fiscal discipline. Sacrifice ratio is measured by the

ratio of the change in output growth to the change in inflation.

2.4 The Impact of Inflation Targeting

To find the impact of inflation targeting on macroeconomic performance, we use propensity score analysis. Propensity score analysis is a quasi-experimental design used to estimate causal effects in observational studies, i.e., studies where units are not randomized to treatment. The literature on the IT effective focuses on the propensity score matching analysis. In the propensity score matching model the data are balanced through resampling or matching control units to treated ones on probabilities of receiving treatment, i.e., the propensity scores.

2.4.1 Treatment Effects of Inflation Targeting

Most approaches to estimating the effects of inflation targeting on inflation and inflation variability fall into estimating average treatment effects. In our study, inflation targeting is considered as a treatment indicating by a binary random variable, $T_i = \{0, 1\}$. The outcome of interest is denoted by Y_i. We specify the inflation rate, the measure of fiscal discipline, inflation variability, interest rate volatility, and exchange rate volatility, sacrifice ratio as the outcome variables. We attempt to find whether Y_i is affected by the inflation targeting framework. For each country, there are two potential outcomes. Y_{0i} is the outcome when inflation targeting is not adopted, while Y_{1i} is the potential outcome if this strategy is adopted.

$$\text{potential outcome} = \begin{cases} Y_{1i} & \text{if } T_i = 1 \\ Y_{0i} & \text{if } T_i = 0. \end{cases} \tag{2.3}$$

We would like to know the causal effect of the adoption of inflation targeting in country i, which is the difference between Y_{1i} and Y_{0i}.[8] The observed outcome, Y_i, can be written in terms of potential outcomes as:

$$\begin{aligned} Y_i &= T_i Y_{1i} + (1 - T_i) Y_{0i} \\ &= Y_{0i} + (Y_{1i} - Y_{0i}) T_i, \end{aligned} \tag{2.4}$$

where $Y_{1i} - Y_{0i}$ is the causal effect of implementing inflation targeting. The average treatment effect can be expressed by the average treatment effect on the treated (ATT) and selection bias.

$$\begin{aligned} \tau_{ate} = \mathbb{E}[Y_i \mid T_i = 1] - \mathbb{E}[Y_i \mid T_i = 0] = &\mathbb{E}[Y_{1i} \mid T_i = 1] - \mathbb{E}[Y_{0i} \mid T_i = 1] \\ &+ \mathbb{E}[Y_{0i} \mid T_i = 1] - \mathbb{E}[Y_{0i} \mid T_i = 0], \end{aligned} \tag{2.5}$$

where $\mathbb{E}[Y_{1i} \mid T_i = 1] - \mathbb{E}[Y_{0i} \mid T_i = 1]$ is the average treatment effect on the treated and $\mathbb{E}[Y_{0i} \mid T_i = 1] - \mathbb{E}[Y_{0i} \mid T_i = 0]$ is the selection bias. Equation (2.5) provides the average causal effect of the outcomes of interest on targeters, which is the expected effect of IT on a randomly drawn country from our sample. The average treatment effect on the treated is the mean effect for those countries that actually have adopted an inflation targeting framework. This effect can be written as the following:

$$\tau_{att} = \mathbb{E}[Y_{1i} - Y_{0i} \mid T_i = 1]. \tag{2.6}$$

We consider two assumptions to estimate τ_{ate} and τ_{att}. First, the treatment must be

[8] We do not observe both Y_{1i} and Y_{0i}, since each country is either targeter or non-targeter. This is called 'missing data problem' introduced by Rosenbaum and Rubin (1983).

randomized across countries, the "unconfoundedness assumption." [9] Second, the likelihood that a country adopts inflation targeting lies between zero and one, the overlap assumption.[10] In our case, the randomization of inflation targeting is infeasible. A central banks' decision is based on whether it adopts IT and its decision relates to the benefits from that treatment, $Y_{i1} - Y_{i0}$. Therefore, there is self-selection into adopting inflation targeting.

2.4.2 Propensity Score Analysis

Inflation targeting selection is a process that permits central banks to adopt inflation targeting in countries that meet some economic and institutional preconditions. Selection bias arises when targeters differ from non-targeters for reasons other than the specific monetary policy framework. Our observational data lack the randomized assignment of countries into the adoption of IT. In this case unconfoundedness assumption will be violated. One way to overcome selection problem is to randomize the assignment, because in a random assignment T_i is independent of potential outcomes. Researchers employ statistical procedures to balance the data before assessing treatment effects. One way to estimate average treatment effect when the unconfoundedness assumption does not hold is propensity score analysis (Rosenbaum and Rubin (1983)). The benefits of using propensity score analysis are as follows. First, this method reduces dimensionality to a one-dimensional score. Second, propensity scores balance the differences between inflation targeting countries and non-targeters.[11]

The propensity score is the "conditional probability of assignment to a particular

[9] Unconfoundedness or ignorability assumption states that $(Y_{1i}, Y_{0i}) \perp\!\!\!\perp T_i \mid X_i$ for all X_i.

[10] Overlap assumption declates that $0 < \pi(X_i) < 1$. The combination of both 'ignorability' and 'overlap' assumptions is called 'strong ignorability assumption' (Rosenbaum and Rubin (1983)).

[11] Targeters and non-targeters with the same value of the propensity score have the same distribution of the observed covariate.

treatment given a vector of observed covariates" (Rosenbaum and Rubin (1983), p. 41). The probability of being treated can be written as the following:

$$\pi(X_i) \equiv Pr(T_i = 1 \mid X_i). \tag{2.7}$$

The balancing property under exogeneity suggests that:

$$T_i \perp\!\!\!\perp X_i \mid \pi(X_i). \tag{2.8}$$

Thus, the ignorability assumption with the propensity score can be written as follows:

$$(Y_{1i}, Y_{0i}) \perp\!\!\!\perp T_i \mid \pi(X_i). \tag{2.9}$$

Propensity score analysis includes two stages. In the first stage, we estimate propensity score, the conditional probability of adopting IT. In the second stage, we match each IT country with a non-targeter based on the set of covariates. After defining a distance measure, we choose the matching algorithm. We report the results of estimating the average treatment effect on the treated using nearest neighbor matching.[12] Nearest neighbor matching selects the r best non-targeter matches for each inflation targeting country. Finally, we use the matched sample for the outcome analysis.

[12]The results of nearest neighbor matching is reported. However, we perform the matching procedure using full, optimal, and genetic matching and we find the similar results for all other matching methods.

2.4.3 Impact Evaluation through a Propensity Score Matching Model

We use different estimates of propensity score to examine the effect of the IT framework on a variety of outcome variables by estimating the average treatment effect on the treated. First, we use the parametric estimate of propensity score. Then, we estimate the propensity score using the nonparametric estimation proposed by (Hirano, Imbens and Ridder (2003)) and a semiparametric single index method.

Parametric Propensity Scores

In the first stage of propensity score matching, we can use a probit model or a logit model to estimate the propensity scores. Thus, we define the conditional probability of receiving treatment as follows:

$$\pi(X_i) = \mathbb{E}(T_i \mid X_i) = (2\pi)^{-1/2} exp[-(X_i\beta_i)^2/2] \tag{2.10}$$

or

$$\pi(X_i) = \frac{e^{X_i\beta_i}}{1 + e^{X_i\beta_i}}, \tag{2.11}$$

where π denotes $Pr(T_i = 1 \mid X_i)$. We define $G(\cdot)$ as the distribution function. Thus, β is selected to maximize the log-likelihood:

$$\mathscr{L}(\beta) = \sum_{i=1}^{N} y_i \log[G(x_i\beta)] + (1 - y_i)\log[1 - G(x_i\beta)]. \tag{2.12}$$

In the first stage estimation of treatment effects, we examine the role of institutional

characteristics and macroeconomic performance on the likelihood of adopting IT. The results of the probit model are presented in Table 2.2.[13] We find a significant and negative relation between openness and the likelihood of adopting IT for the full sample, industrial economies and developing countries. A higher degree of openness lowers the probability of adopting IT. As pointed out by Romer (1993), more open economies are less likely to adopt inflation targeting. Under monetary expansion, the real exchange rate depreciates. Since the harms of real depreciation are greater in more open economies, the degree of openness and the benefits of expansion are inversely related. Our findings show that the real money growth is significant and positively associated with the probability of adopting IT. Money growth has an inflationary pressure, and it increases the likelihood of adopting inflation targeting. Moreover, GDP growth as an indicator of the level of economic development is inversely correlated with the probability of the IT adoption. Our results are consistent with Lucotte (2012) and Samarina, Terpstra and De Haan (2013).

Preconditions play a crucial role in the inflation targeting literature, especially in emerging market economies. The preconditions are necessary for a monetary policy to be successful. These preconditions fall into four categories: institutional independence, well-developed technical infrastructure, economic structure, and a healthy financial system. The most important precondition discussed in the literature that has a huge impact on inflation targeting is a healthy financial system. The banking system should be sound and capital markets well developed to guarantee an effective monetary policy transmission. To examine the role of a healthy financial system for the adoption of inflation targeting we choose central bank assets-GDP ratio and private credit-GDP ratio. Central bank assets-GDP measures the size of the central bank. In our parametric set up, we find that as central banks' balance sheets expand the probability of the IT

[13] We also estimate the propensity score using a logit model (Equations 2.11). The results are similar to the probit estimation.

Table 2.2: Probit models for the full sample, industrial and developing countries

	FULL (1)	IND (2)	DCS (3)
Lagged GDP Growth	-0.099***	-0.177***	-0.090***
	(0.014)	(0.046)	(0.014)
Lagged Credit Deposit	0.007***	0.004***	0.008***
	(0.001)	(0.001)	(0.001)
Lagged Money Growth	0.005***	0.021**	0.003**
	(0.001)	(0.010)	(0.001)
Lagged CB Assets	0.001	-0.015*	0.002
	(0.002)	(0.009)	(0.002)
Lagged Openness	-0.012***	-0.008***	-0.013***
	(0.001)	(0.001)	(0.008)
Lagged Inflation	-0.003**	0.016	-0.003
	(0.001)	(0.015)	(0.001)

[a] The dependent variable is the targeting dummy, which has the value 1 if the country adopts inflation targeting.
[b] *p<0.1; **p<0.05; ***p<0.01

adoption rises in developing countries. However, higher central bank assets-GDP ratio lowers the likelihood of adopting IT in industrial economies. Thus, the balance sheets of central banks matter in the monetary authorities' decision. In industrial economies, the expansion of central banks' balance sheets as a share of GDP causes a loss in their credibility and decreases the probability of adopting IT. Private credit-GDP ratio is used to measure the financial depth. Our results show that it affects the likelihood of adopting IT, meaning that more financially developed countries are more likely to adopt IT. This result is consistent with Lucotte (2012). Our findings indicate that countries that meet some financial and capital market preconditions are more likely to adopt inflation targeting.

Figure 2.1 Shows the scatter plot of the estimated probit propensity score. After propensity scores are estimated, we match targeters to non-targeters based on the estimated propensity scores. If T_i and X_i are dependent, we need to preprocess the data to eliminate the relationship between T_i and X_i. Figure 2.2 illustrates the kernel density of the estimated propensity scores for the full sample, developing countries and industrial economies. The kernel densities of propensity scores for the control and treated units are shown in the dashed lines and solid lines, respectively. We find that the kernel density of propensity scores for countries that did and did not adopt inflation targeting in the full sample, industrial economies, and developing countries are different. This indicates that matching would improve the results of the estimation. Figure 2.3 plots the histograms of the estimated logit propensity scores in the original treated and control groups and histograms of the logit propensity scores in the matched treated and control groups for the full sample. The spread of the estimated propensity scores before and after matching are illustrated in the left and right graphs, respectively. As shown, the distribution of the propensity scores for non-targeters changes after applying the nearest-neighbor matching and it is close to the distribution of the propensity scores for targeters. We examine the balance of each covariate graphically in Figure 2.4–2.6 for all

samples. If the empirical distributions are the same for targeters and non-targeters, the points in the Q-Q plots lie on the 45 degree line. Deviations from it imply differences in the empirical distribution. As shown in these figures, matching would improve the empirical distribution for lagged openness and lagged GDP growth in the full sample.

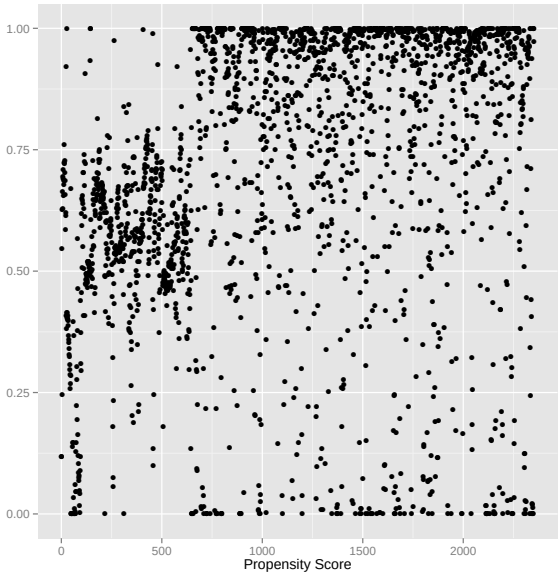
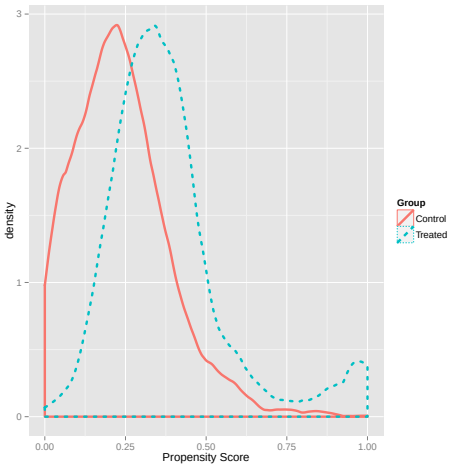
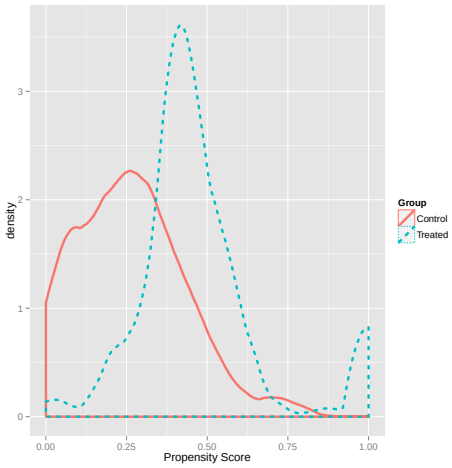


Figure 2.1: Scatter plot of the estimated probit propensity scores

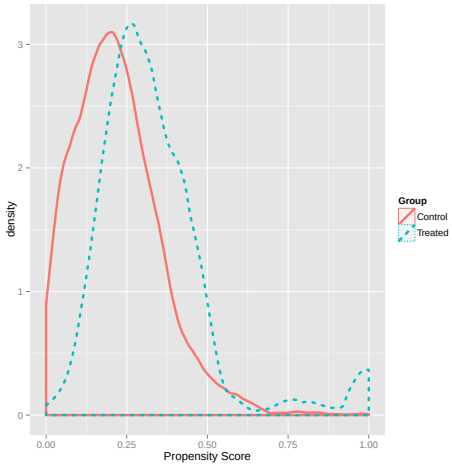
The results of average treatment effect on the treated using parametric propensity scores are presented in Table 2.3. For the full sample including both developed and developing economies, ATT on inflation is negative and statistically significant. Its magnitude is about -2.04, implying that on average, inflation in IT countries has been lower. Our findings indicate that treatment effects in developing countries and industrial economies separately are not statistically significant. We also find that the ATT on debt is significant and negative for all samples. Thus, adopting inflation targeting positively affects fiscal discipline in both developing and industrial economies. The average treatment effect on the treated on inflation variability is negative across the samples. The comparison of the effect of inflation targeting on sacrifice ratio among all subsamples indicate that industrial inflation targeters were able to reduce inflation



(a) Full Sample



(b) Industrial Economies



(c) Developing Countries

Figure 2.2: Kernel density of the estimated probit propensity scores

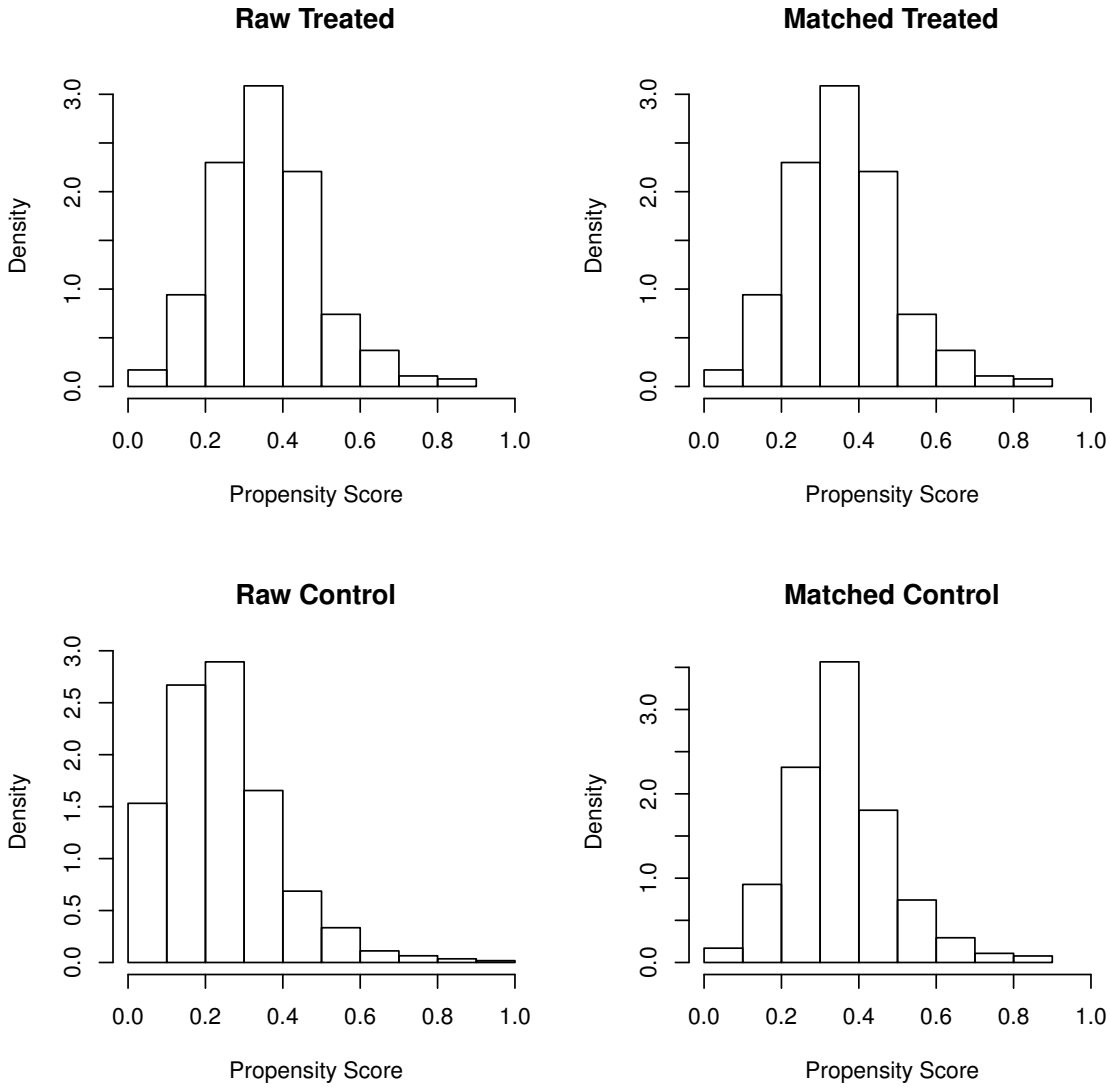
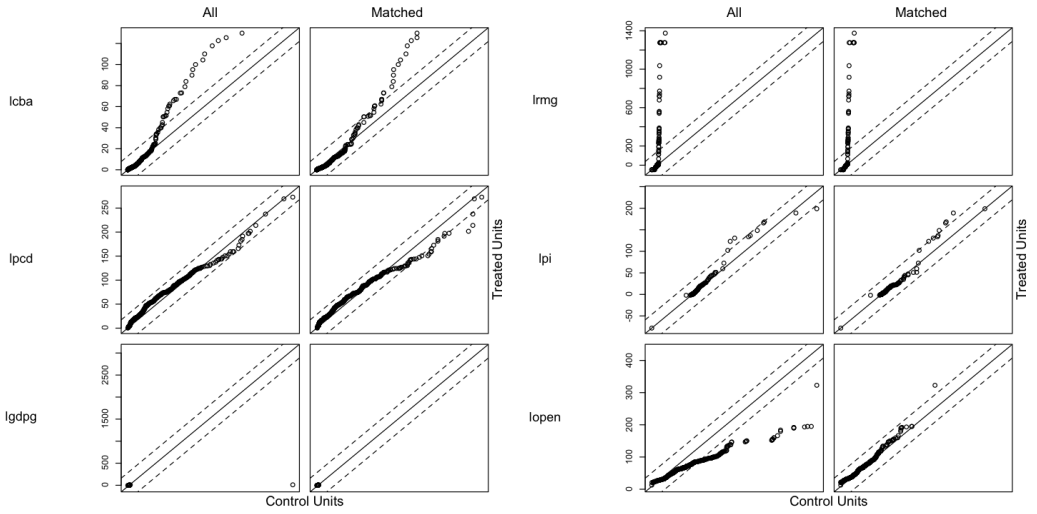
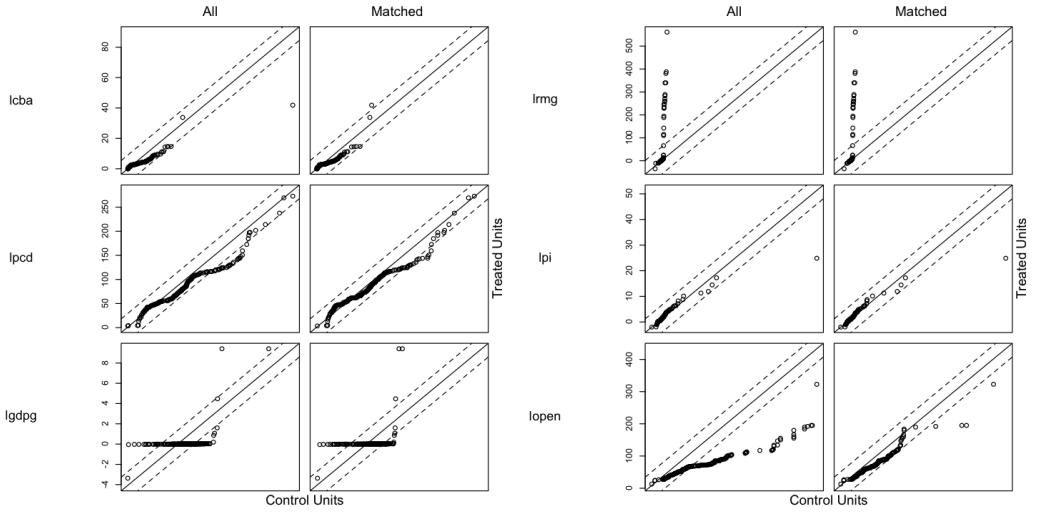


Figure 2.3: Histograms of the estimated propensity scores before and after matching



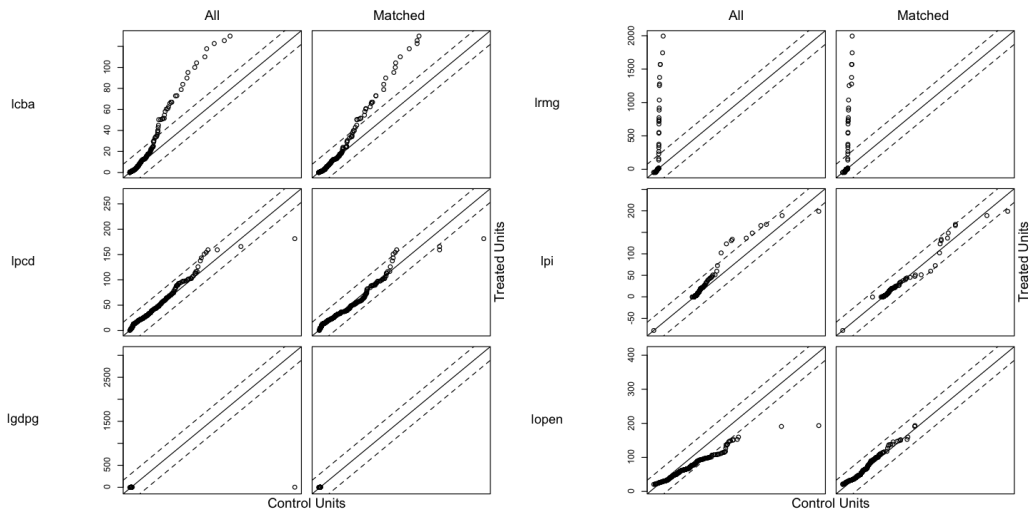
(a) (b)

Figure 2.4: QQ plots for all covariates, full sample



(a) (b)

Figure 2.5: QQ plots for all covariates, industrial economies



(a) (b)

Figure 2.6: QQ plots for all covariates, developing countries

less costly than developing targeters. Interestingly, IT has a larger negative effect on the inflation variability in developing countries than developed economies. The average treatment effect on the treated on interest rate volatility is negative and significant for the full sample. It has been argued in the literature that less volatile interest rates is a sign of more credible central banks. Chadha and Nolan (2001) provide a theoretical model to link transparency and interest rates volatility. They argue that information flows increase the volatility of interest rates. Our results show that the IT regime reduces interest rates volatility. We also examine the relationship between inflation targeting and exchange rate volatility. Our findings suggest that IT reduces exchange rate volatility in developing countries. Nonetheless, it increases the volatility of real exchange rates in industrial economies.

Nonparametric Propensity Score

It has been argued that propensity score analysis is sensitive to the specifications of the propensity score. We must take into consideration the specification of the first

Table 2.3: Average treatment effect on the treated, probit esitmate of $\pi(x)$

	π	$debt$	SR	σ_π	σ_i	σ_s
FULL	-2.04*	-16.16***	0.002	-2.43***	-1.55***	-2.18***
	(1.13)	(2.61)	(0.18)	(0.78)	(0.47)	(0.80)
IND	0.2	-31.01***	-1.21**	-0.02	0.29	2.31***
	(0.24)	(4.91)	(0.50)	(0.19)	(0.22)	(0.73)
DCS	-1.28	-13.56***	-0.05	-2.6**	-1.14**	-1.88**
	(1.58)	(3.17)	(0.18)	(1.15)	(0.55)	(0.97)

[a] Outcomes are inflation (π), government debt-GDP ratio ($debt$), sacrifice ratio (SR), inflation variability (σ_π), interest rate volatility (σ_i), and exchange rate volatility (σ_s).
[b] FULL: full sample, IND: industrial economies, DCS: developing countries.
[c] *p<0.1; **p<0.05; ***p<0.01.

stage estimator for the following reasons. First, the coefficients of the propensity score are poorly estimated in the misspecified propensity score, and this has an influence on the estimated ATT (Zhao (2008)). Second, using the parametric propensity score sacrifices the efficiency of the estimator (Heckman and Ichimura (1998)), even if it removes all biases (Rosenbaum and Rubin (1983)). The following example illustrates how misspecification of propensity score given a vector of covariates x ($\pi(x)$) leads to biased results. Let y be a continuous response, t be the treatment, and τ be the treatment effect, and β is a vector of parameters relating the covariates x to the response in the model $E(y \mid x,t) = g(x;\beta) + \delta t$. Assume $E_x \mid g(x;\beta) \mid < \infty$. Let $\bar{y}_1$ and $\bar{y}_0$ denote the sample averages of treated and control units. In a randomized study, $\hat{\tau} = \bar{y}_1 - \bar{y}_0$ is an unbiased estimator of τ. Similarly, if we denote the average response in treatment group i at $\pi(x)$ by $\bar{y}_{i,\pi(x)}$, then in an observational study $\tilde{\tau} = \bar{y}_{1,\pi(x)} - \bar{y}_{0,\pi(x)}$ is an unbiased estimator of treatment effect (Rosenbaum and Rubin (1983)). Suppose that $\pi(x)$ is not known and misspecified to be some function $\phi(x)$. Then,

$E[\bar{y}_1 - \bar{y}_0 \mid \phi(x)] = \tau + E_x[g(x;\beta) \mid t = 1, \phi(x)] - E_x[g(x;\beta) \mid t = 0, \phi(x)]$ and $\bar{y}_{1,\phi(x)} - \bar{y}_{0,\phi(x)}$ is not unbiased for τ. To deal with the model misspecification problem, Hirano, Imbens and Ridder (2003) introduce an estimation of the average treatment effect by weighting the inverse of a nonparametric estimate of the propensity score. We use the nonparametric series estimator proposed by Hirano, Imbens and Ridder (2003) to estimate a consistent propensity score in a matching framework. This estimator can be used when the functional form of the propensity score and the distribution of the error terms are unknown. They estimate $\pi(x)$ in a sieve approach by the Series Logit Estimator (SLE). Suppose $R^K(x) = (r_{1K}(x), r_{2K}(x), \ldots, r_{kK}(x))'$ be a K-vector of functions where $K = 1, 2, \ldots$. Denote the logistic cdf by $\Lambda(a) = \exp(a)/(1 + \exp(a))$, the SLE is defined by $\hat{\pi}(x) = \Lambda(R^k(x)'\hat{\pi}_K)$ where,

$$\hat{\pi}_K = \underset{\pi}{\operatorname{argmax}} \sum_{i=1}^{N} (T_i \cdot \ln(\Lambda(R^k(x)'\pi)) + (1 - T_i) \cdot \ln(1 - \Lambda(R^k(x)'\pi)). \tag{2.13}$$

$\pi(x)$ is estimated using this method. Table 2.4 summarizes the results of nonparametric series propensity scores. The estimation is stopped at the second power, because standard errors become very large, causing instability in the estimates of the coefficients. Table 2.5 shows the results of the ATT using the nonparametric series propensity score. The average treatment effect on the treated for debt, the inverse measure of fiscal discipline, is statistically significant and negative. In our full sample, we find that inflation targeting reduces sacrifice ratio. Our results show that real exchange rate volatility had significantly increased in developed countries.

Table 2.4: Nonparametric series models for all samples

Covariates	FULL	IND	DCS	Covariates	FULL	IND	DCS
X_1	-0.26345	-0.22829	0.69219	X_5	-0.01792	-0.01525	-0.00527
	(0.0575)	(0.1635)	(0.28033)		(0.0029)	(0.0053)	(0.00681)
X_1^2	-0.04964	0.01458	-0.99506	X_1X_5	0.00048	-0.00018	-0.00673
	(0.0058)	(0.01254)	(0.08301)		(0.0008)	(0.0015)	(0.00033)
X_2	0.01374	-0.00659	0.01262	X_2X_5	0.00007	0.00010	0.00013
	(0.0026)	(0.0055)	(0.00620)		(0.000002)	(0.00004)	(0.00015)
X_1X_2	-0.00029	0.00016	-0.01352	X_3X_5	-0.00002	-0.00091	0.00088
	(0.0007)	(0.0016)	(0.00289)		(0.0002)	(0.0004)	(0.00005)
X_2^2	-0.00008	-0.00005	-0.00003	X_4X_5	0.00025	-0.00005	0.00015
	(0.00001)	(0.00002)	(0.00004)		(0.0001)	(0.0004)	(0.00015)
X_3	-0.01976	0.10937	-0.05180	X_5^2	-0.00001	-0.00001	-0.00011
	(0.0128)	(0.0461)	(0.02318)		(0.00002)	(0.00002)	(0.00005)
X_1X_3	-0.00434	-0.0344	-0.02350	X_6	-0.00580	-0.09000	-0.00538
	(0.0027)	(0.0181)	(0.00973)		(0.0081)	(0.1010)	(0.01344)
X_2X_3	0.00023	0.00016	0.00002	X_1X_6	0.00376	-0.03577	0.00319
	(0.0001)	(0.0004)	(0.00033)		(0.0014)	(0.0266)	(0.00690)
X_3^2	0.00019	0.00104	0.00013	X_2X_6	-0.00006	0.00452	-0.00023
	(0.0001)	(0.0008)	(0.00008)		(0.0001)	(0.0012)	(0.00014)
X_4	-0.05273	-0.06149	-0.02596	X_3X_6	0.00001	-0.00191	-0.00011
	(0.0119)	(0.0409)	(0.01662)		(0.0001)	(0.0044)	(0.00023)
X_1X_4	0.00423	0.00780	-0.01207	X_4X_6	-0.00028	-0.00040	-0.00013
	(0.0024)	(0.0103)	(0.00754)		(0.0004)	(0.0042)	(0.00052)
X_2X_4	-0.00017	0.00015	-0.00056	X_5X_6	0.00005	-0.00235	0.00016
	(0.0001)	(0.0004)	(0.00024)		(0.0001)	(0.0013)	(0.00018)
X_3X_4	-0.00014	-0.00523	-0.00039	X_6^2	0.00004	-0.00110	0.00008
	(0.0005)	(0.0032)	(0.00075)		(0.000003)	(0.0019)	(0.00007)
X_4^2	0.00069	0.00114	0.00052				
	(0.0001)	(0.0008)	(0.00014)				

[a] X_1: lagged central bank assets to GDP, X_2: lagged private credit to GDP, X_3: lagged GDP growth, X_4: lagged real money growth, X_5: lagged lagged inflation, X_6: lagged openness.

[b] *p<0.1; **p<0.05; ***p<0.01.

Table 2.5: Average treatment effect on the treated, nonparametric estimate of $\pi(x)$

	π	$debt$	SR	σ_π	σ_i	σ_s
FULL	2.03	-24.54***	-1.19***	-0.17	0.10	0.16
	(1.59)	(4.29)	(0.38)	(1.12)	(0.67)	(1.13)
IND	0.03	-25.85***	-0.83	0.07	0.04	2.37***
	(0.27)	(5.08)	(0.65)	(0.14)	(0.29)	(0.73)
DCS	0.87	-17.49***	0.32	1.04	-0.55	-1.84
	(2.38)	(6.24)	(0.30)	(1.57)	(1.01)	(1.94)

[a] Outcomes are inflation (π), government debt-GDP ratio ($debt$), sacrifice ratio (SR), inflation variability (σ_π), interest rate volatility (σ_i), and exchange rate volatility (σ_s).
[b] FULL: full sample, IND: industrial economies, DCS: developing countries.
[c] *p<0.1; **p<0.05; ***p<0.01.

Semiparametric Propensity Score

One problem with nonparametric series estimator is that it suffers from the "curse of dimensionality." The curse of dimensionality refers to the poor performance of the nonparametric series method for multivariate data. The behavior of nonparametric estimators deteriorates as the dimension increases because of the sparseness of multidimensional data (Stone (1980)). In other words, in higher dimensions the observations are sparsely distributed and the speed of convergence decreases for higher dimensions. The optimal bandwidth converges at $\mathcal{O}(\mathcal{N}^{\frac{-2}{4+d}})$, where d is the dimension. To break the curse of dimensionality, we use the semiparametric single index model for estimating propensity score. The semiparametric single index model is an alternative approach to mitigate bias arising from the curse of dimensionality. It also can avoid the problem of error distribution misspecification. The single index model is suggested by Klein and Spady (1993). They introduce this semiparametric model where the response is a binary variable. A semiparametric single index model is given by:

$$T = g(X'\beta_0) + u, \tag{2.14}$$

where Y is the dependent variable, $X \in \mathbb{R}^q$ is the vector of explanatory variables, and the functional form of $g(\cdot)$ is unknown. Klein and Spady (1993) suggest estimating the parameters by maximum likelihood methods:

$$\mathscr{L}(\beta, h) = \sum_i (1 - T_i) \ln(1 - \hat{g}_{-i}(X_i'\beta)) + \sum_i T_i \ln(\hat{g}_{-i}(X_i'\beta)), \tag{2.15}$$

where $\hat{g}_{-i}(X_i'\beta)$ is the leave-one-out estimator. After estimating propensity scores using this method, we use them as weights to estimate ATE and ATT. The function $g(\cdot)$ includes any location and level shift, so the vector X_i cannot include an intercept. We need some normalization criterion to identify β. It is easier to impose this normalization on β than on g. Thus, we set the lagged openness coefficient to one. Table 2.6 indicates the results of semiparametric single index models for the full sample, industrial economies, and developing countries. The findings show that as the size of the central banks' balance sheet in developing countries increases, the probability of adopting IT enhances. However, higher central banks' asset results a lower probability of the IT adoption in developed economies. We also find that an increase in private-credit to GDP ratio reduces the likelihood of the IT adoption. To assess the accuracy of our single index estimate, we compare the confusion matrices of the probit and single index models. A confusion matrix shows the actual outcomes versus the predicted outcomes estimated by a model. The confusion matrices are presented in Table 2.7. It can be seen that the single index model correctly classifies 75% of the treatment, while the parametric probit model correctly classifies 71%. It can be seen that semiparametric single index model does better than probit model when modeling inflation targeting. Figure 2.7 shows the scatter

plot of the estimated semiparametric propensity scores. Figure 2.8 indicates kernel densities of the estimated index model. It can be seen that the distribution between control and treated groups are quite different among all samples. Thus, we expect that matching improves the results of treatment effects.

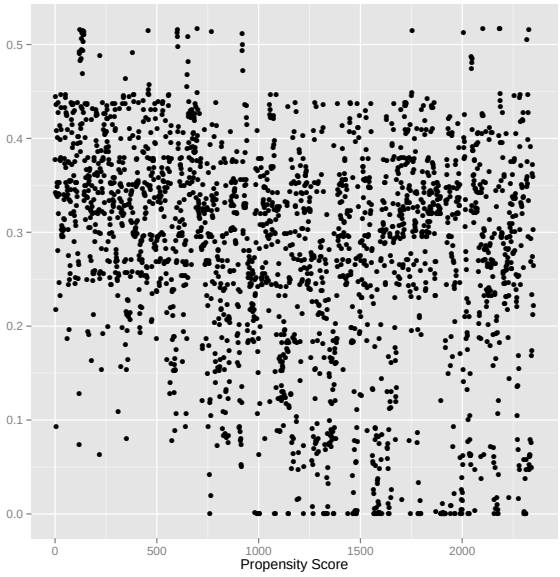
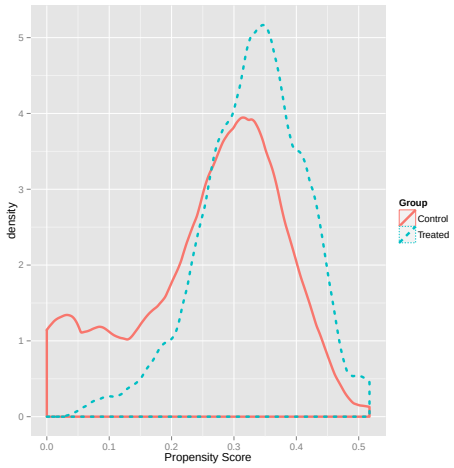
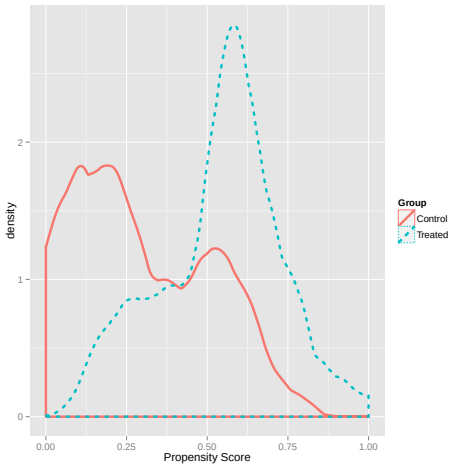


Figure 2.7: Scatter plot of the estimated semiparametric propensity scores

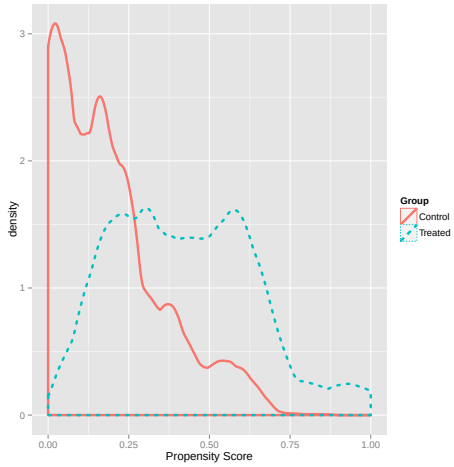
We apply the results of semiparametric single index model in order to find the average treatment effect on the treated. Song (2014) finds that in propensity score analysis, the conditions of the single index propensity score estimate do not affect the asymptotic distribution of treatment effects. This condition holds even when the single index propensity score is cube-root consistent. Table 2.8 indicates the results of ATT using the semiparametric single index estimate of propensity score. Our findings show that IT reduces inflation variability in developing countries and industrial economies. The average treatment effect on the treated for the industrial subsample is -.61 and for developing countries is -4.17. The impact of IT is less in industrial economies than developing countries, implying that developing countries benefit more from adopting inflation targeting in terms of a reduction in inflation uncertainty. The average treatment



(a) Full Sample



(b) Industrial Economies



(c) Developing Countries

Figure 2.8: Kernel density of the estimated semiparametric propensity scores

Table 2.6: Semiparametric single index models for all samples

	FULL (1)	IND (2)	DCS (3)
Lagged Openness	1	1	1
Lagged GDP Growth	-0.46***	-2.06**	-0.81***
	(0.11)	(0.97)	(0.19)
Lagged Money Growth	-0.004	-0.17***	-0.11***
	(0.004)	(0.01)	(0.003)
Lagged Inflation	0.06***	-1.13***	-0.15***
	(0.02)	(0.23)	(0.01)
Lagged CB Assets	-0.15***	-0.39***	0.26***
	(0.02)	(0.14)	(0.04)
Lagged Credit Deposit	-0.04***	0.02	-0.87***
	(0.007)	(0.02)	(0.005)

[a] The dependent variable is the targeting dummy, which has the value 1 if the country adopts inflation targeting.
[b] Lagged openness is normalized to one for the identification in the single index model.
[c] *p<0.1; **p<0.05; ***p<0.01.

Table 2.7: Confusion matrices for the full sample

	Predicted	
Actual	0	1
0	1615	89
1	572	76

(a) Probit Model

	Predicted	
Actual	0	1
0	1698	6
1	584	64

(b) Single Index Model

The diagonal elements contain correctly predicted outcomes, while the off-diagonal ones contain incorrectly predicted (confused) outcomes.

effect on the treated for the government debt-GDP ratio for the full sample, developed economies, and developing countries are -13.69, -25.27, and -7.11, respectively. These results show two features: first, inflation targeting improves fiscal discipline; second, the impact of IT on fiscal discipline in developing countries is significantly larger than that of in industrial economies. IT adoption encourages fiscal authorities to improve fiscal discipline to support central banks to build up their credibility. Most of developing countries that have adopted inflation targeting did not meet the preconditions of the IT adoption. Accordingly, they enhance fiscal discipline more than developed countries in order to convince the private sector of their commitment to price stability. This is consistent with the literature that emphasizes the impact of inflation targeting on the fiscal discipline. Minea and Tapsoba (2014) indicate that inflation targeting improves fiscal discipline only in developing countries.

Table 2.8: Average treatment effect on the treated, single index estimate of $\pi(x)$

	π	$debt$	SR	σ_π	σ_i	σ_s
FULL	0.17	-13.69***	-0.1	-0.78	-0.75**	-2.58***
	(0.96)	(2.02)	(0.13)	(0.56)	(0.31)	(0.58)
IND	-0.87**	-25.27***	0.18	-0.61**	-0.69	1.61**
	(0.42)	(4.29)	(0.48)	(0.26)	(0.44)	(0.79)
DCS	0.12	-7.11*	0.02	-4.17***	0.55	-2.54**
	(2.37)	(3.78)	(0.26)	(1.47)	(0.69)	(1.23)

[a] Outcomes are inflation (π), government debt-GDP ratio ($debt$), sacrifice ratio (SR), inflation variability (σ_π), interest rate volatility (σ_i), and exchange rate volatility (σ_s).
[b] FULL: full sample, IND: industrial economies, DCS: developing countries.
[c] The results are based on lagged openness coefficient normalization in the first stage.
[d] *p<0.1; **p<0.05; ***p<0.01.

There is no consensus in the literature about how the adoption of the IT regime would affect the volatility of exchange rate. It has been suggested that the focus on inflation targeting may move the focus of central banks, especially in emerging markets, away from foreign exchange markets. Mishkin and Savastano (2001) for example, suggest that a floating exchange rate system is a requirement for a well-functioning inflation targeting regime. The reason for this is that in a world of capital mobility, independent monetary policy cannot coexist with a pegged exchange rate regime; this is the so-called "Impossibility of the Holy Trinity." This connection between inflation targeting and floating exchange rates has led some analysts to argue that one of the costs of IT is the increase in exchange rate volatility. However, Gregorio, Tokman and Valdés (2005) discuss this issue in the Chilean context, and show that in Chile (nominal) exchange rate volatility has not been higher than in other countries with floating exchange rates. Similarly, Edwards (2006) argues that a credible monetary policy can reduce the exchange rate volatility.

We examine the relationship between inflation targeting and exchange rate volatility using propensity score matching with the single index propensity score estimate. Our findings suggest that IT reduces exchange rate volatility in developing countries but increases it in industrial economies. The ATT on real exchange volatility for the full sample is -2.58. Lin (2010) shows that inflation targeting has different impacts on exchange rate volatility. She argues that the IT regime significantly lowers the volatility of exchange rate in industrial economies and increases them in developing countries. Rose (2007) also finds that inflation targeters experienced lower real exchange rate volatility than non-targeters. As a robustness check, we find the average treatment effect on the treated using index model with different normalization coefficient. We normalize lagged money growth coefficient. The results are shown in Table 2.9. We find similar results compare with the lagged openness normalization. In general, the choice

of propensity scores, especially the single index model, has a considerable impact on the treatment effect estimates. As a result, within the framework of a semiparametric single index model, the impact of inflation targeting is economically more meaningful. Our empirical study suggests that the single index coefficient regression model, in conjunction with the proposed estimation method could be useful in propensity score analysis.

Table 2.9: Average treatment effect on the treated, single index estimate of $\pi(x)$

	π	$debt$	SR	σ_π	σ_i	σ_s
FULL	1.98	-21.32***	-0.7**	0.03	0.008	-0.76
	(1.69)	(4.46)	(0.35)	(1.23)	(0.68)	(1.34)
IND	0.17	-42.1***	-0.03	-0.32**	0.03	1.96*
	(0.30)	(5.93)	(0.57)	(0.16)	(0.33)	(1.14)
DCS	-0.01	-11.04***	-0.08	-1.54***	0.57	-1.94*
	(2.01)	(3.96)	(1.82)	(0.24)	(0.67)	(1.03)

[a] Outcomes are inflation (π), government debt-GDP ratio ($debt$), sacrifice ratio (SR), inflation variability (σ_π), interest rate volatility (σ_i), and exchange rate volatility (σ_s).
[b] FULL: full sample, IND: industrial economies, DCS: developing countries.
[c] The results are based on lagged money growth coefficient normalization in the first stage.
[d] *p<0.1; **p<0.05; ***p<0.01.

2.5 Concluding Remarks

The purpose of this paper is to examine the causal effect of the IT adoption on macroeconomic performance. To do so, we compare different methods of estimating the average treatment effects of inflation targeting and attempt to find its effectiveness within an efficient framework. We use propensity score matching and weighting models to perform an outcome analysis. Since misspecification of the propensity score leads

us to a biased estimate, we use a nonparametric series estimator proposed by Hirano, Imbens and Ridder (2003). However, this model suffers from the curse of dimensionality. We avoid the curse of dimensionality by using a semiparametric single index model. This study also considers the prominent role of preconditions in IT adoption. One of the necessary preconditions before adopting inflation targeting is a sound financial system and a developed capital market. To find the role of these preconditions, we choose central bank assets-GDP ratio and private credit-GDP ratio in the first stage estimations. We examine the effectiveness of inflation targeting in our outcome analysis by considering inflation, inflation variability, fiscal discipline, interest rate volatility, and real exchange variability.

The results from a propensity score matching model using a probit estimate indicate that inflation targeting lowers inflation in the full sample and improves fiscal discipline in both developing and developed countries. We find that the IT regime negatively affects interest rates volatility. Our findings based on the semiparametric estimate show that IT reduces inflation variability, and this reduction is larger in developing countries. We find that fiscal authorities in developing countries enhance fiscal discipline more than developed countries as a sign of their commitment to price stability. We also examine that the inflation targeting regime reduces the exchange rate volatility in developing countries. However, industrial economies experienced higher exchange rate variability after the adoption of IT. Our comparison among different models and estimates show that the choice of propensity scores has a considerable impact on the treatment effect estimates. Consequently, a semiparametric single index estimate of propensity scores provides the most meaningful results.

3

The Success of the Central Banks in Inflation Targeting Countries

3.1 Introduction

The literature on inflation targeting is divided over the efficacy of inflation targeting. There is one strand of literature where researchers argue that IT strategy curbs inflation expectations due to the credibility, accountability and transparency of central banks (Bernanke and Mishkin (1997), Mishkin and Schmidt-Hebbel (2001), Levin, Natalucci and Piger (2004), Mishkin and Schmidt-Hebbel (2007), Baxa, Horvath and Vasicek (2014)). The opposite view takes the stand that the apparent success of IT regime in most of the countries has been mainly due to favorable shocks affecting the global economy and these economies would have witnessed low and stable inflation even in the absence of an IT regime (Johnson (2002), Ball and Sheridan (2003), Lin and Ye (2007), Genc et al. (2007), Cecchetti and Hakkio (2009))

Most of the existing studies on IT regime examine its efficacy by examining the behavior of inflation after the adoption of this regime. Surprisingly, there is no comprehensive study that takes into account the success of these IT countries in achieving their targets.[1] One notable exception is Albagli and Schmidt-Hebbel (2004). They studied the determinants of deviation of inflation from its target for 19 inflation-targeting central banks from both industrialized and emerging market economies over the 1990s and early

[1] In a related study Neuenkirch and Tillmann (2014) evaluate the central banks' response to inflation gap for a sample of five inflation targeting countries.

2000s. In their panel and cross-sectional analysis, they find that institutional investor rating and central bank independence index affect the central bank's ability in achieving its target. Our study is different from the above mentioned work in several dimensions. To take into account the heterogeneity across the central banks and economic circumstances, our study focuses on the dynamic behavior of the gap between level of inflation and inflation target. This is important because the ability of central bank to achieve its target may depend upon economic circumstances and there may be significant time variation in its ability to attain the explicit inflation target. In addition, our study also includes 8 other countries to make the analysis comprehensive for all the explicit inflation targeters. Secondly, we examine whether the success in achieving their explicit inflation targets is associated with the institutional strength of these countries.

The success in achieving the target announced publicly by the central bank is crucial if the IT central bank wants to gain credibility. There are different reasons why actual inflation may differ from the target. At the time of the adoption of the IT regime, the central banks want to anchor inflationary expectations over medium to long-horizon. Therefore, the short-term gap between actual inflation and target may not reflect the inability of the central banks to hit their target. However, the central bank will lose credibility if the gap is non-zero for a considerable period of time. The gap may also arise because of unpredictable shocks, but the impact of these unpredictable shocks should not persist for a long period. We use this feature of inflation targeting and propose to test the effectiveness of the IT countries in meeting their target by decomposing the gap between actual inflation and the target into predictable and unpredictable components. We argue that a successful IT regime should bring down the predictable component of the inflation gap to zero over the medium-horizon if they are successful in bridging the gap that was predictable in advance. Our approach is motivated by Friedman's stabilization policy hypothesis (1953) where he argued that a perfectly successful central banker should

make inflation perfectly stable. One consequence of a perfectly stable inflation is that it becomes unpredictable in a sense that a constant inflation forecast model can't be improved upon. It should be noted that unpredictability is a consequence of superior monetary policy in this context. The linkage between the success of monetary policy and the decline in predictability of inflation has also been shown by Boivin and Giannoni (2006) and Kishor and Kochin (2007). The empirical evidence presented in D'Agostino and Surico (2012) for the twentieth century also supports the above hypothesis where they find that the inflation forecasts based on money growth and output growth were significantly more accurate than the naïve forecasts only during the regimes associated with neither a clear nominal anchor nor a credible commitment to fight inflation.

We examine the success of the IT countries in meeting their target by estimating the predictable component of inflation gap from a parsimonious time-varying autoregressive model. The conditional expectation of this TVP–AR model is the predictable component of the inflation gap. The TVP–AR model takes into account the fact that the capability of the central bank to achieve its target varies over time and is affected by institutional characteristics like fiscal situation, central bank independence and financial market depth among others. Our approach is able to capture the gradual transition of actual inflation to its target over time.[2]

We find considerable heterogeneity in the success of the IT countries in bridging the gap between actual inflation and the target in the years immediately after the adoption of the IT regime. We find that the predictable component of inflation gap was close to zero for the countries with relatively low level and volatility of inflation even at the

[2]One could argue that use of a multivariate model will yield a superior estimate of the predictable component. However, the purpose of our study is not to find the most superior forecast of inflation gap. The use of a simple AR model gives us a simple benchmark that can be improved upon by the inclusion of more variables in the information set. Therefore, the presence of a predictable component in inflation gap should also imply the presence of a predictable component if the information set of the model is expanded.

beginning of this regime. However, we find that the predictable component of inflation converged to zero implying higher degree of success in achieving the target for almost all the IT countries after few years of the adoption of IT. Interestingly, we also find that the predictable component of inflation gap started declining few years before these countries publicly joined the IT regime. This implies that the central banks of the IT adopting countries started targeting inflation implicitly before becoming an explicit inflation targeter.

Our findings that in addition to cross-country heterogeneity, there is also significant time-variation in the success of the IT countries in achieving their targets can reconcile the two conflicting views on the effectiveness of IT. The finding that the IT countries have been successful in achieving their target is consistent with the literature that suggests that IT regime leads to a gradual build up in the credibility of the central banks (Neumann and von Hagen (2002), Carare and Stone (2006), Creel and Hubert (2010), de Mendonca and de Guimaraes (2012)). The finding that there is considerable cross-country heterogeneity in the performance of the central banks immediately after the adoption is consistent with the literature which suggests the countries that started with high inflation benefitted more from this regime (Levin, Natalucci and Piger (2004), Mishkin and Schmidt-Hebbel (2007) and Batini and Laxton (2007)). Our panel data analysis suggests that the relative success of these countries in achieving their targets is influenced by their institutional characteristics. In particular, we find that high debt-GDP ratio constrains the ability of the central bank to bridge the gap between inflation and target. We also find that financial development indicators and macroeconomic performance significantly affect the inflation gap in these IT countries.

3.2 Data Description

One of the contributions of our paper is to create a comprehensive database of explicit inflation targets for all the IT countries. Table 3.1 shows the list of countries that have adopted IT regime. It includes information on the date of adoption, the initial target and the target at the end of the 2013. If there is a range for the target, we consider midpoints of target ranges. Israel and Poland have the highest gap between the two periods' target level, 14.5 to 2 and 8.25 to 2.5 percent, respectively. Figure 3.1 represents the target level at the date of adoption compared to the target level in 2013. Panel (a) shows the target level at the adoption date and panel (b) depicts the level in 2013. In general, the target level has been decreasing over the past 25 years.

Table 3.1 also shows the type of target path for each IT country. The literature has classified the behavior of inflation targets into two categories: 'convergence' and 'stationary' target path. Convergence rates relate to the inflation targeters in which initial target levels were high, gradually converging to a lower level. Stationary rates indicate a constantly low level of inflation. In addition, we classify each country into industrial or emerging market economies based on their level of economic development. Ruge-Murcia (2014) finds that Canada is an exception, where the price-level itself is stationary.

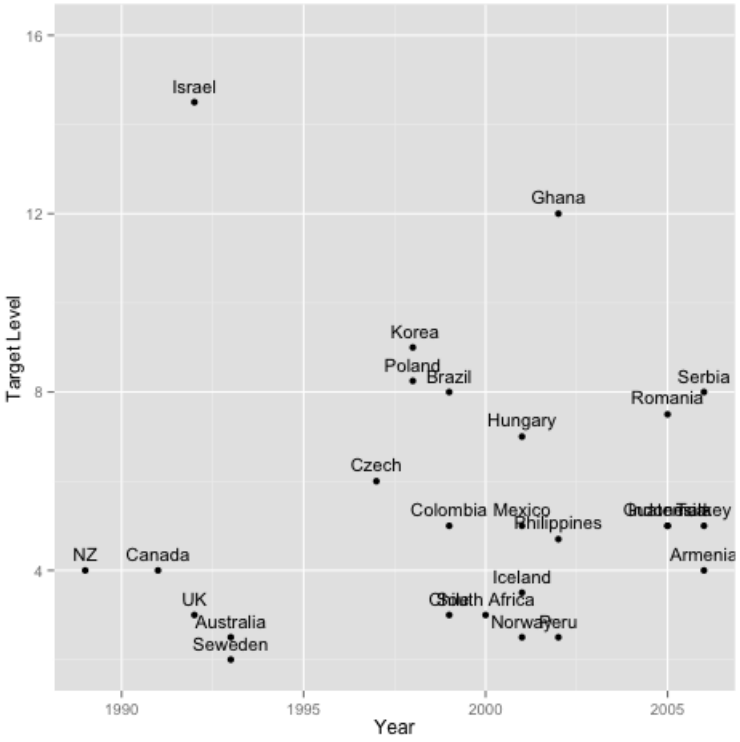
The data on consumer prices have been obtained from the IMF's International Financial Statistics and FRED from 1980 through 2013 on a quarterly basis. The data on inflation targets have been obtained from the central banks' websites, and other studies (Mishkin and Schmidt-Hebbel (2001), Batini and Laxton (2007), Hammond (2012) and Leyva (2008)).[3] Figure 3.2 presents the annual inflation rates and targets for our samples. The vertical lines indicate the date of IT adoption. A visual inspection

[3]More details on inflation target data are available upon request.

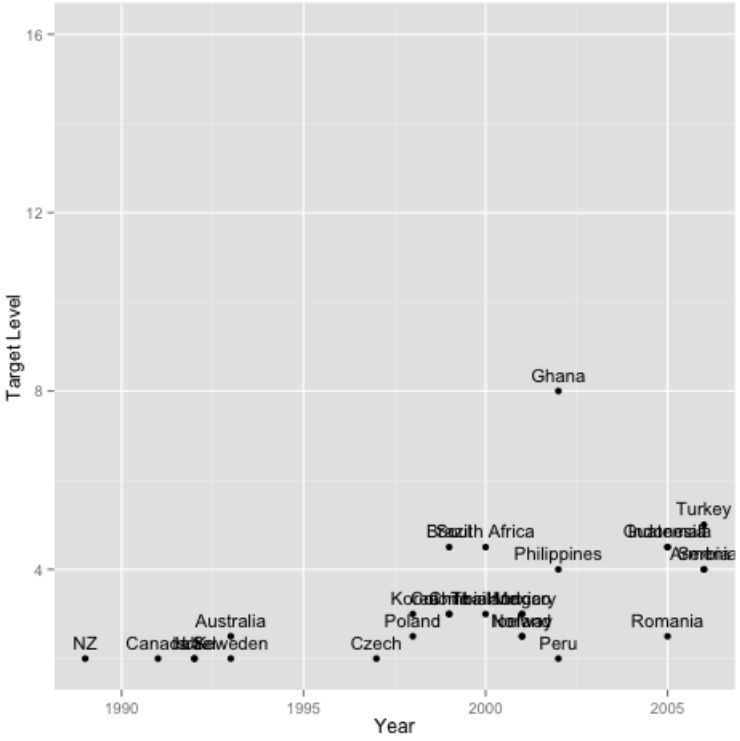
Table 3.1: Inflation targeting countries in the world, 1989–2013

Countries	Adoption Date	Target (adoption date)	Target (2013)	Group	Target Path
Armenia	*2006Q1*	4	4	EME	Convergence
Australia	*1993Q2*	2.5	2.5	IND	Stationary
Brazil	*1999Q2*	8	4.5	EME	Convergence
Canada	*1991Q1*	4	2	IND	Stationary
Chile	*1999Q3*	3	3	EME	Stationary
Colombia	*1999Q3*	5	3	EME	Convergence
Czech	*1997Q4*	6	2	EME	Stationary
Ghana	*2002Q1*	12	8	EME	Convergence
Guatemala	*2005Q1*	5	4.5	EME	Convergence
Hungary	*2001Q2*	7	3	EME	Convergence
Iceland	*2001Q1*	3.5	2.5	IND	Stationary
Indonesia	*2005Q3*	5	4.5	EME	Convergence
Israel	*1992Q1*	14.5	2	EME	Stationary
Mexico	*2001Q1*	5	3	EME	Stationary
New Zealand	*1989Q4*	4	2	IND	Stationary
Norway	*2001Q1*	2.5	2.5	IND	Stationary
Peru	*2002Q1*	2.5	2	EME	Stationary
Philippines	*2002Q1*	4.7	4	EME	Stationary
Poland	*1998Q1*	8.25	2.5	EME	Stationary
Romania	*2005Q3*	7.5	2.5	EME	Convergence
Serbia	*2006Q3*	8	4	EME	Convergence
South Africa	*2000Q1*	3	4.5	EME	Stationary
South Korea	*1998Q2*	9	3	EME	Stationary
Sweden	*1993Q1*	2	2	IND	Stationary
Thailand	*2000Q2*	1.75	3	EME	Stationary
Turkey	*2006Q1*	5	5	EME	Convergence
UK	*1992Q3*	3	2	IND	Stationary

[a] EME and IND indicate Emerging Market and Industrial Economies, respectively.
[b] Adoption dates and inflation targets are taken from the central banks' web pages. Country group and target path are based on Schmidt-Hebbel (2009).



(a) Target Level at the Adoption Date



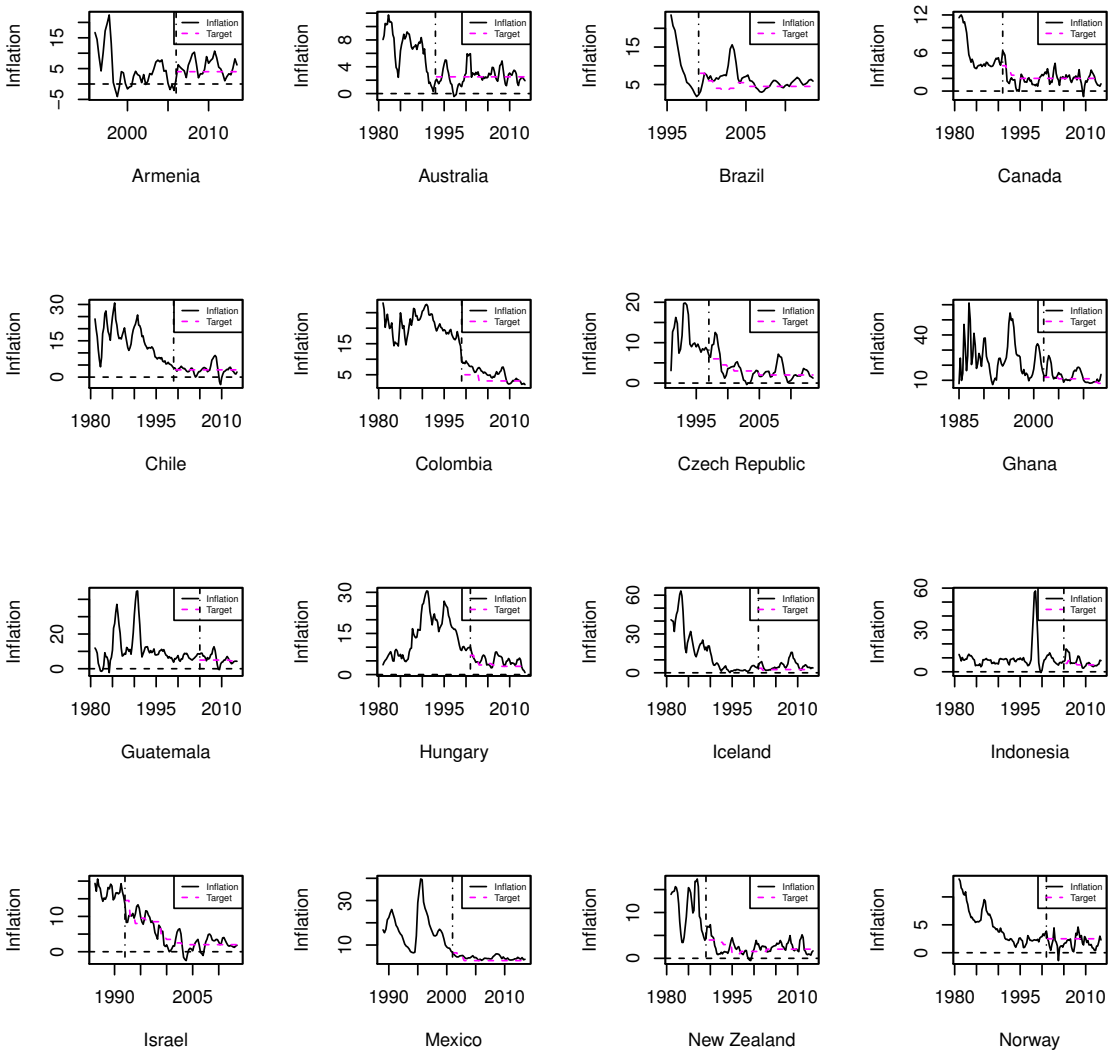
(b) Target Level in 2013

Figure 3.1: Target level at the adoption date and 2013

Table 3.2: Descriptive statistics of inflation

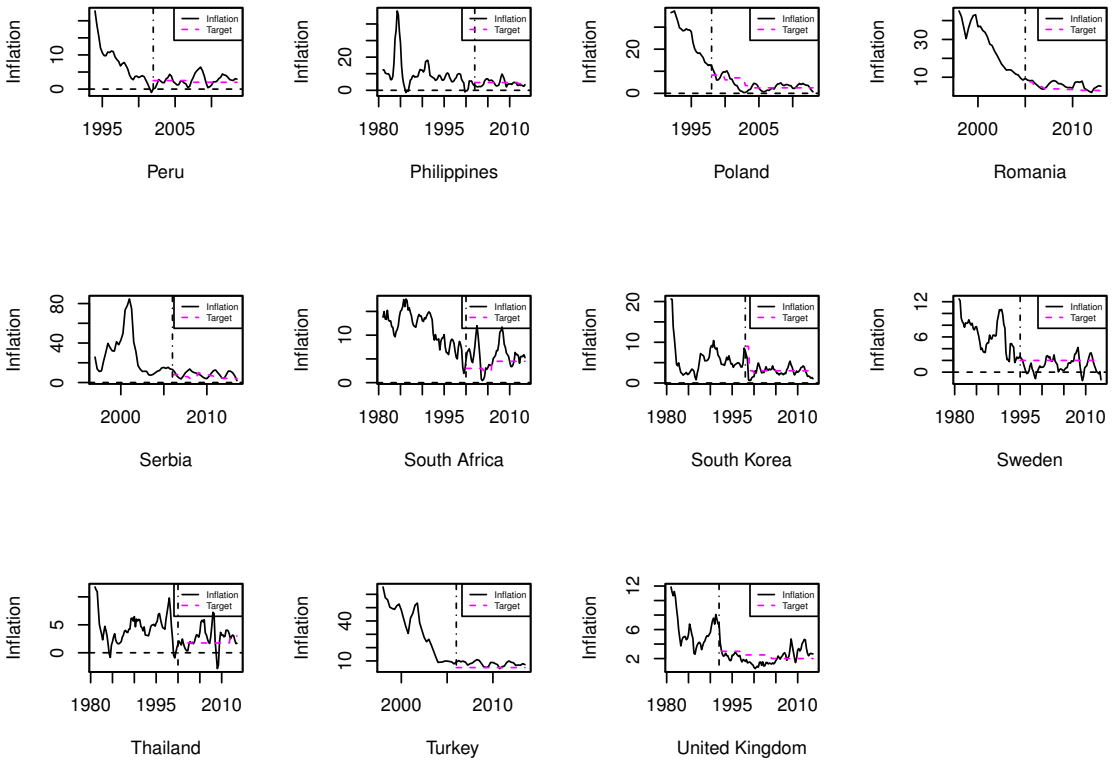
Countries	Period	Mean	St Dev	Countries	Period	Mean	St Dev
	Pre-IT	10.70	23.20		Pre-IT	10.41	4.57
Armenia	Post-IT	5.54	2.66	New Zealand	Post-IT	2.31	1.40
	Whole	*8.69*	*18.14*		*Whole*	*4.50*	*4.49*
	Pre-IT	6.49	3.07		Pre-IT	4.69	3.04
Australia	Post-IT	2.62	1.30	Norway	Post-IT	1.81	1.11
	Whole	*4.10*	*2.85*		*Whole*	*3.58*	*2.86*
	Pre-IT	12.25	14.11		Pre-IT	13.05	13.87
Brazil	Post-IT	6.32	2.49	Peru	Post-IT	2.66	1.49
	Whole	*7.72*	*7.39*		*Whole*	*7.52*	*10.78*
	Pre-IT	5.77	2.73		Pre-IT	9.82	8.86
Canada	Post-IT	1.96	1.15	Philippines	Post-IT	4.23	1.85
	Whole	*3.12*	*2.51*		*Whole*	*7.87*	*7.68*
	Pre-IT	14.43	6.95		Pre-IT	24.23	8.40
Chile	Post-IT	3.03	2.14	Poland	Post-IT	3.87	2.82
	Whole	*9.55*	*7.84*		*Whole*	*9.62*	*10.56*
	Pre-IT	20.26	4.28		Pre-IT	22.52	11.98
Colombia	Post-IT	5.17	2.10	Romania	Post-IT	5.44	1.90
	Whole	*13.82*	*8.33*		*Whole*	*13.21*	*11.85*
	Pre-IT	10.72	4.12		Pre-IT	26.53	21.23
Czech	Post-IT	3.12	2.62	Serbia	Post-IT	8.06	3.15
	Whole	*5.14*	*4.58*		*Whole*	*18.83*	*18.64*
	Pre-IT	24.82	12.38		Pre-IT	11.19	3.65
Ghana	Post-IT	12.86	4.42	South Africa	Post-IT	5.71	2.63
	Whole	*20.03*	*11.58*		*Whole*	*8.94*	*4.20*
	Pre-IT	11.05	9.32		Pre-IT	5.73	3.54
Guatemala	Post-IT	5.70	2.90	South Korea	Post-IT	2.89	1.23
	Whole	*9.64*	*8.48*		*Whole*	*4.38*	*3.05*
	Pre-IT	14.17	7.40		Pre-IT	6.85	2.56
Hungary	Post-IT	4.87	1.75	Sweden	Post-IT	1.37	1.34
	Whole	*10.66*	*7.48*		*Whole*	*3.39*	*3.26*
	Pre-IT	9.15	8.86		Pre-IT	4.26	2.55
Iceland	Post-IT	5.65	3.32	Thailand	Post-IT	2.63	1.87
	Whole	*7.63*	*7.2*		*Whole*	*3.61*	*2.43*
	Pre-IT	10.00	9.10		Pre-IT	45.02	24.88
Indonesia	Post-IT	7.02	3.64	Turkey	Post-IT	7.98	1.71
	Whole	*9.20*	*8.18*		*Whole*	*31.62*	*26.73*
	Pre-IT	16.86	1.84		Pre-IT	5.85	2.32
Israel	Post-IT	4.49	3.99	UK	Post-IT	2.17	0.91
	Whole	*7.11*	*6.27*		*Whole*	*3.48*	*2.36*
	Pre-IT	16.20	8.68				
Mexico	Post-IT	4.31	0.83				
	Whole	*9.64*	*8.33*				

[a] 'Pre-IT' refers to the period before the inflation targeting is adopted by each county. 'Whole' refers to the entire sample.



(a)

Figure 3.2: Annual inflation rates and targets in inflation targeters, 1980– 2013



(b)

Figure 3.2: Annual inflation rates and targets in inflation targeters, 1980– 2013

suggests that over medium to long-horizons though there are significant and protracted gap between actual and the inflation target at the beginning of the IT regime for most of the countries, this gap seems have narrowed down over time.

Table 3.2 shows the descriptive statistics of the inflation rates for all 27 countries. Inflation targeters like Colombia, Ghana, Poland, Romania and Serbia have the highest pre-IT inflation levels; the average of those is above 20 percent. However, the mean of post-IT inflation is significantly low. A substantial gap exists between the means before and after the policy. This gap for Colombia, Ghana, Poland, Romania and Serbia is 15.09, 11.96, 20.36, 17.08 and 18.47 percent, respectively.

Conventionally, inflation variability is measured by the standard deviation of inflation. Table 3.2 also presents the standard deviation for pre- and post-IT. A significant reduction in the standard deviation is noted after the adoption of IT. This dramatic reduction in the standard deviation can be seen in targeters such as Brazil, Ghana, Peru, Romania, Serbia and Turkey. Overall, Figure 3.2 and Table 3.2 depict the existence of a lower mean and standard deviation in the post-IT period.

3.3 A Time-Varying Parameter Model for Inflation Gap

In this section, we propose to test the success of the IT countries in achieving their inflation targets. There are different ways to assess the success of the IT regimes in achieving their targets. The simplest method is to look at the inflation gap between actual inflation and the target over time. Figure 3.2 plots inflation and inflation targets for all the countries together. We observe two main features of this data. First, the difference between the target and actual inflation is time-varying. Secondly, this gap is

not just a white noise. This implies that there is a predictable component in the inflation gap and this predictability varies over time. The predicability of the inflation gap can arise due to several reasons. First, interest rate smoothing behavior by the central bank can lead to a gradual adjustment towards the target. Secondly, there is a lag in monetary policy transmission and this lag tends to be higher for prices than real economic activity. Thirdly, the central bank may have a medium-run horizon and they want to achieve the target not in the very short term.

We study the success of IT regime by decomposing inflation gap into two components: a predictable and an unpredictable component. The predictable component of the inflation gap should disappear over time if the IT regime is successful in achieving its target. Admittedly, if a central bank announces its target, it is not expected to hit the target within a quarter, but we anticipate the inflation gap, that is forecastable, to disappear over medium to long-horizon. Actual inflation may always turn out to be different than the target because of unanticipated shocks, but a successful and credible central bank should not let this deviation persist.

The hypothesized relationship between the predictable component of inflation gap and effectiveness of the IT regime is motivated by the monetary policy effectiveness literature where researchers like Boivin and Giannoni (2006) and Kishor and Kochin (2007) among others have shown that the aggressive policy stance towards inflation causes a decline in inflation predictability. This idea was originally proposed by Friedman (1953) when he discussed the role of stabilization policy and predictability of inflation. The empirical evidence presented in D'Agostino and Surico (2012) also support the above hypothesis. They find that the inflation forecasts based on money growth and output growth were significantly more accurate than the naïve forecasts only during the regimes associated with neither a clear nominal anchor nor a credible commitment to

fight inflation. Therefore, in case of a perfectly successful IT regime, the only difference between the actual inflation and the target will be the unforecastable news in the data.

We measure the predictable component of inflation gap in a very parsimonious way. We fit an ARMA(p,q) model to inflation gap for all the IT countries. We find that AR(1) best approximates the inflation gap data for all the IT countries using the BIC. There are alternative ways to estimate AR(1) model in our example. We can fit the following fixed coefficient model:

$$\pi_t^{dev} = \alpha + \beta \pi_{t-1}^{dev} + \nu_t. \tag{3.1}$$

In the above model, the systematic part or the predictable component is the conditional mean, $\alpha + \beta \pi_{t-1}^{dev}$, and the unsystematic component is the error term, ν_t. If monetary policy is perfectly successful in achieving its target, then $\alpha = \beta = 0$. Intercept represents the bias and the slope coefficient, β measures the persistence of shock to inflation gap. The problem with a fixed coefficient model is that it would not be able to capture the time variation in success of the IT central banks as it restricts the coefficients.[4] The fixed coefficient model will restrict both the intercept and the slope coefficient to be constant across time. This implies that the behavior of the central bank for the full sample has remained fixed and the persistence property of the shocks affecting the inflation gap has also remained the same. To take care of the problems associated with a fixed coefficient model, we modify the above model and allow the coefficients to vary with time. In particular, we allow the coefficients to follow a random walk. Our time-varying parameter (TVP) model becomes:

[4]We also performed a simple likelihood ratio test for the null of no time -variation and in most of the countries, we reject the null of no time-variation.

$$\pi_t^{dev} = \alpha_t + \beta_t \pi_{t-1}^{dev} + \nu_t. \tag{3.2}$$

The subscript t signifies time-varying coefficients. There are alternative approaches of modeling time variation that includes structural break as well as Markov switching in the reaction function coefficients. The usual test of time variation has a low power against the alternative, that is, it is difficult to distinguish between different forms of time variation. As in Boivin and Giannoni (2006), we note that structural break models are very special cases of time variation and does not allow for the gradual evolution of monetary policy. Moreover, time-varying parameter model may also be used as a good approximation of multiple breaks in the reaction function coefficients.[5]

The state-space representation of the above model is given by:

$$\begin{aligned} Y_t &= F_t \theta_t + \nu_t, \qquad \nu_t \sim \mathcal{N}(0, V_t), \\ \theta_t &= G_t \theta_{t-1} + w_t, \quad w_t \sim \mathcal{N}(0, W_t). \end{aligned} \tag{3.3}$$

The system matrices are:

$$F_t = \begin{pmatrix} 1 & Y_{t-1} \end{pmatrix}, \quad V_t = \sigma_\nu^2, \tag{3.4}$$

$$G_t = I_2, \quad W_t = \begin{pmatrix} \sigma_\alpha^2 & 0 \\ 0 & \sigma_\beta^2 \end{pmatrix}, \tag{3.5}$$

where $\theta_t = (\alpha_t, \beta_t)'$. Y_t is π_t^{dev} and we assume the initial state, θ_0, is normally distributed with the mean m_0 and variance G_0 and the sequences ν_t and w_t are independent of θ_0.

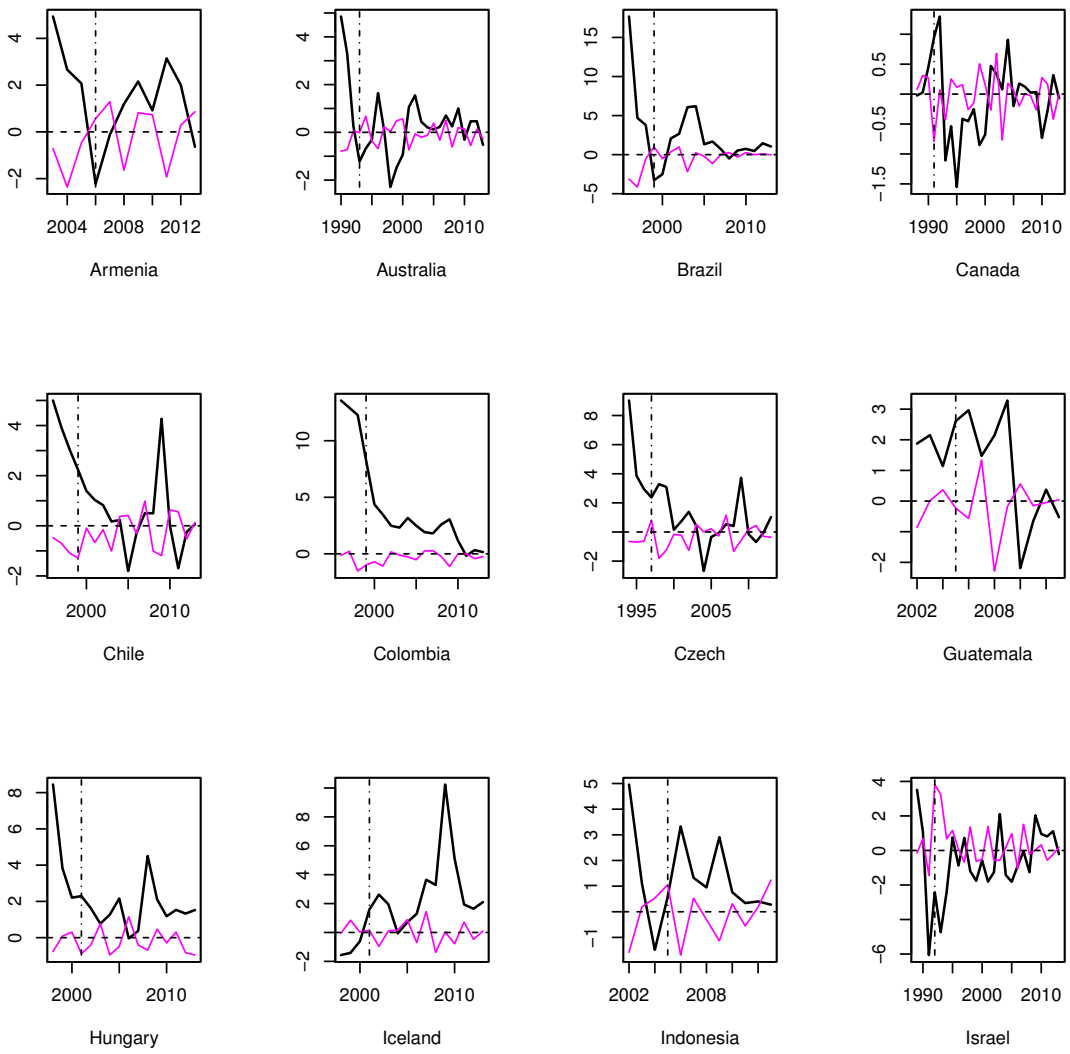
[5] Stock and Watson (2002) and Boivin and Giannoni (2006) discuss merits of the TVP model over other forms of structural break.

We use Kalman filtering algorithms to obtain the means and variances of the conditional distributions of the unobservable states given the data. Petris, Petrone and Campagnoli (2009) argue that a naive use of the Kalman filter causes numerical instability issues. One way to overcome this problem is to define more robust algorithms. We utilize a singular value decomposition-based algorithm proposed by Wang, Libert and Manneback (1992). Given observed data, $\{\pi_1^{dev}, \ldots, \pi_T^{dev}\}$, we find the optimal 'signal extraction' and the optimal 'h-step ahead prediction' of states and data.[6]

Figure 3.3 shows the time-varying conditional expectations of the inflation deviation from its target. The residuals which are the unpredictable component from our model are also plotted along with the predictable component which is the conditional mean. The vertical line represents the date of adoption of the IT regime. For comparison, we also estimate the conditional mean three years prior to the adoption. Since the inflation targets prior to adoption are not available, we use the initial inflation target for each country. In many cases, these targets were known in advance since the countries announce them prior to the official adoption of IT regime.

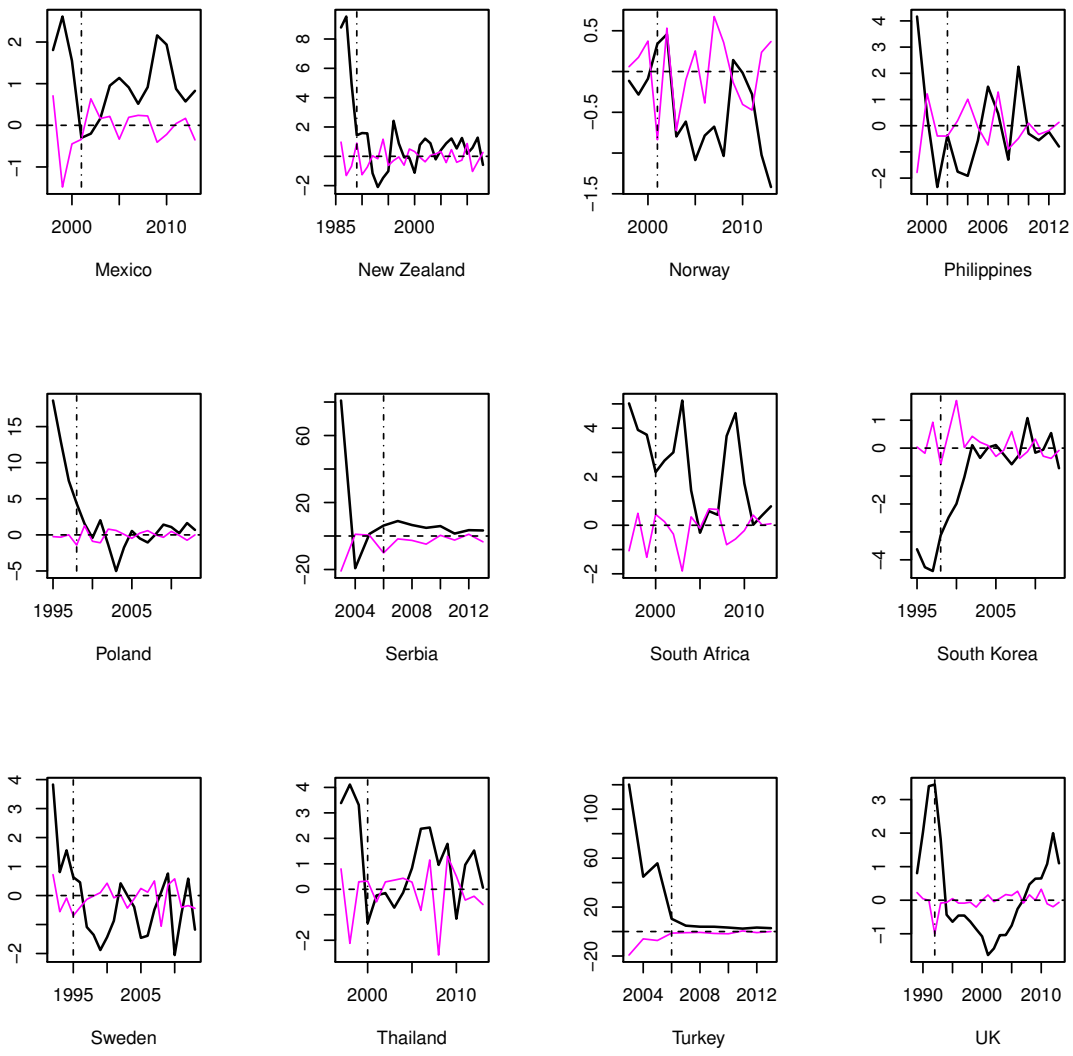
We observe some clear and interesting patterns in our estimated results. First, we find that there is considerable heterogeneity in the success of the IT countries in bridging the gap between actual inflation and the target in the years immediately after the adoption of the IT regime. We find that the conditional mean of the inflation gap was close to zero for countries with relatively low level and volatility of inflation even at the beginning of this regime. For example, we can clearly observe that the conditional mean in Australia, Canada, Chile, New Zealand and Sweden hovered around zero for most of the time period after the adoption of the IT regime. On the other hand, there are countries like Brazil, Colombia, Guatemala, Iceland, Mexico among others where the conditional mean

[6]For details, see Zivot and Yollin (2012).



(a)

Figure 3.3: TV conditional mean of inflation gap and residuals from the TVP–AR model



(b)

Figure 3.3: TV conditional mean of inflation gap and residuals from the TVP–AR model

was not close to zero during the initial years of this regime. However, we find that the predictable component of inflation converged to zero implying higher degree of success in achieving the target for almost all the IT countries after few years of the adoption of IT.

Interestingly, we also find that the predictable component of inflation gap starts declining few years before these countries publicly joined the IT regime. Since the targets are not available prior to the date of adoption, we use the target level announced at the time of the adoption of IT. The results imply that the central banks of the IT adopting countries started targeting inflation implicitly before becoming an explicit inflation targeter. Usually, the countries make an announcement about their intention to move to full-fledged inflation targeting at a future date. There is usually a time lag involved between the announcement and the formal move to new regime. Our results that the predictable component starts declining before the formal date of adoption may reflect this time lag. Secondly, we find that for most of the countries, the residuals or the unpredictable component in the TVP–AR model is significant. This implies that the naïve way of just looking at inflation gap and not making the distinction between the predictable and the unpredictable component would not provide us the proper understanding into the effectiveness of the IT regime in meeting its target.

Our findings that in addition to cross-country heterogeneity, there is also significant time-variation in the success of the IT countries in achieving their targets can reconcile the two conflicting views on the effectiveness of IT. The finding that the IT countries have been successful in achieving their target is consistent with the literature suggesting that the IT regime leads to a gradual build up in the credibility of the central banks (Neumann and von Hagen (2002), Carare and Stone (2006), Creel and Hubert (2010), de Mendonca and de Guimaraes (2012)). The finding that there is considerable cross-country heterogeneity in the performance of the central banks immediately after the adoption is consistent

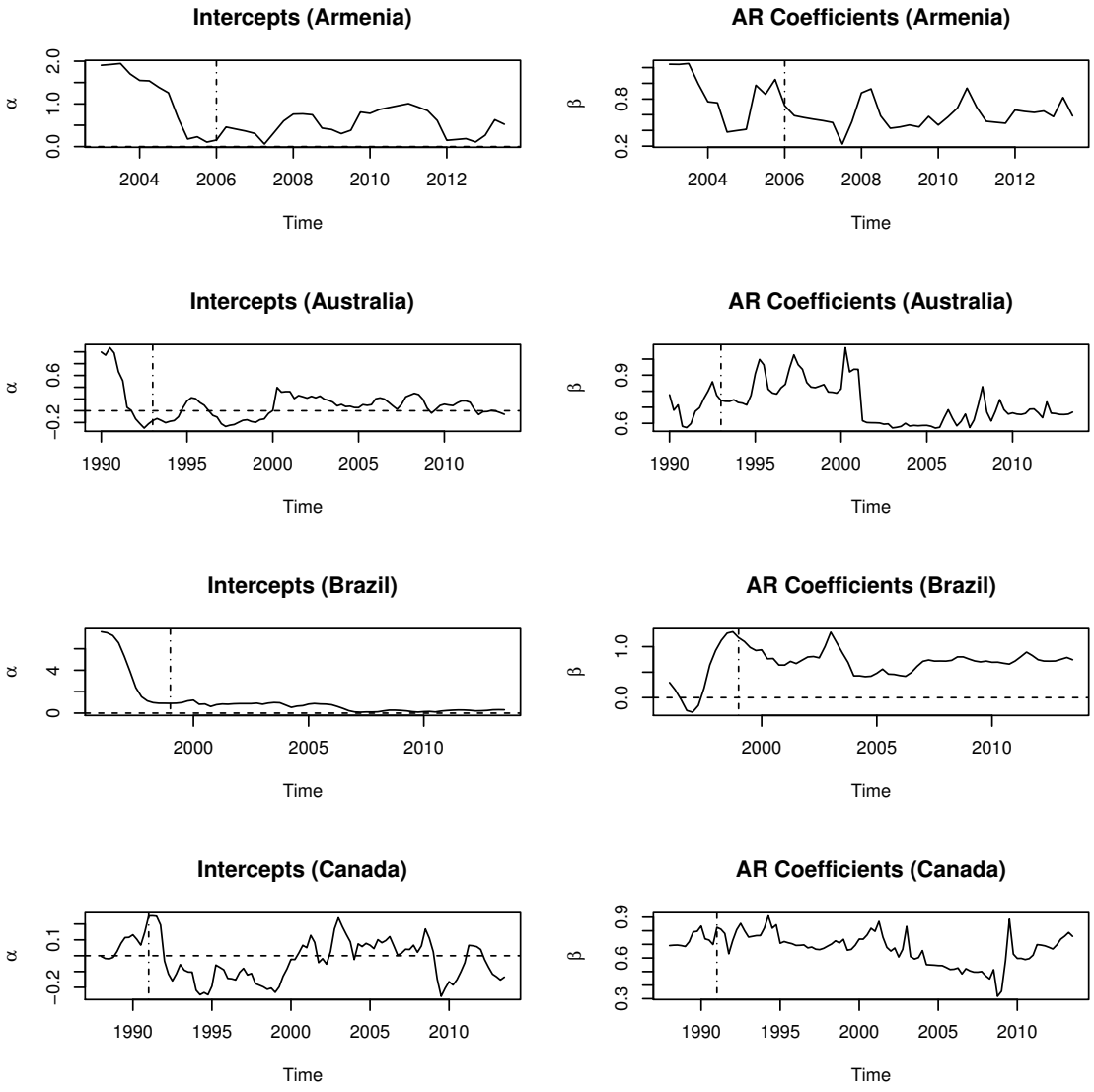
with the literature which suggests the countries that started with high inflation tended to have benefited more from the IT regime in terms of lower level and volatility of inflation over a medium to long-horizon. Our estimates also suggest that the conditional mean of inflation gap for these emerging economies has gradually declined over time was not very close to zero at the beginning of the IT regime.

Our approach estimates the conditional mean of inflation gap using information from only the past values of inflation gap. It is conceivable that the expansion of information set in the calculation of conditional mean may provide us a different estimate. However, it should be noted that our estimated conditional mean consistently show a clear pattern for all the countries and even if information set is expanded, we should be able to find similar pattern in the data. Moreover, a complex model is more prone to mis-specifiation especially since we are estimating the conditional mean of all the IT countries.

To dig deeper into the behavior of predictable component, we look at the evolution of the intercept, α, and the slope, β, separately. Figure 3.4 shows the time-variation in α and β coefficients. The left graphs show the intercept coefficients over time, α_t, and the right graphs present the time-varying AR coefficients, β_t. The vertical lines in each panel indicate the date of the adoption of IT.

The results for time-varying intercept and slope coefficients suggest that the estimated intercepts are driving the results in countries where the predictable component of inflation was significant at the beginning of the IT regime. This was not the case for the countries with low level and volatility of inflation. These are also the countries with very low conditional mean or the predictable component.[7]

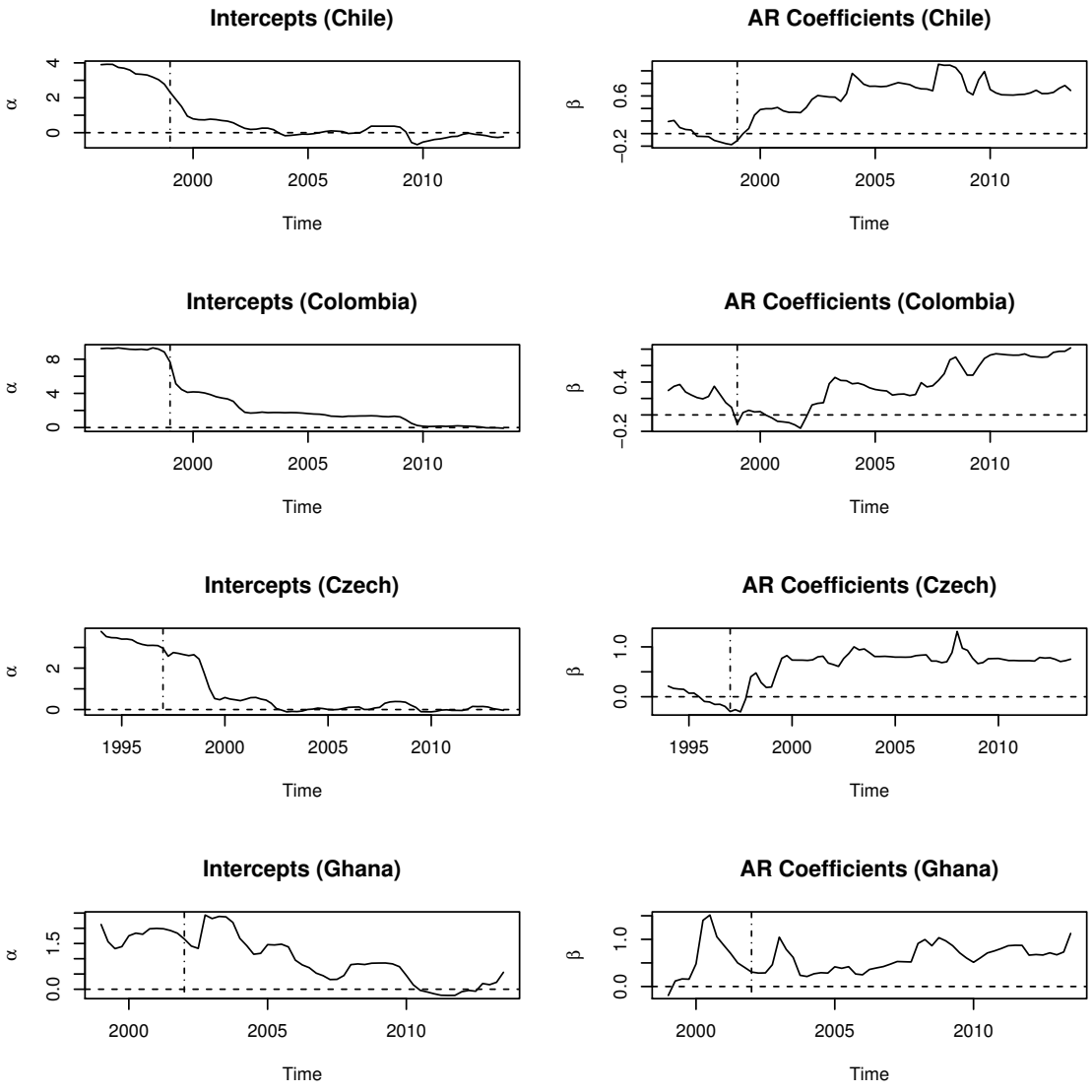
[7]It should be noted that the persistence parameter beta for inflation gap is different than the inflation persistence parameter that has attracted widespread attention from researchers. One of the implications of that strand of research is that higher credibility of a central bank is associated with lower persistence implying that a shock to inflation disappears quickly as inflationary expectations are anchored. For



(a)

Figure 3.4: Filtered time-varying coefficients

example, see Cogley, Primiceri and Sargent (2010), Tillmann (2012) among others.



(b)

Figure 3.4: Filtered Time-Varying Coefficients

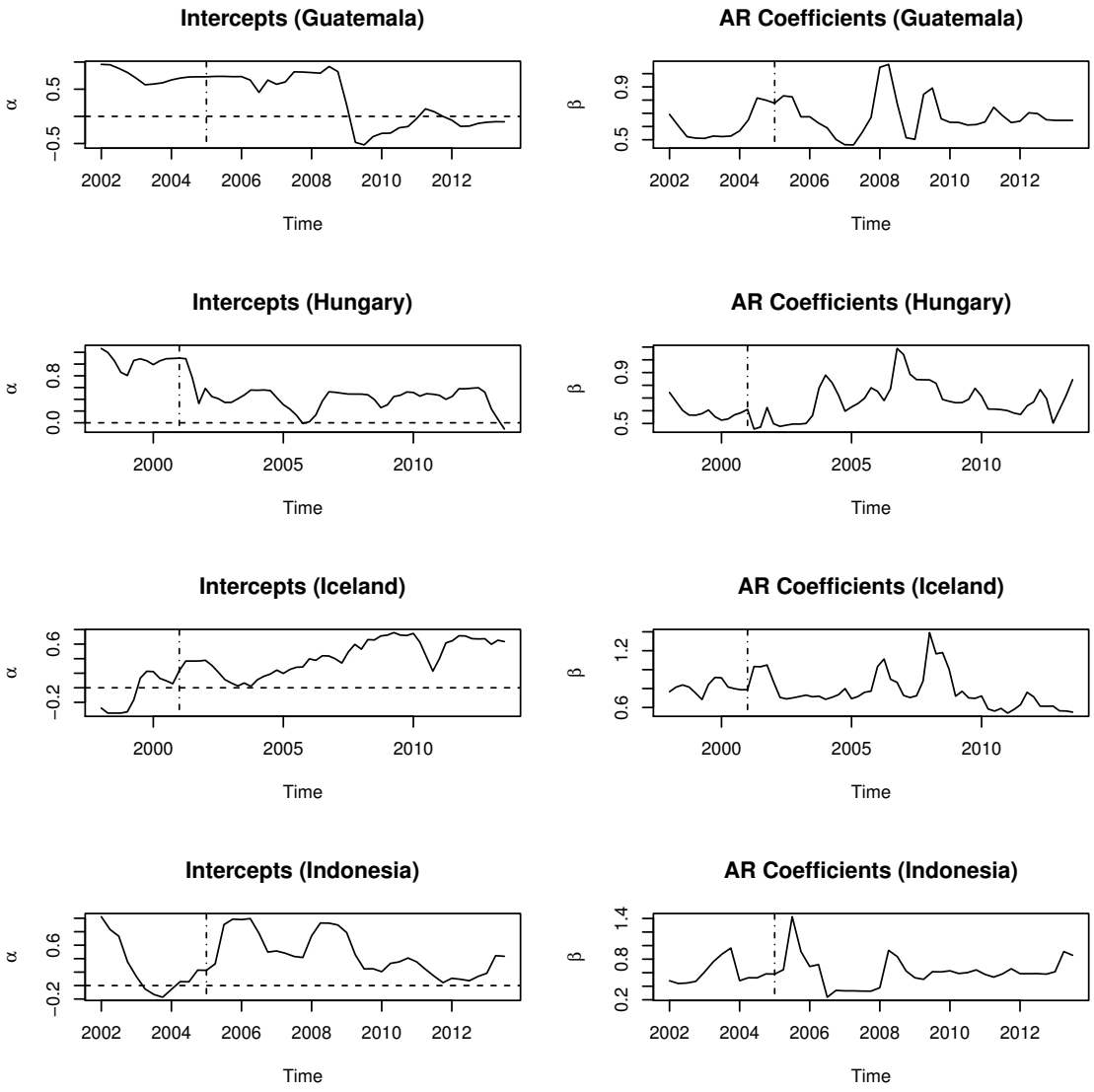


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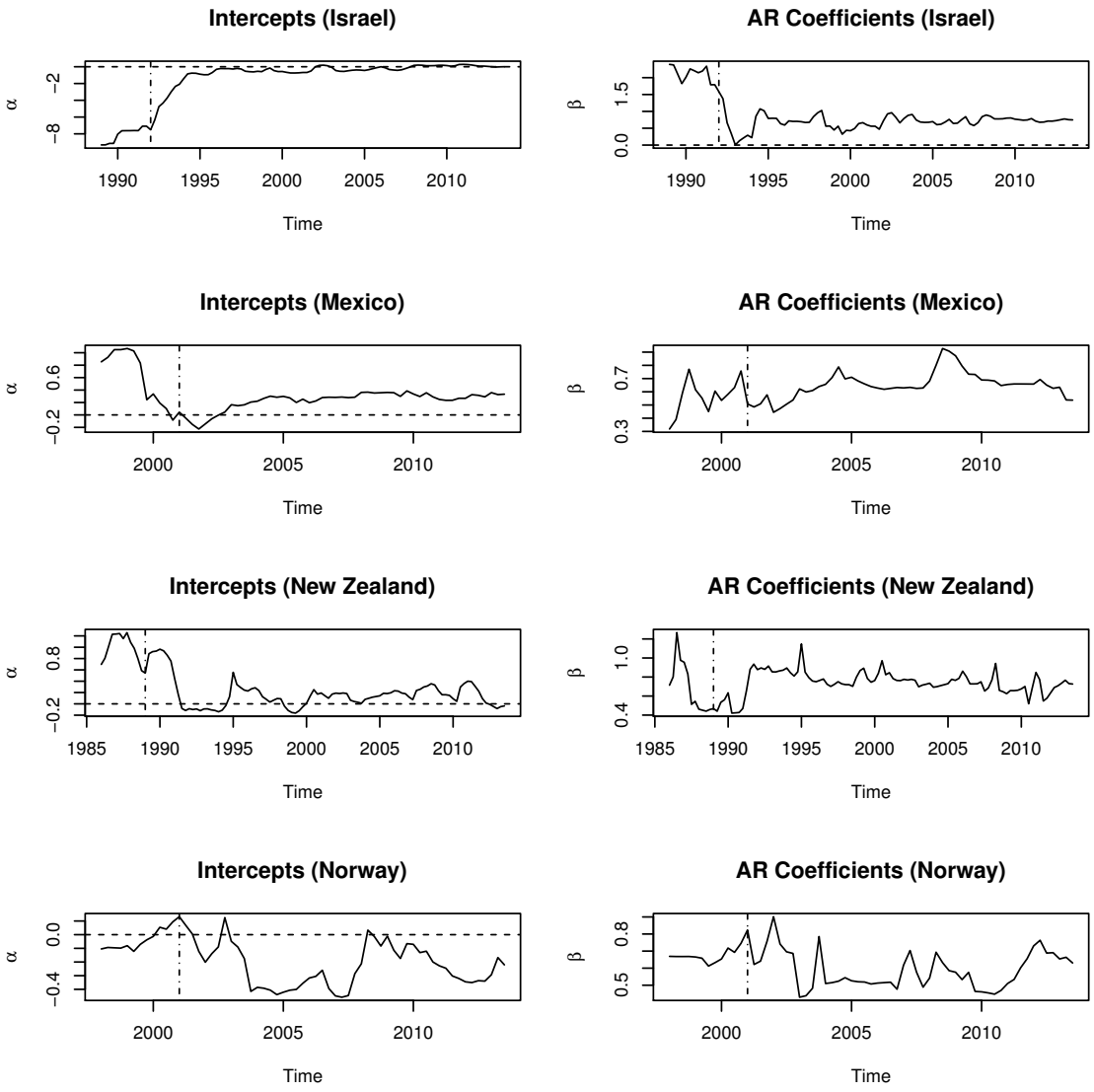
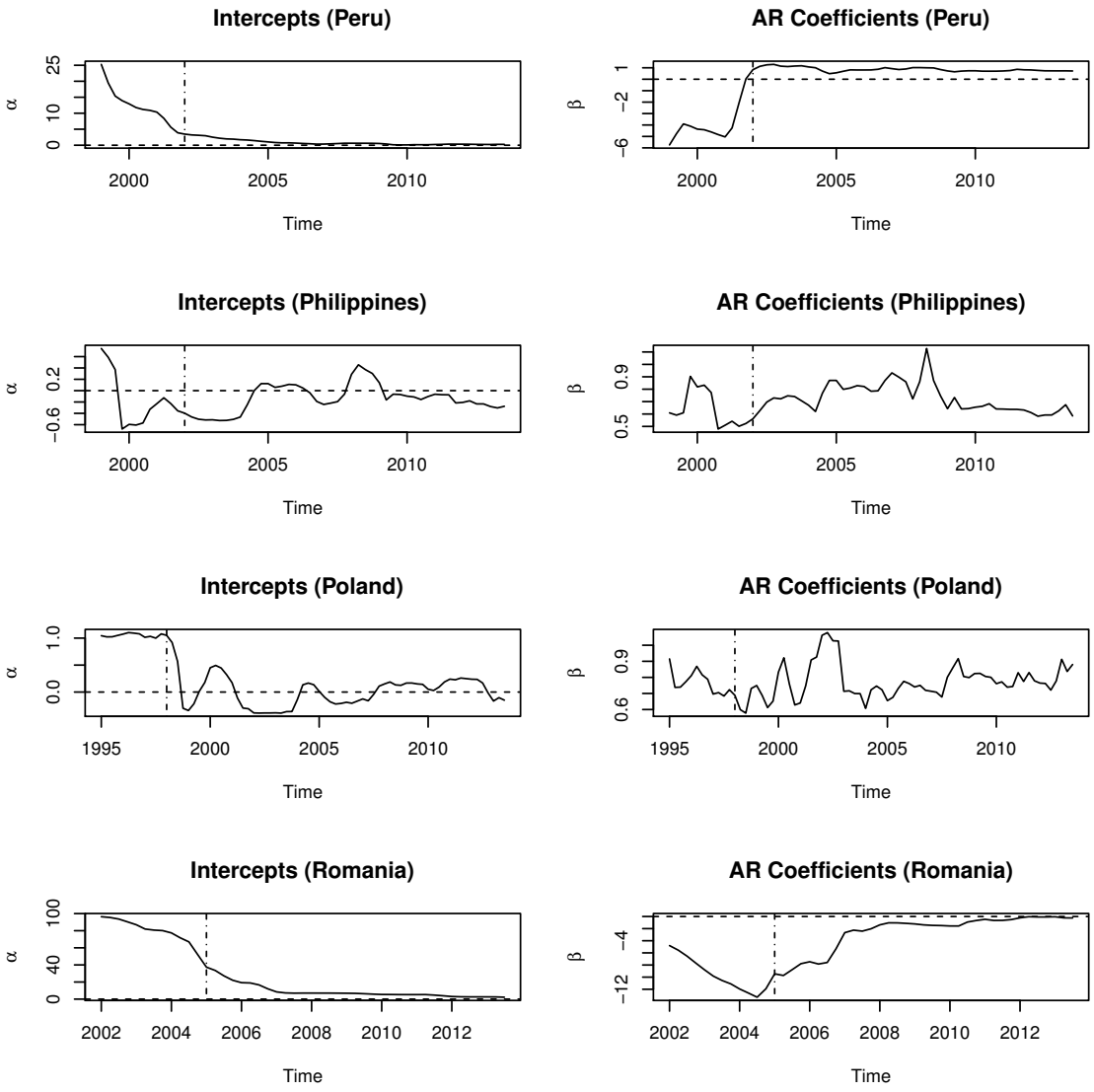
Figure 3.4: Filtered Time-Varying Coefficients



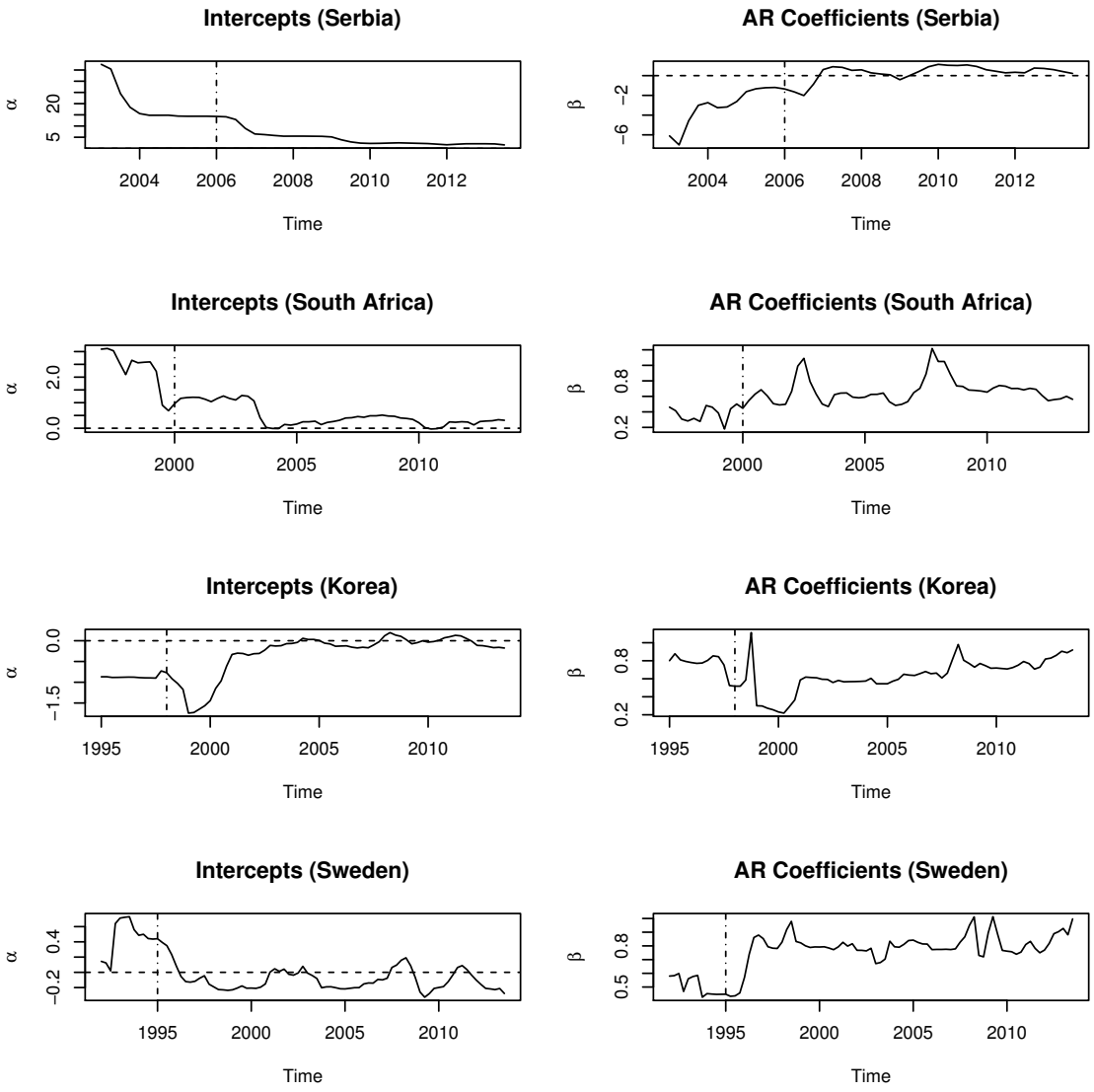
(d)

Figure 3.4: Filtered Time-Varying Coefficients



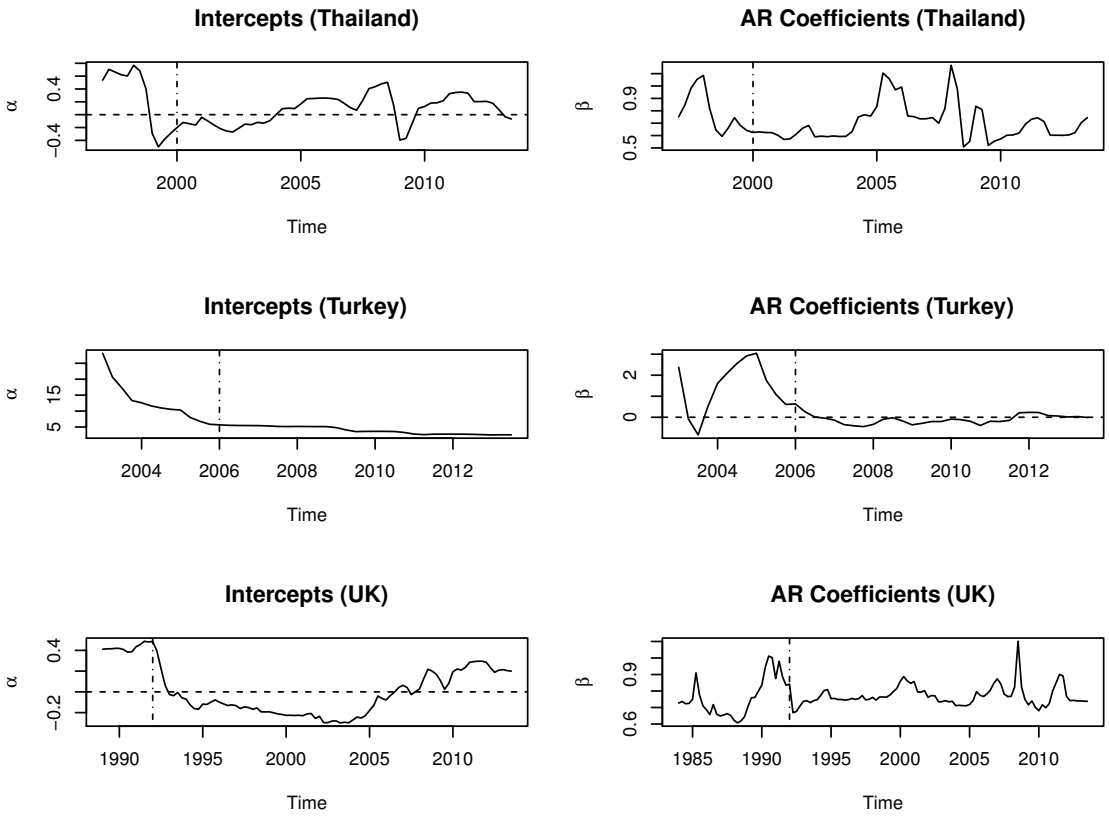
(e)

Figure 3.4: Filtered Time-Varying Coefficients



(f)

Figure 3.4: Filtered Time-Varying Coefficients



(g)

Figure 3.4: Filtered Time-Varying Coefficients

3.4 Institutional Characteristics and Inflation Targeting Effectiveness

It has been argued in the literature that the success of IT depends on the institutional strength of the country that adopts this regime. Mishkin and Schmidt-Hebbel (2001) suggest that the success of full-fledged inflation targeting is based on five pillars: the absence of other nominal anchors, an institutional commitment to price stability, the lack of fiscal dominance, policy instrument independence and accountability. In this section, we examine this hypothesis by investigating whether the success of IT countries in achieving their targets is determined by the strength of their institutions. To do so, we examine the role of fiscal situation, central bank independence, financial market development and macroeconomic outcomes. Fiscal stance is measured by the debt-GDP ratio. We measure the financial market development using domestic private credit to the real sector by deposit money banks. We obtain the data on these variables from the International Financial Statistics published by the International Monetary Fund. Financial depth and financial sophistication are measured by stock market capitalization to GDP and Central Bank Assets to GDP, respectively. The data are obtained from the World Bank. The central bank independence measure is calculated by the turnover rate of the central bank governor's tenure (Cukierman, Webb and Neyapti (1994)). The rapid turnover signifies less autonomy and instability in the policy regime. This index is the inverse measure of central bank independence. The details of the construction of this index is provided in Appendix A. We also use GDP per capita as the measure of macroeconomic outcomes in our analysis. Since we are interested in the relationship between inflation gap and institutional characteristics, we only consider the post-IT sample period for each country.

To examine the impact of institutions on the deviation of actual inflation from the

target, we consider a dynamic fixed-effects specification:

$$Y_{it} = X_{i,t}\beta_1 + W_{it}\beta_2 + \eta_i + \lambda_t + \epsilon_{i,t}, \tag{3.6}$$

where $Y_{it} = \pi_{it}^{dev} = \pi_{it} - \pi_{it}^{*}$. X_{it} includes strictly exogenous regressors, W_{it} are predetermined regressors including lags of Y. η_i is the country-specific characteristics and λ_t is the time-specific effect. $X_{i,t}$ is a $(K-1)*1$ vector of regressors and $\epsilon_{i,t} \sim \mathcal{N}(0, \sigma_\epsilon^2)$ is a random disturbance. We assume the following:

$$\begin{aligned}
&\sigma_\epsilon^2 \geq 0, \\
&E(\epsilon_{i,t}, \epsilon_{j,s}) = 0 \quad i \neq j \quad or \quad t \neq s, \\
&E(\eta_i, \epsilon_{j,t}) = 0, \\
&E(X_{i,t}, \epsilon_{j,s}) = 0.
\end{aligned} \tag{3.7}$$

In our analysis, we regress inflation gap on a set of regressors including its own lag, GDP growth, money growth, central bank independence index, central bank assets to GDP ratio, stock market capitalization to GDP and private credit to GDP ratio. In addition of inflation gap, we also consider cumulative inflation gap as a dependent variable because central banks may not try to achieve their target every period because of the noise in the aggregate inflation data, but instead they may want to focus on cumulative deviation as consistent deviation from the target may affect its credibility.

Table 3.3 summarizes the estimation results for the panel analysis. Our panel estimation includes both the individual and time-specific effects. We also use Panel

Corrected Standard Errors (PCSE) introduced by Beck and Katz (1995). The results are economically meaningful and signs on the coefficients are consistent with the existing findings in the literature. To control for the lag dependence, we include the lag of dependent variable as explanatory variables. The results suggest significant dependence of inflation and cumulative inflation gap on their past. This is consistent with the findings of the previous section.

Higher debt-GDP ratio is a measure of increased debt burden and has bearing on the conduct of the monetary policy. We find that higher debt burden is associated with higher inflation gap and this relationship is significant at all levels of significance. This relationship remains robust to the use of cumulative deviation as a dependent variable. This finding is consistent with the fiscal dominance theory which suggests that fiscal indiscipline constrains monetary policy and may affect the central bank's ability to function prudently. We observe that the inverse of central bank independence index measured by the central bank governor's turnover ratio has a positive impact on the inflation deviation and cumulative inflation deviation. It implies that greater central bank autonomy lowers the inflation gap and cumulative inflation deviation. The independence of central banks is one of the preconditions for adopting inflation targeting. There is a consensus in the central banking literature that greater central bank independence is associated with lower and more stable inflation (Mishkin and Schmidt-Hebbel (2001) and Batini and Laxton (2007)).

The variable real money growth is used as an indicator of inflationary pressure in the economy. We find that an increase in real money growth is associated with lower inflation gap and cumulative inflation gap. This is a counterintuitive result. One proposed explanation of this counterintuitive sign is that in many emerging economies real money growth reflects the level of financial development. This is especially true in

Table 3.3: Institutional characteristics and inflation gap: panel estimation results

	Dependent variable	
	π^{dev}	π^{dev}_{csum}
π^{dev}_{t-1}	0.419^{***}	
	(0.075)	
π^{dev}_{t-2}	-0.180^{***}	
	(0.062)	
$\pi^{dev}_{csum,t-1}$		1.224^{***}
		(0.074)
$\pi^{dev}_{csum,t-2}$		-0.340^{***}
		(0.066)
Real money growth	-0.064^{**}	-0.070^{***}
	(0.025)	(0.026)
Private credit-GDP ratio	0.010^{**}	0.011^{***}
	(0.004)	(0.003)
Real GDP growth	22.939^{***}	12.457
	(7.995)	(8.361)
Central bank independence	1.634	1.400
	(2.452)	(1.977)
CB Assets-GDP ratio	0.005	0.009
	(0.023)	(0.024)
government debt-GDP ratio	0.026^{***}	0.029^{***}
	(0.008)	(0.008)

[a] The dependent variables are inflation gap, π^{dev}, and the cumulative inflation gap, π^{dev}_{csum}.
[b] The robust standard errors are reported in parentheses, according to the Beck and Katz (1995) method, a.k.a. Panel Corrected Standard Errors (PCSE).
[c] *p<0.1; **p<0.05; ***p<0.01

countries where dollarization is a strong feature of the economy. In this scenario, finding a negative coefficient on real money growth is not surprising. We also find that higher GDP growth is associated with higher inflation gap. Higher inflation due to higher GDP growth will lead to an increase of inflation gap in countries with stationary target rates.

We also examine the relationship between financial market depth indicators and inflation gap. For this purpose, we look at two measures of financial soundness: central bank assets to GDP and private credit to GDP ratios. We don't find significant relationship between central bank assets to GDP ratio and inflation gap. However, we find that private credit to GDP ratio positively and significantly affects inflation and cumulative inflation gap. If private credit is just an indicator of financial market depth, then we would have expected inflation gap to go down in response to higher private credit to GDP ratio. However, it has been argued that in many emerging economies a rapid increase in private credit may indicate overheating the economy and in that case it's not surprising that we find positive relationship with inflation and cumulative inflation gap.

Overall, our results from the panel analysis are largely consistent with the literature where researchers have argued that for the success of inflation targeting regime, stable and strong institutional set up is required. We find that the success of IT countries in terms of achieving their targets is strongly associated with the extent of fiscal discipline and macroeconomic performance.

3.5 Concluding Remarks

This paper examines the effectiveness of inflation targeting countries in terms of their success in achieving their explicit inflation targets. Keeping in mind that there are

unanticipated shocks that can affect actual inflation, we propose to test the effectiveness of the central bank by decomposing the inflation gap, the difference between actual inflation and inflation targets, into predictable and unpredictable components. We argue that the predictable component of inflation gap, which we measure by the conditional mean of a time-varying parameter autoregressive model should converge to zero if the IT regime is successful in achieving the target. Our results find considerable heterogeneity in the success of these IT countries in achieving their targets at the start of this policy regime. We find that countries like Canada and New Zealand have been consistently successful, whereas there was a gradual decline in the predictable component of inflation gap in some emerging market economies like Colombia, Guatemala and Turkey. Interestingly, we also find that the predictable component of inflation gap started declining few years before these countries publicly joined the IT regime. This implies that the central banks of the IT adopting countries started targeting inflation implicitly before becoming an explicit inflation targeter. Our panel data analysis suggests that the relative success of these countries in achieving their targets is influenced by their institutional characteristics particularly by fiscal discipline and macroeconomic performance.

4

Monetary Unification and the Behavior of Eurozone Bond Yields

4.1 Introduction

To what extent is monetary integration effective? This paper asks how European monetary union has influenced bond yields before and after the European crisis. We examine the causal effect of monetary unification by linking the treatment effect literature to the monetary unification impact context. Our approach determines how monetary integration affects bond yields by taking into account the econometric problems such as the selection problem and model misspecification.

European Monetary System established in March 1979 including France, Germany, Italy, Denmark, Ireland, Luxembourg, and Netherlands to link all members' currencies and prevent fluctuations in the exchange rate. After its success, the European Community agreed to sign the Maastricht Treaty in 1992 to create a common Economic and Monetary Union. For Eurozone Monetary Union (EMU) a single monetary policy is set by the European Central Bank. This is the case of a unilateral monetary union in which a small country pegs its currency to the currency of a large country interpreted as "dollarization." Union members adopts the Euro because of greater stability in its value over their currency.

After the formation of the European Monetary Union researchers wondered whether the Economic and Monetary Union in Europe has been successful. In order to examine

its success, they study the effect of monetary unification on price stability (McKinnon (2008) and Rogers (2007)), interest rate stability (Beetsma and Giuliodori (2010)), openness and real exchange volatility (Rogers (2007)). One strand of the literature on the effectiveness of monetary unification concerns bond yield convergence. Ehrmann et al. (2011) study the convergence of European bond markets from 1993 to 2008. They show that monetary union led to the integration of bond markets across euro area countries. The uniqueness of the convergence in the Euro area suggests that this phenomenal is due to monetary unification rather than a global tendency toward convergence across all industrial economies. Other studies such as Faini, Duranton and Hau (2006) and Gomez-Puig (2009) scrutinize the effect of monetary unification on sovereign bond yields and yield spreads before the European Sovereign Debt Crisis. The literature has mostly focused on the bond convergence subsequent to monetary unification prior to European crisis. There is lack of extensive study to find the causal effect of monetary unification by considering both periods before and after the crisis.

The need to evaluate the performance of monetary unification has been steadily rising over the past decade. We focus on micro-econometric techniques to solve the fundamental evaluation problem. We examine the causal effect of monetary unification on sovereign bond yields by answering the question of whether the reduction in the level and volatility of bond yields is due to monetary unification. The differences between members' outcome after joining monetary union reveal the true unification impact. Therefore, we link the average treatment effect literature to monetary unification context in order to estimate this causal effect. Nonetheless, country specific factors are one of the main determinants of sovereign bond yield spreads in European monetary union (Costantini, Fragetta and Giovanni (2014)); members and non-members differ in more aspects than just joining monetary union. Thus, our experiment is not randomized and we self-select the treated group consists of all industrial European union members, even

though there are some differences in macroeconomic performance of the monetary union members. To capture country specific factors and to reduce selection bias, we apply propensity score analysis. Propensity score analysis involves two stages of estimating propensity score and estimating treatment effects; however, the parametric propensity score is misspecified and treatment effects are inconsistent. Thus, we apply the semiparametric single index model proposed by Klein and Spady (1993) to estimate the propensity score in the first stage.

The results of the average treatment effect on the treated using propensity score weighting with semiparametric propensity scores show different behavior before and after the European Sovereign Debt Crisis: monetary unification reduces the level and volatility of long-term bond yields and the level of short-term yields for the period from 1993–2008. This holds true for yield spreads—spreads of 15-year sovereign bond yields over the German Bund benchmark. In other words, yield spreads decreased in monetary union members before the banking crisis; however, it increased after the crisis. Our findings demonstrate that after the European crisis, government debt dramatically increased and banking crises led to a decline in tax revenues and a rise in government spending which is consistent with Reinhart and Rogoff (2009), Reinhart and Rogoff (2013).

4.2 Related Literature

Adopting a single currency is the result of constrained optimization. The constraint is that the freedom of capital flows, floating exchange rates, and monetary unification cannot coexist. Nevertheless, monetary union dominates floating exchange rate given the freedom of capital flows (Wyplosz (1997)). One feature of monetary integration is

that it eliminates the time inconsistency problem and reduces the volatility of exchange rate. Mundell (1973) analyzes determinants of optimal currency areas. He denotes that a single currency implies a single central bank. In a currency union, a common interest rate sets for all members, whereas fiscal policy is implemented at the country level (Gali and Monacelli (2008)). The optimal policy for the common monetary authority is to stabilize inflation in the union as a whole. Nevertheless, for attaining price stability, fiscal authority implements fiscal policies at the country level. Its main drawback is that the use of a single currency lowers the central bank independence of member countries.

On the other hand, one of the advantages of a currency union is reducing the transaction costs of trade which is more substantial than the effect from fixed exchange rates (Alesina and Barro (2002) and Frankel and Rose (2002)). Alesina and Barro (2002) show that adopting a single currency enhances credibility although its cost is the loss of monetary independence. Another benefit of the adoption of a common currency is that it reduces the welfare costs of monetary policy competition when the economies are open to trade (Pappa (2004)).

Currency union members also benefit from adopting a common currency through the risk channel. Studies have suggested that monetary unification has strengthened the co-movement of stock and bond market (Kim, Moshirian and Wu (2004)) which is the other benefit of unification via risk sharing channel. Researchers investigate the impact of fiscal policies and public debt on government bond yields. They attempt to find whether joining monetary union has an impact on risk premium and liquidity premium. Risk premium is defined as interest differentials between bonds issued by monetary union and Germany, whereas, liquidity premium is a premium that investors receive for the risk that they are not able to liquidate their investment. Risk premium reflects positive risk of default and it is positively associated with the level of indebtedness and

deficit. Even risk premia among monetary union members is correlated with credit risk defined as the yield spread between low grade US corporate bonds and treasury bonds (see, inter alia, Bernoth, von Hagen and Schuknecht (2004)).

If government bond yields include risk premium, increasing indebtedness leads to higher bond yields. European union countries have experienced a lower default risk premium; however, this benefit declines with the larger public debt as it is noted in the literature. The monetary union member's security is subject to default risk and foreign asset, e.g. German Bund, is considered as a risk-free asset. Default risk premium positively depends on the default probability of the risky monetary union member. Default risk will be affected by a change in the overall economic situation of a country. In a recession, government revenue decreases and the probability of default rises. On the other hand, liquidity risk is crucial to monetary union members. Yield differentials across European monetary union members reflect liquidity risk. If the member's bond market is more liquid, the liquidity risk premium declines. Thus, an increase in the debt size reduces the issuer country's interest rate. This liquidity effect is reduced with European union.

The question that has been asked over the past decade is whether monetary unification in Europe has been successful per se. Researchers, on the one hand, examine the success by evaluating trade, exchange rate volatility, price stability, and bond yields behavior among European monetary union members. We find a few work in this line of studies such as Rose and Engel (2002) indicating that the higher degree of integration is associated with more trade and less volatile exchange rates. Beetsma and Giuliodori (2010) and Rogers (2007) also argue that unification leads to more stable prices. On the other hand, researchers take a close look at the link between monetary unification and interest rates.

Faini, Duranton and Hau (2006) scrutinize the effect of fiscal policy among the monetary union members. They find that a specific fiscal policy in one member will have an effect on the level of interest rate and its spread not only in that particular country but in other monetary union members. They address "interest rate spillovers" and argue that the substantial spillovers are more significant for high debt countries. Furthermore, Gomez-Puig (2009) find that after the beginning of Currency Union, yield spreads declined. In other words, after the introduction of the Euro, the risk premia on the Eurozone sovereigns bonds reduced; however, yield spreads rose after the Lehman Brothers shock in 2008 in response to domestic banks' failures. These findings suggest that the spread increased more where debt-GDP ratios were higher. During 2009, the relationship between spreads and domestic fiscal stress remained the same. So higher sovereign spread was associated with future lower growth (Mody and Sandri (2012)).

After the Lehman Brothers bankruptcy in 2008 the crisis transmitted to Europe. It was followed by European Sovereign Debt Crisis started in 2009. During this period, government debt dramatically increased and we witnessed a decline in tax revenues and a rise in government spending. Most of European union members engaged in massive bailouts. The banking crises led to deep and prolonged asset market collapses associating with declines in output and employment. In other words, the real value of government debt dramatically boosted (Reinhart and Rogoff (2009) and Reinhart and Rogoff (2013)). Thus, the higher probability of default in European union members has asymmetric effect on the behavior of sovereign bond yields.

The literature has mostly focused on the bond convergence after monetary unification prior to European crisis. Ehrmann et al. (2011) indicate that bond markets converge after the formation of currency union. They study the convergence of European bond

markets from 1993 to 2008. They find that monetary union led to the integration of bond markets across euro area countries. However, the co-movement is unique to the euro area members suggesting that this convergence is due to monetary unification rather than a global tendency toward convergence across all industrial countries. The literature links the Eurozone yield on government bonds to the credit risk component. Some argue that credit risk have been greater after monetary union (Codogno, Favero and Missale (2002)). In order to identify the change in the yield spreads, Kerstin and Burcu (2012) examine whether these changes are due to the change in macroeconomic fundamentals or due to the change in the pricing of sovereign risk. They find that the factors changing yield spread varies over time. The debt level of a monetary union member explained yield spread behavior before the financial crisis. However, after the financial crisis, an increase in the price of risk because of the higher likelihood of sovereign default risk explains the yield differentials. Costantini, Fragetta and Giovanni (2014) analyze the determinants of sovereign bond yield spreads. They argue that debt-GDP differentials are the main long-run drivers of sovereign spreads.

4.3 Data and Estimation Framework

4.3.1 Data Description

The European monetary union consists of 28 Member States. There is a set of conditions of entry for new states to join the European Union called Copenhagen criteria. In this study, we include industrial European Union member states who have replaced their national currency with the single currency, the Euro. The Euro was first introduced in 1999 as “book” money. There are 12 industrial member states form the euro area. Our treated group contains these countries. We include 24 industrial countries in our control group. Table 4.1 lists all countries in the treated and control groups.

Table 4.1: List of countries in the treated and control groups

Treated	Control	Control
Austria	Argentina	Norway
Belgium	Armenia	Poland
Finland	Australia	Saudi Arabia
France	Canada	Singapore
Germany	China	South Africa
Greece	Czech Republic	South Korea
Ireland	Denmark	Sweden
Italy	Hungary	Switzerland
Luxembourg	Iceland	Turkey
Netherlands	Israel	UAE
Portugal	Japan	United Kingdom
Spain	New Zealand	United States

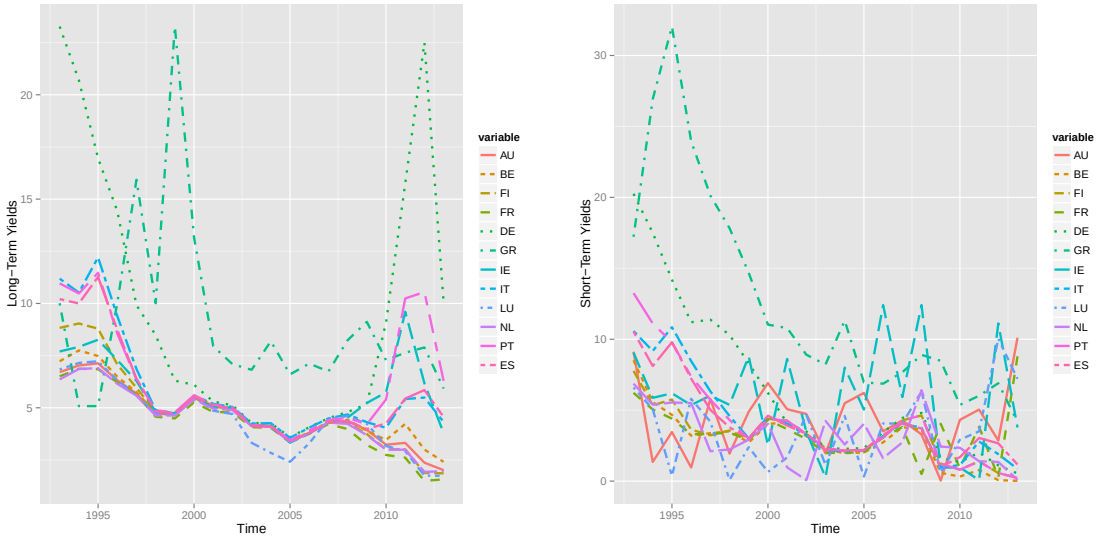
In order to compare the results before and after European Sovereign Debt Crisis, we consider three samples: a time period from 1993 to 2008, before the European crisis, a time period from 2009 to 2013, and the full sample which contains the data from 1993 to 2013. We estimate the causal effect using annual data. In the first stage estimation, the covariates include government debt-GDP ratio, GDP growth, real money growth, inflation, openness which is trade as a percentage of GDP, and the yield spread which is the spread between each country's government bond and the average of the bond yield for Germany and France. In the second stage estimation, outcomes are long-term sovereign bond yield (i_{15YR}), the volatility of long-term bond yield (σ^i_{15YR}), short-term yield (i_{TB}), the volatility of short-term bond yield (σ^i_{TB}). We determine the risk premium as the spread between each European union member's long-term rate and long-term bond yield of Germany. Within the Eurozone, the German market has the majority of the trading activity between other monetary union markets. Long-term rates are yields on 15-year treasury bonds. Short-term rates are the weighted average yield on 13-week treasury notes allotted at last tender of month. The data are obtained from

the International Monetary Fund's World Development Indicators and International Financial Statistics.

The short-term and long-term sovereign bond yields for Eurozone—the treated group—are shown in Figure 4.1. Panel (a) shows the long-term yield from 1993 to 2013. It turns out that the long-term yield among different countries in the treated group move together except for Greece for the period before the crisis; however, for the sample period from 2008 to 2013 the pattern has been changed. We do not observe a similar co-movement for the short-term interest rates (Panel (b)). Government bond yields in selected countries has been reduced especially after the the European crisis of 2008-2009. In the next sections, we aim to examine whether the reduction in bond yields are due to joining monetary union or global factors affecting the interest rates. Figure 4.2 indicates the volatility of short-term and long-term bond yields. As we see in Panel (a), the volatility of long-term bond yields fluctuates more after the crisis compared with those from 1993 through 2008. However, this is not the case for the volatility of short-term yields. The fluctuations remain high even after the banking crisis. Figure 4.1 and 4.2 demonstrate that monetary unification may affect long-term bond yields more than short-term yields. Furthermore, The behavior of short-term yields has not been changed after the banking crisis, but there is a change in the level and volatility of long-term yields. Figure 4.3 plots sovereign yield spread in European union members. Interestingly, after forming monetary union bond yield spreads had been disappeared and risk premia had reduced until the crisis. After the crisis, the gap started to widen.

4.3.2 Estimation Framework

A significant amount of work has been done on examining monetary unification impact, but none of them point to its causal effect. We link the literature in the monetary



(a) Long-Term Bond Yields (b) Short-Term Bond Yields

Figure 4.1: Sovereign bond yields in selected countries

(a) The Volatility Long-Term Yields (b) The Volatility of Short-Term Yields

Figure 4.2: The volatility of bond yields in selected countries, 1993–2013

Figure 4.3: Sovereign yield spreads in selected countries, 1993–2013

union impact to the treatment effect literature and capture the causal effect of monetary unification. Joining monetary union is considered as a binary treatment. The outcome of interests are bond yields, yield spreads, and the volatility of bond yields. For each member, we define two potential outcomes. The outcome when the country is not part of the monetary union and a potential outcome in a monetary union member. The difference between these potential outcomes is defined as the causal effect. In order to capture this causal effect, we estimate the average treatment effect on the treated which is defined as the conditional expectation of the difference in potential outcomes given joining European monetary union.

Country specific factors are one of the main determinants of sovereign bond yield spreads in European monetary union (Costantini, Fragetta and Giovanni (2014)). We take into account the idiosyncratic characteristics among each member; however, our observational data lack the randomized assignment of countries into joining European union and we have sample selection problem. One way to overcome the selection problem is to randomize the assignment, because in a random assignment treatment is

independent of potential outcomes. Researchers employ statistical procedures to balance the data before assessing treatment effects. We apply propensity score analysis in order to examine the effect of joining European union on the bond yields and deal with the selection bias in our estimation. In the propensity score literature, two procedures of matching and weighting are mentioned; propensity score matching model in which the data is balanced through resampling or matching control units to treated ones on probabilities of receiving treatment, i.e., the propensity scores, and propensity score weighting in which the propensity scores are used as sampling weights to perform a weighted outcome analysis.

Propensity score matching has some drawbacks. One disadvantage of this method is that it only accounts for observed covariates. Covariates that are not observed would not be accounted for in the matching. In the propensity score matching model, hidden bias remains after matching because the procedure only takes into account the observed covariates. In hidden bias, countries are not comparable in a way that was not measured. The second disadvantage of propensity score matching is that nearest-neighbor matching has a small bias, especially when the outcome is not predictable. Thus, matching methods lead us to the worst covariate balance (Busso, DiNardo and McCrary (2014)).

To overcome these problems, researchers use bias-corrected matching or propensity score weighting, where the bias will be reduced, especially when the model is properly specified. Busso, DiNardo and McCrary (2014) argue that the weighting method performs well in terms of both bias and variance when the overlap assumption is satisfied. In comparison to bias-corrected matching, weighting has lower variance. To make sure that our results are robust and overcome the above-mentioned problems in the matching procedure, we use propensity score weighting in which the inverse probability of treatment is used as a weight. Propensity score weighting has some

advantages over propensity score matching. As Guo and Fraser (2014) emphasize, propensity score weighting enhances internal validity rather than external validity. It also does not require a continuous or normally distributed outcome variable. Moreover, propensity score weighting uses the most participants in the outcome analysis without losing observations as matching method does. Considering propensity scores as weights, the population average treatment effect on the treated can be written as the following weighting algorithm:

$$\begin{aligned}\tau_{att} &= \mathbb{E}[Y_{1i} - Y_{0i} \mid T = 1] = \mathbb{E}[\mathbb{E}[Y_{1i} - Y_{0i} \mid X, T = 1] \mid T = 1] \\ &= \mathbb{E}[\mathbb{E}[Y_{1i} - Y_{0i} \mid X] \mid T = 1] = \mathbb{E}[\tau(X) \mid T = 1], \end{aligned} \tag{4.1}$$

where T is the treatment taking value one if the country joins monetary union. Y_{0i} is the outcome when the country has not joined monetary union, while Y_{1i} is the potential outcome if the country has joined monetary union. Furthermore,

$$\begin{aligned}\mathbb{E}[\tau(X = x) \mid T = 1] &= \int \tau(x) dF(x \mid T = 1) \\ &= \frac{\int \tau(x)\pi(x) dF(x)}{\int \pi(x) dF(x)}. \end{aligned} \tag{4.2}$$

where $\pi(x)$ is the propensity score. We identify τ_{att} through the moment equation:

$$\mathbb{E}[\psi(Y, T, X, \tau_{att}, \pi(X))] = 0, \tag{4.3}$$

where the moment equation $\psi(\cdot)$ can be written as:

$$\psi(y,t,x,\tau_{att},\pi(x)) = \frac{y\cdot t}{\pi(x)} - \frac{y\cdot(1-t)}{1-\pi(x)} - \tau_{att}. \tag{4.4}$$

The solution to the following equation is the ATT estimator:

$$(1/N)\sum_{i=1}^{N}\psi(Y_i,T_i,X_i,\hat{\tau}_{att},\hat{\pi}(X_i)) = 0, \tag{4.5}$$

where $\hat{\pi}(X_i)$ is the estimated propensity score. Hirano, Imbens and Ridder (2003) apply nonparametric series estimate of propensity score in the first stage to find average treatment effect on the treated in the second stage leading to the estimator:

$$\hat{\tau}_{att} = (1/N)\sum_{i=1}^{N}\frac{Y_i\cdot T_i}{\hat{\pi}(X_i)} - \frac{Y_i\cdot(1-T_i)}{1-\hat{\pi}(X_i)}. \tag{4.6}$$

We estimate propensity scores using parametric and semiparametric methods. However, the parametric propensity score suffers from model misspecification and the results of average treatment effect on the treated will be inconsistent. We apply semiparametric propensity score for the outcome analysis.

4.4 Monetary Unification and Changes in Bond Yields

Some studies indicate that differences in macroeconomic performance among countries is the key element of monetary integration. The comparison between the outcome of interest in members and non-members does not provide the unification impact. In order the make the treated group comparable to the control group, we first estimate propensity

scores. Then, we compare bond yields among members and non-members by using the propensity score as a weight. In this section, we study the behavior of bond yields after monetary unification and throughout the European crisis.

4.4.1 The Likelihood of Joining Monetary Union

In the first stage, we estimate the propensity score—the conditional probability of joining European union. We consider macroeconomic predictors such as openness and real money growth along with the spreads of 15-year sovereign bond yields over the German and France bonds benchmark in the eurozone. Table 4.2 shows the results of the parametric and semiparametric single index models. Model (1) summarizes the results of the logit model, whereas model (2) indicates semiparametric single index model suggested by Klein and Spady (1993). Our parametric model suffers from model misspecification and we rely on model (2).

Table 4.2: The first stage estimation: the probability of joining EMU

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
Lagged Debt	0.01***	1	0.01***	1	0.01***	1
	(0.002)		(0.003)		(0.002)	
Lagged GDP Growth	-0.002	-0.007***	-0.13***	0.004***	-0.002	0.01***
	(0.003)	(0.0001)	(0.007)	(0.0002)	(0.005)	(0.0008)
Lagged Money Growth	-0.11***	-0.013***	-0.02	-0.003***	-0.08***	-0.31***
	(0.02)	(0.001)	(0.05)	(0.001)	(0.02)	(0.007)
Lagged Inflation	-0.009	0.008***	-0.4	-0.07	-0.01	0.14***
	(0.01)	(0.0003)	(0.6)	(0.06)	(0.02)	(0.02)
Lagged Openness	-0.009***	0.02***	-0.006***	0.003***	-0.008	0.009***
	(0.001)	(0.0004)	(0.002)	(0.001)	(0.001)	(0.002)
Lagged itbspread	-0.11***	0.01***	-0.11***	-0.007	-0.11***	-0.15***
	(0.01)	(0.001)	(0.05)	(0.013)	(0.01)	(0.01)

[a] The dependent variable is a binary variable, which has the value 1 if the country joins European union.
[b] (1) is the parametric (logit) model. (2) is the semiparametric single index model.
[c] Lagged debt coefficient is normalized to one for identification in the index model.
[d] *p<0.1; **p<0.05; ***p<0.01

Our findings indicate that for the period before the European crisis, the higher degree of GDP growth increases the likelihood of joining monetary union. The results support the fact that if a country joins European monetary union, they must meet certain criteria. Our results also indicate that more open economies are more likely to join European union. This finding is consistent with Rose and Engel (2002) who show that currency union members have more trade and less volatile exchange rates. The yield spreads contain information about default risk. We find that the greater the yield spreads, the higher the probability of joining monetary union implying that monetary unification lowers sovereign bond yield differentials. Interestingly, we observe different pattern after the European crisis. The coefficients of yield spreads become statistically insignificant. In the next section, we explain why the yield spreads change over time by analyzing the connection between yield spread, government debt-GDP ratio, and monetary unification.

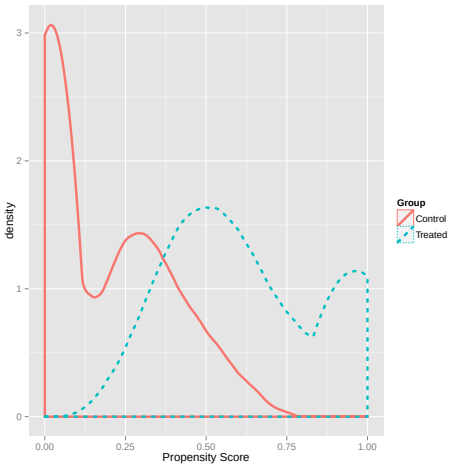
4.4.2 Monetary Unification Impact on the Bond Market

To find the impact of monetary unification on bond yields and bond yield spreads, we estimate average treatment effect on the treated using estimated propensity scores as weights. The literature has examined the changes in the behavior of bond yields since the introduction of the Euro (e.g. Mody and Sandri (2012), Gomez-Puig (2009)). However, it focuses on the bond market differentials before the European crisis. After the Lehman Brothers bankruptcy in 2008 the crisis transmitted to Europe. It was followed by European Sovereign Debt Crisis started in 2009. Banking crises directly caused the higher government debt-GDP ratios (Reinhart and Rogoff (2009)). We examine the role of monetary unification since the creation of monetary union by considering country's idiosyncratic characteristics before and after the banking crisis in Europe.

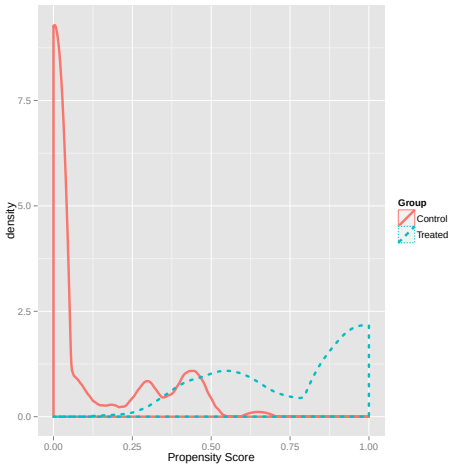
Table 4.3 presents information on the pre-treatment covariates before and after

weighting using logit propensity scores. The second and third columns, $E(Y_1 \mid T = 1)$ and $E(Y_0 \mid T = 1)$, show the treatment and control means for each covariate. The last column, $E(Y_0 \mid T = 0)$, shows the unweighted means. The forth column, KS, is the p-value of the Kolmogorov-Smirnov test. Kolmogorov-Smirnov test is used to show a significant difference across entire distributions. The null hypothesis is that the samples are drawn from the same distribution. The results indicate that the average treatment on the treated is sensitive to the choice of covariates. Figure 4.5 illustrates the spread of the estimated propensity scores in the treatment and control groups. Panel (a) in Figure 4.6 illustrates the standardized effect size of pre-treatment variables. It checks balance and compares the effect of weights on the magnitude of difference between weighted control group and unweighted treatment group on each pre-treatment covariate. This is shown by the mean of the covariate balance metrics 'mean' or the maximum of the balance metrics 'max'. The left graph shows absolute standard difference using effect size, whereas, the right graph indicates the absolute standard difference using the Kolmogrov-Smirnov statistics. In panel (a), substantial reductions in effect sizes are observed for most covariates (blue lines). Closed red circles show a statistically significant difference. Panel (b) in Figure 4.6 indicates p-values for the Kolmogorov-Smirnov test. The Q-Q plot compares the quantiles of the observed p-values to the quantiles of the uniform distribution, showing whether group differences observed before and after weighting are consistent with what we expect to see in a random assignment. Before weighting (closed circles), the groups have statistically significant differences on many covariates (i.e., p-values are near zero). After weighting (open circles), the p-values are generally closer to the 45-degree line. This indicates that the p-values are larger than would be expected in a randomized study.

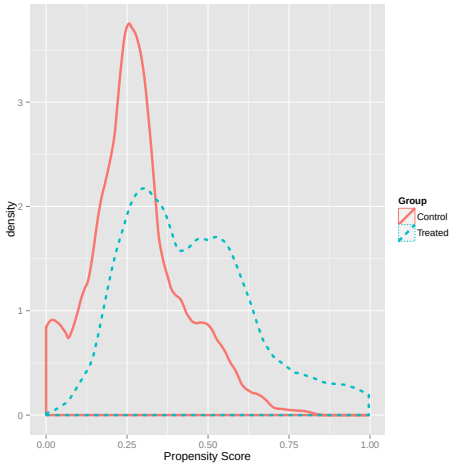
We apply the estimated parametric and semiparametric propensity scores as weights



(a) Sample Period 1993–2008



(b) Sample Period 2009–2013



(c) Sample Period 1993–2013

Figure 4.4: Kernel density of the estimated semiparametric propensity scores

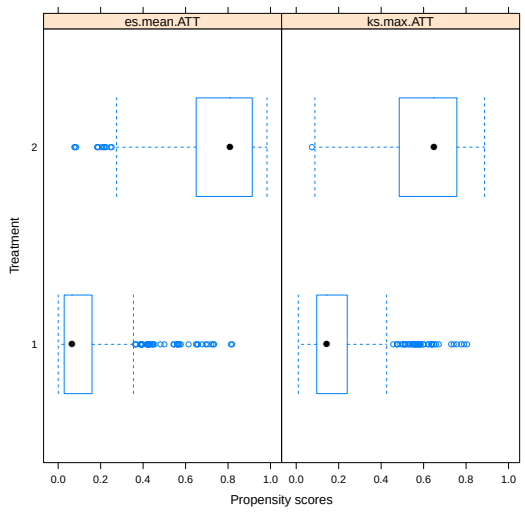
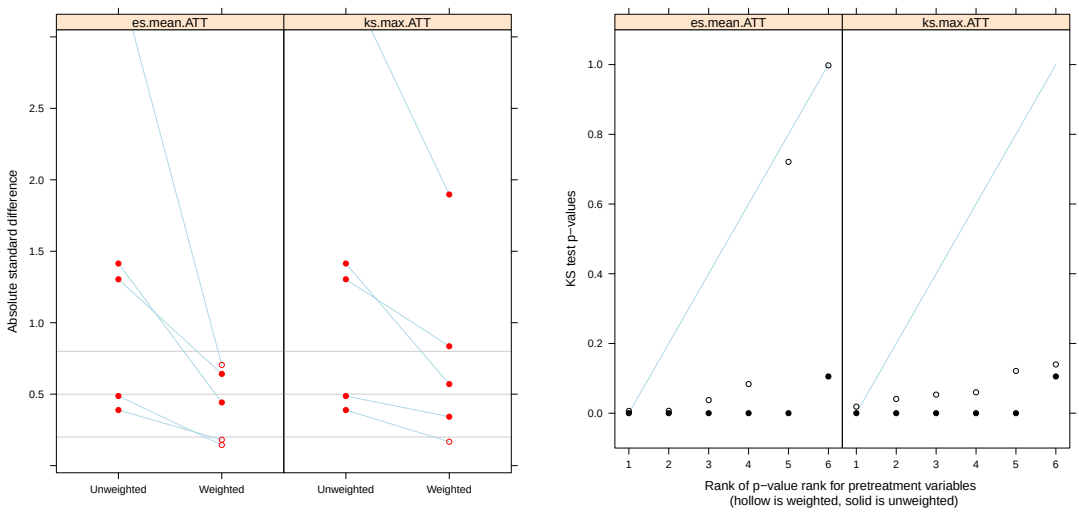


Figure 4.5: Boxplots of the estimated logit propensity scores



(a) Standardized effect size of pretreatment variables

(b) Kolmogorov-Smirnov p-values for weighted variables

Figure 4.6: Density estimation of the estimated logit propensity scores

ES and KS specify the method for summarizing across balance metrics. 'es.mean' uses the effect size or the absolute standardized bias and summarizes across variables with the mean and the 'ks.max' uses the Kolmogorove-Smirnov statistics to assess balances and summarizes using the maximum across variables.

Table 4.3: Balance of the treatment and comparison groups, logit model

	$E(Y_1 \mid T=1)$	$E(Y_0 \mid T=1)$	KS	$E(Y_0 \mid T=0)$
Lagged Debt	73.25	65.59	0.24	53.40
Lagged GDP Growth	0.58	0.39	0.41	94.23
Lagged Money Growth	0.62	0.95	0.14	12.55
Lagged Inflation	1.13	1.28	0.21	3.37
Lagged Openness	68.93	76.09	0.10	99.72
Lagged Interest Spread	-0.24	1.05	0.20	7.75

Table 4.4: Balance of the treatment and comparison groups, single index model

	$E(Y_1 \mid T=1)$	$E(Y_0 \mid T=1)$	KS	$E(Y_0 \mid T=0)$
Lagged Debt	75.64	54.99	0.32	53.40
Lagged GDP Growth	0.58	102.83	0.39	94.23
Lagged Money Growth	1.22	4.74	0.20	12.55
Lagged Inflation	1.40	3.57	0.21	3.37
Lagged Openness	80.19	103.60	0.10	99.72
Lagged Interest Spread	1.24	7.88	0.32	7.75

to estimate the causal effect of monetary unification.[1] Table 4.5 and 4.6 summarize the results of the average treatment effect on the treated using propensity score weighting and matching on long-term interest rate, short-term interest rate, and their volatilities. The findings are based on three sample periods: 1993–2008, 2009–2013, and the full sample (1993–2013). Before the European crisis (1993–2008), treatment effects on long-term interest rate, the volatility of long-term interest rate, and the short-term interest rate are -3.87, -2.71, and -3.45, respectively. It indicates that monetary unification reduces not only the level of interest rates, but the volatility of long-term interest rates. The results hold true for the full sample (1993–2013); however, the magnitudes are smaller than those before the European crisis. Our findings are consistent with Gomez-Puig (2009) who demonstrates that after the adoption of the Euro the risk

[1] Song (2014) finds that in propensity score analysis, the conditions of semiparametric propensity score do not affect the asymptotic distribution of treatment effects.

premium on the bonds of eurozone sovereigns declined. To compare these results with the impact on yield bonds differentials, we consider the yield spreads as an outcome. We define the yield spreads as the spreads of 15-year sovereign bond yields over the German Bund benchmark. The treatment effect of the period 1993–2008 is negative and statistically significant. The sovereign spreads is highly correlated with growth during this period implying the effectiveness of monetary unification. These results are consistent with Mody and Sandri (2012). Interestingly, both the level and volatility of bond yields had been reduced after forming European monetary union. One way to look at the reduction in yield spreads is that monetary unification increases the credibility of monetary policy and leads to the higher degree of central bank independence. However, monetary unification affects the trade-off between credibility and flexibility of monetary policy (Beetsma and Giuliodori (2010)).

Table 4.5: Average treatment effect on the treated, propensity score weighting

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
i_{15YR}	-0.23	-3.87***	1.26***	-0.83	0.06	-2.36***
	(0.23)	(1.43)	(0.60)	(0.77)	(0.24)	(0.89)
σ^i_{15YR}	-1.21***	-2.71***	0.64***	-0.15	-0.58***	-2.27***
	(0.23)	(0.86)	(0.26)	(0.25)	(0.16)	(0.79)
i_{TB}	-2.93	-3.45**	-0.39	-1.82*	-2.47	-2.18*
	(2.77)	(1.71)	(0.47)	(0.96)	(2.23)	(1.17)
σ^i_{TB}	-2.06*	-0.17	0.44	0.81*	-1.31	-0.27
	(1.11)	(0.60)	(0.34)	(0.42)	(0.83)	(0.67)

[a] Outcomes are long-term interest rate (i_{15YR}), The volatility of long-term interest rates (σ^i_{15YR}), short-term interest rate (i_{TB}), and the volatility of short-term interest rate (σ^i_{TB}).

[b] (1) is the ATT based on the parametric model. (2) is the ATT based on index model.

[c] *p<0.1; **p<0.05; ***p<0.01

Table 4.6: Average treatment effect on the treated, propensity score matching

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
	(1)	(2)	(1)	(2)	(1)	(2)
i_{15YR}	0.17	-1.38	-0.81	1.41	0.18	-10.21***
	(0.46)	(6.40)	(0.85)	(2.89)	(0.36)	(3.79)
σ^{i}_{15YR}	-0.85	-1.72	0.02	-14.19	-0.25	-8.83***
	(0.53)	(3.87)	(0.36)	(19.09)	(0.17)	(2.76)
i_{TB}	-4.97	-1.62	-2.34**	-2.81*	-2.38	-3.83***
	(3.87)	(3.33)	(0.98)	(1.69)	(2.03)	(1.22)
σ^{i}_{TB}	-3.76	-0.58	-0.57	0.99	-1.21	-1.41*
	(1.99)	(2.27)	(0.59)	(1.01)	(1.03)	(0.64)

[a] Outcomes are long-term interest rate (i_{15YR}), The volatility of long-term interest rates (σ^{i}_{15YR}), short-term interest rate (i_{TB}), and the volatility of short-term interest rate (σ^{i}_{TB}).

[b] (1) is the ATT based on the parametric model. (2) is the ATT based on index model.

[c] *p<0.1; **p<0.05; ***p<0.01

The behavior of bond yields dramatically changed after the european crisis. European Sovereign Debt Crisis started in 2009 followed by the Lehman Brothers bankruptcy caused an increase in the government debt-GDP ratios in monetary union members. Our findings show that there is a disconnection between joining European monetary union and a reduction in short-term and long-term sovereign bond yields. It can be seen in Table 4.5 that treatment effects for the period after the crisis are not statistically significant. Paolo, Giancarlo and Ciovanni (2015) argue that this disconnection is due to the role of the higher risk of default in sovereign bonds. This can be the main reason of widening government bond yield differentials across eurozone countries. In other words, after a financial crisis government debt dramatically increased. Reinhart and Rogoff (2013) argue that banking crises lead to sharp declines in tax revenues as well as significant increases in government spending. Thus, defaults in European union

members tend to rise when many countries are simultaneously experiencing domestic banking crises. Costantini, Fragetta and Giovanni (2014) also show that debt-GDP differentials are the main long-run drivers of sovereign spreads. Based on Reinhart and Rogoff (2009) the aftermath of severe financial crises explains three characteristics. First, asset market collapses are deep and prolonged. Second, the aftermath of banking crises is associated with declines in output. Third, the value of government debt tends to explode, rising an average of 86 percent.

4.5 Robustness Check

As a robustness check, we apply the semiparametric propensity score based on different normalization. Table 4.7 summarizes the results of the first stage estimation by normalizing the lagged money growth coefficient. We find a consistent results with normalization based on lagged debt coefficient. Model (1) indicates the results from 1993 to 2008. We find negative and significant results for the lagged government debt-GDP ratio coefficient. This is consistent with Lane (2012) suggesting that higher debt lowers the likelihood of joining monetary union. Thus, public debt plays a significant role in monetary unification. Codogno, Favero and Missale (2002) also argue that liquidity explains only a small fraction of sovereign spreads and public debt plays a role especially for Italy and Spain.The results confirm that more open economies have the higher chance to join European union. We also find that the higher the interest rate spread, the more likely that the country joins European union. Furthermore, higher degree of debt-GDP ratio lowers the probability of forming monetary union.

The results of average treatment effect on the treated through propensity score weighting is presented in Table 4.8. It indicates that joining monetary union lowers the level and volatility of long-term interest rates and the level and volatility of short-term

interest rates for the period from 1993 to 2008. Faini, Duranton and Hau (2006) link between monetary unification and sovereign bond spreads through the budget balance and sovereign debt channel. Different results after the crisis can be explained by liquidity risks, primarily expected fiscal imbalances (debt-GDP differentials) as the main determinants of sovereign bond yield spread in the long run. This suggests that policy makers are willing to reduce the high sovereign spreads.

Table 4.7: The first stage estimation: the probability of joining EMU

	(1)	(2)
Lagged Money Growth	1	1
Lagged Debt	-0.16***	-0.002***
	(0.06)	(0.0009)
Lagged GDP Growth	0.03***	0.004***
	(0.004)	(0.0001)
Lagged Inflation	-5.03***	-0.01***
	(0.86)	(0.004)
Lagged Openness	0.22***	-0.001***
	(0.03)	(0.0005)
Lagged itbspread	2.35***	-0.001
	(0.21)	(0.002)

[a] The dependent variable is the binary variable of joining EMU.
[b] (1) is the index model for the sample 1993–2008. (2) is the index model for the sample 1993–2013.
[b] Lagged real money growth is normalized to one for the identification in the single index model.
[c] *p<0.1; **p<0.05; ***p<0.01

Table 4.8: Average treatment effect on the treated, propensity score weighting

	(1)	(2)
i_{15YR}	-1.71*	-1.78**
	(1.03)	(0.73)
σ^i_{15YR}	-5.02*	-1.86*
	(2.67)	(0.58)
i_{TB}	-3.72*	-2.06*
	(2.22)	(1.07)
σ^i_{TB}	-2.73***	0.03
	(1.03)	(0.56)

[b] (1) is the ATT from the index model for the sample 1993–2008. (2) is the ATT from the index model for the sample 1993–2013.

[b] Lagged real money growth is normalized to one in the first stage estimation.

[c] *p<0.1; **p<0.05; ***p<0.01

Table 4.9: The first stage estimation: all members except Greece and Portugal

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
Lagged Debt	0.01***	1	0.007**	1	0.01***	1
	(0.002)		(0.003)		(0.002)	
Lagged GDP Growth	-0.002	0.004**	-0.12***	0.003***	-0.002	0.006***
	(0.004)	(0.002)	(0.005)	(0.0001)	(0.005)	(0.0008)
Lagged Money Growth	-0.1***	0.01***	-0.01	-0.002**	-0.06***	-0.02***
	(0.02)	(0.009)	(0.07)	(0.001)	(0.02)	(0.007)
Lagged Inflation	-0.03	-0.43***	-0.5	-0.09	-0.11***	0.003
	(0.06)	(0.03)	(0.54)	(0.09)	(0.07)	(0.02)
Lagged Openness	-0.008***	0.12	-0.004***	0.007**	-0.007***	0.008***
	(0.001)	(0.01)	(0.001)	(0.003)	(0.001)	(0.002)
Lagged itbspread	-0.16***	-0.12***	-0.11***	-0.003	-0.15***	-0.14***
	(0.02)	(0.03)	(0.05)	(0.002)	(0.02)	(0.06)

[a] The dependent variable is a binary variable, which has the value 1 if the country joins European union.
[b] (1) is the parametric (logit) model. (2) is the semiparametric single index model.
[c] Lagged debt coefficient is normalized to one for identification in the index model.
[d] *p<0.1; **p<0.05; ***p<0.01

Table 4.10: Average treatment on the treated, all members except Greece and Portugal

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
i_{15YR}	-0.27	-4.34***	1.04	-1.01	-0.12	-2.81***
	(0.24)	(0.89)	(0.69)	(0.98)	(0.25)	(1.18)
σ^i_{15YR}	-1.04***	-0.96***	0.53*	-0.11	-0.58***	-2.82***
	(0.17)	(0.33)	(0.29)	(0.39)	(0.14)	(1.03)
i_{TB}	-3.65	-4.12***	-0.14	-0.13	-3.23	-1.98
	(3.36)	(1.71)	(0.52)	(0.67)	(2.84)	(1.25)
σ^i_{TB}	-2.2	-2.39	0.7*	1.17***	-1.44	-1.05***
	(1.36)	(1.78)	(0.39)	(0.43)	(1.04)	(0.55)

[a] Outcomes are long-term interest rate (i_{15YR}), The volatility of long-term interest rates (σ^i_{15YR}), short-term interest rate (i_{TB}), and the volatility of short-term interest rate (σ^i_{TB}).

[b] (1) is the ATT based on the parametric model. (2) is the ATT based on index model.

[c] *p<0.1; **p<0.05; ***p<0.01

Table 4.11: Average treatment effect on the treated, propensity score matching, No Greece and Portugal

	1993–2008		2009–2013		1993–2013	
	(1)	(2)	(1)	(2)	(1)	(2)
	(1)	(2)	(1)	(2)	(1)	(2)
i_{15YR}	-0.03	-2.48*	0.58	-1.37	0.12	-6.38***
	(0.43)	(1.44)	(0.61)	(8.75)	(0.34)	(2.13)
σ^{i}_{15YR}	-0.89***	-0.3	0.12	-1.73	-0.39***	-3.14***
	(0.20)	(0.42)	(0.31)	(5.21)	(0.13)	(1.00)
i_{TB}	-4.73	-1.81	-0.32	1.84	0.21	-8.8***
	(3.53)	(1.87)	(0.81)	(1.93)	(0.38)	(2.93)
σ^{i}_{TB}	-2.97*	-0.41	0.82	1.75	-0.61*	-4.84***
	(1.81)	(0.57)	(0.49)	(1.13)	(0.37)	(1.64)

[a] Outcomes are long-term interest rate (i_{15YR}), The volatility of long-term interest rates (σ^{i}_{15YR}), short-term interest rate (i_{TB}), and the volatility of short-term interest rate (σ^{i}_{TB}).

[b] (1) is the ATT based on the parametric model. (2) is the ATT based on index model.

[c] *p<0.1; **p<0.05; ***p<0.01

4.6 Concluding Remarks

Country specific factors are one of the main determinants of sovereign bond yields in European monetary union. We apply propensity score analysis to capture the country specific factors and to overcome the self-selection problem. In the first stage estimation, in order to deal with model misspecification we apply a semiparametric single index model. We find that the higher degree of GDP growth increases the likelihood of joining monetary union. Interestingly, currency union members have more trade and less volatile exchange rates. We study the default risk by measuring the sovereign yield differentials in the Eurozone. We indicate that monetary unification lowers sovereign bond yield differentials.

We use the estimated parametric and semiparametric propensity scores in order to estimate the causal effect of monetary unification. The average treatment effect on the treated results indicate that monetary unification reduces not only the level of interest rates, but the volatility of long-term interest rates meaning that after the introduction of the Euro the risk premium on the bonds of Eurozone sovereigns declined. Monetary unification increases the credibility of monetary policy and leads to the higher degree of central bank independence. The behavior of bond yields and sovereign spreads changed after the European Sovereign Debt Crisis started in 2009. Banking crises caused higher debt and we witnessed a rapid rise in yield spreads and the connection between banks and sovereign. Higher risk of default in sovereign bonds was the main reason of widening government bond yield differentials across Eurozone countries. Investors started to question the ability of certain monetary union governments of meeting their debt obligations and began requiring higher default risk premia.

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Appendix A

This Appendix provides the list of inflation targeting countries along with the adoption dates, target level at the adoption date and their country groups. It also presents the control units with their country groups.

Table A1: Treated group (targeters)

Countries	Adoption Date	Target	Group
Armenia	2006Q1	4	DCS
Australia	1993Q2	3	IND
Brazil	1999Q2	8	DCS
Canada	1991Q1	4	IND
Chile	1999Q3	3	DCS
Colombia	1999Q3	5	DCS
Czech	1997Q4	6	DCS
Ghana	2002Q1	12	DCS
Guatemala	2005Q1	5	DCS
Hungary	2001Q2	7	DCS
Iceland	2001Q1	4	IND
Indonesia	2005Q3	5	DCS
Israel	1992Q1	15	DCS
Mexico	2001Q1	5	DCS
New Zealand	1989Q4	4	IND
Norway	2001Q1	3	IND
Peru	2002Q1	3	DCS
Philippines	2002Q1	5	DCS
Poland	1998Q1	8	DCS
Romania	2005Q3	8	DCS
Serbia	2006Q3	8	DCS
South Africa	2000Q1	3	DCS
South Korea	1998Q2	9	DCS
Sweden	1993Q1	2	IND
Thailand	2000Q2	2	DCS
Turkey	2006Q1	5	DCS
UK	1992Q3	3	IND

DCS denotes developing countries and IND indicates industrial economies.

Table A2: Control group (non-targeters)

Countries	Group	Countries	Group
Albania	DCS	Madagascar	DCS
Algeria	DCS	Malawi	DCS
Argentina	DCS	Malaysia	DCS
Armenia	DCS	Maldives	DCS
Austria	IND	Mali	DCS
Azerbaijan	DCS	Malta	IND
Belarus	DCS	Moldova	DCS
Belgium	DCS	Morocco	DCS
Belize	DCS	Mozambique	DCS
Bolivia	DCS	Myanmar	DCS
Bulgaria	DCS	Nepal	DCS
China	DCS	Netherlands	IND
Costa Rica	DCS	Nicaragua	DCS
Cyprus	IND	Niger	DCS
Denmark	IND	Saudi Arabia	DCS
Ecuador	DCS	Senegal	DCS
Egypt	DCS	Singapore	IND
El Salvador	DCS	Slovenia	IND
Estonia	DCS	Spain	IND
Fiji	DCS	Sri Lanka	DCS
France	IND	Sudan	DCS
Germany	IND	Swaziland	DCS
Greece	IND	Tanzania	DCS
India	DCS	Tunisia	DCS
Iran	DCS	Uganda	DCS
Ireland	IND	Ukraine	DCS
Italy	IND	United Arab Emirates	DCS
Jamaica	DCS	United States	IND
Japan	IND	Uruguay	DCS
Jordan	DCS	Vanuatu	DCS
Kazakhstan	DCS	Venezuela	DCS
Kenya	DCS	Vietnam	DCS
Lebanon	DCS	Yemen	DCS
Libya	DCS	Zambia	DCS
Luxembourg	IND	Zimbabwe	DCS
Macedonia	DCS		

DCS denotes developing countries and IND indicates industrial economies.

Appendix B

In this appendix, we explain how to construct the central bank independence measure. Cukierman, Webb and Neyapti (1994) develop four measures of central bank independence and measure their correlation with the inflation outcomes. The legal index, the rate of turnover of central bank governors, an index based on a questionnaire answered by specialists and an aggregation of the legal index with the turnover rate. They conclude that the legal independence is negatively related to the inflation in industrial countries, but not in developing countries. We consider the turnover of central bank governors as an index for central bank independence. We use the turnover index because this index is more accurate than the legal index or questionnaire based criterion in the emerging market economies. This index is more accurate in those countries because of the fact that the legal index is based on central bank laws and it doesn't reflect the central bank independence.

We construct the index based on the findings of Cukierman, Webb and Neyapti (1994) by assuming that above a threshold, a rapid turnover of central bank governors determines a higher dependence and a lower $ICBI$. If the political authorities frequently choose a new governor, they have the opportunity to pick those who favor the nominators' will. Frequent turnover reflects firing those who challenge the government. This is true especially in developing countries. Therefore, the measure for this index is in accordance with the electoral cycle for the central banks. If the turnover of central bank governor is four years the index will be .25, and so on.

Using the turnover index, we find the central bank independence for all inflation targeters. Table B1 presents the average annual turnover rates in our sample countries for two time periods, 1980–1999 and 2000–2013. The average annual turnover rates

are calculated from the ratio of governor changes to the number of years in that period. The average turnover rate during 1980–1999 ranges from a minimum of 0.0 to a maximum of 0.2. An average turnover of 0.0 indicates no change in the last 20 years. Canada, Colombia, the Czech Republic, Hungary and the United Kingdom are the few examples of totally independent structures. However, countries like Chile, Poland and Turkey have the highest rates of dependency. The central banks' independence has increased from the period 1980– 1999 to 2000– 2013. In the first period, there are five countries with totally independent central banks; whereas, after 2000 it has risen to 13 countries. In general, the average annual turnover rate reduced significantly in 15 countries, i.e. the degree of central bank independence has been increasing over time.

Table B1: Average annual turnover rates of central bank governors in targeters

Countries	1980–1999	2000–2013	Countries	1980–1999	2000–2013
Armenia	0.10	0.07	New Zealand	0.15	0.07
Australia	0.05	0.00	Norway	0.15	0.00
Brazil	0.05	0.07	Peru	NA	0.14
Canada	0.00	0.00	Philippines	0.15	0.07
Chile	0.20	0.07	Poland	0.20	0.14
Colombia	0.00	0.07	Romania	0.15	0.00
Czech	0.00	0.00	Serbia	NA	0.21
Ghana	0.15	0.21	South Africa	0.05	0.00
Guatemala	NA	NA	South Korea	0.10	0.00
Hungary	0.00	0.00	Sweden	0.10	0.14
Iceland	0.10	0.00	Thailand	0.15	0.00
Indonesia	0.05	0.00	Turkey	0.20	0.00
Israel	0.15	0.14	UK	0.00	0.00
Mexico	0.10	0.14			

Average number of changes a year Schmidt-Hebbel (2009).

CURRICULUM VITAE

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Education

2015 Ph.D., Economics, University of Wisconsin-Milwaukee, Milwaukee, WI
2009 M.A., Economics, University of Tehran, Tehran, Iran
2006 B.A., Economics, Yazd University, Yazd, Iran

Fields of Interest

Primary: Monetary Economics
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Research Papers

- On the Effectiveness of Inflation Targeting: Evidence from Semi/nonparametric Approach (with N. K. Kishor, S. Song)
- Examining the Success of the Central Banks in Inflation Targeting Countries: The Dynamics of Inflation Gap and the Institutional Characteristics (with N. K. Kishor) *under review*.
- Ranking Forecast Models by Stochastic Error Distance and Survival Information Criteria (with N. Ebrahimi, E. S. Soofi)
- Monetary Unification and the Behavior of Bond Yields (with N. K. Kishor, S. Song)

Work in Progress

- Parametric control function approach to estimate the impact of oil shocks

Conference Presentations

2014 Illinois Economic Association, *44th annual meetings*, Chicago, IL
2014 Wisconsin Economic Association, *annual conference*, Steven's Point, WI
2015 UWM, *Department of Economics, Weekly seminars*, Milwaukee, WI
2015 Midwest Economic Association, *annual meeting*, Minneapolis, MN

Research Experience

2014 **Research Assistant**, University of Wisconsin-Milwaukee, Milwaukee, WI
2009 **Financial Analyst**, Cooperative Development Bank, Tehran, Iran
2008 **Research Associate**, Tehran Municipality, Tehran, Iran
2007 **Research Assistant**, Management and Planning Organization, Yazd, Iran
2003–2006 **Research Assistant**, Yazd University, Yazd, Iran

Teaching Experience

2014–2015 **Adjunct Faculty**, Sheldon B. Lubar School of Business, UWM

- Principles of Finance, Financial Institutions

2011–2014 **Instructor**, Department of Economics, UWM

- Principle of Macroeconomics, Economics of Personal Finance, Money and Banking

2010–2014 **Graduate Assistant**, Department of Economics, UWM

- Economics Statistics, Mathematical Economics, Economic Forecasting Methods, Analytic Models for Managers

2008 **Lecturer**, Saipa (Iranian car manufacturer) employees, Tehran, Iran

- Statistical Analysis with SPSS

Honors and Awards

2014 William L. Holahan Prize for Outstanding Teaching, UWM
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Academic Service

2015 **Discussant**, Midwest Economic Association, Minneapolis, MN
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Professional Affiliations

Member of the American Economic Association
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