Quantitative Modelling of UK Housing Prices

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Abstract

This thesis investigates the value of housing which is a specific group of investment assets and a major component of household wealth for the UK, in particular the primary valuation drivers of the UK housing prices, by using quantitative modelling. Understanding the primary valuation drivers of housing prices will make market participants aware of the size of their risk exposure and can help them to detect early signals of the possibility of investment opportunities. Policy-makers can use information about the underlying valuation drivers of the house prices to stabilize the market. This thesis contributes to literature both methodologically and empirically. This thesis proposes a three-step theoretical framework for studying the drivers of housing prices. The rationale is that people make investment decisions by studying the underlying costs and benefits. Additionally, people respond to expectations under the given behaviour rules, which refer to the institutions in place. There are a series of empirical findings. Firstly, the classical fixed parameter models are poor in terms of robustness, especially the regression coefficient changes in both magnitude and sign over samples. The time varying coefficients indicate the possibility of institutional changes and the changes in expectations. Secondly, the thesis supports the bounded rationality expectation hypothesis implying that the UK housing bubbles reflect people's biased expectations. The UK house prices were undervalued from 1996Q1 to 2002Q4; and thereafter overvalued. As a proportion, the bubble ranges from -52% to 27.4% in log scale. Thirdly, the thesis empirically supports that the UK housing market experiences both fast-moving and slow-moving institutional changes over previous decades. Fourthly, the thesis does not support the feedback theory. Overall, the three-step theoretical framework is empirically supported. Through a series of institutional changes, people's biased expectations are playing a far more important role in driving the UK house prices than the fundamentals.

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Any errors in the thesis are author's own responsibility.

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Chapter 1. Introduction

1.1 The Need for the Housing Valuation

This thesis investigates the value of housing which is a specific group of investment assets, in particular the primary valuation drivers of the UK housing prices, by using quantitative modelling. In practice, there are direct housing investments such as ownership of residences; and indirect housing investments such as investment in companies that develop and manage housing, and Real Estate Investment Trusts (REIT). Throughout this thesis, the term of housing primarily means private residential and is interchangeable with real estate and property.

Housing prices are important at three levels. Firstly, at the macroeconomic level, housing appears to lead the business cycle (Leamer, 2007). This is because increasing house prices can make homeowners feel more secure, motivating willingness to consume, while providing them collateral against which they can borrow. Higher purchasing power, and greater readiness to use it, can thus raise demand in the economy and increase economy activity and *vice versa*.

Secondly, at the corporate level, financial firms' risks/returns are built up when house prices are increasing. The high yield on housing incentive financial firms, particularly banks, to indulge in lending to house developers and homebuyers. The financial risks materialized in the aftermath of house price declines. The impacts are asymmetrical, being more significant in the recession period than in the boom period.

Thirdly, at the household level, housing is a major asset in the household portfolio. Changes in house prices have significant influence on the wealth holdings of households, and the distribution of wealth within the economy.

1.2 General Introduction to the Thesis

1.2.1 Chapter 2: Literature Review

Chapter 2 proposes a three-step theoretical framework for studying the primary drivers of housing prices. Firstly, what common factors may drive the housing risk-return? Secondly, how the desirability of outcome or expectation drives people to behave on the house prices (Lucas critique)? Thirdly, how the changes in institutions will affect the housing market? The rationale is that people make investment decisions by studying the underlying costs and benefits. Additionally, people respond to expectations under the given behaviour rules, which refer to the institutions in place. Following the three-step framework, Chapter 2 reviews literature from three interrelated aspects:

- Firstly, the value of investments, especially the common factors that are specific to the UK housing price in a closed economy and an open economy, respectively.
- Secondly, the 'value' of housing and the implications of four typical expectation hypotheses, namely, Irrational Expectation Hypothesis, Adaptive Expectation Hypothesis, Rational Expectation Hypothesis, and Bounded Rationality Expectation Hypothesis.
- Thirdly, the institutions and the effect of institutional changes on UK house pricing.

Throughout Chapter 2, there are considerable controversies among the literature. Therefore, Chapters 3 through to 7 run a battery of quantitative models for two purposes:

- Firstly, whether the three-step analytical framework is empirically supported?
- Secondly, what drives UK housing prices by quantifying the effect of these common factors, expectations and institutional changes?

1.2.2 Chapter 3: Updating the Econometric Modelling of House Prices in the United Kingdom

Chapter 3 replicates the principal equations of Hendry (1984) to four recent datasets. This chapter aims to demonstrate the limitations of Hendry (1984), which set the scene for the development of models in Chapters 4 through to 7. Chapter 3 addresses two issues:

- Firstly, Hendry (1984) is the last major work on the UK housing market using classical demand and supply equations, in which house prices are determined by the demand for housing. It is an interesting study to see if the result of Hendry (1984) is replicable by the similar datasets, in particular more recent datasets?
- Secondly, Brown *et al.* (1997) suggest the early studies, including Hendry (1984), are poor in terms of robustness. The chapter considers whether simple modifications can improve the model fit and robustness?

The findings are mixed. In the data descriptive section, the findings are roughly consistent with Hendry (1984) in the same time period. However, the regression coefficients change in both magnitude and sign over samples indicate the poor robustness of Hendry (1984). Chapter 3 finds that some naïve modifications will improve the fit of the underlying equation. However, it is unclear why people should make such a modification. Brown *et al.* (1997) suggest that time varying coefficients indicate the possibility of institutional changes and the changes in the unobservable components of economic variables, such as expectations. Chapters 4 through to 7 will address the effect of institutional changes and expectations on the UK housing prices step by step.

1.2.3 Chapter 4: Econometric Modelling of UK House Prices in an Open Economy

Chapter 4 incorporates the Foreign Portfolio Investment (FPI) into the equations of Chapter 3, *ceteris paribus*. FPI reflects one institutional changes in the UK since the 1970s that Hendry (1984) does not consider. Chapter 4 considers two issues:

- Firstly, whether an open economy framework is empirically superior to its closed economy counterpart, in terms of model robustness?
- Secondly, whether FPI drives the UK's house prices to a statistically significant extent?

The findings in Chapter 4 are generally consistent with Chapter 3, which demonstrate that an open economy framework is not empirically superior to its closed economy counterpart in the absence of suitable modelling techniques. Both of Chapters 3 and 4 suggest the classical fixed parameter demand and supply equations are inappropriate in studying house prices in the UK. Furthermore, changes in FPI do not statistically significantly drive the UK house prices, under the given models.

1.2.4 Chapter 5: Identification of House Price Bubbles using User Cost in a State Space Model

The time varying coefficients in Chapters 3 and 4 prompt Chapter 5 to investigate the effect of expectations on housing prices. Chapter 5 considers two issues:

- Firstly, how much variation in house price results from bubbles?

- Secondly, whether the bounded rationality expectation hypothesis will best fit into the UK housing market?

This thesis suggests that persistent and substantial divergence between market price and its equilibrium value is evidence of a bubble. The bounded rationality hypothesis argues that people make expectations and decisions to help them satisfice, rather than make theoretically optimal decisions. The chapter contributes to the literature both methodologically and empirically. Firstly, this chapter proposes a user cost framework within a state space model. The user cost framework suggests that people should be indifferent between renting and purchasing, given the same cost and housing attributes. The user cost of holding a house is the sum of six components, namely, foregone interest, property tax, maintenance cost, the risk premium for the larger uncertainty of purchasing relative to renting, and the marginal tax for the house buyer. A state space model consists of two equations: a measurement equation (or signal equation) and a state equation (or transition equation). The measurement equation illustrates the relationship between observed variables and unobserved state variables. The state equation illustrates the dynamics of the unobserved state variables, normally in the form of an AR(p) in the state vector.

Using a user cost framework within a state space model has clear methodological advantages. In the first step, the fundamental house price-rent ratio is calculated using the enhanced user cost framework, which has the benefit when compared to many prior papers incorporating all relevant variables. In the second step, the method can advantageously estimate the level of any bubble by incorporating the fundamental price-rent ratio into a state space model by taking advantage of a Kalman filter. Secondly, the empirical results indicate that UK house prices were undervalued from 1996Q1 to 2002Q4; and thereafter overvalued. As a proportion, the bubble ranges from -52% to 27.4% in log scale, which is indeed quite a substantial range. The chapter supports the bounded rationality expectation hypothesis implying the UK housing bubbles reflect people's biased expectations.

1.2.5 Chapter 6: Investigation of Institutional Changes in the UK Housing Market by Structural Break Tests and Time Varying Parameter Models

Distinct from Chapter 5, Chapter 6 expands Chapters 3 and 4 by empirically studying the time varying coefficients from two aspects:

- Firstly, whether the institutional changes in the UK housing market are empirically supported by using the Bai and Perron (1998) structural break tests and the Time Varying Parameter (TVP) models in which the parameters vary with time?
- Secondly, whether the institutional changes in the UK have short (less than 1 year) or long term (more than 1 year) effects?

This chapter contributes to the literature from two aspects. Firstly, the dates of structural breaks or fast-moving institutional changes appear to match market shocks rather than political events. It seems the unexpected shock, in particular the financial crisis, caused people to coordinate their future anticipations around the rules of the economy and thereby led to a structural break.

Secondly, this chapter expands on the literature by using three novel Kalman filtering based Time Varying Parameter (TVP) models to quantify the slow-moving institutional changes in the UK housing market. The three TVP models are; the Time Varying Parameter with Principal Component Analysis (TVP-PCA), Time Varying Parameter with Principal Component Analysis and Bubbles (TVP-PCA-Bubble), and Time Varying Parameter with Error Correction Model (TVP-ECM). The TVP models empirically suggest that people's biased expectations or housing price bubbles are playing much more important role in driving the UK house prices than ever. However, the effects of fundamental variables on housing prices are decaying over time. Overall, the TVP models suggest there are long term institutional changes in the UK over previous decades.

1.2.6 Chapter 7: Understanding the Causal Relationship between Changes in House Prices and Bubbles: Evidence from the UK Regional Panel Data

To check whether the time series analyses in Chapters 3 through to 6 are robust over time, Chapter 7 applies the panel data analysis to four recent UK datasets and considers two issues:

- Firstly, whether the bounded rationality expectation hypothesis best fit into the UK housing market in the context of panel data analysis?
- Secondly, whether the feedback theory (Shiller, 1990,2007) is supported in the UK housing market?

The bounded rationality expectation captures the idea that asset prices overreact to relevant information on fundamentals. However, people learn from their mistakes and attempt to satisfice by acting as rationally as possible. The feedback theory (Shiller, 1990,2007) suggests that when house prices as a whole appreciate significantly, this generates many investor success stories, and these stories entice potential investors, who naively extrapolate that they will achieve the same success if they invest too, and *vice versa*. The repetition of this process drives prices higher and higher and *vice versa*, for a while. The feedback theory implies that there is a positive feedback causal relationship between people's expectations and the subsequent house prices and *vice versa*. The feedback theory appears as a type of adaptive expectation hypothesis which means that people usually form their expectations of an economic variable by taking a weighted mean of past values and an 'error adjustment' term.

This chapter contributes to the literature from two aspects. Firstly, the chapter empirically indicates that the changes in people' expectations best fit the bounded rationality hypothesis in the context of the panel data analysis. Relative to Shiller (2007), the chapter estimates the regional fundamental value takes account of mortgage rates, people's risk aversions, taxes and the most recent UK datasets. Relative to Mayer (2007) and Hubbard and Mayer (2009), the study incorporates the people's unbiased expected capital gain and the quarterly adjusted risk premium into the estimation of the fundamental house price. Secondly, the chapter provides the first empirical evidence to justify the statistically significant feedback causality, between the changes in bubble and the contemporaneous changes in house prices by using the Fixed Effects Model (FEM). The feedback causality is robust even when taking the mortgage rate and the more recent datasets into account. This chapter supports the bounded rationality hypothesis best fit into the UK housing market. However, the chapter does not support the feedback theory (Shiller, 1990,2007) because an increase in bubble could cause a subsequent decrease in house price, *ceteris paribus*. The positive feedback causal relationship between the changes in house price and the contemporaneous changes in bubble are asymmetrical. One unit changes in bubble could approximately drive one unit changes in house price, after controlling for the fundamental variables. By contrast, one unit changes in house price only causes about 60% unit changes in bubble. Furthermore, the regression coefficients changes modestly over time indicate that there are institutional changes.

Overall, the findings in Chapters 3 through to 7 are consistent and support the three-step analytical framework in Chapter 2. Simply put, housing prices are not only determined by fundamental economic variables but also people's expectations, under the given institutions in place. Through a series of institutional changes, people's biased expectations are playing a far more important role in driving the UK house prices than the fundamentals.

Chapter 2. Literature Review

This chapter reviews the value of housing, in particular which factors are specific to housing investment. Understanding the primary valuation drivers of housing prices will make market participants aware of the size of their risk exposure and can help them to detect early signals of the possibility of investment opportunities. Furthermore, policy-makers can use information about the underlying valuation drivers of the house prices to stabilize the market.

Reilly and Brown (2011) regard an investment as the current commitment of funds for a period of time with the aim of deriving future payments that will compensate the investor for three things. Firstly, the time the money is committed that is the pure rate of interest. Secondly, the expected rate of inflation during this time period and thirdly, the uncertainty of payments from the investment. In financial markets, the typical investor will range from individuals and governments, to a diverse selection of institutions. The investment instruments include not only stocks and bonds, but also housing and so on.

Generally, investments are valued using Markowitz's emphasis on 'nothing ventured, nothing gained, but do not put all eggs into one basket' and Tobin's insights into the risk-return trade-off (Fabozzi and Markowitz, 2002). Furthermore, one can capture the influences of macroeconomic events on individual assets through microeconomic characteristics (Rosenberg and Marathe, 1976), essentially common factors.

This chapter proposes a three-step theoretical framework for studying the primary drivers of housing prices. Firstly, what common factors may drive the housing risk-return? Secondly, how the desirability of outcome or expectation drives people to behave on the house prices (Lucas critique)? Thirdly, how the changes in institutions will affect the housing market? The rationale is that people make investment decisions by studying the underlying costs and benefits. Additionally, people respond to expectations under the given behaviour rules, which refer to the institutions in place.

Housing often provides excellent risk-return trade-off and good diversification potential to stocks and bonds portfolios. Relative to the stocks and bonds investment, direct housing investment provides many advantages. For example,

- Direct control of the property which rewards the owner from two aspects, rental income and capital gain;
- Highly likely to have residual value no matter what kind of shock it may experience in the space and capital markets;
- Ability to use more leverage by using mortgage;
- Ability to diversify geographically;
- Often an inflation hedge in the long run;
- Many expenses are tax deductible in specific countries.

However, direct housing investment also has some typical disadvantages. For instance,

- Poor liquidity and difficult to evaluate;
- Lack of divisibility indicates a single investment can be a huge part of the investor's portfolio;
- High information and transaction costs;
- High operating and maintenance costs.

Although altogether, these features make direct housing investment interesting, they are specific to each market participant. However, housing investment is not necessarily different to other types of investment (Parker, 2012). Following the three-step framework, Section 2.1 reviews the common factors in the housing market. Section 2.2 reviews the formation and effect of people's expectation of the housing market. Section 2.3 reviews the institutions and institutional changes in the UK since 1970s.

2.1 The Common Factors in the Housing Market

A factor model provides a good framework for valuing investments (Zivot and Wang, 2006; Alexander, 2008; Tsay, 2010). With multi variable regressions, people can quantify the impact of one or more factors on asset risks and returns. According to the characteristics of the factors, there are three typical multifactor models. The macroeconomic factor model, in which, the factors are observable economic and financial time series like interest rates, as measures of pervasive or common factors in asset returns. In the fundamental factor model, people use observable asset specific attributes like dividend yield, to determine factors in asset returns. The statistical factor model refers to the extraction of unobservable factors from asset returns, such as the Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT) for stock pricing. However, there are some conditions that underpin the use of CAPM, including high liquidity and minimum transactions costs which are not met in the case of direct housing investment. All three types of factor models share the general specification:

$$R_{i,t} = \alpha_i + \beta_{1,i} f_{1,t} + \beta_{2,i} f_{2,t} + \cdots + \beta_{k,i} f_{k,t} + \varepsilon_{i,t} \qquad 2.\ 1$$

$R_{i,t}$ is the return on asset i in time period t, $f_{k,t}$ is the k-th common factor in time period t, $\beta_{k,i}$ is the factor beta or coefficient for asset i on the k-th factor which allows people to study the individual effects of each factor on asset return, *ceteris paribus*. $\varepsilon_{i,t}$ is the asset specific error term which is the unexplainable components of return on asset i. Common factor models can take the time series and/or cross section data. In general, the common factors are stationary with unconditional moments; error terms are uncorrelated with each of the common factors; and error terms are serially uncorrelated.

Obviously, before applying the factor models, one has to theoretically identify which common factors may attribute to the asset returns. The theoretical housing literature can date back to the 1920s or even earlier. Most of the earlier literature focuses on the US.

Vanderblue (1927) and Simpson (1933) are pioneers of the study of the housing speculation and depression between 1916 and 1927 in the US, particularly in Florida. Hoyt (1933) studies the cyclical fluctuations of land values for rational real estate investment policy using one hundred years of land values in Chicago, US. Thereafter, literature studies the long cycles in residential construction from three perspectives. Investigations of a primarily descriptive character, for example, Newman (1935) provides the necessary facts and suggestions for empirical study of the problem. Investigations containing statistical analysis, for example, Wenzlick (1933) suggests there is a very weak link between the general business cycle and mortgage foreclosure, particularly in Greater St. Louis, US. Wenzlick (1933) suggests construction is not a good measure of supply, either in terms of money or of permits. Investigations containing multiple correlation analysis, for instance, Derksen (1940) suggests the construction cycle is an example of a cycle independent of the variations in a general business cycle. Building on Tinbergen's

Closed System of Equations, Derksen (1940) suggests that it is possible to predict the housing construction a couple of years in advance.

Since the 1950s, rising literature studies the demand for and supply of housing, using a number of common factors, such as capital formation, cost of renting, taxation, migration, monetary policies, inflation, mortgages, nominal and real interest rate, housing services, inflation expectation, capital gain, capital market constraints, income, and so on.

For instance, Grebler *et al.* (1956) suggest net capital formation in the housing sector shows a downward trend from 1890 to 1950; and there is no evidence of upward trend in per capita residential wealth. Grebler *et al.* (1956) infer that people's preference for housing changed between 1890 and 1950. Reid (1958) challenges Grebler *et al.* (1956) by applying simple multivariate regression analysis. However, Grebler *et al.* (1959) clarify their arguments and defends Reid (1958)'s criticism.

Shelton (1968) develops a theoretical model for evaluating whether it is economically better for people to own or rent their houses. The break-even point for people to buying a home is when the rent equals the total economic cost. The model can be shown as:

$$\frac{Rent}{Market\ Value} \equiv \frac{Total\ Economic\ Cost}{Market\ Value} = \frac{Prop.Tax + Maint. + Obs. + Int. + Return\ on\ Investment}{Market\ Value} \qquad 2.2$$

In equation (2.2), $Prop.Tax$ is property tax, $Maint.$ is maintenance cost, $Obs.$ is obsolescence cost, $Int.$ is mortgage rate. Shelton (1968) argues that the potential investment return and duration of tenancy play a critical role for deciding whether to rent or buy. Weiss (1978) criticizes Shelton (1968) does not consider the taxes on capital gain. Due to the existence of discriminatory taxes in some countries, capital gains impact people differently (Weiss, 1978). Relative to Shelton (1968), the user cost framework (Hendershott and Hu, 1983; Poterba, 1985,1992) has the advantage of quantifying the level of housing price deviation from its fundamental value. Given its importance in empirical analysis, this thesis will explicitly review the user cost framework in Chapter 5.

Mishkin (1976) argues that housing would be a less desirable portfolio asset if people's debt holdings and income volatility are high; or anticipated income and gross financial holdings are low. The illiquidity of the durable asset would increase the effective opportunity cost of holding the asset that is the liquidity risk premium. Similarly, McCulley (2008) argues that liquidity is not measured properly by the traditional monetary aggregate, but by people's state of mind, in particular their 'appetite for risk'. Generally, a higher appetite for risk would lead to higher liquidity and *vice versa*.

There is a great deal of confusion about the link between expected inflation, mortgage payments and capital gain on housing investment (Schwab, 1982,1983). The first view argues that the nominal interest rate, which is the sum of inflation and the real interest rate, is a primary determinant of housing prices. For instance, Feldstein (1976) proposes a theoretical monetary growth model in which one can study the long-run impact of inflation, income tax, and the rate of interest on the cost of capital and the process of capital accumulation. Feldstein (1976) argues that the tax rates and saving behaviour determine the effect of inflation on capital intensity. Poterba (1985) suggests higher overall inflation normally drives up the nominal mortgage interest rate and generates higher nominal capital gains for homeowners. When the tax rate on housing gains is inconsequential, homeowners bear only partial higher interest costs but receive full housing gains. Expected inflation consequently reduces the effective expense of homeownership. The increase in expected inflation may have contributed to approximately 30% of increases in real house prices in the 1970s. Conversely, Kearl (1979) supports the hypothesis that fixed rate mortgages lead to deviations in the housing market in the face of expected inflation. The anticipation of inflation does not deteriorate the household's real financial position, yet it has increased the real cost of debt service. Consequently, the anticipation of inflation drives an inter-temporal reallocation of people toward more saving and less consumption at the current term. These effects lead to a higher real cost of housing capital, lower demand for housing, and a lower equilibrium of housing prices and return, *ceteris paribus*. Fama and Gibbons (1982) demonstrate the hypothesis of Mundell (1963) and Tobin (1965) that the expected real return component of the interest rate is inversely related to the expected inflation. In the Mundell-Tobin framework, the variation in expected inflation leads to variation in the expected real return. However, Fama and Gibbons (1982) suggest the variation in expected real return is more fundamentally a result of the capital expenditures process. The second view proposes that demand for housing is independent of inflation expectation. Arcelus and Meltzer (1973) suggest that only real variables such as real interest rate are important. The third view suggests that the truth lies somewhere between the first two views (Schwab, 1982,1983). Housing demand is a function of both the real interest rate and inflation expectation. Expected inflation has a greater effect on those that are prone to be constrained by capital market imperfections. Hendershott and Hu (1983) illustrate that a low income elasticity and capital market imperfections could offset the impact of the inflation-induced relative decline in the real user cost of housing on the accumulation of housing capital.

The earlier empirical literature uses cross section and/or time series regressions. For instance, builds on Muth (1960) and Lee (1968), Leeuw (1971) studies the demand for housing by using cross section regression in log linear specification. For renter families, with deflated expenditure as the dependent variable, the equation is

$$R - P = \alpha + \beta_1(Y - Q) + \beta_2(P - Q) \qquad 2.3$$

With price as dependent, the equation is

$$P - Q = \alpha + \beta_1(Y - Q) + \beta_2(R - P) \qquad 2.4$$

R is median rental expenditure, P is an index of rental price, Y is median income, and Q is an index of the general price level.

There are two typical microeconomic approaches in modelling housing prices. First, the monocentric approach is based on the urban general equilibrium theory (Muth, 1969). Second, the hedonic price approach, which is based on the microeconomic consumer theories (Rosen, 1974). The monocentric approach assumes the housing price is a function of homogeneous units, 'housing services', which are priced according to the distance-transport cost trade-offs. The hedonic price approach appears more suitable than the monocentric approach as housing investment is characteristic for its durability, heterogeneity, and spatial fixity.

Rosen (1974) suggests the hedonic price approach treats goods as a package of inherent attributes. The relative price of one good is the sum of its marginal or implicit prices fitted through the regression analysis. Freeman (1979) proposes the theoretical framework for the application of the hedonic price approach to housing. The house price hedonic regression can be estimated by regressing the housing price against its key attributes, by using cross sectional and/or time series data. Freeman (1979) suggests there are three key attributes in the housing market, namely, Structural attribute (S) such as the size of a building, Accessibility or Locational attribute (A) such as the distance to central business districts; and Neighbourhood (N) attribute such as the quality of surroundings. Thus, the housing price (P) is a function of S, A and N, as equation (2.5).

$$P = F(S, A, N) \qquad 2.5$$

The hedonic model has two steps (Rosen, 1974). The first step aims to fit the marginal price for the attribute of interest by running the housing price against its attributes. The second step is to identify the inverse demand curve function, based on the implicit price function in first step. However, Bartik (1987) disagrees with Rosen's estimation procedures. Bartik (1987) and Chin and Chau (2003) suggest that the problems of hedonic estimation result from the endogeneity of both price and quantities of attributes in the context of a non-linear budget constraint, rather than the interaction between demand and supply.

The hedonic price approach shares the main characteristics of the general time series and/or cross sectional data approaches. For instance, people only need to collect certain data such as housing price and the composition of housing attributes. The hedonic price approach allows people to study the individual effect of each housing attribute on housing price, *ceteris paribus*. However, this has a couple of specific limitations when compared to the general time series and/or cross sectional data approaches. For example, the hedonic price approach works only on the assumption of market equilibrium, whereas a large amount of literature disagrees with this assumption in the housing market. Moreover, hedonic regression is quite data consuming and some of the attributes are hard to measure. With hedonics, one must be aware of endogeneity, especially if one wants to construct a price curve. Finally, it does not explicitly consider the external factors such as taxes and interest rates (Chin and Chau, 2003).

The rest of the thesis focuses on the UK housing market for two reasons. Firstly, it is interesting to study the housing market in other countries, given that the bulk of earlier literature focuses on the US. Secondly, the quality of datasets and market characteristics are comparable to the US. However, the analysis methodology can also apply to other countries.

Early UK housing literature (Whitehead, 1974; Mayes, 1979; Hendry, 1984) is built on the framework of demand and supply equations in which house prices are determined by the demand for housing. Through reviewing Hendry (1984), people can get a brief idea about how to apply factor models, especially the macroeconomic factor model and fundamental factor model into the UK housing market. Section 2.1.1 reviews Hendry (1984) which is a closed economy framework. Section 2.1.2 extends the housing literature into an open economy framework.

2.1.1 Factor Models in a Closed Economy Framework

In order to address the equilibrium housing price, Hendry (1984) firstly considers a static state where the completion of new houses C is exactly offset by the depreciation of the physical housing stock H.

$$C = \delta H \qquad 2.6$$

Where δ is the depreciation rate. The equilibrium meant the market is 'cleared' and has 'no inherent tendency to change'. Equilibrium house price is where demand equals supply. Therefore, it generates a 'normal profit' to the construction industry when C is provided. The demand curve is a downward sloping curve, which indicates people want to buy more at lower prices. The supply curve is an upward sloping curve meaning that sellers are likely to supply more at higher prices. Sometimes, under certain circumstances, supply is a vertical line indicating that supply is constant.

On the demand side, there are three sets of underlying factors: (1) demographic (e.g. the changes of household formation and working age population, changes in birth rates, employment and unemployment rate); (2) service flow (the utility derived from the size, quality, type); (3) asset demand (the relative yield obtained from home ownership as against ownership of alternatives).

(1) The population size and composition significantly affect the number of shelter units and may in turn influence the size of average unit. Theoretically, there are N/F households given the population size of N with an average family size of F. This situation presents if, and only if, there is no homelessness and no one occupies additional dwelling units. Realistically however, a lot of people buy additional dwelling units for investment purposes. Thus, even though conditional on population size and family size, the number of owner occupied houses varies with underlying

factors such as credit availability, incomes, wealth holdings. Econometric modelling of demographic factors needs further improvement, despite rising attention over the past decades (Buckley and Ermisch, 1982; Mankiw and Weil, 1989).

(2) The service flows provided by housing is a comprehensive bundle of attributes. Buckley and Ermisch (1982) suggest such a flow is frequently proportional to the housing stock reflected as a number of units in time series analyses. This assumption seems extremely inappropriate, being conditional on an assumption of constant composition within the physical housing stock H. Hendry (1984) suggests a constant price weighted average of the value of all existing units would be a more rational measuring of housing stock, denoted by K. This is analogous to the measure for 'capital stock'. Hence, K is the accumulated depreciation of past constant price investment in housing. If the relative prices of the components comprising of a house are variable, then K and H deviate over time. The relative price of the two inputs changes for a cost-minimizing builder who builds homogeneous units. It appears that K and H do not differ substantially even though one of the relative figures changes dramatically. Given there is no measure of private sector K, people have to tolerate crude proxy of K by H.

(3) Incomes and the relative prices determine the corresponding assets demand. In theory, the selection of shelter (rented or owned) is separable from the level of demand. However, the taxes on housing inevitably influence asset and service demands. For instance, both net rental incomes and nominal capital gains generated from changes in house prices are taxed on a landlord in the UK. Neither the implicit rental revenues (the rent saved by living in the owned house) nor capital appreciations are taxed on an owner-occupier of a single unit. Hendry (1984) suggests rent controls on landlords are popular and tenure regulations are favourable to tenants, pushing further discouragement to let houses. However, Britain has probably the most liberalised private renting market in the European Union (EU) since 1989. The less security of tenure and long-term taxation imbalance between the rental and owned making it more attractive to rent than own than it was in before. The typical landlord has treated the buy-to-let as the mainstream of personal investments, and the tenants are now composited by far more immigrations and younger people.

Without presenting a formal life-cycle model, equation (2.7) illustrates the anticipated sign of partial derivatives:

$$H^D = f\left(\underset{-}{Ph/P}, \underset{+}{Y}, \underset{-}{\rho}, \underset{-}{R}, \underset{-}{R^m}, \underset{+}{M}, \underset{?}{T}, \underset{+}{N}, \underset{?}{F}\right) \qquad 2.7$$

Where, ρ is the real rental rate, R is the representative market interest rate, R^m is the mortgage rate, M is the gross mortgage advances, and T is the tax rate. And then, a log-linear specification is selected as consistent with the positivity of physical housing stock H, and this provides a flexible framework for a range of transformations on the endogenous variable including all of those exhibited in data description.

In a dynamic condition, the real housing stock evolves as equation (2.8):

$$H_t = (1 - \delta_t)H_{t-1} + C_t \qquad 2.8$$

Where C_t denotes private new completions plus net supply from other sectors such as the rental markets. Depreciation rate δ_t likely changes with economic conditions but is treated as constant. When $H_t = H_{t-1}$ and $C_t = C\forall_t$, the equilibrium of (2.8) reproduces equation (2.6). At any given time, C_t is tiny compared to H_{t-1} and it is relatively dependant on the volume of construction in progress. Thus, H_{t-1} is a fixed supply of dwelling in the short term. Consequently, in the short run the demand for the existing housing will determine the house price. However, in the long run, demand determines the quantity of housing.

Hendry (1984) suggests there are three factors which operate to induce dynamic feedbacks which likely alter the stock of available housing. Initially, capital gains are made by developers on land but these are taxed, unlike those made by owner-occupiers on their dwellings, distorting their relative incentives. Secondly, excess profits accruing on the stock of construction in progress is likely to alter the time profile of new construction. Thirdly, the relative price of land to construction cost changes and this induces substitution and the kind of dwelling desired. Static models are useless in studying the feedback mechanisms. However, the adjustment must continue until markets, stock and flow, are again in joint equilibrium, with new construction yielding normal profits.

Alhashimi and Dwyer (2004) argue that neoclassical analysis of the housing market with its concentration on aggregated competitive markets is inadequate to study the housing market. The bulk of literature (Miller, 1982; Liu *et al.*, 1990) suggests that the housing market may be imperfect, or at least inefficient (Linneman, 1986; Gau, 1987). The neoclassical competitive model suggests that buyers want to buy more housing services at minimum prices. Sellers want to sell more housing services at maximum prices. One implicit assumption is buyers and sellers are independent. However, it is hard to measure how buyers and sellers can maximise returns if they do not hold perfect knowledge and analysis ability. Sometimes, people will buy one house while simultaneously selling another which indicates the market transactions are interdependent in a chain.

Out of equilibrium, Hendry (1984) studies the effects of expectations regarding inflation and variations in asset prices on current housing prices by studying the cubic excess demand models and the cubic difference equations. However, Hendry (1984) concludes that these cubic models do not provide superior modelling ability.

2.1.2 Factor Models in an Open Economy Framework

The earlier housing literature, including Hendry (1984), assumes a closed economy, an economy that does not interact with the rest of world. Given the dramatic developments of globalization over the past half century, there is no real closed economy in today's world. So, it appears somewhat problematic to model house prices without the consideration of international factors. Since the 1990s, rising literature studies house prices in an open economy. An open economy is one in which there are economic activities between the domestic and international community.

In the 1990s, the literature primarily focuses on the relationship between the few explicit open economy variables and house prices. For example, Benson *et al.* (1997) argue the appreciation of the Canadian dollar will stimulate the Canadian demand for Washington properties in the US which, in turn, drive higher home prices. Jiang *et al.* (1998) suggest that the Foreign Direct Investment (FDI) make the housing sector perform well in Shanghai, China, despite the government's tight monetary policy and the recession of the housing sector in the rest of China over the same period. Muellbauer and Murphy (2008) propose the unintended impact of the exchange rate is one of the dilemmas in determining house prices. The dilemma being if short-term interest rates are increased for the purpose of cooling excessive house price appreciation, the real exchange rate might be raised. If the exchange rate overshoots, this may also hit a country's real economy via the volatility of interest rates and credit availability, then, influencing house prices.

Post the Subprime Crisis, growing attention is paid to the effects of global macroeconomic imbalances on the asset pricing and financial crisis. The global macroeconomic imbalance refers to the imbalances between investment and savings in the major world economies (The Turner Review, 2009). For example, the substantial capital flows from current account surplus countries like Asian emerging economies to the deficit countries like the US and the UK. Given some of the surplus economies are committee to managing the exchange rates regime, the rising surplus claims are typically taken in the form of central bank reserves. These reserves are generally investing not in a wide array of equity, property or fixed income assets, but almost exclusively in apparently risk-free or close to risk-free government bonds or government guaranteed bonds.

The key controversy among the literature is whether there is a causal relationship between the capital inflows and excessive liquidity (Whelan, 2010). If a causal relationship exists, then the global macroeconomic imbalance affects house pricing via credit mechanism. Bini-Smaghi (2009) proposes the US house boom would have been more modest and its burst less significant if US households had improved net savings. Global macroeconomic imbalances play a key role in the recent house prices boom-bust cycle (Astley *et al.*, 2009; Bernanke, 2009; Guha, 2009; Portes, 2009). Adam *et al.* (2011) suggest that home prices are positively related to the deterioration of the current account. Some literature (Caballero and Krishnamurthy, 2006; Aoki *et al.*, 2009) is not limited to the context of global macroeconomic imbalance. However, they argue that capital inflows are likely to appreciate asset prices.

Obstfeld and Rogoff (2009) and Whelan (2010) argue that the global imbalances and house price movements are correlated though there is no causal effect. The real culprits behind the recent house prices boom-bust cycle are financial regulatory failures and policy errors. Inadequate financial supervision allowing lower credit standards for mortgage borrowing is certainly a reason for the boom in home prices in the US and some other markets. Even if the huge foreign demand for US Treasury bonds depresses long term real interest rates and then fuel house prices, the US regulators such as the Federal Reserve, can counteract such impacts via its control over short term rates. It is the easy credit conditions resulting from the loose monetary policy causing the housing boom.

Some recent research uses the applied general equilibrium theory. For instance, Berrak and Olena (2010) investigate the housing markets through the monetary open-economy Dynamic Stochastic General Equilibrium (DSGE) model. Their findings reveal that international shocks account for approximately 50% of residential investment and close to 10% of home prices swing.

The following paragraphs review an open economy framework in general.

When compared to a closed economy, a self-sufficient community, the key element of an open economy is the cross border economic activities. Mankiw (2011) suggests an open economy interacts with others through two channels. First, it imports and exports goods/services in global goods markets. Second, it purchases and sells capital assets, such as equities and debts, in global financial markets. Each channel represents a type of imbalance. The first one measures a cross border goods/services flow. The second would measure a cross border capital flow. These two flows are two sides of the same coin. For an economy as a whole, net capital inflows must always equal net imports. This is because at an equilibrium foreign exchange market, the value of goods/services and capital assets received must equal the value of goods/services and capital assets delivered. Expressed by identity, Imports + Capital Outflow = Exports + Capital Inflow. Rearranging this equation, Capital Inflow – Capital Outflow = Imports –Exports. Put simply, Net Capital Inflow = Net Imports, or Net Capital Inflow = Trade Deficit. In order to finance its trade deficit, a country must sell its capital assets in global financial markets. Consequently, capital is flowing into the economy when an economy is running a trade deficit by exactly the same amount, Capital Account Surplus = Current Account Deficit, and *vice versa*. The Balance of Payment (BOP) identity assumes: Current Account + broadly defined Capital Account + Balancing Item = 0. The Balancing Item is simply a statistical error, which assures that the sum of the capital account and current account is zero. In macroeconomics, the broadly defined Capital Account = Foreign Direct Investment + Foreign Portfolio Investment + Other Investment + Reserve Account. The reserve account is the ‘Change in Central Bank Reserves’ only. Therefore, the global macroeconomic imbalance just mirrors the trade imbalance.

Mankiw (2011) argues the market for loanable funds and the market for foreign exchange are the two pillars of an open economy. Net capital inflow is the variable that connects these two markets. This is because net capital inflow is the proportion of the supply of loanable funds as it provides the demand for dollars for foreign exchanges. In the loanable funds market, real interest rate determines the quantity of loanable funds supplied (National Saving) and the quantity of loanable funds demanded (Domestic Investment). A higher real interest rate will discourage domestic investment but incentive national saving. As a higher real interest rate means higher real investment return, the real interest rate is positively related to capital inflow. In the foreign exchange market, real exchange rate determines the demand (Net Export) and supply (Net Capital Outflow). An appreciation of the real domestic exchange rate reduces the quantity of domestic currency demanded in the foreign exchange market. Hence, the real domestic exchange rate is also positively related to capital inflow.

According to Mankiw (2011), capital flow into major trade deficit countries has increased dramatically over the past decades. For example, the capital inflow increases from 0.5% to 5.7% of GDP between 1980 and 2006 in the US. There is no simple and appropriate answer to the influence of trade deficit, or capital inflow, on the US economy. If an individual can go into debt, so can an economy (Mankiw, 2011).

Overall, a closed economy framework can be explored to an open economy framework by incorporating international economic activities, either by net capital inflows or by net imports. In practice, it appears capital flow outperforms the rest of the open economy variables for three reasons. Initially, it is possible to investigate the primary sources of capital inflow, which makes the study of asset prices in an open economy more precise. Secondly, the effects of real exchange rates and the real interest rate on an economy will ultimately reflect on the changes in capital inflows. Thirdly, the use of a component of capital inflow helps to reduce the risk of multicollinearity when applying the multivariate linear regressions. In particular, the real exchange rate, the real interest rate and the mortgage rate may be highly correlated with each other.

The following paragraphs present the theoretical links between house prices and capital flow. The purpose is to illustrate that people can extend a closed economy model to an open economy model by incorporating Foreign Portfolio Investment (FPI).

The massive capital inflow is a double edged sword (Makin, 1999; Hattari and Rajan, 2011). On one hand, larger capital inflows finance economic growth by supplementing liquidity and facilitating new technology. During the boom period, the high yield in an economy will attract capital inflows which, in turn, built up an economy's risks/returns by expanding credit and investment. On the other hand, the volatility of capital inflows is the approximate driver of many of the financial disasters, e.g., the East Asian Financial Crisis from 1997 to 1998. The previous boom continues until the reversal of capital inflow where asset prices reversed sharply and forced a structural regime on the fundamental economy. The impacts are asymmetrical being more significant in the recession period than in the boom period.

The pattern of capital flows has two apparent characteristics. Firstly, private flows are the primary sources of capital, dominated by Foreign Direct Investment (FDI) and Foreign Portfolio Investment (FPI). Secondly, the capital flows are subject to the boom-bust swings (Secretariat, 1999). Conventional wisdom suggests FDI and FPI are two quite different issues. FDI refers to the investment to acquire a lasting management interest in an operating enterprise. FDI flows are relatively stable, driven by foreign investors' long term considerations, such as the underlying economy and the degree of openness. Conversely, FPI is a passive investment in the securities of another country. FPI flows are unstable and subject to pressure from increased/decreased demand for new investment, which are generated by foreign investors' short term considerations, such as interest rate differentials, exchange rate movements and speculations. Conventional wisdom suggests regulators should selectively deregulate FDI transactions but maintain and even strengthen monitors of FPI.

Friedman (1987) argues foreign investors' preferences will change the equilibrium asset prices and yield relationships determined in domestic markets, given the rapid increase of capital inflows. Relative to domestic investors, foreign investors tend to hold much more of their portfolios in short term assets rather than long term assets. Hence, rising capital inflows tend to increase the risk premium on long term asset. Furthermore, rising capital inflows decrease the cost of capital on short term assets because foreign investors bear some of the risks associated with the domestic economic activities.

Olaberría (2012) suggests net FPI inflows are more likely to appreciate real asset prices than other types of capital inflows, even when controlling for other variables such as growths of GDP and inflation. Furthermore, capital inflows have much larger influence on asset pricing in emerging markets than in industrialized markets. By contrast, Xu and Chen (2012) argue that domestic monetary policy plays a far more important role in driving China's house prices than FPI flows. From this viewpoint, both of Whelan (2010) and Xu and Chen (2012) suggest the impacts of capital flow on asset prices can be effectively regulated by domestic macroeconomic regulations.

To sum up, a couple of findings emerge. Initially, the impact of current account surplus and capital account deficit on house prices should be the same, and *vice versa*. Secondly, although the capital inflow is likely to appreciate asset prices, it is not necessarily a problem in itself. The key thing is the appropriate domestic macroeconomic regulations, such as monetary policy and regulations on capital flows.

2.2 The Expectation Hypotheses

Conventional wisdom defines 'value' as relating purely to monetary value such as price. However, Reddy (1991) defines value as a combination of 'using value' and 'value in use', both of which correlate to substitutability and functionality. The value defined by Reddy (1991) appears very sensible in the housing market. Alhashimi and Dwyer (2004) suggest the classical monetary price is simply one component of a perceived value. Perceived value includes both exchange price and ancillary costs that attend any sale which is more individualistic and personal than price. The threefold of ancillary costs cover price related costs such as agent's fees and mortgage costs; time related costs such as search costs; and psychology related costs such as anxiety, satisfaction and expectation. Some ancillary costs will vary during purchase and consumption, in particular those related to psychology and expectations.

To reveal how people's psychology and expectations will affect housing prices, this chapter looks into four typical expectation hypotheses. Sections 2.2.1 through 2.2.4 review irrational expectation hypothesis, adaptive expectation hypothesis, rational expectation hypothesis, and quasi-rational or bounded rationality hypothesis, respectively.

2.2.1 Irrational Expectation Hypothesis

Keynes (1936) distinguishes between short-run and long-run expectations (Harcourt and Riach, 1997; Hoover, 1997). Entrepreneurs' short-run expectations determine the scale of their current output which, in turn, determines the macroeconomic equilibrium and the effective demand. Entrepreneurs' long-run expectations determine the amount of their investment in plant and machinery, followed by the aggregate demand. It is other's long-run expectations that govern which demands entrepreneurs could anticipate in the short-run. Expectations are not single-valued. In the short-run, entrepreneurs may consider a range of possibilities, each with an attached numerical probability. It is unclear whether Keynes (1936) believes that the long-run expectations can be dealt with using the same approach. It is the diversity of people's expectations about the expected values of financial assets which prevents the asset prices from experiencing massive volatility.

A general criticism to Keynes (1936) is that it does not have a clear hypothesis or a single mechanical algorithm for the formation of expectations. Keynes's arguments lead either to adaptive expectations which subsume the formation of short-run expectations, or to a 'mob psychology' dealt with expectations, see (Rutherford, 1984; Harcourt and Riach, 1997; Hoover, 1997). Furthermore, Rutherford (1984) disagrees with the distinction that Keynes (1936) makes between short-run and long-run expectations.

Building on Keynes (1936), Akerlof and Shiller (2010) suggest that animal spirits, people's irrational expectation and non-economic motivation, are the force that drives the economy and asset returns. Akerlof and Shiller (2010) expand Keynes (1936) by suggesting that the changes in people's expectations can attribute to the five different aspects of animal spirits, namely, confidence, fairness, corruption and antisocial behavioural, money illusion, and stories.

- Confidence and the feedback mechanisms between it and the economy that amplify disturbances is the cornerstone of Akerlof and Shiller (2010).
- The setting of prices depends significantly on the feeling of fairness.
- When studying the functioning of the economy, one must also be aware of the economy's sinister side. For instance, the tendencies toward corruption and the failures that disrupt it at long intervals or in invisible places.

- Money illusion refers to people that are confused by inflation and/or deflation and fails to reason through its impacts.
- The sense of reality is correlated with the story of one's life and of the lives of others. The aggregate of these stories is a national or global story, which itself plays a significant role in the economy.

These five aspects are closely linked with each other. It is the changes in any one or more of these aspects that are driving the economy.

Friedman (1953) argues that irrational people who use biased beliefs will consistently lose money and will not survive in the financial market. So, irrational people cannot influence asset prices in the long-run. Using a parsimonious model with no intermediate consumption, Kogan *et al.* (2006) demonstrate that long-run survival and asset price impact are two independent concepts. Irrational people can survive and even dominate rational people. Even when irrational people cannot survive, their non-economic behaviour can still have a substantial impact on asset prices. By taking the intermediate consumption into account, Berrada (2006) suggests irrational people with low consumption share have a far smaller impact than Kogan *et al.* (2006) suggest. Berrada (2006) shows that people's influence on asset prices is increasing in their consumption share and argues that biased people can considerably impact equilibrium quantities.

Given house prices are largely set by negotiation between buyers and sellers through a system that centres on agents, it is a bargaining process rather than the arm's length. Many sellers may fail to put their houses on the market if they believe the prices are too low and are more likely to wait for better times. Alhashimi and Dwyer (2004) suggest that people buy homes infrequently, with a tiny proportion of households active at any one time. Little changes in the aggregate behaviour of a few people could, regionally at least, have substantial influences on house prices. Therefore, house prices are likely to be set through people's irrational expectations, see (Clayton, 1996; Alhashimi and Dwyer, 2004; Akerlof and Shiller, 2010).

2.2.2 Adaptive Expectation Hypothesis

Adaptive Expectation Hypothesis (AEH) is a plausible and empirically sensible approach in studying expectations (Cagan, 1956; Friedman, 1957). One simple version of adaptive expectations is

$$P^e = P^e_{t-1} + \lambda(P_{t-1} - P^e_{t-1}) \qquad 2.9$$

P^e is the expected value at current term, $P^e_{t-1}$is the current value that was predicted last term, and P is this term's actual value, λ ranges between 0 and 1.

AEH is a backward looking expectation which means that people usually form their expectations of an economic variable by taking a weighted mean of past values and an 'error adjustment' term. In a more general case,

$$P^e = (1-\lambda)\sum_{j=0}^{\infty}(\lambda^j P_j) \qquad 2.10$$

P_j is actual value at $j\text{-}th$ period in the past.

AEH can sometimes be a helpful hypothesis in econometric practice (Chow, 1989,2011). Some literature quantifies the level of a housing price bubble by using the user cost framework based on the backward looking expectation, or AEH (Poterba, 1992; Quigley and Raphael, 2004; Girouard *et al.*, 2006).

A general criticism to the AEH is that the adaptive expectations boil down to a hypothesis of how historical data affect current and/or future data. When people make a forecasting error, resulting from a stochastic shock, it will be fairly hard for people to accurately forecast the economic variable again, even if the variable experiences no additional shocks. This is because the AEH only ever incorporate part of their errors. Since the introduction by Muth (1961), the Rational Expectation Hypothesis (REH) has replaces the AEH in mainstream economics. Evans and Ramey (2006) suggest REH is superior to AEH in providing optimal expectations. However, adaptive expectations may coincide with rational expectations, given a constant policy regime (Harcourt and Riach, 1997; Hoover, 1997).

2.2.3 Rational Expectation Hypothesis

Gertchev (2007) suggests that there are three prevalent definitions of rational expectation. The first one corresponds to Muth (1961) which suggests all people need not hold the same expectations of the objective distribution. However, the weighted average of expectations is equal to the forecasting of the relevant economic model, see (Redman, 1992). The second, narrowest, definition suggests that all people possess the same subjective probability distributions, which coincide with the objective distribution. The third, weakest definition, solely asserts that people make economically rational expectations in the sense only to the point where the marginal gain becomes just equal to the marginal cost, see (Feige and Pearce, 1976). The three distinct definitions of rational expectations are not necessarily exclusive and can be identified.

Harcourt and Riach (1997) suggest the rational expectations are usually formulated as:

$$_{t-1}P_t^e = E_{t-1}(P_t|\Omega_{t-1}) \qquad 2.\ 11$$

Equation (2.11) suggests that the expectation of P_t developed at time t-1 is the mathematical expectation of P_t conditional on all the information available at time t-1. The information set Ω_{t-1} in any theoretical account covers the model hypothesized by the theory. In empirical analysis, the rational expectation formula is regarded as a regression of P_t on the variables in Ω_{t-1}. The error terms from this regression are independent of P_t, and has an expected value of zero. The estimated values are the expected values.

In asset pricing theory, expectations govern asset valuation. Rational expectations equilibrium implies that the current price of an asset has incorporated all the relevant information and that it is equal to the sum of discounted future cash flows.

$$P_t = \frac{C_1}{1+i_1} + \frac{C_2}{(1+i_2)^2} + \cdots + \frac{C_N}{(1+i_N)^N} \qquad 2.\ 12$$

P_t is the fundamental market price of an asset at time t, C_N is the expected cash flow payment at time $t+N$, N is the number of payments, i_N is the market interest rate at time $t+N$.

REH suggests the release of new information determines the change in people's expectation which, in turn, determines the changes in asset prices. Given the information which enters the economy are random, changes in prices must also be random, making abnormal returns impossible to predict consistently (Radner, 1979; Gertchev, 2007).

Under the rational expectation hypothesis, there are several theoretical arguments that an asset price could exceed its fundamental value, which refers to the rational asset price bubble. Based on symmetric information in which all people share the same information, the expectational difference equation allows a stock price to involve a rational bubble element apart from the market fundamentals component, see (Diba and Grossman, 1988a,b). The rational bubbles component of a stock price follows an explosive process, under symmetric information. Based on asymmetric information in which people have different information but still share a common prior distribution, the presence of a rational bubble need not be widely known, see (Brunnermeier, 2003). Therefore a rational investor only holds bubble assets when he/she believes he/she can resell the bubble assets to a less informed investor in the future. Allen *et al.* (1993) argue that the necessary conditions for an expected rational bubble to occur is that each person must be short sale constrained at some period in the future. Unfortunately, literature does not explicitly discuss the distribution of a rational bubble under the circumstances of asymmetric information.

There are three prevalent reasons to justify the popularity of the REH. Initially, REH describes a coherent, and even unavoidable, extension of rationality to the form of people's expectation. People's purposeful action, by virtue of its own nature, is expected to be void of systematic expectation mistakes. People are not purely rational when the same expectation mistakes repeat from time to time. Secondly, the REH targets to transform it from a pure hypothesis into a necessary principal. The rejection of REH would make some economic theories impracticable. Thirdly, people regard REH as an appropriate tool for undertaking research, particularly in a dynamic perspective, which is consistent with the contemporary positivist methodology.

Lucas defends the REH not on grounds of realism, but as a consistency criterion for economic models. On the contrary, Keynes's framework concerns the substance of the economy instead of the form of models. From an economic policy perspective, the biggest difference between

Lucas's REH and Keynes's expectations is in Lucas's willingness to permit our ignorance of the future to a set of limited government policies. Whereas Keynes (1936) is more optimistic and possesses a spontaneous urge for action (Harcourt and Riach, 1997; Hoover, 1997).

Like the AEH, REH also asserts that people adapt to learn and change from experience. AEH suggests people gradually adapt after a certain situation. However, REH suggests people have the ability to rapidly adapt and simultaneously learn from their economic environment as it takes place. Furthermore, REH is a forward looking expectation. According to Lucas (1976), the REH implies that existing econometric models of the time could not apply to evaluate the effects of government policy, given the parameters of these econometric models would change when the economic policy changes.

In regard to the criticisms about REH, there are several misunderstandings. Here, the chapter makes it clarification. Firstly, REH does not apply to everyone. Instead, it argues that some people may be over-optimistic or over-pessimistic though on average the market is rational. Secondly, REH does not require every individual to collect and form the expectations for them. More often some people will depend on others' expectations, such as well-known economists. When these economists' expectations are rational, then the economy as a whole might be rational. Thirdly, when people's expectations turn out to be mistakes, it does not necessarily mean that a better course of choice was available or would have been preferable, under the revealed reality. These expectation mistakes are shocks in the economy which are random with a mean of zero and have a variance less than that associated with any other model of prediction. Fourthly, REH does not argue that people can automatically know which information is more important in formulating expectations. However, people are adaptive and can learn. Thus, REH is best regarded as a long-run argument. Finally, Attfield *et al.* (1986) claim that people can make rational expectations even when variables are formulated by unique and unusual processes. This is because people will have enough information to generate a sensible estimation of the process.

Beyond these misunderstandings, there are additional criticisms about REH. For instance, although people make rational expectations, the representative people describing these actions may not satisfy rationality assumptions, see (Janssen, 1993). Furthermore, market anomalies such as the asset price bubble-burst cycle indicates the market as a whole may be occasionally irrational. Akerlof and Shiller (2010) suggest so many economists have gone so far in the direction of REH that they ignore the vital dynamics underlying financial crises. Failing to incorporate people's irrational expectation and noneconomic action into the model can mislead us to the real sources of trouble. In housing literature, Xiao and Randolph Tan (2007) quantify the changes in the housing bubble using the rational expectation hypothesis.

2.2.4 Quasi-rational or Bounded Rationality Hypothesis

Unlike the REH, behavioural finance acknowledges that people's expectations, individually and collectively, are affected by inadequate information and the inability to process the information they have in an unbiased fashion. Consequently, people display bounded rationality. Assuming bounded rationality, people make expectations and decisions to help them satisfice rather than make theoretically optimal decisions. People collect what they think to be a sufficient amount of information and apply heuristics to achieve an acceptable decision. People take steps to achieve short-run targets, as long as they assist people toward their ultimate desired target.

Conlisk (1996) suggests there are four reasons for incorporating bounded rationality into economic study. Firstly, there is a bulk of empirical evidence that bounded rationality is important, see (Froot and Obstfeld, 1991; Black *et al.*, 2006). Secondly, models of bounded rationality have documented themselves in a wide range of impressive work. Thirdly, the popular justifications for assuming full rationality are unconvincing. Finally, deliberation about an economic decision is an expensive activity, and sensible hypotheses require that people incorporate all expenses.

The behavioural financial models in particular the Adaptive Market Hypothesis (AMH), suggest that given people must adapt to survive (satisfice), asset prices can be temporarily mispriced and no one investment strategy can continually outperform. Success in the market is an evolutionary process.

Langlois (1990) suggests people's limitations may take the form of an inability to process a complex optimization problem. However, such a limitation makes people not bounded rational but bounded skilful. Rationality is a matter of doing the best one can with the given knowledge and abilities. The philosophy of acting reasonably already implies limited abilities and has boundedness built in.

Hendry (1984) argues that ‘sensible’ expectations, which are not systematically biased, yet are not fully efficient seems to provide a more reasonable and realistic compromise in the UK’s housing market. Bounded rationality helps to interpret the anomalies of financial markets (Genesove and Mayer, 2001; Scanlon and Whitehead, 2010; Schiliro, 2011).

2.3 The Institutions and Institutional Changes in the UK Since 1970s

2.3.1 The Institutions and Institutional Changes

There is controversy on the relationship between market participants and institutions. Rational choice approach regards institutions as a strategic choice and/or a result of an economics game. Therefore, market participants are rule makers and their practices generate norms, making rapid deviations costly and thus institutionalizing the practices. Others view market participants as rule takers (North, 1990; Hall and Soskice, 2003; Helmke and Levitsky, 2004). North (1990) explicitly excludes organizations as institutions. For instance, North (1990) regards banks as organizations instead of institutions. Yet the banking system itself is essentially shaped by the institutional system (Roland, 2004). However, the recent literature (Morgan *et al.*, 2010) suggests market participants and institutions are mutually constitutive of each other.

Without denying the importance of formal institutions, recent literature (Hall and Soskice, 2003; Helmke and Levitsky, 2004) emphasises ‘the importance of informal rules and understandings to securing equilibria in the many strategic interactions of the political economy’. The shared beliefs among interdependent people are foundational to their expectations of how others will behave. Laws are not the sole determinant of these shared beliefs. The primary determinant of the stability of a system is the extent to which beliefs about its functioning and benefits are popularly shared among people.

Hall and Soskice (2003) conceptualize two typical types of political economies according to how firms coordinate their endeavours. The Coordinated Market Economies (CMEs) are characterized for the non-market relations, collaboration, credible commitments and deliberative calculation on the part of firms. On the contrary, the Liberal Market Economies (LMEs) are characterized for the arms-length, competitive relations, competition and formal contracting, and the operation of supply and demand in line with price signalling. The typical LMEs include the US and the UK while most of continental European countries are CMEs. However, the framework of Hall and Soskice (2003) is overly static, with institutional changes only seen as rapidly exogenous shocks, see (Kang, 2006; Hancké, 2009).

Roland (2004) distinguishes between sets of institutions based on whether they change slowly and continuously or rapidly and irregularly. The slow-moving institution is also named 'culture', including values, beliefs and social norms. The evolution of culture is significantly linked to the development of technology and scientific knowledge. Like culture, technology and knowledge evolve slowly and continuously. However, the pace may vary. The development of technology and culture are fairly hard to predict because they are subject to the laws of the evolution of knowledge. On the contrary, fast-moving institutions such as political institutions and/or legal systems do not necessarily change frequently, but can changes more rapidly even almost overnight. Slow-moving institutions are good candidates to impact fast-moving institutions. Slow-moving institutions must change continuously so that they produce inconsistencies with fast-moving institutions which, in turn, create pressure for change.

Roland (2004) suggests that it is the interaction between slow-moving institutions and fast-moving institutions that drives the institutional changes which, in turn, compounded with technology advances that which drives economic growth. Institutional changes are driven by social forces that favour it and are resisted by those that would experience a loss from it. The balance of power between those social forces determines the dynamics of change. Nonetheless, the changes in the relative strengths of those social forces also depend on the existing institutions. Therefore, reforms (fast-moving institutions) in a given economy must in part build on its local conditions (slow-moving institutions). From another perspective, the characteristics of a given institutional change are likely to differ between economies, either in terms of directionality or degree.

Similarly, Culpepper (2005) suggests the sufficient condition for institutional change is the change in ideas, with the process by which people apply triggering events to coordinate their future anticipations around the new rules of the economy. The formal institutional framework argues that legal change will precede and cause behavioural change in the practice of an economy. Culpepper (2005) argues that legal reform is often a necessary but insufficient condition for institutional change in Coordinated Market Economies, given people's shared beliefs can persist even after changing the formal laws. Where coordinated financial systems depend mainly on the strategic interaction of dominant market participants. Institutions do not automatically change their response to regulatory reform. The institutions change only when the dominant market participants within the system are willing to devise their new cognitive maps.

In literature, people study institutions in two different ways, either as exogenously given constraints (North, 1990); or as endogenously-appearing self-enforcing rules (Aoki, 2001). If the constraints they impose are not enforced, the institutions will be meaningless. For the purpose of investigating specific institutions, it suffices to treat institutions as exogenous and study their impacts on human behaviour and interaction (Roland, 2004).

2.3.2 Institutional Changes in the UK Since 1970s

Following Roland (2004) and Culpepper (2005), this section reviews the institutional changes in the UK since the 1970s from two perspectives, political and legal changes; and norms and technological change.

At the political and legal level, British government concentrates on Keynesian economic policies and transforms Britain into a welfare state from 1945 to 1979. Through the Thatcher revolution since 1979, Britain transitioned to a more free market economy or a neoliberal model thereafter. Generally speaking, the economic liberalization process in the UK is sudden and decisive, for example, the 'Big Bang' in 1986. One of the key characteristics of the UK economic liberalization is minimal state intervention. This means the state 'steer' and regulate economic activity but do not 'row' and intervene as an economic player. According to Hall and Soskice (2003), what defines a liberal market economy is not the character of state intervention but how firms coordinate their endeavours. Therefore, the institutional in the UK does not change as much as many may think. Obviously, there is room for disagreement about such matters.

Konzelmann *et al.* (2010) suggest the political and economic climates of the 1970s and early 1980s significantly influenced the US and the UK returns to neoliberal model. With the failure of the Bretton Woods Agreement in 1971, international capital movement restrictions and fixed currency regimes are no longer in place among major Western economies. Therefore, the economic liberalization begins with capital flow deregulation. In the UK, the Heath government attempts to liberalize the money markets and stimulate competition among banks by introducing a policy of 'Competition and Credit Control' in 1971. Consequently, quantitative restrictions on bank lending are removed and interest rates tend to play a key role in the allocation of credit. Meanwhile, in response to increasing unemployment, the Heath government introduces a 'dash for growth'. Therefore, increasing bank lending stimulates monetary expansion and economic growth. However, with the fight for a backdrop of worldwide inflationary situations during the 1970s, the housing market speculation inflates a housing bubble which eventually leads to the Secondary Banking Crisis between 1973 and 1975. From 1976 to 1979, the Callahan government strongly convinces the value of many of Friedman's monetarism ideas. However, they do not get the chance to put these ideas into practice.

Baddeley (2005) suggests significant institutional changes, especially those implemented by the Thatcher government from 1979 onwards, exacerbates the instability of the housing market. Thatcher's reform can be broadly divided into three categories. Firstly, the financial changes with deregulation, for instance, the removal of constraints on mortgage rationing. Secondly, the fiscal changes, including changes in incentive to purchase. Thirdly, changes impacting the supply of alternatives to owner occupation.

Deregulation influences the housing markets via financial markets (Muellbauer and Murphy, 1997; Baddeley, 2005). The deregulation of the Building Societies in 1981 allows a substantial increase in mortgage liquidity and market instability. Financial deregulation reduces the vital role of Building Societies in offering mortgage lending backed by household savings. A wide range of other financial institutions enter into the mortgage lending market and this mortgage lending could be backed by a range of instruments such as the short-term money market funds. The removal of mortgage constraints increases the average leverage rates and the UK housing market volatility, due to the terms of mortgages becoming more flexible.

Shiwakoti *et al.* (2008) suggest that about 80% of the total assets of Building Societies eventually transfer to the banking sector, since the enactment of the UK Building Societies Act

1986. According to O’Connor (2010), the proportion of total mortgages outstanding provided by Building Societies dramatically declines from more than 60% in the mid-1980s to 14% by 2010. Therefore, any analysis based on the data of Building Societies alone should take these institutional changes into account. Building Societies are non-profit cooperatives with low legal minimum reserve ratios, which ensure that they run on small margins of lending over borrowing interest rates.

Baddeley (2005) argues that financial uncertainty starts to creep into the mortgage market as interest rates rise in response to the inflationary consequences of the Lawson boom from 1986 to 1988 in the UK. Throughout the 1980s and early 1990s, lot of borrowers hold variable rate mortgages which depend on high multipliers of their incomes and have an inadequate financial ability to adapt to interest rate increases. Increases in unemployment accompanied with rises in mortgage rates meant that more people have to default on their mortgages which, in turn, translate into pressure for declining house prices. Consequently, mortgage lenders are facing uncertain cash-flow and they have to increase financial stringency. Because the mortgages are no longer backed up with retail deposits, the Building Societies are unlikely to reduce costs during downturns by cutting their interest payments to depositors.

Other fiscal reforms impact the substitutes for owner-occupation such as council house sales and the declining investment in public housing; generate additional pressures in the owner-occupied market.

Apart from the rapid political and legal changes, there are also slow but continuous institutional changes at the norms and technological level. For example, the proportion of UK households who owned their own homes increases from 56% to above 68% from 1981 to 2007. On the contrary, the private rental sector in the UK declines from 33% in the 1960s to 10% in the 1980s and the figure has not yet significantly recovered. The right to buy council houses in the 1980s and the consequent reluctance of local authorities to build have placed additional pressure on private rents; and could be a possible source of breaks in the relationship between rental and ownership.

Ortalo-Magné and Rady (2002) suggest that the stimulation of owner occupation increases housing demand by providing more and cheaper mortgages and privatizing state-owned housing exacerbates market volatility. Furthermore, prior to the ‘Big Bang’ liberalization, the City is populated by small, specialist companies which are largely immune from takeover. The liberalization process gives rise to the ‘Wimbledon Effect’, where a successful London financial market is increasingly composed of foreign actors, see (Konzelmann *et al.*, 2010). Information Technology makes it possible for affiliates of overseas firms to operate internationally and more rapidly to engage in supervisory arbitrage.

The wave of ‘short-termism’ in the UK since the 1960s accompany with financial innovation and deregulation drive people to become increasingly impatient for a quick return on their investments. Traditionally, banks used deposits to fund loans that they then leave on their balance sheets until maturity which refers to the originate-to-hold model. Banks and Building Societies transit to the more aggressive originate-to-distribute model, especially from 2001 to 2006. Financial assets turn into people’s gambling chips. In the UK, the extraction of equity from houses to finance additional investment is a notably form to enhance household leverage over the past decades. In particular, the financial innovation and deregulation make the US and the UK financial industries more dependent than ever on the housing market in terms of mortgage securitization since the 1990s. Mortgage securitization refers to the financial practice of pooling various types of mortgages as pass-through securities, or collateralized mortgage obligations to various investors. Take the massively used originate-to-distribute model for example, the mortgage lenders borrow short-term cheap funding from the capital markets, and then lend long-term expensive mortgages to mortgage borrowers. Through the selling of mortgage backed securities to other investors, mortgage lenders not only raise capital to meet their short-term liabilities but also improve their asset liquidity and profitability. Because more than one class of pass-through securities may be backed by a single mortgage pool, mortgage securitization and the originate-to-distribute mode will dramatically amplify the volume of mortgage related derivatives and financial risks. Schwarcz (2007) argues that the securitization and the originate-to-distribute model create moral hazards, given these lenders do not have to live with the credit consequences of their loans. Consequently, the mortgage underwriting standards decrease.

2.3.3 Evaluation of the Liberalization Since 1970s

With the economic liberalisation since the 1970s, the industrialized economies make the transition from a manufacturing to a service-based economy. Financial services sector transition from a pure financial intermediary into an industry in its own right; and significantly increase competition among financial corporations, see (Toporowski, 2002). Gamble (2009) suggests financial services become the engine of growth in many countries, particularly in the US and the UK. According to the OECD Factbook 2009, the percentage of value added by financial services to the total value added, increases from 15% in 1975 to 33% in 2007, in the UK.

However, the global financial crisis in 2008 not only presents a 'shock event', but also incentivizes rising people to critique and re-evaluate the liberalization and institutional changes over the past decades. For instance, people criticize the US and UK institution's lack of transparency and communication and the inability to exercise macro-prudential regulation within the market as a whole. However, through investigating the differing performance of four major Liberal Market Economies (LMEs), the US, the UK, Canada and Australia, Konzelmann *et al.* (2010) deny the failure of the LME variety of capitalism. Instead the Subprime Crisis results from the failure of the neoclassical variety of liberal capitalism.

Palley (2009) argues that the liberalization or neoliberal model since the 1980s inaugurates an era of wage stagnation. The essential argument is that the neoliberal model depends on rising borrowing and asset price inflation, to cover the inadequate aggregate demand resulting from wage stagnation and increasing wealth inequality. The new institutions are always unsustainable. However, financial innovation and liberalization helps the neoliberal's model going far longer than expected. Financial instability hypothesis (Minsky, 1992) is a good candidate to interpret these delay mechanisms.

Minsky (1992) suggests that a free market economy is inherently unstable. In times of stability, people will extrapolate the current stability forward into the future, which stimulates higher risk bearing, especially in levered investments. Minsky's framework is evolutionary instability. Simply put, it argues 'success breeds excess breeds failure'. The basic Minsky instability cycle begins with 'hedge finance' when people expect incomes which are sufficient to cover interest and outstanding loans. It then enters into 'speculative finance' when incomes are only sufficient to repay interest. The basic Minsky cycle ends with 'ponzi finance' when incomes are insufficient to repay interest payments and people are primarily relying on capital gains to cover their obligations. By contrast, the super Minsky cycle takes several basic cycles, allowing rising supply of and demand for financial risk. Minsky's framework incorporates institutions, evolutionary dynamics and human psychology. Empirically, it is roughly consistent with the developments over the past decades. Since the 1980s, there are three business cycles, namely, 1981-1990, 1991-2001, and 2002-2009. Each of these business cycles is consistent with a basic Minsky cycle in which people take on increasingly more financial risk. The period as a whole is consistent with the super Minsky cycle involving financial deregulation, innovation and changes in people's appetite for risk. Minsky (1992) regards a capitalist crisis as a purely financial phenomenon where financial instability results from the progressive removal of market disciplines.

According to Palley (2009), the structural Keynesianism and the generic Marxist beyond the Minsky's framework by suggesting that there is an underlying real economic problem regarding wage stagnation and deterioration of wealth distribution. Financial excess is always a patch of the fundamental economic contradiction. Therefore, their institutional design would have a significantly larger public sector and more government intervention, in particular regarding the financial sector.

2.4 Conclusion

This chapter reviews what factors are specific to the UK housing market from three aspects. Firstly, what common factors may drive the housing risk-return? Secondly, how the desirability of outcome or expectation drives people to behave based on house prices (Lucas critique)? Thirdly, how the changes in institutions will affect the housing market?

Among the three factor models, this chapter reviews the application of the macroeconomic factor model and the fundamental factor model in the housing market in terms of a closed economy and open economy framework. This thesis discusses the statistical factor model such as the principal component analysis in Chapter 6. Unsurprisingly, people are likely to ask two questions about the factor model literature. Firstly, is the methodology of Hendry (1984) still suitable to the UK housing market using more recent datasets? Secondly, is an open economy framework superior to a closed economy framework?

Given the four expectation hypotheses have quite different implications on housing price and investment practice, it is interesting to study which one is more suitable to the UK housing market.

Given Britain experienced a battery of formal and informal political and social changes since the 1970s, it is interesting to investigate how the effect of common factors and expectations behave on the UK housing market over time.

Through care and due diligence, investigation of the above issues on a timely basis, academic researchers can evaluate and develop economics theories with more sound evidence, economically rational investors can develop more sensible investment strategy; and policymakers can regulate the market more effectively.

In the remainder of the thesis, Chapter 3 re-estimates the principal equations of Hendry (1984) to four recent British housing datasets. Chapter 4 expands the equations of Hendry (1984) to an open economy framework by incorporating Foreign Portfolio Investment (FPI). Chapter 5 accesses the expectation hypotheses by proposing the user cost framework in a state space model. Chapter 6 investigates the institutional changes in the UK housing market, by using the structural break tests and time varying parameter models. Chapter 7 studies the causal relationships between people's expectations and house price changes using the UK regional panel data. Chapter 8 concludes the thesis.

Chapter 3. Updating the Econometric Modelling of House Prices in the United Kingdom

3.1 Introduction

Following the Literature Review, this chapter replicates the principal equations of Hendry (1984) to four recent datasets. The purpose of this chapter is to demonstrate the limitations of Hendry (1984), which sets the scene for the development of models in Chapters 4 through to 7. Specifically, this chapter addresses two issues.

- Firstly, Hendry (1984) is the last major work on the UK housing market using classical demand and supply equations in which house prices are determined by the demand for housing. It is interesting to study whether his result is replicable by similar datasets, in particular more recent datasets.

- Secondly, Brown *et al.* (1997) suggest that early studies, including Hendry (1984), are poor in terms of robustness, and find that the regression coefficients vary in both sign and magnitude over samples. The chapter considers whether simple modifications can improve the model fit and robustness.

This chapter excludes the subsections of 'A Dynamic Model of the Market for Owner occupied Housing' and the closely related 'The Autoregressive Distributed Lag Representation', 'Cubic Excess Demand Model' and the 'Cubic Difference Equation' in Hendry (1984) for two reasons. Initially, Hendry (1984) concludes that the 'Restricted Parameterisation' model is superior to the 'Cubic Excess Demand Model' and the 'Cubic Difference Equation' models. Secondly, the 'dynamic models' in Hendry (1984) assume that the underlying data generating process is stable and apply fixed parameter models, which is technically the same as the 'Restricted Parameterisation' model.

The chapter is structured in the following way. Section 3.2 describes the datasets. Section 3.3.1 refers to the descriptive statistics. Section 3.3.2 presents a possible expectations model. Section 3.3.3 illustrates a restricted parameterisation model. Section 3.4 concludes the chapter.

3.2 Data Description

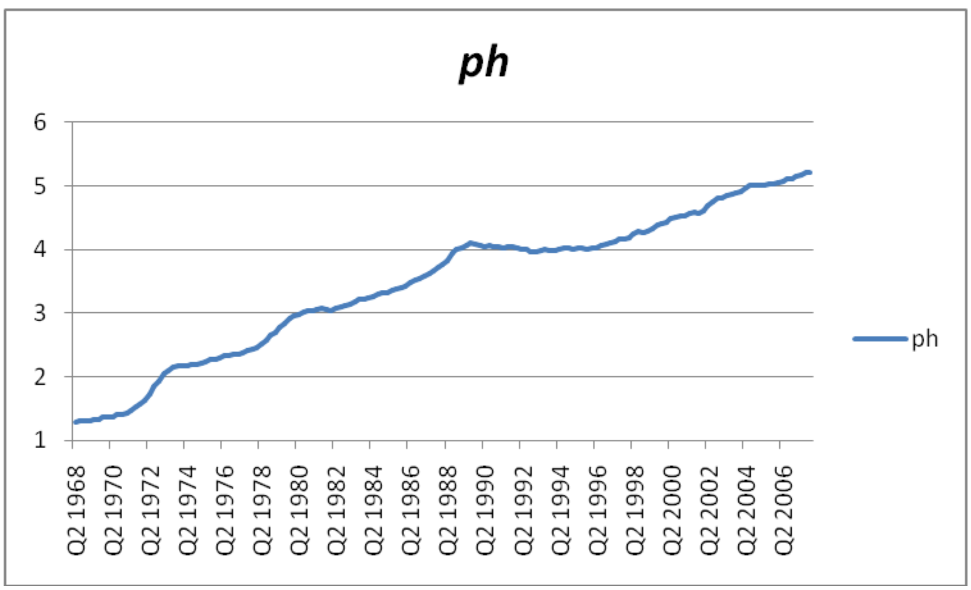
The data included in this study are Department for Communities and Local Government (DCLG) House Price Index (HPI), the Retail Price Index (RPI), the mortgage rates of Building Societies, the composite mortgage rate of Building Societies and Banks, aggregate mortgage outstanding of Building Societies and Banks, real aggregate household disposable income and the house completions series from the United Kingdom. All the quarterly time series data were collected from DataStream and cover the period from 1968Q2 to 2007Q4. The starting dates are chosen by the availability of data for the HPI and the ending dates are chosen by the availability of data for the house completions. The chapter sets the House Price Index (HPI) and the Retail Price Index (RPI) equal to 100 at 2002Q1. Except where specifically mentioned, all the variables are in nominal terms. Throughout this chapter, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts.

This chapter investigates four datasets, namely, 1968Q2-1982Q4; 1983Q1-2007Q4, 1968Q2-2007Q4 and 1995Q1-2007Q4. The dataset 1968Q2-1982Q4 is used to examine whether the results of Hendry (1984) are replicable by using a similar dataset. The dataset of Hendry (1984) ranges from 1959Q1 to 1982Q2. The other three datasets investigate whether the findings of 1968Q2-1982Q4 are robust over samples. The dataset 1995Q1-2007Q4 uses the composite mortgage rate of Building Societies and Banks, while all the remaining three datasets use the mortgage rate of Building Societies. The date for 1995Q1 is chosen by the availability of data for the composite mortgage rate.

There are different datasets available on house prices for the UK. The chapter uses the Department for Communities and Local Government (DCLG) House Price Index (HPI) primarily because it has one of the longest time span which is comparable to Hendry (1984). DCLG HPI uses the mix-adjusted method, which is based on weighted averages. DCLG HPI uses mortgage completion data supplied by a few large lenders. By contrast, Hendry (1984) uses the second hand HPI which is simple average till 1968Q2 and then weighted average. Additionally, Hendry (1984) uses the data of gross mortgage outstanding and nominal mortgage rate from Building Societies. However, Building Societies have contributed to a declining proportion of the UK's aggregate mortgage outstanding since the financial deregulation and innovations of the 1980s. Therefore, this chapter uses net secured lending to individual house purchase from Building Societies and Banks to proxy the aggregate mortgage outstanding, which accounts for more than 75% of the UK's total mortgage outstanding by 2007Q4 according to the Bank of England. The chapter uses both the mortgage rates of Building Societies and composite mortgage rate of Building Societies and Banks for illustration purposes. In Appendices, Table A and Table B display the variable sources and definitions; Table C illustrates a basic variable summary.

Figure 3.1 plots nominal house prices index in log scale. House prices appreciate by six fold from 1968Q2 to 1982Q2 which is roughly consistent with Hendry (1984), although Hendry uses a different HPI. The price boom continues until 1988Q4 and increased by 254% relative to 1982Q2. From 1989Q1 to 1995Q4, the UK house prices remain stable, and then house prices increase by three fold between 1996Q1 and 2007Q4.

Figure 3.1 House Price Index (ph_t)



Given the dominant trend in Figure 3.1 masks the short-run price fluctuations, Figure 3.2 displays the quarter to quarter proportional variations, $\Delta_1 ph_t$, which is the first natural log difference of house price index. The quarterly changes in house prices peak at 1972 and bottom out at 1992. The change in house price is positive for most of the time and shows 'cyclical' behaviour. The findings in Figure 3.2 are consistent with Hendry (1984) between 1968Q2 and 1982Q2; the quarterly changes in house price remain stable from 1983 to 1986; climb in 1988;

the price declines most of the time from 1989Q4 to 1996Q1; and remains modestly volatile thereafter.

Figure 3.2 Quarterly Changes in HPI ($\Delta_1 ph_t$)

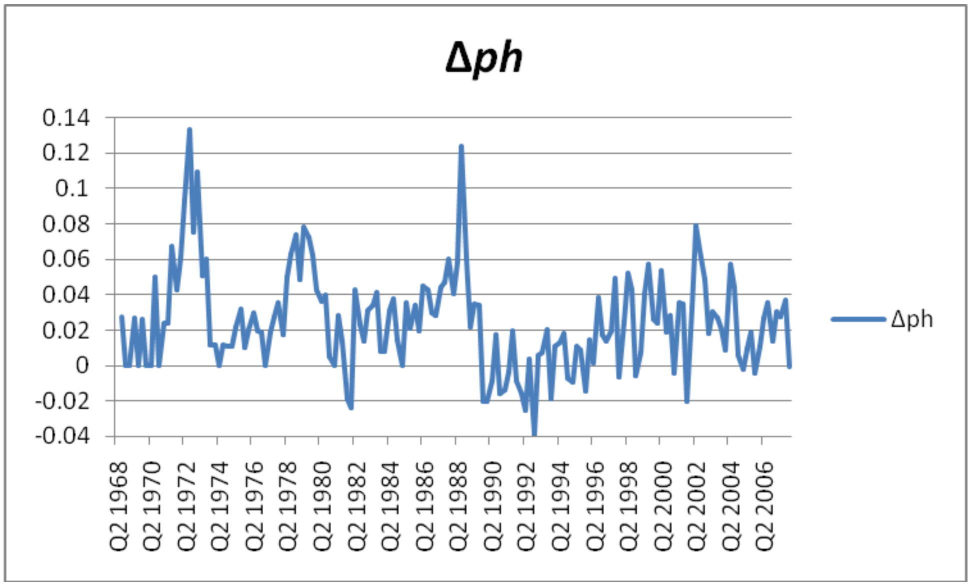


Figure 3.3 plots the annual changes in house prices index $\Delta_4 ph_t$ against the annual changes in retail price index $\Delta_4 p_t$, for the purpose of displaying the 'cyclical' behaviour of house prices. Where, $\Delta_4 ph_t = ph_t - ph_{t-4}$ and $\Delta_4 p_t = p_t - p_{t-4}$. Figure 3.3 shows several interesting findings. Initially, the annual variations in house prices are far more volatile than those of the retail price index. Secondly, these two time series are impressively asynchronous, seemingly illustrating changes in house prices not only causing general inflation by several years but also on average exceeding the changes in retail prices. Consequently, real house price $(ph - p)_t = logPH_t/logP_t$, which are nominal house prices deflated by inflation, should have increased. Figure 3.4 suggests that real house prices $(ph - p)_t$ remain constant from 1968 to 1971; mushroom from 1972Q1 to 1973Q4; and then decrease by 60% from 1974Q1 to 1977Q3; experience remarkably growth between 1978 and 1989, despite reporting modest recession in 1980; real house prices experience a significant reduction from 1989 to 1995; and then increase dramatically and peak at 2007Q4.

Figure 3.3 Annual Rates of Change in House Prices ($\Delta_4 ph_t$) and Retail Price Index ($\Delta_4 p_t$)

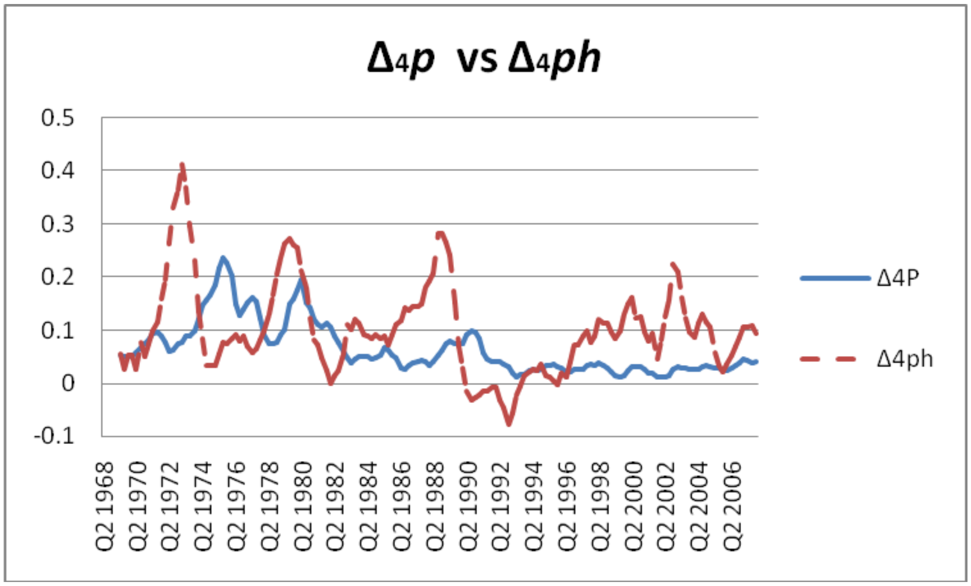
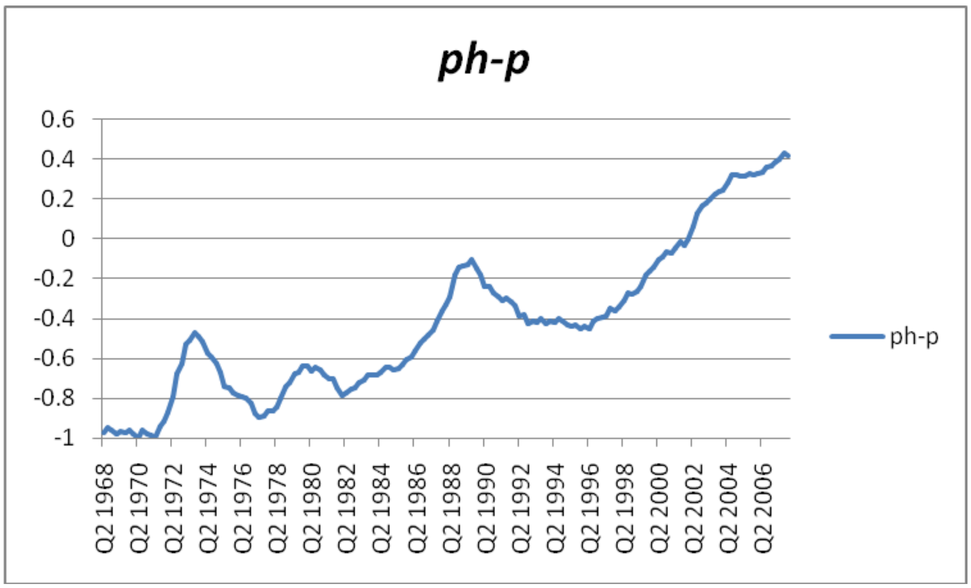
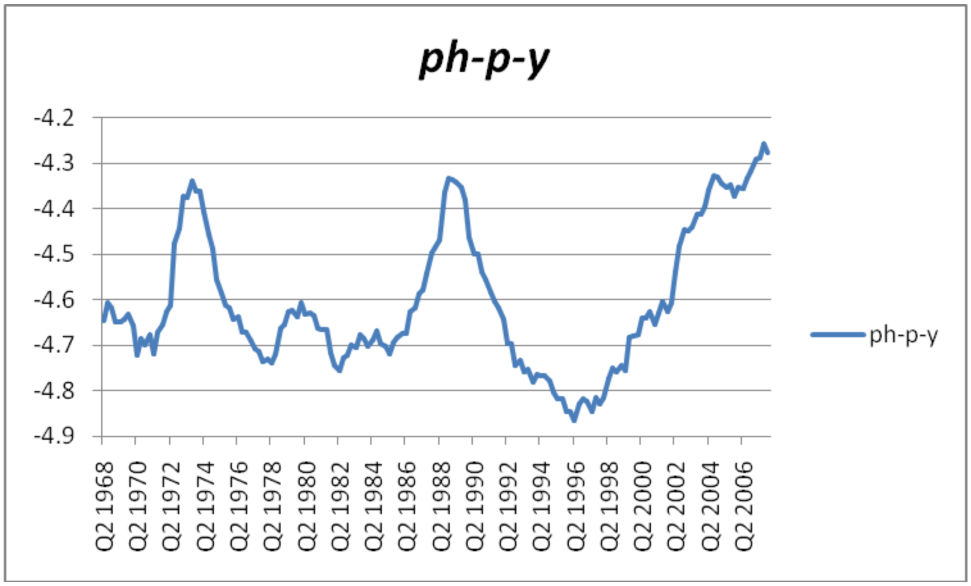


Figure 3.4 Real House Prices $(ph - p)_t$



Based on the hypothesis that home prices and incomes share some common trends in the long-term, aggregate demand for a home should be a stable function of the average income. So, a higher price-income ratio means housing prices are too high. From Figure 3.5, which exhibits the price-income ratio, the UK house price-income ratio reports dramatic fluctuation and the ratio constantly converge to a ‘base level’.

Figure 3.5 Price-income Ratio $(ph - p - y)_t$



The real disposable income is an average evaluation that covers the aggregate population, but the specific groups of sellers and buyers that determine the house prices may have income that is significantly different from the population mean. Furthermore, the price-income ratio measures the local purchasing ability relative to the local housing prices (Himmelberg *et al.*, 2005); it does not consider the purchasing power from outside of the local statistical area.

The average value of housing per unit income $(ph + h - p - y)_t = log(Ph \times H)_t / log(P \times Y)_t$, is the next closely related data variable. It is fairly hard to measure this variable accurately because HPI Ph is related to owner occupied housing, while $P.Y$ is aggregate disposable income. On the one hand, it is inappropriate to use HPI Ph if H is represented by the total housing stock, unless in the extremely rare case that homes owned by landlords and authorities have the same average price as privately owned homes. On the other hand, if the owner occupied stock is selected to proxy H, $P.Y$ is not the most relevant income variable for the reasons exhibited above. Following Hendry (1984), this chapter selects the owner occupied stock of housing, using data on completion of private sector, to proxy physical housing stock H.

Figure 3.6 plots the average value of housing per unit income $(ph + h - p - y)_t$ against the real value of the mortgage stock $(m - p - h)_t$. Figure 3.6 shows there is a much larger gap between these two time series than that in Hendry (1984). And the correlation between these two variables changes over time. According to the author's calculation, the correlations between the two variables are -0.7979, 0.0023, -0.0551 and 0.5577 for 1968Q2-1982Q4, 1983Q1-2007Q4, 1968Q2-2007Q4 and 1995Q1-2007Q4, respectively.

Figure 3.6 Average Value of Housing per unit Income $(ph + h - p - y)_t$ and Real Value of Mortgage Stock $(m - p - h)_t$

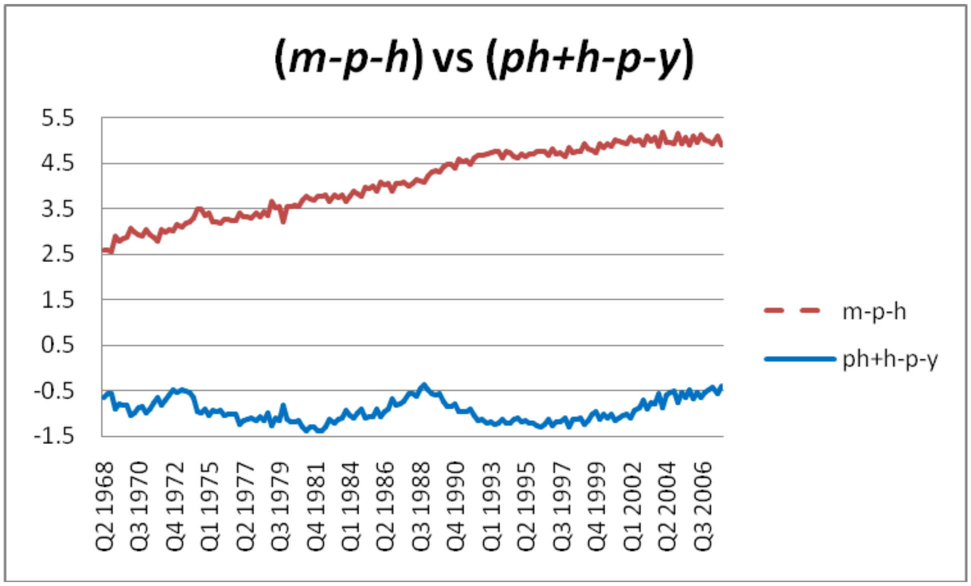
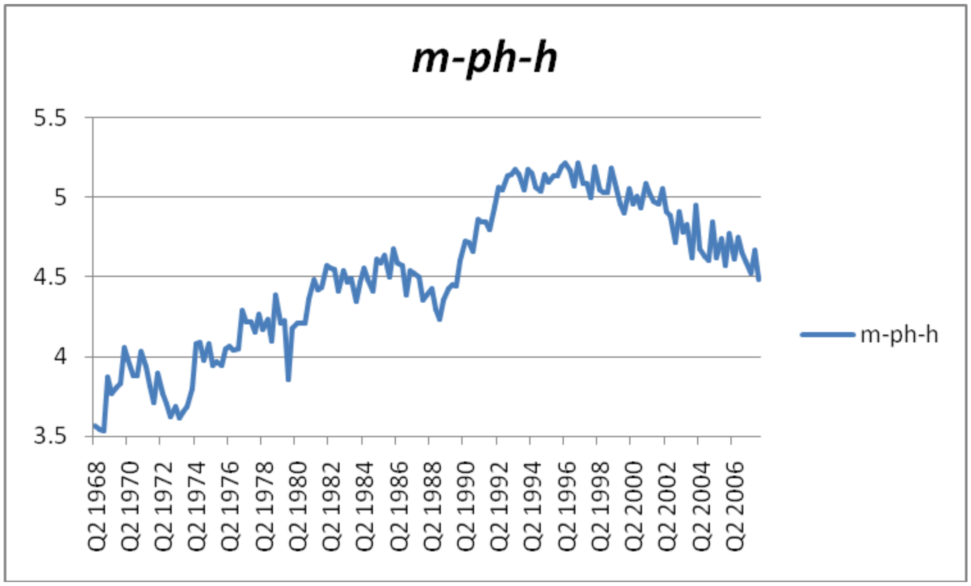


Figure 3.7 displays the borrowed to own equity ratio $(m - ph - h)_t$. Although it experiences several short time reductions, the borrowed to own equity ratio remains an upward trend from 1968 to 1986; peaks at 1995Q2; and then enters into the long-time downward movement without a significant rebound by 2007Q4. Figure 3.7 reveals mortgage leverage plays a rising role in home transactions prior to 1996. Thereafter, the ratio declines primarily because of the significant increase in house prices since 1996. The increase in home prices improves the proportion of equity, and then reduces the level of leverage. Overall, the findings in Figures 3.1 through to 3.7 are roughly consistent with Hendry (1984) over the period from 1968Q2 to 1982Q2.

Figure 3.7 Ratio of Borrowed to Own Equity $(m - ph - h)_t$



3.3 Empirical Estimates of the UK House Prices

Section 3.3.1 displays the descriptive statistics. Section 3.3.2 investigates a possible expectations model and a restricted parameterisation in Section 3.3.3. Throughout the chapter, EVIEWS 7.2 executes the ADF unit root tests; STATA 12 conducts all the reminder of estimations. All the empirical equations apply to the four datasets simultaneously for the purpose of comparison.

3.3.1 Descriptive Statistics

Following Hendry (1984), the chapter firstly investigates equation (3.1) for each variable to assess the autoregressive characteristics over time. Equation (3.1) is a typical Augmented Dickey-Fuller (ADF) test specification with constant and three lagged first differenced dependent variable. Given equation (3.1) does not necessarily is the optimal ADF test specification, Table 3.2 displays the ADF test according to the Enders (2010) testing procedure in which the ADF test specification explicitly considers the optimal lag length of the first differenced dependent variable; and the selection of constant and/or trend terms.

$$\Delta_1 x_t = \alpha_0 + \alpha_1 x_{t-1} + \sum_{i=1}^{3} \alpha_{1+i}\, \Delta_1 x_{t-i} + \varepsilon_t \qquad 3.\ 1$$

$\Delta_1 x_t = x_t - x_{t-1}$. x_t denotes the economic variable. α_0 is constant. α_i is the constant coefficient for the i-th lagged variable. ε_t is error term or residual. Table 3.1 shows the results for the four datasets. Except for a few exceptions, such as the changes in mortgage outstanding $\Delta_1 m_t$ for 1995Q1-2007Q4, the majority of regressions report residual non-normality, heteroskedasticity and/or autocorrelation. Apart from the changes in house completion $\Delta_1 h_t$ for the sample 1968Q2-2007Q4, at least one of the coefficients is statistically insignificant for the rest of the regressions at the 5% significance level.

From an econometrics perspective, when the error terms present the heteroskedasticity and/or autocorrelation, the 'normal' standard errors will be too small to find the properly coefficient significant effect. Usually, one could use the White standard errors and/or Newey-West standard errors (White, 1980; Newey and West, 1987) to correct for the heteroskedasticity and/or autocorrelation. However, this chapter does not attempt these 'robust' standard errors primarily because the sample size of this chapter is fairly small. There are 159 observations for the full dataset 1968Q2-2007Q4 and 59 observations for the sample 1968Q2-1982Q4. In small samples, White (1980) 'robust' standard errors can be more biased than conventional ones (MacKinnon and White, 1985; MacKinnon, 2013).

Table 3.1 Time Series Descriptions

$\Delta_1 \boldsymbol{x_t} = \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1 x_{t-1}} + \sum_{i=1}^{3} \boldsymbol{\alpha_{1+i}}\, \Delta_1 \boldsymbol{x_{t-i}} + \boldsymbol{\varepsilon_t}$

Δx_t	x_{t-1}	Δx_{t-1}	Δx_{t-2}	Δx_{t-3}	α_0	$Adj.R^2$	$\hat{\sigma}$	ς_1	ς_2	ς_3
1968Q2-1982Q4										
$\boldsymbol{\Delta_1 ph_t}$	-.007	.4448***	.3016**	-.0272	.0253*	0.4216	.0236	.0876*	.4650	.5765
	(.0056)	(.1398)	(.147)	(.1384)	(.0134)					
$\boldsymbol{\Delta_1 y_t}$	-.0418	-.1604	.0169	-.1244	.1679	0.0122	.0211	.0754*	.6405	.3886
	(.0294)	(.1375)	(.1397)	(.1369)	(.1131)					
$\boldsymbol{\Delta_1 m_t}$	.0018	.8273***	.0312	-.1247	-.0070	0.6463	.0057	.0583*	.1023	.8458
	(.0014)	(.1408)	(.1810)	(.1422)	(.0124)					
$\boldsymbol{\Delta_1 p_t}$	-.0005	.4300***	.0726	.0684	.0136	0.1762	.0153	.0000***	.002***	.007***
	(.0043)	(.1421)	(.1574)	(.1466)	(.0124)					
$\boldsymbol{\Delta_1 R_t^*}$	-.1222*	.1500	.1003	-.1172	1.1486*	0.0308	1.1225	.0000***	.5989	.1090
	(.0677)	(.1369)	(.1410)	(.1418)	(.6364)					
$\boldsymbol{\Delta_1 h_t}$	-.1159	-.3836***	-.2128	-.383***	.4077	0.2771	.1067	.0684*	.6540	.0136**
	(.0858)	(.1328)	(.1388)	(.1256)	(.3141)					
1983Q1-2007Q4										
$\boldsymbol{\Delta_1 ph_t}$	-.0025	.4525***	-.0975	.2542***	.0187	0.2369	.0220	.0827*	.6030	.0016***
	(.00396)	(.0999)	(.1103)	(.09965)	(.0167)					
$\boldsymbol{\Delta_1 y_t}$	-.0107**	-.458***	-.0588	.0157	.0578**	0.1790	.0110	.0122**	.3504	.2599
	(.0051)	(.1006)	(.1093)	(.0996)	(.0228)					
$\boldsymbol{\Delta_1 m_t}$	-.0043**	.4502***	-.1074	.3665***	.0603**	0.7509	.0071	.0431**	.0001***	.0002***
	(.0020)	(.0944)	(.1051)	(.0938)	(.0270)					
$\boldsymbol{\Delta_1 p_t}$	-.009***	.0148	.2742***	-.1832*	.0472***	0.1665	.0073	.0000***	.0015***	.0000***
	(.0031)	(.0990)	(.0951)	(.0965)	(.0142)					
$\boldsymbol{\Delta_1 R_t^*}$	-.039*	.1500	.0420	.1904*	.2710	0.5480	.0463	.0000***	.0002***	.5150
	(.0234)	(.0999)	(.0980)	(.0972)	(.1807)					
$\boldsymbol{\Delta_1 h_t}$	-.1282*	-.6848***	-.4576***	-.538***	.4802*	0.5947	.0725	.0032***	.8314	.0000***
	(.0756)	(.0946)	(.1025)	(.083)	(.277)					
1968Q2-2007Q4										
$\boldsymbol{\Delta_1 ph_t}$	-.0029*	.4446***	.0569	.1531*	.0187***	0.3367	.0227	.0731*	.0404**	.0258**
	(.0017)	(.0807)	(.0885)	(.0801)	(.0069)					
$\boldsymbol{\Delta_1 y_t}$	-.0019	-.2518***	.0121	-.0600	.0164	0.0488	.0155	.0113**	.0000***	.8325***
	(.004)	(.0814)	(.0838)	(.0806)	(.0168)					
$\boldsymbol{\Delta_1 m_t}$	-.001***	.6035***	-.0533	.2945***	.0198***	0.7774	.0069	.0020***	.0050***	.0030***
	(.0005)	(.0778)	(.0920)	(.0770)	(.0069)					
$\boldsymbol{\Delta_1 p_t}$	-.005***	.3101***	.2666***	.0042	.0257***	0.4590	.0110	.0000***	.0000***	.0000***
	(.0015)	(.0813)	(.0822)	(.0798)	(.0067)					
$\boldsymbol{\Delta_1 R_t^*}$	-.0561**	.1404*	.0746	-.0330	.4366**	0.0237	.8022	.0000***	.0002***	.4660

	(.0262)	(.0808)	(.0816)	(.0816)	(.2195)					
$\boldsymbol{\Delta_1 h_t}$	-.1173**	-.5248***	-.2906***	-.444***	.4282**	0.4507	.0873	.0189**	.4414	.0000***
	(.0555)	(.0771)	(.0823)	(.0707)	(.2033)					
1995Q1-2007Q4										
$\boldsymbol{\Delta_1 ph_t}$	.0016	.2959**	-.2363	.1452	.0112	0.0322	.0211	.0002***	.6303	.0410**
	(.0078)	(.1460)	(.1486)	(.1463)	(.0344)					
$\boldsymbol{\Delta_1 y_t}$	-.0249*	-.4115***	-.0952	.1163	.1223*	0.1453	.0099	.0017***	.6933	.3933
	(.0137)	(.1406)	(.1525)	(.1392)	(.0632)					
$\boldsymbol{\Delta_1 m_t}$	.0010	.2311	-.0270	.1997	-.0038	0.0242	.0075	.1525	.0013***	.0034***
	(.0041)	(.1446)	(.1481)	(.1498)	(.0532)					
$\boldsymbol{\Delta_1 p_t}$	.00602	-.2248	.0145	-.3423**	-.0168	0.1335	.0051	.0000***	.4181	.0000***
	(.0074)	(.1379)	(.1415)	(.1345)	(.0339)					
$\boldsymbol{\Delta_1 R_t^*}$	-.1077**	.5545***	-.0064	-.0042	.5574**	0.2870	.2222	.0529*	.0570*	.5314
	(.0514)	(.1424)	(.1653)	(.1494)	(.2687)					
$\boldsymbol{\Delta_1 h_t}$	.0685	-1.019***	-.7832***	-.733***	-.2373	0.7690	.0630	.0005***	.4329	.2248
	(.1289)	(.1423)	(.1518)	(.1101)	(.4705)					

Notes: Adj. R^2 is the adjusted R^2 of the regression. $\hat{\sigma}$ is the standard deviation of the regression. ς_1 denotes for the Skewness-Kurtosis Normality Test with the null hypothesis of the data is normally distributed. ς_2 denotes for the Breusch-Pagan Test for Heteroskedasticity with the null hypothesis of the data is homoscedasticity. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation with the null hypothesis of there is no autocorrelation of any order up to p. The figures for ς_1, ς_2 and ς_3 are p-values. Δ_1 means first difference. ph_t is the house price index, y_t represents the real household disposable income, m_t is the mortgage outstanding, p_t is the general index of retail price. h_t is the physical housing stock. R_t^* is the after tax mortgage rate. The figures for the diagnostic tests are p-$values$. Subsample 1995Q1-2007Q4 uses the composite mortgage rate of Building Societies and Banks. All the rest of the samples use the mortgage rate from Building Societies. Coefficient standard errors in parentheses (·). In Appendices, Table A and Table B display the variable definitions and sources. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively.

According to the testing procedure of Enders (2010), Table 3.2 displays the results of Augmented Dickey Fuller (ADF) unit root tests for each variable where the appropriate number of lagged differences is identified by the Bayesian Information Criteria (BIC). Except for aggregate mortgage outstanding m_t, all the rest of the variables are stationary at first log difference in all the four datasets. The findings from Table 3.1 and Table 3.2 are generally consistent with Hendry (1984).

Table 3.2 ADF Unit Root Tests

ADF Unit Root Test							
	ph_t	y_t	m_t	p_t	h_t	$r^*(BS)_t$	$r^*(Comp.)_t$
1968Q2-1982Q4							
Level	0.7968	0.7037	0.9988	0.9711	0.4012	0.3625	/
1st Difference	0.0150**	0.0000***	0.3040	0.0009***	0.0000***	0.0000***	/
1983Q1-2007Q4							
Level	0.8650	0.2484	0.5091	0.3440	0.5819	0.6151	/
1st Difference	0.0556*	0.0001***	0.5665	0.0398**	0.0000***	0.0000***	/
1968Q2- 2007Q4							
Level	0.3521	0.9080	0.0507*	0.0143**	0.0645*	0.4371	/
1st Difference	0.0008***	0.0000***	0.4746	0.1016*	0.0000***	0.0000***	/
1995Q1- 2007Q4							
Level	0.9705	0.2876	0.9923	0.9977	0.9890	0.1873	0.1443
1st Difference	0.0000***	0.0000***	0.0000***	0.0447**	0.0000***	0.0055***	0.0028***

Notes: ph_t is the house price index, y_t represents the real household disposable income, m_t is the mortgage outstanding, p_t is the general index of retail price. h_t is the physical housing stock. $r^*(BS)_t$ is the after-tax mortgage rate from Building Societies. $r^*(Comp.)_t$ is the after-tax composite mortgage rate from Building Societies and Bank. The figures shown in the table are $p\text{-}values$. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively. The appropriate number of lagged difference for the ADF unit root test is identified by the Bayesian Information Criteria (BIC). The ADF test specifications for the after-tax mortgage rates $r^*(BS)_t$ and $r^*(Comp.)_t$ include constant only. For the rest of variables, the ADF test specifications include both of constant and trend.

The results of unit root tests do not ensure that the differenced time series alone merits analysis for a couple of reasons. Firstly, the findings of the ADF test will be biased, in particular when the underlying time series are highly volatile and over a long time horizon. Secondly, even though some variables are individually non-stationary, the linear combination of them might be stationary. The second reason refers to cointegration. The extent of autocorrelation in the residuals from the linear combination of the variables can indicate the presence of cointegration. When the residual of the linear equation itself is not significantly autocorrelated, then the cointegration is credible and *vice versa* (Hendry, 1984). Equation (3.2) examines such a chance and Table 3.3 shows the results. To make the results comparable to Hendry (1984), the chapter examines the residuals of equation (3.2) by using the Durbin-Watson (DW) statistics instead of the ADF tests. Throughout the thesis, the figures for 'Hendry's Eq.()' are drawn from Hendry (1984) for comparison purposes; the 'wrongly signed' coefficients are in bold. 'Wrongly signed' coefficient means the implied economic relationship violates the classical economic theory and therefore biased. This chapter assumes a coefficient is 'properly signed' when it is consistent with Hendry (1984). In reality, the linkage between two variables might be suppressed by the other variables, especially in a complex dynamic economy. Consequently, it is fairly hard to judge whether a coefficient is 'properly signed', without the control of the other omitted variables such as people's expectations. It does not make a lot of sense to talk about 'wrongly signed' coefficients when they are statistically no different from zero.

$$\widehat{ph_t} = \alpha_1 p_t + \alpha_2 y_t + \alpha_3 m_t + \alpha_4 h_t + \alpha_5 R_t^* + \alpha_0 + \varepsilon_t \qquad 3.2$$

Table 3.3 Investigates the Cointegration

$\widehat{\boldsymbol{ph}_t} = \boldsymbol{\alpha_1 p_t + \alpha_2 y_t + \alpha_3 m_t + \alpha_4 h_t + \alpha_5 R_t^* + \alpha_0 + \varepsilon_t}$						
Hendry's Eq.(14)	α_1	α_2	α_3	α_4	α_5	α_0
	0.30	1.78	0.48	-1.16	0.23	-3.7
	T	R^2	$\hat{\sigma}$	DW	$DW(d_l)$	$DW(d_u)$
	94	0.9959	5.4%	0.82	1.56	1.78
1968Q2 – 1982Q4	α_1	α_2	α_3	α_4	α_5	α_0
	.0694	1.7612***	.5240***	-.0511	.0181***	-9.9291***
	(.1387)	(.3114)	(.1389)	(.0600)	(.0049)	(.6265)
	T	$Adj. R^2$	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$	$DW(d_u)$
	59	0.9929	.0516	.7554***	1.41	1.77
1983Q1 – 2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	-2.153***	3.668***	.5734***	**.4009*****	.0373***	-11.4297***
	(.4392)	(.3041)	(.155)	(.0968)	(.0063)	(.4105)
	T	$Adj. R^2$	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$	$DW(d_u)$
	100	0.9754	.0877	.6193***	1.57	1.78
1968Q2 – 2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	.7726***	2.0597***	**-.0565**	**.4039*****	.0391***	-9.2915***
	(.1121)	(.1543)	(.0797)	(.0766)	(.0047)	(.3761)
	T	$Adj. R^2$	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$	$DW(d_u)$
	159	0.9909	.1064	.4658***	1.67	1.81
1995Q1 – 2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	-.0655	.7537***	1.225***	-.0227	.002	-14.599***
	(.4050)	(.2628)	(.1357)	(.0533)	(.0109)	(.3036)
	T	$Adj. R^2$	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$	$DW(d_u)$
	52	0.9949	.0287	.6237***	1.35	1.77

Notes: ph_t is the house price index, p_t is the general index of retail price. y_t represents the real household disposable income, m_t is the mortgage outstanding, h_t is the house completion proxies for the physical housing stock. R_t^* is the after-tax mortgage rate. $\alpha_1$through α_5 are coefficients. α_0 is constant, ε_t is residual. The $DW(d_l)$ and $DW(d_u)$ are the lower and upper bound of Durbin-Watson statistic critical values at the 5% significance level, respectively. Source: http://www.stanford.edu/~clint/bench/dwcrit.htm Throughout the chapter, the 'wrongly signed' coefficients are in bold. Coefficient standard deviations are in parentheses. ***, ** and * means statistically significant at the 1%, 5% and 10% significance level, respectively.

Given the observed DW statistics are smaller than their corresponding lower critical DW values ($DW(statistic) < DW(d_l)$), one can rejects the null hypothesis of no positive autocorrelation and conclude that the equation (3.2) has positive autocorrelation among the residuals (Gujarati and Porter, 2009). Thereby, this chapter fails to find any cointegration, and there is no evidence to believe that the linear combination of the variables in equation (3.2) may be stationary. It appears the results of equation (3.2) are in contrast to Hendry (1984). Given *T=94* and 5 independent variables in Hendry (1984), the lower critical DW value (d_l) should be approximately 1.56 at the 5% significance level. In Hendry (1984), the DW statistic value 0.82 is below its lower critical DW value 1.56 ($DW(statistic) < DW(d_l)$). Therefore, Hendry (1984) is wrong to conclude that the linear combination of the level variables is stationary in his equation (14).

3.3.2 A Possible Expectation Model

To capture how people form their expectations about house prices, Hendry (1984) illustrates a possible expectation model as equation (3.3). Equations (3.3) through (3.5) are estimated by the classical Ordinary Least Square (OLS) which is typical fixed parameter estimation.

$$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_0 + \varepsilon_t \qquad 3.3$$

Where, $\Delta_1 ph_t$ is changes in house price, $\Delta_1^2 p_t = \Delta_1 p_t - \Delta_1 p_{t-1}$ is the changes in inflation rate. $\Delta_1 m_t$ is changes in aggregate mortgage outstanding. $R_t^0 = R_t^*/100$. R_t^* is the mortgage rate after marginal tax. $\Delta_4 p_t = p_t - p_{t-4}$ is the annual changes in Retail Price Index (RPI). $(ph + h - p - y - c_a)_t$ is the average value of housing per unit of income. $(m - ph - h - c_b)_t$ is the ratio of borrowed to own equity. c_a and c_b denote the corresponding historical means of the feedback effects, respectively. $(y - h)_t$ is the real income per household. α_0 is constant, ε_t is residual. α_1 through α_6 are regression coefficients.

This chapter sets the historical means of feedback effects $c_a = c_b = 0$. Given the historical means of feedback effects (c_a and c_b) are constants, whatever the values they are, the coefficients for equation (3.3) are unaffected by c_a and c_b or a specific dataset, *ceteris paribus*. This is because incorporating a constant into a time series is equivalent to parallel shift a time series by the same amount for the whole data period. This has nothing to do with the changes in the shape of the time series.

Table 3.4 exhibits the results of equation (3.3). In Table 3.4, none of the four datasets fits into the possible expectations model as Hendry (1984). The majority of coefficients are insignificant and/or 'wrongly signed'. Table 3.4 further indicates the regression coefficients change in both sign and magnitude over datasets, which supports Brown *et al.* (1997). From an econometric perspective, the changes in coefficients over time refer to the parameter instability which implies the models are probably mis-specified. From an economics perspective, the changes in coefficients might mirror the institutional changes in the housing market (Lucas, 1976; Brown *et al.*, 1997). Brown *et al.* (1997) suggest the institutional changes are said to occur if an economic relationship changes over time, which is identified by the change in one or more of the coefficients in the regression.

Table 3.4 The Outputs for Equation (3.3)

$$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_0 + \varepsilon_t}$$

	α_1	α_2	α_3	α_4	α_5	α_6	α_0
Hendry's Eq(16)	0.28***	0.48	-0.12**	0.01	0.18***	0.35***	-0.22***
	(0.10)	(0.30)	(0.06)	(0.01)	(0.04)	(0.09)	(0.05)
1968Q2-1982Q4	.4839**	1.8062***	**.0450**	**-.0279**	**-.0608**	**-.0107**	.1842
	(.2199)	(.4714)	(.0974)	(.0893)	(.10355)	(.0337)	(.3249)
1983Q1-2007Q4	.7450***	.7194**	**.0892**	**-.0035**	**-.0148**	.0386*	.0405
	(.213)	(.3480)	(.2986)	(.0218)	(.0331)	(.0218)	(.1358)
1968Q2-2007Q4	.5096***	.6455***	-.0062	.0101	-.0066	.0077	.0413
	(.1552)	(.2061)	(.0795)	(.0112)	(.0153)	(.0145)	(.0591)
1995Q1-2007Q4	1.2919***	.0034	**.5496**	.0704	.1008	.0952***	-.5064
	(.3113)	(.3565)	(.5409)	(.0882)	(.1135)	(.0262)	(.4776)

Notes: $\Delta_1 ph_t = ph_t - ph_{t-1}$. $\Delta_1^2 p_{t-1} = \Delta_1 p_t - \Delta_1 p_{t-1}$. $\Delta_4 p_t = p_t - p_{t-4}$. ph_t is the house price index, m_t is the mortgage outstanding. $R_t^0 = R_t^*/100$. R_t^* is the after-tax mortgage rate. p_t is the general index of retail price. h_t is the physical housing stock. y_t represents the real household disposable income. c_a and c_b denotes the corresponding historical means of the feedback effects. Throughout the chapter, the 'wrongly signed' coefficients are in bold. Standard deviations are in parentheses. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively.

To investigate whether simple modifications improve the model fitting and robustness, this chapter investigates hundreds of alternative equations to equation (3.3) by changing the numbers of lags and/or the orders of differences to the independent variables. The 'better' alternative model satisfies the following three criteria. Firstly, the coefficients are signed consistently with Hendry (1984). Secondly, the coefficients are statistically significant in as many cases as possible. Thirdly, the model reports the smallest Akaike Information Criterion (AIC) statistic among the alternative models. Such a modification strategy also applies to equations (3.4) and (3.5).

Table 3.5 reports the alternative equations to equation (3.3) with the diagnostic tests for residual normality, heteroskedasticity, autocorrelation, model specification and multicollinearity. Unfortunately, few of the alternative equations are as good as Hendry (1984).

From Table 3.5, except for the lagged second log difference of RPI $\Delta_1^2 p_{t-1}$, none of the rest independent variables are statistically significant at the 5% significance level, for the sample 1995Q1-2007Q4. The lagged changes in mortgage outstanding $\Delta_1 m_{t-1}$ have a negligible influence on the changes in house prices for the time period 1968Q2-1982Q4 and 1995Q1-2007Q4, as the coefficients are statistically insignificant. The coefficients for $(R^0 - \Delta_4 p)_{t-1}$ are insignificant for the datasets 1983Q1-2007Q4 and 1995Q1-2007Q4. For the sample 1968Q2-2007Q4, all the coefficients are statistically significant. The adjusted R^2 are 0.46, 0.457, 0.455 and 0.211 for the four datasets, respectively. The adjusted R^2 means the four alternative equations can interpret no more than 50% of the total variation in house prices which are lower than the R^2, 0.67, reported in Hendry (1984). Although a low adjusted R^2 is not evidence for a poor model (Gujarati and Porter, 2009), the general violation of diagnostic tests would indicate a poor model.

In Table 3.5, all the alternative equations exhibit multicollinearity which suggests some of the independent variables are highly correlated. Apart from the alternative equation for 1968Q2-1982Q4, all the other three alternative equations also report residual autocorrelations. Thus, the coefficients in Table 3.5 are biased more or less (Gujarati and Porter, 2009).

Hendry (1984) suggests that it is hard to understand precisely what properties to ascribe to equation (3.3). On one hand, all of the independent variables are lagged so equation (3.3) can be used for *ex ante* predictions. On the other hand, it is unknown why people should form anticipations in the way illustrated by equation (3.3), and the alternative equations in Table 3.5. So, even if people can find some much better fitted alternative equations for equation (3.3), it is unclear why it should be this.

Table 3.5 The Alternative Equations for Equation (3.3)

Hendry's Eq.(16)	$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_0 + \varepsilon_t}$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_0
	0.28***	0.48	-0.12**	0.01	0.18***	0.35***	-0.22***
	(0.10)	(0.30)	(0.06)	(0.01)	(0.04)	(0.09)	(0.05)
The alternative equations for equation (3.3)							
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 \Delta_1 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1^2 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_0
	.4367**	.6729	-.2912*	.5366***	.0374**	.5674***	.0044
	(.2097)	(.4516)	(.1703)	(.1066)	(.0160)	(.1084)	(.0182)
	Adj. R^2	AIC	ς_1		ς_2		ς_3
	0.4600	-243.0497	.2037	.2220		.2270	
	ς_4	Centred VIF Value		Remark			
	.0591*	2 VIF Values > 10		This model reports multicollinearity.			
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1^2 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_0
	.9792***	.3192**	-.13299	.5423***	.02698**	.6325***	.0109*
	(.2154)	(.1580)	(.1782)	(.0807)	(.0124)	(.0861)	(.0059)
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.4566	-506.5692	.1236	.5877		.0201**	
	ς_4	Centred VIF Value		Remark			
	.1267	2 VIF Values > 10		This model reports multicollinearity and residual autocorrelation.			
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-2} + \alpha_3 (R^0 - \Delta_4 p)_{t-2} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_0
	.8405***	.3641***	-.1706***	.5729***	.0403**	.6352***	.0110**
	(.1352)	(.1226)	(.0462)	(.0615)	(.0167)	(.0669)	(.0042)
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.4550	-745.9825	.1619	.2576		.0301**	
	ς_4	Centred VIF Value		Remark			
	.2277	2 VIF Values > 10		This model reports multicollinearity and residual autocorrelation.			
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-1} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_0
	1.5282***	.1133	-.6735	.2755	.0538	.2919*	.0175**
	(.397)	(.4847)	(.7599)	(.2789)	(.2422)	(.1527)	(.0077)
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.2106	-253.8633	.2001	.7588		.0270**	
	ς_4	Centred VIF Value		Remark			
	.2579	3 VIF Values > 10		This model reports multicollinearity and residual autocorrelation.			

Notes: ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticit. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. The figures for the ς_i tests are $p\text{-}values$. As a rule of thumb, a figure of centred VIF>10 indicates the corresponding variable report the multicollinearity, see (O'Brien, 2007). Standard deviations are in parentheses. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively.

3.3.3 A Restricted Parameterisation

Hendry (1984) suggests that the tactic of directly removing insignificant variables is unlikely to yield a reasonable regression. Initially, regressions with near orthogonal variables yet explainable parameters are likely to offer ‘robust’ traits of time series. Secondly, a regression with relatively few independent variables not only helps to avoid the trap that an excessive number of variables cause over fitting, but also makes the regression easier to understand. However, excessively simplified regressions would also lose invariance to potential disturbances. Thirdly, it appears reasonable to employ lagged instead of contemporaneous variables both to eliminate the reliance on problematic exogeneity assumptions and to enhance the implement of the chosen equation for practical predicting.

To study the resulting choice of a model which accounts for the available evidence clearly necessitates new evidence. Hendry (1984) tests a restricted parameterisation equation as (3.4).

$$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4 (m-p-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 \Delta_1 (ph-p-y)_{t-1} + \alpha_7 \Delta_2 (m-p)_{t-3} + \alpha_8 r_t + \alpha_9 \Delta_7 r_t + \alpha_{10} \Delta_1 h_t + \alpha_0 + \varepsilon_t \qquad 3.4$$

Where, $A_n(\cdot)$ is a restricted Almon polynomial. $A_n(x_t) = \frac{2}{n(n+1)} \sum_{i=0}^{n} (n-i) x_{t-i}$.

The restricted Almon polynomial $A_n(x_t)$ provides a weighted average of x_{t-i}, with linearly decreasing weights. Throughout the thesis, $(ph-p-y)_t$ is the ratio of house price to income, $\mathrm{r_t}$ is the natural log of mortgage rate. The dataset 1995Q1-2007Q4 uses the composite mortgage rate of Building Societies and Banks, while all the remaining three datasets use the mortgage rate of Building Societies. All the remaining model specifications are the same as the earlier equations. Table 3.6 shows the results for equation (3.4). From Table 3.6, the results for equation (3.4) do not make any economic sense, even if without the diagnostic tests, given the majority of coefficients are insignificant and/or ‘wrongly signed’. In particular, eight out of ten regression coefficients are statically insignificant for the sample 1983Q1-2007Q4 at the 5% significance level. Consistent with the results for equation (3.3), the parameters of equation (3.4) change both in sign and magnitude over datasets.

Table 3.6 The Outputs for Equation (3.4)

$$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4 (m-p-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 \Delta_1 (ph-p-y)_{t-1} + \alpha_7 \Delta_2 (m-p)_{t-3} + \alpha_8 r_t + \alpha_9 \Delta_7 r_t + \alpha_{10} \Delta_1 h_t + \alpha_0 + \varepsilon_t}$$

Hendry's Eq.(17)	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.24***	11.4***	0.57***	0.122***	0.53***	-0.18***	0.45***
	(0.11)	(4.8)	(0.22)	(0.026)	(0.10)	(0.05)	(0.15)
	α_8	α_9	α_{10}	α_0	/	/	/
	-0.013	-0.027*	-3.0	-1.01***	/	/	/
	(0.021)	(0.015)	(2.3)	(0.37)			
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4573***	12.896	.7201**	**-.0950**	.1210	-.0445	.1853
	(.1496)	(10.418)	(.3203)	(.0966)	(.11995)	(.04903)	(.1331)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0368	**.0114**	-.0093	.1699	/	/	/
	(.0324)	(.0226)	(.03217)	(.4678)			
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0416	24.447**	.1637	.0191	**-.0240**	-.0239	.5741***
	(.1100)	(12.273)	(.4066)	(.0269)	(.0400)	(.0196)	(.1716)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0298*	**.0181**	**.0257**	-.1234	/	/	/
	(.0153)	(.0123)	(.0228)	(.1847)			
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.2086**	18.856**	.5254**	**-.025*****	.0294	-.0079	.2322***
	(.0850)	(7.559)	(.240)	(.0091)	(.0189)	(.0145)	(.0710)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0248***	**.0089**	**.0201**	.1086	/	/	/
	(.0079)	(.0093)	(.0178)	(.0821)			
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.2235	54.5707	**-.6537**	.4107**	**-.2273**	-.1789**	.7442***
	(.1467)	(35.149)	(.5283)	(.1929)	(.1521)	(.0840)	(.2558)
	α_8	α_9	α_{10}	α_0	/	/	/
	.0903**	-.0387	-.0790**	-2.755**	/	/	/
	(.04116)	(.0293)	(.0363)	(1.200)			

Notes: ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively. 'Wrongly signed' coefficients are in bold. Standard deviations are in parentheses.

Following the strategy of Table 3.5, Table 3.7 illustrates the better alternative equation for equation (3.4) with a range of diagnostic tests. Unfortunately, none of the alternative equations in Table 3.7 provides us with reasonable fit as in Hendry (1984). According to Table 3.7, more than half of the coefficients are statistically insignificant at the 5% significance level for the sample 1968Q2-1982Q4. The alternative equation for 1983Q1-2007Q4 violates the assumption of residual normality, and only two of the coefficients are statistically significant at the 5% significance level. There are more coefficients which are statistically significant for the sample 1968Q2-2007Q4. However, this equation violates four out of five diagnostic tests. The alternative equation for the sample 1995Q1-2007Q4 satisfies the five diagnostic tests, none of the coefficients are statistically significant at the 5% significance level. Overall, the alternative equations for equation (3.4) are far from economically sensible.

Table 3.7 The Alternative Equations for Equation (3.4)

Hendry's Eq.(17)	$\boldsymbol{\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4(m-p-h)_{t-1} + \alpha_5(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_t + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_0 + \varepsilon_t}$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.24***	11.4***	0.57***	0.122***	0.53***	-0.18***	0.45***
	(0.11)	(4.8)	(0.22)	(0.026)	(0.10)	(0.05)	(0.15)
	α_8	α_9	α_{10}	α_0	/	/	/
	-0.013	-0.027*	-3.0	-1.01***	/	/	/
	(0.021)	(0.015)	(2.3)	(0.37)			
The alternative equations for equation (3.4)							
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3_{t-1} + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4\Delta_1(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-1} + \alpha_8\Delta_1 r_{t-1} + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.9611***	24.039***	.555*	.0579*	.0269	-.5435***	.1321
	(.1968)	(8.9272)	(.2953)	(.0316)	(.0283)	(.1650)	(.1042)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0318	-.0145	-.0295	-.0103	/	/	/
	(.0275)	(.0112)	(.0296)	(.0076)			
	Adj.R^2	AIC	ς_1 (p-value)	ς_2 (p-value)		ς_3 (p-value)	
	0.5902	-248.5856	.4320	.2791		.3555	
	ς_4 (p-value)	Centred VIF Value		Remark			
	.3873	All VIF values < 10		Half of the coefficients are insignificant.			
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1^2 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3_{t-2} + \alpha_3 A_2(\Delta_1 y_t)_t + \alpha_4\Delta_1^2(m-p-h)_{t-1} + \alpha_5\Delta_2(y-h)_{t-1} + \alpha_6(ph-p-y)_{t-3} + \alpha_7\Delta_2(m-p)_{t-1} + \alpha_8 r_{t-3} + \alpha_9 r_{t-4} + \alpha_{10}\Delta_3 h_{t-4} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1850*	17.1300	.1050	.0092	.0860***	-.0138	.6755***
	(.0946)	(11.2332)	(.2874)	(.0116)	(.0265)	(.0127)	(.103)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0051	-.0353	-.0448	.013	/	/	/
	(.0357)	(.0363)	(.0219)	(.0588)			
	Adj.R^2	AIC	ς_1 (p-value)	ς_2 (p-value)		ς_3 (p-value)	
	0.3651	-487.396	.0024***	.8132		.0221**	
	ς_4 (p-value)	Centred VIF Value		Remark			
	.1505	2 VIF Values > 10		This model is poor. Most of the coefficients are insignificant.			
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-3} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1^2(m-p-h)_{t-2} + \alpha_5\Delta_1^2(y-h)_{t-2} + \alpha_6\Delta_1^2(ph-p-y)_{t-3} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_{t-1} + \alpha_9\Delta_7 r_{t-1} + \alpha_{10}\Delta_1 h_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.3243***	27.002***	.5338**	.0178	.0201	-.0921	.1087
	(.0954)	(7.3220)	(.2374)	(.0832)	(.0832)	(.0678)	(.0681)
	α_8	α_9	α_{10}	α_0	/	/	/
	-.0106*	-.0159*	-.0517***	.0293**	/	/	/
	(.0064)	(.009)	(.0185)	(.0133)			
	Adj.R^2	AIC	ς_1 (p-value)	ς_2 (p-value)		ς_3 (p-value)	
	0.3609	-707.1701	.7131	.0301**		.0001***	
	ς_4 (p-value)	ς_5 (p-value)		Remark			
	.0233**	2 VIF Values > 10		This model violates four basic assumptions.			
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1^2 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3\Delta_1(A_2(\Delta_1 y_t)) + \alpha_4\Delta_3(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-2} + \alpha_8\Delta_1 r_{t-2} + \alpha_9\Delta_7 r_{t-2} + \alpha_{10}\Delta_1^2 h_{t-2} + \alpha_0 + \varepsilon_t$						

α_1	α_2	α_3	α_4	α_5	α_6	α_7
.1847	61.358	.0029	.0208	.0536	-.2277	.4005*
(.1551)	(51.157)	(.3107)	(.0399)	(.0367)	(.2423)	(.2303)
α_8	α_9	α_{10}	α_0	/	/	/
-.0150	-.0294	-.0368*	.0157	/	/	/
(.0646)	(.0212)	(.0188)	(.0056)			
Adj.R^2	AIC	ς_1 (p-value)	ς_2 (p-value)		ς_3 (p-value)	
0.3499	-217.1956	.4782	.9651		.2774	
ς_4 (p-value)	Centred VIF Value		Remark			
.6555	All VIF Values < 10		This model is poor. Most of the coefficients are insignificant.			

Notes: ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticit. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. The figures for the ς_i tests are *p-values*. As a rule of thumb, a figure of centred VIF>10 indicates the corresponding variable report the multicollinearity, see (O'Brien, 2007). Standard deviations are in parentheses. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively.

As a comparison to equation (3.4), Hendry (1984) examines equation (3.5). Table 3.9 presents the findings for equation (3.5).

$$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4 (m-ph-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t \qquad 3.5$$

Where, $F_{13}(x) = \Delta_1(x_{t-1} + x_{t-3})$ and $\bar{x}_t = (x_t + x_{t-1})/2$.

Relative to equation (3.4), equation (3.5) removes changes in physical housing stock $\Delta_1 h_t$; replaces real value of the mortgage stock $(m-p-h)_t$ and ratio of house price to income $(ph-p-y)_{t-1}$ by ratio of borrowed to own equity $(m-ph-h)_{t-1}$; uses the original interest rates $\bar{R}^0_t$ instead of natural logarithmic and takes two dummy variables into account. Hendry (1984) defines the two dummy variables as:

- $D_1 = 1$ in 1967Q3 and zero otherwise;
- $D_2 = 1$ in 1981Q3 and 1982Q1, -2 in 1982Q2 and zero otherwise.

As the full dataset used in this chapter ranges from 1968Q2 to 2007Q4, this chapter sets dummy variables as Table 3.8.

Table 3.8 Dummy Variables for Equation (3.5)

Dataset	$D_1 = 1$	$D_2 = 1$	$D_2 = -2$
Hendry (1984)	1967Q3; 0 otherwise	1981Q3 & 1982Q1	1982Q2; 0 otherwise
1968Q2-1982Q4	1979Q2; 0 otherwise	1981Q4 & 1982Q1;	1982Q2; 0 otherwise
1983Q1-2007Q4	1997Q2; 0 otherwise	2006Q1 & 2007Q1; 0 otherwise	/
1968Q2-2007Q4	1979Q1; 0 otherwise	1997Q1 & 2007Q1; 0 otherwise	/
1995Q1-2007Q4	1997Q2; 0 otherwise	2006Q1 & 2007Q1; 0 otherwise	/

Table 3.9 The Outputs for Equation (3.5)

$$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4 (m - ph - h)_{t-1} + \alpha_5 (y - h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m - p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t$$

Hendry's Eq.(18)	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.22***	14.0***	0.42***	0.178***	0.47***	0.85***	0.54***
	(0.07)	(4.9)	(0.07)	(0.027)	(0.08)	(0.12)	(0.11)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-0.22***	-0.50***	-3.5***	-2.1***	-3.0***	/	/
	(0.09)	(0.20)	(0.4)	(0.3)	(0.05)		
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4282***	8.8207	.5451**	.0297	**-.0089**	.4181	.2547
	(.1381)	(10.1835)	(.2104)	(.0375)	(.0405)	(.2842)	(.2534)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.4946*	-.0943	-.6837	-2.5211***	-.0879	/	/
	(.2662)	(.3060)	(2.198)	(.8780)	(.1510)		
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.0009	21.543*	.3110	.0248	.0128	.8547***	.7501***
	(.1161)	(12.709)	(.3353)	(.0169)	(.0191)	(.3099)	(.1847)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.52370***	**.1395**	-.6022	.6086	-.1119	/	/
	(.1739)	(.4575)	(2.366)	(1.7200)	(.0881)		
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0971	16.814**	.5289***	.0042	.0040	.6952***	.5090***
	(.0822)	(7.492)	(.1792)	(.0111)	(.0120)	(.1731)	(.1141)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.5147***	-.1546	.3020	-.0188	.0008	/	/
	(.1118)	(.2414)	(2.2888)	(1.619)	(.0477)		
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.2797**	53.453	**-.1241**	.0466*	.0479	.7814	.4604
	(.1464)	(35.452)	(.4899)	(.0236)	(.0377)	(.5006)	(.3697)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.4452	**.8234**	-1.0671	.8642	-.2392**	/	/
	(.8288)	(1.4104)	(2.3095)	(1.595)	(.1039)		

Notes: ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively. 'Wrongly signed' coefficients are in bold. Standard deviations are in parentheses.

The findings in Table 3.9 show a large number of coefficients that are statistically insignificant and/or 'wrongly signed', and present time varying parameters. Because the sets of dummy variables in this chapter are differ from Hendry (1984), and there is no prior theoretical assumption on the relationship between dummy variables and house prices, the signs of dummy variables in Tables 3.9 and 3.10 are not necessarily consistent with Hendry (1984).

Hendry (1984) suggests that the equation shown as equation (3.5) satisfies most of the model's selection criteria. Unfortunately, it does not fit into the chapter's datasets. Table 3.10 shows the better alternative models. In Table 3.10, the AIC value ranges from -737.7 to -229.5. The alternative model for 1968Q2-1982Q4 satisfies all the basic assumptions; the alternative model for 1982Q4-2007Q4 rejects the Ramsey RESET test at the 5% significance level which implies there is a specification error; the alternative model for 1968Q2-2007Q4 might report residual autocorrelation; and the alternative model for 1995Q1-2007Q4 rejects the null of residual normality at the 10% level. However, more than half of coefficients are again statistically insignificant across the four datasets. The adjusted R^2 for the four datasets are 0.5956, 0.3935, 0.4009 and 0.3636, respectively. Overall, the alternative equations for equation (3.5) are poor.

Table 3.10 The Alternative Equations for Equation (3.5)

Hendry's Eq.(18)	$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m - ph - h)_{t-1} + \alpha_5(y - h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m - p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t}$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.22***	14.0***	0.42***	0.178***	0.47***	0.85***	0.54***
	(0.07)	(4.9)	(0.07)	(0.027)	(0.08)	(0.12)	(0.11)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-0.22***	-0.50***	-3.5***	-2.1***	-0.30***	/	/
	(0.09)	(0.20)	(0.4)	(0.3)	(0.05)		
The alternative equations for equation (3.5)							
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m - ph - h)_{t-1} + \alpha_5 \Delta_1(y - h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m - p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4631***	6.2378	.4731**	.0288	.0465*	.4807*	.2928
	(.1262)	(9.435)	(.2043)	(.0204)	(.0233)	(.2734)	(.2426)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.6195***	-.1878	-1.1966	-2.6213***	-.0800	/	/
	(.2024)	(.2772)	(2.1186)	(.8411)	(.0657)		
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.5956	-265.255	.6804	.3534		.4975	
	ς_4	Centred VIF Value		Remark			
	.3812	All VIF Values <10		Half of the coefficients are insignificant.			
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4(m - ph - h)_{t-1} + \alpha_5 \Delta_1(y - h)_{t-1} + \alpha_6 F_{13}(p)_{t-2} + \alpha_7 F_{13}(m - p)_{t-1} + \alpha_8 \bar{R}^0_{t-2} + \alpha_9 \Delta_1 R^0_{t-2} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4314***	8.5742	.1195	.0109	.0829***	.5377**	.4501***
	(.1239)	(13.1711)	(.3735)	(.0122)	(.0215)	(.2308)	(.1178)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.4569***	-.7438**	-.3807	1.9497	-.0343	/	/
	(.1265)	(.3640)	(2.0752)	(1.5644)	(.0649)		
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.3935	-491.113	.1002	.4303		.4032	
	ς_4	Centred VIF Value		Remark			
	.0318**	All VIF Values <10		Half of the coefficients are insignificant.			
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4 \Delta_1(m - ph - h)_{t-1} + \alpha_5 \Delta_1(y - h)_{t-2} +$						

	$\alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1790**	13.26*	.6153**	.0653***	.0612***	.5834***	.4577***
	(.0830)	(7.317)	(.2402)	(.0180)	(.019)	(.0917)	(.0917)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.5364***	-.2827	.1564	.4372	.0255***	/	/
	(.1027)	(.2376)	(2.2175)	(1.5833)	(.0067)		
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.4009	-737.67	.3340	.1530		.0001	
	ς_4	Centred VIF Value		Remark			
	.2333	All VIF Values <10		This model reports residual autocorrelation.			
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_4 ph_t + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2 (\Delta_1 y_t)_{t-1} + \alpha_4 \Delta_1 (m-ph-h)_{t-1} + \alpha_5 \Delta_2 (y-h)_{t-2} + \alpha_6 F_{13}(p)_{t-2} + \alpha_7 F_{13}(m-p)_{t-2} + \alpha_8 \Delta_4 \bar{R}^0_{t-2} + \alpha_9 \Delta_1 R^0_{t-2} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4731***	34.587	.3085	.06496*	.0311	1.1738**	.5665**
	(.1174)	(36.73)	(.3734)	(.0320)	(.0369)	(.5570)	(.265)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.4387	-1.039	-1.1896	-.7266	-.0052	/	/
	(.5891)	(1.164)	(1.8302)	(1.3183)	(.0116)		
	Adj.R^2	AIC	ς_1		ς_2		ς_3
	0.3636	-229.51	.0724*	.9145		.2810	
	ς_4	Centred VIF Value		Remark			
	.5085	All VIF Values <10		This model is poor. Most of the coefficients are insignificant.			

Notes: ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticit. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. The figures for the ς_i tests are $p\text{-}values$. As a rule of thumb, a figure of centred VIF>10 indicates the corresponding variable report the multicollinearity, see (O'Brien, 2007). Standard deviations are in parentheses. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively.

3.4 Conclusion

To set a scene for the development of analysis models in Chapters 4 through to 7, this chapter re-estimates the principal equations of Hendry (1984) to four datasets for two research questions. Firstly, whether the empirical results of Hendry (1984) are replicable by using similar datasets. The findings are mixed. In the data description section, the findings are roughly consistent with Hendry (1984) in the same time period. However, his econometric models fall when fitted into the chapter's four datasets. Throughout the chapter, the regression coefficients change in both magnitude and sign over samples which support Brown *et al.* (1997). Secondly, the chapter considers whether simple modifications improve model fitting. The chapter finds that some naïve modifications, such as changing the number of lag length for independent variables, will improve the fitting of the underlying equation. However, the alternative equations are far from economically sensible, as the alternative equation violates one or more assumptions of regression analysis. Some much better alternative equations might emerge if one keeps trying such a modification procedure. However, it is unclear why people should make such a modification, and statistical significance does not entail a superior economic explanation. Even if one alternative equation properly captures the historical linkage between those variables, it may be inappropriate for predictions or analysis in another dataset which refers to the model’s stability and the model’s uncertainty. Model stability focuses on how long a predictive relationship stays in effect, while model uncertainty concentrates on how one selects amongst many competing quantitative models, see (Pesaran and Timmermann, 2002).

From an econometrics perspective, the change in coefficients refers to the parameter instability, implying that the fixed parameter models are probably mis-specified. From an economics perspective, the parameter instability might result from the institutional changes in the UK housing market. Thereby, a more suitable and parsimonious approach to the representation of an unstable economic system is to develop a model using a methodology which takes account of the institutional changes.

Chapter 4. Econometric Modelling of UK House Prices in an Open Economy

4.1 Introduction

This chapter incorporates the Foreign Portfolio Investment (FPI) into the principal equations of Hendry (1984), *ceteris paribus*. Through comparison with Chapter 3, this chapter demonstrates that the classical fixed parameter demand and supply equations are poor in terms of robustness and unsuitable to studying the UK house prices, even taking account of FPI. FPI reflects one of the institutional changes since the 1970s that Hendry (1984) does not consider. This chapter addresses two issues.

- Firstly, whether an open economy framework is empirically superior to its closed economy counterpart in terms of model robustness?
- Secondly, whether FPI drives the UK's house prices to a statistically significantly extent?

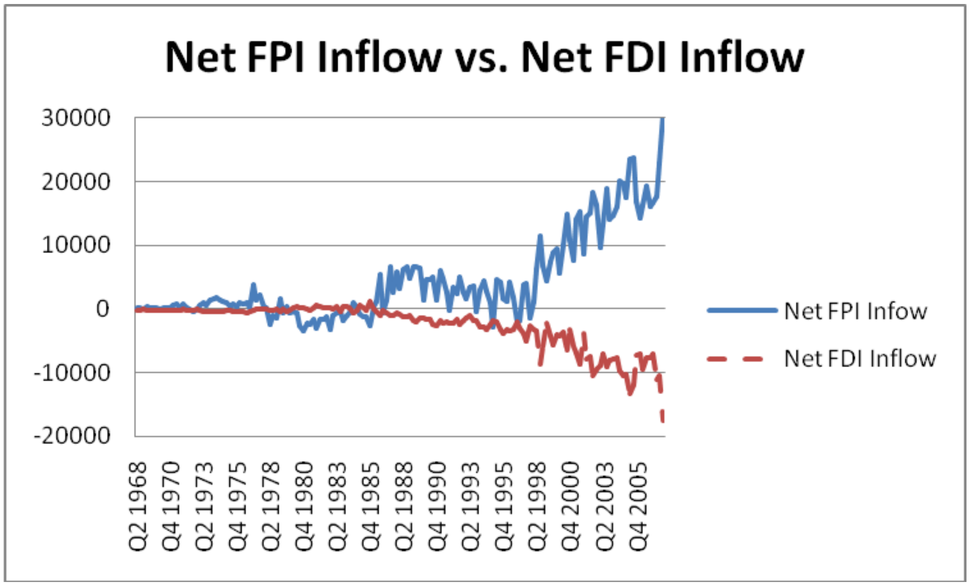
4.2 Data Description

The data included in this study are the Department for Communities and Local Government (DCLG) House Price Index (HPI), the Retail Price Index (RPI), the mortgage rates of Building Societies, the composite mortgage rate of Building Societies and Banks, the aggregate mortgage outstanding of Building Societies and Banks, the real aggregate household disposable income, the house completions series, foreign exchange reserves, net exports of good/services and net Foreign Direct Investment (FDI) inflow from the United Kingdom. All the quarterly time series data were collected from DataStream and cover the period from 1968Q2 to 2007Q4. The starting dates are chosen by the availability of data for the HPI and the ending dates are chosen by the availability of data for the house completions. The chapter sets the House Price Index (HPI) and the Retail Price Index (RPI) equal to 100 at 2002Q1. Except where specifically mentioned, all the variables are in nominal terms. Throughout this chapter, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts. Apart from the new variables, foreign exchange reserves, net exports of good/services and net FDI inflow, all the rest of the variables are the same as in Chapter 3.

To make the empirical results comparable to Chapter 3, this chapter also uses four datasets, namely, 1968Q2-1982Q4, 1983Q1-2007Q4, 1968Q2-2007Q4 and 1995Q1-2007Q4. The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. In the Appendices, Table A and Table B display the variable sources and definitions; Table C illustrates a basic variable summary.

Following Martin and Morrison (2008), the chapter calculates the raw FPI data by identity: FPI Inflow = Change in Foreign Exchange Reserves – Net Exports – Net FDI Inflow. Figure 4.1 plots the FDI against FPI in raw data. Figure 4.1 suggests the net FDI inflow to the UK remains incredibly stable and ignorable value from 1968Q2 to 1986Q2; decreases (increasing net FDI outflow) between 1986Q3 and 1998Q2; and is dramatically volatile thereafter. FPI inflow appears stable and insignificant between 1968Q2 and 1979Q2; impressively, it fluctuates from 1979Q3 to 1996Q2; thereafter, it increases substantially. The net FDI inflow and FPI inflow range from -17,638 to 1,099 and -3,379 to 30,648 million Great Britain Pounds, respectively. The presence of negatives and positives indicate that the capital flows, either FDI or FPI, might be reversed under certain macroeconomic conditions. Although there is a massive FPI inflow most of time, the UK reports substantial net FDI outflow. For instance, there are 17 billion Great Britain Pounds net FDI outflow by 2007Q4. FPI is much more volatile than FDI, as their standard deviations are 6,780 million and 3,479 million, respectively. Such great volatility is primarily attributable to the last two decades. Considering that these two variables report incredibly high correlation, -0.94, any regression which incorporates these two variables simultaneously may report severe multicollinearity. From another perspective, these two variables may share some common driving forces, e.g. the underlying economy.

Figure 4.1 Net FDI inflow vs. FPI inflow



Notes: The currency unit is Great Britain Pound Millions at raw data scale. A minus sign indicates net outflow.

Following Hendry (1984), this chapter uses the log-linear specification to apply the multiple linear regressions. Log-linear specification reduces the skewness of response variables, which may improve the model fit (Barthel *et al.*, 2010).

A constant of 3,380 is added to the net FPI inflow series before applying the natural log transformation. Such a parallel upward shift does not change the pattern of the raw FPI series but ensures that the minimum value of the transformed series equals 1 which, in turn, ensures the log transformation is applicable. In the literature, Barthel *et al.* (2010) set the negative observations equal to 0.1 before taking the natural log transformation. Xu and Chen (2012) incorporate the non-logged FPI into a log-linear model. In fact, all the three aforementioned handling techniques to non-positive values are biased. Firstly, although the arbitrarily added constant does not influence the pattern of the raw time series, it does affect the pattern of the transformed series because the natural log is a nonlinear transformation. Secondly, set negatives which equal a small positive value also change the pattern of the time series variable. Even worse, it blinds us to the level and changes in negative values especially when there are a lot of negatives. In this chapter, 39 out of the 159 FPI observations are negatives, which is a great many. Thirdly, it is not unusual to combine the logged and non-logged variables in the right hand side of an equation, as Hendry (1984) did, and there should not be technical issues. However, the coefficients of non-logged variable is not elasticity anymore (one unit increase in capital flow will cause 1% change in logged dependent variable). More importantly, the model fitting would be poor. Overall, the method of adding a constant to negatives appears superior to the others for this chapter.

4.3 Empirical Modelling of the UK House Prices in an Open Economy

4.3.1 Descriptive Statistics

To investigate the autoregressive characteristics, the chapter firstly estimates equation (4.1) for foreign portfolio investment fpi_t. The description to the rest of the variables has been displayed in the last chapter.

$$\Delta_1 fpi_t = \alpha_0 + \alpha_1 fpi_{t-1} + \sum_{i=1}^{3} \alpha_{1+i} \Delta_1 fpi_{t-i} + \varepsilon_t \qquad 4.1$$

$\Delta_1 fpi_t = fpi_t - fpi_{t-1}$ is the first natural log difference of FPI. α_0 is constant. α_i is the constant coefficient for the i-th lagged variable. ε_t is error term or residual. Table 4.1 displays the results of equation (4.1) for fpi_t in terms of four datasets, and reveals various fits. fpi_t exhibits residual non-normality and heteroskedasticity in all of the four datasets at 1% significance level; and reports residual autocorrelation in 1983Q1-2007Q4, at the 5% significance level.

Table 4.1 Time Series Descriptions to fpi_t

$\boldsymbol{\Delta_1 fpi_t = \alpha_0 + \alpha_1 fpi_{t-1} + \sum_{i=1}^{3} \alpha_{1+i} \Delta_1 fpi_{t-i} + \varepsilon_t}$										
$\boldsymbol{\Delta_1 fpi_t}$	fpi_{t-1}	$\Delta_1 fpi_{t-1}$	$\Delta_1 fpi_{t-2}$	$\Delta_1 fpi_{t-3}$	α_0	$Adj.R^2$	$\hat{\sigma}$	ς_1	ς_2	ς_3
1968Q2-1982Q4										
	-.2801	-.4536**	-.3486*	-.43***	2.0993	0.3399	1.26	.000***	.000***	.483
	(.2085)	(.2028)	(.1856)	(.1502)	(1.655)					
1983Q1-2007Q4										
	-.22***	-.511***	-.442***	-.33***	2.017***	0.5463	.501	.000***	.000***	.041**
	(.0597)	(.0799)	(.0784)	(.0685)	(.5308)					
1968Q2-2007Q4										
	-.129*	-.567***	-.444***	-.42***	1.1295*	0.3920	.856	.000***	.000***	.692
	(.0726)	(.0899)	(.0882)	(.0751)	(.6216)					
1995Q1-2007Q4										
	-.0851	-.469***	-.581***	-.357**	.8655	0.3487	.516	.000***	.000***	.176
	(.1041)	(.1546)	(.1355)	(.1367)	(.9693)					

Notes: Adj. R^2 is the adjusted R^2 of the regression. $\hat{\sigma}$ is the standard deviation of the regression. ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticit. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. The figures for ς_1, ς_2 and ς_3 are *p-values*. ***, ** and * represent statistically significant at the 1%, 5% and 10% significance level, respectively. Coefficient standard errors are in parentheses.

Table 4.2 reports the ADF unit root test for fpi_t. From 1983Q1 to 2007Q4, FPI is stationary at the second log difference at the 5% significance level; while it is stationary at the first log difference for the rest of the three samples at the 1% significant level.

Table 4.2 ADF Unit Root Tests for fpi_t

	1968Q2-1982Q4	1983Q1-2007Q4	1968Q2-2007Q4	1995Q1-2007Q4
Level	0.8282	0.9998	0.6081	0.7928
1st Difference	0.0000***	0.0000***	0.0001***	0.0000***

Notes: The figure shows in the table is *p-value*. The appropriate number of lagged difference for the ADF unit root test is identified by the Bayesian Information Criteria (BIC). The ADF test specification for FPI includes constant only. *** means statistically significant at the 1% significance level.

As the findings of stationary do not entail that the differenced time series alone merit analysis, this chapter investigates equation (4.2) which is analogous to the investigation of cointegration. Relative to equation (3.2) in Chapter 3, equation (4.2) incorporates the fpi_t, *ceteris paribus*. Throughout the thesis, the figures for 'Hendry's Eq.()' are drawn from Hendry (1984) for illustration purposes; the 'wrongly signed' coefficients are in bold.

$$\widehat{ph}_t = \alpha_1 p_t + \alpha_2 y_t + \alpha_3 m_t + \alpha_4 h_t + \alpha_5 R_t^* + \alpha_6 fpi_t + \alpha_0 + \varepsilon_t \qquad 4.2$$

Table 4.3 Investigates the Cointegration

Panel A: Equation with fpi_t						
$\widehat{ph}_t = \alpha_1 p_t + \alpha_2 y_t + \alpha_3 m_t + \alpha_4 h_t + \alpha_5 R_t^* + \alpha_6 fpi_t + \alpha_0 + \varepsilon_t$						
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6
	.0690	1.7464***	.5306***	-.0447	.0182***	.0031
	(.1397)	(.3147)	(.1404)	(.0616)	(.0049)	(.0058)
	α_0	T	Adj.R^2	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$
	-9.9839	59	0.9928	.05196	.7642***	1.36
	(.6393)					
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6
	-1.4343***	3.0544***	.4108***	**.4011*****	.0329***	.0722***
	(.4343)	(.3117)	(.1467)	(.0886)	(.0059)	(.0165)
	α_0	T	Adj.R^2	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$
	-10.458***	100	0.9794	.0802	.7231	1.55
	(.4365)					
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6
	.8851***	2.011***	**-.1161**	**.4022*****	.0387***	.0299***
	(.1148)	(.1509)	(.0799)	(.0745)	(.0046)	(.0096)
	α_0	T	Adj.R^2	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$
	-9.0757***	159	0.9914	.1034	.4984	1.66
	(.3722)					
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6
	-.2234	.6053**	1.2984***	-.0217	.0034	.0173**
	(.399)	(.2642)	(.1360)	(.0515)	(.0105)	(.0084)
	α_0	T	Adj.R^2	$\hat{\sigma}$	$DW(statistic)$	$DW(d_l)$

	-14.329*** (.3215)	52	0.9952	.0278	.6754	1.35
Panel B: Equation without fpi_t						
$\widehat{ph}_t = \alpha_1 p_t + \alpha_2 y_t + \alpha_3 m_t + \alpha_4 h_t + \alpha_5 R_t^* + \alpha_0 + \varepsilon_t$						
Hendry's Eq.(14)	α_1	α_2	α_3	α_4	α_5	α_0
	0.30	1.78	0.48	-1.16	0.23	-3.7
	T	R^2	$\hat{\sigma}$	DW	$DW(d_l)$	$DW(d_u)$
	94	0.9959	5.4%	0.82	1.56	1.78
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_0
	.0694	1.7612***	.5240***	-.0511	.0181***	-9.9291***
	(.1387)	(.3114)	(.1389)	(.0600)	(.0049)	(.6265)
	T	$Adj.R^2$	$\hat{\sigma}$	DW (statistic)	$DW(d_l)$	$DW(d_u)$
	59	0.9929	.0516	.7554***	1.41	1.77
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	-2.153 ***	3.668***	.5734***	**.4009** ***	.0373***	-11.4297***
	(.4392)	(.3041)	(.155)	(.0968)	(.0063)	(.4105)
	T	$Adj.R^2$	$\hat{\sigma}$	DW(statistic)	$DW(d_l)$	$DW(d_u)$
	100	0.9754	.0877	.6193***	1.57	1.78
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	.7726***	2.0597***	**-.0565**	**.4039** ***	.0391***	-9.2915***
	(.1121)	(.1543)	(.0797)	(.0766)	(.0047)	(.3761)
	T	$Adj.R^2$	$\hat{\sigma}$	DW(statistic)	$DW(d_l)$	$DW(d_u)$
	159	0.9909	.1064	.4658***	1.67	1.81
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_0
	-.0655	.7537***	1.225***	-.0227	.002	-14.599***
	(.4050)	(.2628)	(.1357)	(.0533)	(.0109)	(.3036)
	T	$Adj.R^2$	$\hat{\sigma}$	DW(statistic)	$DW(d_l)$	$DW(d_u)$
	52	0.9949	.0287	.6237***	1.35	1.77

Notes: ph_t is the house price index, p_t is the general index of retail price. y_t represents the real household disposable income, m_t is the mortgage outstanding, h_t is the house completion proxies for the physical housing stock. R_t^* is the after-tax mortgage rate. fpi_t is foreign portfolio investment. $\alpha_1$through α_6 are coefficients. α_0 is constant, ε_t is residual. The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. Throughout the chapter, the 'wrongly signed' coefficients are in bold. The $DW(d_l)$ and $DW(d_u)$ are the lower and upper bound of Durbin-Watson statistic critical values at the 5% significance level, respectively. Source: http://www.stanford.edu/~clint/bench/dwcrit.htm Coefficient standard deviations are in parentheses. ***, ** and * denote for statistically significant at the 1%, 5% and 10% significance level, respectively. Panel B is drawn from Table 3.3 in Chapter 3.

Table 4.3 shows the findings for the cointegration tests. To make the results comparable to Hendry (1984) and Chapter 3, the chapter examines the residuals of equation (4.2) by using the Durbin-Watson (DW) statistics instead of the ADF tests.

Panel A of Tables 4.3 through to 4.10 show the results for a given equation with FPI. Panel B of Tables 4.3 through to 4.10 is essentially drawn from Tables 3.3 through to 3.10 which show the results for an equation without FPI, *ceteris paribus*. The purpose is to address whether an open economy model is superior to its closed economy counterpart.

Panel A in Table 4.3 rejects the null hypothesis that the residuals for equation (4.2) have no positive autocorrelations, because the observed DW statistics are smaller than their corresponding lower bound DW critical values over the four datasets. So, the linear combination of the variables in equation (4.2) is nonstationary and there is no cointegration over the four datasets, which are consistent with the findings in panel B. Table 4.3 suggests that the incorporation of FPI does not enhance the presence of cointegration.

4.3.2 A Possible Expectation Model

Equation (4.3) incorporates the lagged first log differenced FPI $\Delta_1 fpi_{t-1}$ into the equation (16) of Hendry (1984) which is a possible expectation model. Following Hendry (1984), equations (4.3) through (4.5) are estimated by the classical Ordinary Least Square (OLS).

$$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t \qquad 4.3$$

Where, $\Delta_1 ph_t$ is changes in house price, $\Delta_1^2 p_t = \Delta_1 p_t - \Delta_1 p_{t-1}$ is the changes in inflation rate. $\Delta_1 m_t$ is changes in aggregate mortgage outstanding. $R_t^0 = R_t^*/100$. R_t^* is the after-tax mortgage rate. $\Delta_4 p_t = p_t - p_{t-4}$ is the annual changes in Retail Price Index (RPI). $(ph + h - p - y - c_a)_t$ is the average value of housing per unit of income. $(m - ph - h - c_b)_t$ is the ratio of borrowed to own equity. c_a and c_b denote the corresponding historical means of the feedback effects, respectively. $(y - h)_t$ is the real income per household. fpi_t is foreign portfolio investment. α_0 is constant, ε_t is residual. α_1 through to α_6 are regression coefficients. Like Chapter 3, the chapter sets $c_a = c_b = 0$. Panel A of Table 4.4 shows the results for equation (4.3).

Table 4.4 shows pretty poor fits, whether it incorporates fpi_t or not. More than half of the coefficients are statistically insignificant and/or ‘wrongly signed’ for all the four datasets. Moreover, the regression coefficients change in both sign and magnitude over samples.

Table 4.4 The Outputs for Equation (4.3)

Panel A: Equation with fpi_t								
$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t}$								
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
1968Q2-1982Q4	.4801**	1.899***	**.0567**	**-.0455**	**-.0849**	**-.0057**	.0044*	.2601
	(.2155)	(.4653)	(.0956)	(.0881)	(.1025)	(.0332)	(.0026)	(.3215)
1983Q1-2007Q4	.7424***	.7087**	**.0476**	**-.0027**	**-.0133**	.0353	.0028	.0381
	(.2129)	(.3480)	(.3010)	(.0218)	(.0331)	(.0220)	(.0027)	(.1357)
1968Q2-2007Q4	.5037***	.6447***	-.0110	.0114	**-.0058**	.0065	.0034*	.0393
	(.1540)	(.2045)	(.079)	(.0111)	(.0152)	(.0144)	(.0019)	(.0586)
1995Q1-2007Q4	1.2756***	.0013	**.5469**	.0711	.1016	.0943***	.0011	-.5088
	(.3207)	(.3604)	(.5468)	(.0892)	(.1148)	(.0268)	(.0040)	(.4828)
Panel B: Equation without fpi_t								
$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_0 + \varepsilon_t}$								
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
Hendry's Eq(16)	0.28***	0.48	-0.12**	0.01	0.18***	0.35***	/	-0.22***
	(0.10)	(0.30)	(0.06)	(0.01)	(0.04)	(0.09)		(0.05)
1968Q2-1982Q4	.4839**	1.8062***	(.0450)	(-.0279)	(-.0608)	(-.0107)	/	.1842
	(.2199)	(.4714)	(.0974)	(.0893)	(.10355)	(.0337)		(.3249)
1983Q1-2007Q4	.7450***	.7194**	(.0892)	(-.0035)	(-.0148)	.0386*	/	.0405
	(.213)	(.3480)	(.2986)	(.0218)	(.0331)	(.0218)		(.1358)
1968Q2-2007Q4	.5096***	.6455***	-.0062	.0101	(-.0066)	.0077	/	.0413
	(.1552)	(.2061)	(.0795)	(.0112)	(.0153)	(.0145)		(.0591)
1995Q1-2007Q4	1.2919***	.0034	(.5496)	.0704	.1008	.0952***	/	-.5064
	(.3113)	(.3565)	(.5409)	(.0882)	(.1135)	(.0262)		(.4776)

Notes: $\Delta_1 ph_t = ph_t - ph_{t-1}$. $\Delta_1^2 p_{t-1} = \Delta_1 p_t - \Delta_1 p_{t-1}$. $\Delta_4 p_t = p_t - p_{t-4}$. ph_t is the house price index, m_t is the mortgage outstanding. $R_t^0 = R_t^*/100$. R_t^* is the after-tax mortgage rate. p_t is the general index of retail price. h_t is the physical housing stock. y_t represents the real household disposable income. c_a and c_b denotes the corresponding historical means of the feedback effects. fpi_t is foreign portfolio investment. The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. Throughout the chapter, the 'wrongly signed' coefficients are in bold. Coefficient standard deviations are in parentheses. ***, ** and * denote statistically significant at the 1%, 5% and 10% significance level, respectively. Panel B is drawn from Table 3.4 in Chapter 3.

To capture the well fitted possible expectation models, this chapter again investigates hundreds of alternative equations to equation (4.3) by changing the numbers of lags and/or the orders of differences to the independent variables. Following Chapter 3, the 'better' alternative model is selected by three criteria. Firstly, the coefficients are signed consistent with Hendry (1984) for a given model. Secondly, the coefficients are statistically significant in as many cases as possible. Thirdly, the model reports the smallest Akaike Information Criterion (AIC) statistic among the alternative models.

Table 4.5 illustrates the alternative equations to equation (4.3) with the diagnostic tests for residual normality, heteroskedasticity, autocorrelation, model specification and multicollinearity.

Table 4.5 The Alternative Equations for Equation (4.3)

Panel A: Equation with fpi_t								
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.4522**	.6484	-.2855*	.5418***	.0360**	.5617***	.0033	.0055
	(.2075)	(.4466)	(.1684)	(.1054)	(.0158)	(.1072)	(.0023)	(.0180)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4726	-243.4601	.1633	.1835	.5132	.0769*	2 VIF Values > 10	
	Remark							
	This model reports specification error and multicollinearity.							
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1^2 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_t + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.9132***	.2681*	-.0920	.5653***	.0266**	.6549***	.0055**	.0101*
	(.2136)	(.1570)	(.1759)	(.0800)	(.0122)	(.0852)	(.0026)	(.0058)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4766	-509.4014	.2009	.5185	.0154**	.2132	2 VIF Values > 10	
	Remark							
	This model reports residual autocorrelation and multicollinearity.							
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-2} + \alpha_3 (R^0 - \Delta_4 p)_{t-2} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_t + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.838***	.3641***	-.1709***	.5682	.039**	.6267***	.0012	.0111***
	(.1354)	(.1228)	(.0463)	(.0619)	(.0168)	(.0679)	(.0016)	(.0042)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4534	-744.5971	.1551	.3272	.0465**	.2267	2 VIF Values > 10	
	Remark							
	This model reports residual autocorrelation and multicollinearity.							
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-1} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_7 \Delta_1 fpi_t + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	1.3764***	.117	-.7685	.3050	.0432	.3222**	.0060	.0163**
	(.417)	(.483)	(.7616)	(.279)	(.2415)	(.1544)	(.0052)	(.0077)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.2163	-253.4087	.2234	.8046	.0417**	.6232	3 VIF Values > 10	
	Remark							
	More than half of the coefficients are insignificant. This model reports residual autocorrelation and multicollinearity.							
Panel B: Equation without fpi_t								
Hendry's Eq.(16)	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 (ph + h - p - y - c_a)_{t-1} + \alpha_5 (m - ph - h - c_b)_{t-1} + \alpha_6 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	0.28***	0.48	-0.12**	0.01	0.18***	0.35***	/	-0.22***
	(0.10)	(0.30)	(0.06)	(0.01)	(0.04)	(0.09)		(0.05)
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 \Delta_1 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1^2 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.4367**	.6729	-.2912*	.5366***	.0374**	.5674***	/	.0044
	(.2097)	(.4516)	(.1703)	(.1066)	(.0160)	(.1084)		(.0182)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4600	-243.0497	.2037	.2220	.2270	.0591*	2 VIF Values > 10	
	Remark							
	This model reports specification error and multicollinearity.							

1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1^2 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.9792***	.3192**	-.13299	.5423***	.02698**	.6325***	/	.0109*
	(.2154)	(.1580)	(.1782)	(.0807)	(.0124)	(.0861)		(.0059)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4566	-506.5692	.1236	.5877	.0201**	.1267	2 VIF Values > 10	
	Remark							
	This model reports residual autocorrelation and multicollinearity.							
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-2} + \alpha_3 (R^0 - \Delta_4 p)_{t-2} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-2} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	.8405***	.3641***	-.1706***	.5729***	.0403**	.6352***	/	.0110**
	(.1352)	(.1226)	(.0462)	(.0615)	(.0167)	(.0669)		(.0042)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4550	-745.9825	.1619	.2576	.0301**	.2277	2 VIF Values > 10	
	Remark							
	This model reports residual autocorrelation and multicollinearity.							
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1^2 p_{t-1} + \alpha_2 \Delta_1 m_{t-1} + \alpha_3 (R^0 - \Delta_4 p)_{t-1} + \alpha_4 \Delta_1 (ph + h - p - y)_{t-1} + \alpha_5 \Delta_1 (m - ph - h)_{t-1} + \alpha_6 \Delta_1 (y - h)_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_0
	1.5282***	.1133	-.6735	.2755	.0538	.2919*	/	.0175**
	(.397)	(.4847)	(.7599)	(.2789)	(.2422)	(.1527)		(.0077)
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.2106	-253.8633	.2001	.7588	.0270**	.2579	3 VIF Values > 10	
	Remark							
	This model reports residual autocorrelation and multicollinearity.							

Notes: The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticity. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. (O'Brien, 2007) suggests a variable reports the multicollinearity when the corresponding centred Variance Inflation Factor (VIF) > 10. The figures reported for the diagnostic tests are $p\text{-}values$, except for the VIF values. Panel B is drawn from Table 3.5 in Chapter 3.

The diagnostic tests in Table 4.5 suggest none of the selected alternative equations present economically sensible fit. Panel A of Table 4.5 suggests, for the dataset 1968Q2-1982Q4, the adjusted R^2 is 0.47, which is lower than the adjusted R^2, 0.67, reported for the equation (16) in Hendry (1984). A low adjusted R^2 is not evidence of a poor model (Gujarati and Porter, 2009). However, the poor coefficient significance and violation of diagnostic tests would indicate a poor model. For the dataset 1968Q2-1982Q4, 3 out of 7 independent variables are statistically insignificant at the 5% significance level. Even worse, this model violates the assumptions of no multicollinearity and residual independence. For the remaining three datasets, the alternative equations report residual autocorrelation and multicollinearity. The collinearity is probably due to the substantial values of household income $y_t$and mortgage outstanding $m_t$dominate the values for the ratio of borrowed to own equity $(m - ph - h)_t$ and the real income per household

$(y-h)_t$. For the dataset 1995Q1-2007Q4, more than half of the coefficients are statistically insignificant at the 5% significance level. Apart from the alternative equation for 1983Q1-2007Q4, none of the rest of FPI is statistically significant at the 5% significance level, implying that the changes in FPI $\Delta_1 fpi_t$ cannot be statistically significant in driving the changes in house prices, after controlling the other economic variables.

4.3.3 A Restricted Parameterisation

Equation (4.4) incorporates $\Delta_1 fpi_{t-1}$into the equation (17) of Hendry (1984) which is a restricted parameterisation model, *ceteris paribus*.

$$\begin{aligned}\Delta_1 ph_t = {} & \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4 (m-p-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \\ & \alpha_6 \Delta_1 (ph-p-y)_{t-1} + \alpha_7 \Delta_2 (m-p)_{t-3} + \alpha_8 r_t + \alpha_9 \Delta_7 r_t \\ & + \alpha_{10} \Delta_1 h_t + \alpha_{11} \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t \qquad 4.\,4\end{aligned}$$

Where, $A_n(\cdot)$ is a restricted Almon polynomial, $A_n(x_t) = \frac{2}{n(n+1)} \sum_{i=0}^{n} (n-i) x_{t-i}$.

$A_n(x_t)$ provides a weighted average of x_{t-i}, with linearly decreasing weights. Table 4.6 shows the results for equation (4.4).

Table 4.6 The Output for Equation (4.4)

Panel A: Equation with fpi_t							
$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4 (m-p-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 \Delta_1 (ph-p-y)_{t-1} + \alpha_7 \Delta_2 (m-p)_{t-3} + \alpha_8 r_t + \alpha_9 \Delta_7 r_t + \alpha_{10} \Delta_1 h_t + \alpha_{11} \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t}$							
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4919***	12.322	.8048**	**-.1003**	.1225	-.0385	.1696
	(.1457)	(10.077)	(.3127)	(.0935)	(.1160)	(.0475)	(.1289)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0298	**.0044**	-.0134	.0043*	.1983	/	/
	(.0316)	(.0222)	(.0312)	(.0022)	(.4525)		
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0425	24.413*	.1598	.0189	**-.0239**	-.0238	.5717***
	(.1116)	(12.342)	(.4140)	(.0273)	(.0403)	(.0198)	(.1773)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0299*	**.0181**	**.0255**	.0002	-.1220	/	/
	(.0154)	(.0124)	(.0232)	(.0028)	(.1872)		
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.2251***	18.694**	.5342**	**-.024*****	.0277	-.0081	.2152***
	(.0853)	(7.523)	(.2389)	(.0091)	(.0188)	(.0144)	(.0716)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0243***	**.0079**	**.0167**	.0026	.1039	/	/
	(.0078)	(.0093)	(.0178)	(.0017)	(.0818)		

1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.1487	47.8058	**-.6866**	.4958**	**-.2970***	-.2136**	.6932***
	(.1546)	(35.0031)	(.5220)	(.2002)	(.1584)	(.0867)	(.2553)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	.0870**	-.0440	-.0918**	.0092	-3.2622**	/	/
	(.0407)	(.0292)	(.0371)	(.0067)	(1.2410)		

Panel B: Equation without fpi_t

$$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4 (m-p-h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 \Delta_1 (ph-p-y)_{t-1} + \alpha_7 \Delta_2 (m-p)_{t-3} + \alpha_8 r_t + \alpha_9 \Delta_7 r_t + \alpha_{10} \Delta_1 h_t + \alpha_0 + \varepsilon_t$$

Hendry's Eq.(17)	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.24***	11.4***	0.57***	0.122***	0.53***	-0.18***	0.45***
	(0.11)	(4.8)	(0.22)	(0.026)	(0.10)	(0.05)	(0.15)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-0.013	-0.027**	-3.0	/	-1.01	/	/
	(0.021)	(0.015)	(2.3)		(0.37)		
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4573***	12.896	.7201**	**-.0950**	.1210	-.0445	.1853
	(.1496)	(10.418)	(.3203)	(.0966)	(.1199)	(.0490)	(.1331)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0368	**.0114**	-.0093	/	.1699	/	/
	(.0324)	(.0226)	(.0322)		(.4678)		
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0416	24.447**	.1637	.0191	**-.024**	-.0239	.5741***
	(.1100)	(12.273)	(.4066)	(.0269)	(.040)	(.0196)	(.1716)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0298*	**.0181**	**.0257**	/	-.1234	/	/
	(.0153)	(.0123)	(.0228)		(.1847)		
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.2086**	18.856**	.5254**	**-.025*****	.0294	-.0079	.2322***
	(.0850)	(7.559)	(.240)	(.0091)	(.0189)	(.0145)	(.0710)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0248***	**.0089**	**.0201**	/	.1086	/	/
	(.0079)	(.0093)	(.0178)		(.0821)		
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.2235	54.5707	**-.6537**	.4107**	**-.2273**	-.1789**	.7442***
	(.1467)	(35.149)	(.5283)	(.1929)	(.1521)	(.0840)	(.2558)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	.0903**	-.0387	-.0790**	/	-2.755**	/	/
	(.04116)	(.0293)	(.0363)		(1.200)		

Notes: ***, ** and * mean statistically significant at the 1%, 5% and 10% significance level, respectively. 'Wrongly signed' coefficients are in bold. Panel B is drawn from Table 3.6 in Chapter 3.

From Table 4.6, either panel A or panel B, the results do not make any economic sense even without the diagnostic tests, given the majority of coefficients are insignificant and/or 'wrongly signed'. The regression parameters for equation (4.4) change in both sign and magnitude over datasets.

Following Table 4.5, Table 4.7 illustrates the better alternative equations to equation (4.4) with a range of diagnostic tests. Panel A of Table 4.7 suggests the alternative equation for 1983Q1-2007Q4 violates the assumption of residual normality and independence. The alternative model for 1968Q2-2007Q4 reports residual heteroskedasticity, autocorrelation, specification error and multicollinearity. Although the alternative equations for 1968Q2-1982Q4 and 1995Q1-2007Q4 satisfy all the diagnostic tests, the fit of these two models is poor as more than half of the coefficients are statistically insignificant.

Table 4.7 The Alternative Equations for Equation (4.4)

Panel A: Equation with fpi_t							
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4(m-p-h)_{t-1} + \alpha_5(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_t + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_{11}\Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.9355***	23.523***	.6127**	.0485	.0273	-.5129***	.1169
	(.1931)	(8.736)	(.2908)	(.0314)	(.0277)	(.1624)	(.1023)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0284	-.0152	-.0305	.0034*	-.0091	/	/
	(.0270)	(.0109)	(.0290)	(.0020)	(.0074)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.6080	-250.1831	.4744	.2944	.2530	.6182	All VIFs < 10
	Remark						
	More than half of the coefficients are insignificant.						
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3_{t-1} + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4\Delta_1(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-1} + \alpha_8\Delta_1 r_{t-1} + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_{11}\Delta_1 fpi_t + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1910**	17.209	.1107	.0088	.0871***	-.0125	.6438***
	(.0940)	(11.1456)	(.2852)	(.0115)	(.0263)	(.0127)	(.1043)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0078	-.0322	-.0396*	.0043	.0185	/	/
	(.0355)	(.0361)	(.0219)	(.0028)	(.0585)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.3746	-488.0422	.0020***	.8186	.0145**	.2257	2 VIFs > 10
	Remark						
	This model reports residual autocorrelation and multicollinearity. Half of the coefficients are insignificant.						
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-3} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1^2(m-p-h)_{t-2} + \alpha_5\Delta_1^2(y-h)_{t-2} + \alpha_6\Delta_1^2(ph-p-y)_{t-3} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_{t-1} + \alpha_9\Delta_7 r_{t-1} + \alpha_{10}\Delta_1 h_{t-1} + \alpha_{11}\Delta_1 fpi_t + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.3422***	26.757***	.5248**	.0232	.0132	-.0979	.0958
	(.0959)	(7.295)	(.2365)	(.0830)	(.0830)	(.0677)	(.0685)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0102	-.0162*	-.0448**	.0025	.0285	/	/
	(.0063)	(.009)	(.0191)	(.0017)	(.0133)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.3658	-707.4236	.7345	.0363**	.0001***	.0259**	2 VIFs > 10
	Remark						
	This model violates four diagnostic tests. More than half of the coefficients are insignificant.						
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1^2 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3\Delta_1(A_2(\Delta_1 y_t)) + \alpha_4\Delta_3(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-2} + \alpha_8\Delta_1 r_{t-2} + \alpha_9\Delta_7 r_{t-2} + \alpha_{10}\Delta_1^2 h_{t-2} + \alpha_{11}\Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1201	66.2298	.0214	.0126	.0601	-.2178	.4410*
	(.1686)	(51.4176)	(.3115)	(.0408)	(.0373)	(.2426)	(.2341)

	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0214	-.0258	-.0367*	.0077	.0142**	/	/
	(.0650)	(.0215)	(.0189)	(.0079)	(.0058)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.3490	-216.499	.6561	.9088	.7164	.2655	All VIFs < 10
	Remark						
	Majority of coefficients are insignificant.						
Panel B: Equation without fpi_t							
Hendry's Eq. (17)	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4(m-p-h)_{t-1} + \alpha_5(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_t + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.24***	11.4***	0.57***	0.122***	0.53***	-0.18***	0.45***
	(0.11)	(4.8)	(0.22)	(0.026)	(0.10)	(0.05)	(0.15)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-0.013	-0.027*	-3.0		-1.01***	/	/
	(0.021)	(0.015)	(2.3)		(0.37)		
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3_{t-1} + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4\Delta_1(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-1} + \alpha_8\Delta_1 r_{t-1} + \alpha_9\Delta_7 r_t + \alpha_{10}\Delta_1 h_t + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.9611***	24.0394***	.555*	.0579*	.0269	-.5435***	.1321
	(.1968)	(8.9272)	(.2953)	(.0316)	(.0283)	(.1650)	(.1042)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0318	-.0145	-.0295		-.0103	/	/
	(.0275)	(.0112)	(.0296)		(.0076)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.5902	-248.5856	.4320	.2791	.3555	.3873	All VIFs < 10
	Remark						
	Half of the coefficients are insignificant.						
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1^2 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3_{t-2} + \alpha_3 A_2(\Delta_1 y_t)_t + \alpha_4\Delta_1^2(m-p-h)_{t-1} + \alpha_5\Delta_2(y-h)_{t-1} + \alpha_6(ph-p-y)_{t-3} + \alpha_7\Delta_2(m-p)_{t-1} + \alpha_8 r_{t-3} + \alpha_9 r_{t-4} + \alpha_{10}\Delta_3 h_{t-4} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1850*	17.1300	.1050	.0092	.0860***	-.0138	.6755***
	(.0946)	(11.2332)	(.2874)	(.0116)	(.0265)	(.0127)	(.103)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0051	-.0353	-.0448		.013	/	/
	(.0357)	(.0363)	(.0219)		(.0588)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.3651	-487.3959	.0024***	.8132	.0221**	.1505	2 VIFs > 10
	Remark						
	This model is poor. Most of the coefficients are insignificant.						
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-3} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1^2(m-p-h)_{t-2} + \alpha_5\Delta_1^2(y-h)_{t-2} + \alpha_6\Delta_1^2(ph-p-y)_{t-3} + \alpha_7\Delta_2(m-p)_{t-3} + \alpha_8 r_{t-1} + \alpha_9\Delta_7 r_{t-1} + \alpha_{10}\Delta_1 h_{t-1} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.3243***	27.002***	.5338**	.0178	.0201	-.0921	.1087
	(.0954)	(7.3220)	(.2374)	(.0832)	(.0832)	(.0678)	(.0681)
	α_8	α_9	α_{10}	α_{11}	α_0	/	/
	-.0106*	-.0159*	-.0517***		.0293**	/	/
	(.0064)	(.009)	(.0185)		(.0133)		
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
	0.3609	-707.1701	.7131	.0301**	.0001***	.0233**	2 VIFs > 10
	Remark						
	This model violates four basic assumptions.						
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1^2 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3\Delta_1(A_2(\Delta_1 y_t)) + \alpha_4\Delta_3(m-p-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-1} + \alpha_6\Delta_1(ph-p-y)_{t-1} + \alpha_7\Delta_2(m-p)_{t-2} + \alpha_8\Delta_1 r_{t-2} + \alpha_9\Delta_7 r_{t-2} + \alpha_{10}\Delta_1^2 h_{t-2} + \alpha_0 + \varepsilon_t$						
	α_1	α_2	α_3	α_4	α_5	α_6	α_7

.1847	61.358	.0029	.0208	.0536	-.2277	.4005*
(.1551)	(51.157)	(.3107)	(.0399)	(.0367)	(.2423)	(.2303)
α_8	α_9	α_{10}	α_{11}	α_0	/	/
-.0150	-.0294	-.0368*		.0157	/	/
(.0646)	(.0212)	(.0188)		(.0056)		
Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF
0.3499	-217.1956	.4782	.9651	.2774	.6555	All VIFs < 10
Remark						
This model is poor. Most of the coefficients are insignificant.						

Notes: The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticity. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. (O'Brien, 2007) suggests a variable reports the multicollinearity when the corresponding centred Variance Inflation Factor (VIF) > 10. The figures reported for the diagnostic tests are $p\text{-}values$, except for the VIF values. Panel B is drawn from Table 3.7 in Chapter 3.

Equation (4.5) incorporates $\Delta_1 fpi_{t-1}$ to the equation (18) of Hendry (1984).

$$\begin{aligned} \Delta_1 ph_t = {} & \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4 (m - ph - h)_{t-1} + \alpha_5 (y - h)_{t-1} + \\ & \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m - p) + \alpha_8 \bar{R}^0_{t-3} \\ & + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_{12} \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t \qquad 4.5 \end{aligned}$$

Where, $F_{13}(x) = \Delta_1(x_{t-1} + x_{t-3})$ and $\bar{x}_t = (x_t + x_{t-1})/2$.

Relative to equation (3.4), equation (3.5) removes changes in physical housing stock $\Delta_1 h_t$; replaces the real value of the mortgage stock $(m - p - h)_{t-1}$ and ratio of house price to income $(ph - p - y)_{t-1}$ by ratio of borrowed to own equity $(m - ph - h)_{t-1}$; uses the original interest rates $\bar{R}^0_t$ instead of natural logarithmic and takes two dummy variables into account. Table 4.8 defines the dummy variables.

Table 4.8 Dummy Variables for Equation (4.5)

Dataset	$D_1 = 1$	$D_2 = 1$	$D_2 = -2$
Hendry (1984)	1967Q3; 0 otherwise	1981Q3 & 1982Q1	1982Q2; 0 otherwise
1968Q2-1982Q4	1979Q2; 0 otherwise	1981Q4 & 1982Q1;	1982Q2; 0 otherwise
1983Q1-2007Q4	1997Q2; 0 otherwise	2006Q1 & 2007Q1; 0 otherwise	/
1968Q2-2007Q4	1979Q1; 0 otherwise	1997Q1 & 2007Q1; 0 otherwise	/
1995Q1-2007Q4	1997Q2; 0 otherwise	2006Q1 & 2007Q1; 0 otherwise	/

Table 4.9 displays the results for equation (4.5). Again, a large number of coefficients are statistically insignificant and/or 'wrongly signed'; and the parameters vary over time. Because the sets of dummy variables in this chapter are differ from Hendry (1984), and there is no prior theoretical assumption on the relationship between dummy variables and house prices, the signs

of dummy variables in Tables 4.9 and 4.10 are not necessarily consistent with Hendry (1984). Hendry (1984) suggests that the model shown as equation (4.5) satisfies most of the model selection criteria. Unfortunately, it does not fit into this chapter's datasets, either panel A or panel B.

Table 4.9 The Output for Equation (4.5)

Panel A: Equation with fpi_t							
$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4 (m - ph - h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_{12} \Delta_1 fpi + \alpha_0 + \varepsilon_t}$							
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4375***	9.3793	.5755***	.0342	**-.0188**	.4600	.2628
	(.1361)	(10.027)	(.2080)	(.0370)	(.0404)	(.2809)	(.2493)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.4335	-.0478	-.6287	-2.2746**	.0032	-.1127	/
	(.2649)	(.3026)	(2.163)	(.878)	(.0021)	(.1495)	
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0126	20.982	.2671	.0250	.0116	.8711***	.7357***
	(.1174)	(12.7439)	(.3399)	(.0169)	(.0196)	(.3111)	(.1858)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.5251***	**.1304**	-.5455	.5844	.0022	-.1117	/
	(.1742)	(.4584)	(2.3714)	(1.7232)	(.0027)	(.0882)	
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.1175	16.453**	.5226***	.0063	.0019	.7119***	.4950***
	(.0817)	(7.4018)	(.1770)	(.0110)	(.0119)	(.1711)	(.1129)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.5149***	-.1263	.2769	.2043	.0036**	-.0080	/
	(.1105)	(.2388)	(2.2607)	(1.6027)	(.0017)	(.0473)	
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.2488	47.8419	**-.1569**	.0481*	.0387	.7135	.4314
	(.1526)	(36.3271)	(.4946)	(.0238)	(.0397)	(.5111)	(.3738)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.5918	**.4216**	-1.1305	.9520	.0054	-.2297**	/
	(.8550)	(1.5116)	(2.3243)	(1.6083)	(.0070)	(.1052)	
Panel B: Equation without fpi_t							
$\boldsymbol{\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2 (\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4 (m - ph - h)_{t-1} + \alpha_5 (y-h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_0 + \varepsilon_t}$							
Hendry's Eq.(18)	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	0.22***	14.0***	0.42***	0.178***	0.47***	0.85***	0.54***
	(0.07)	(4.9)	(0.07)	(0.027)	(0.08)	(0.12)	(0.11)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-0.22***	-0.50***	-3.5***	-2.1***	/	-3.0***	/
	(0.09)	(0.20)	(0.4)	(0.3)		(0.05)	
1968Q2-1982Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.4282***	8.8207	.5451**	.0297	**-.0089**	.4181	.2547
	(.1381)	(10.1835)	(.2104)	(.0375)	(.0405)	(.2842)	(.2534)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.4946*	-.0943	-.6837	-2.5211***	/	-.0879	/
	(.2662)	(.3060)	(2.198)	(.8780)		(.1510)	
1983Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.0009	21.543*	.3110	.0248	.0128	.8547***	.7501***
	(.1161)	(12.709)	(.3353)	(.0169)	(.0191)	(.3099)	(.1847)

	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.52370***	**.1395**	-.6022	.6086	/	-.1119	/
	(.1739)	(.4575)	(2.366)	(1.7200)		(.0881)	
1968Q2-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	.0971	16.814**	.5289***	.0042	.0040	.6952***	.5090***
	(.0822)	(7.492)	(.1792)	(.0111)	(.0120)	(.1731)	(.1141)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.5147***	-.1546	.3020	-.0188	/	.0008	/
	(.1118)	(.2414)	(2.2888)	(1.619)		(.0477)	
1995Q1-2007Q4	α_1	α_2	α_3	α_4	α_5	α_6	α_7
	-.2797*	53.453	**-.1241**	.0466*	.0479	.7814	.4604
	(.1464)	(35.452)	(.4899)	(.0236)	(.0377)	(.5006)	(.3697)
	α_8	α_9	α_{10}	α_{11}	α_{12}	α_0	/
	-.4452	**.8234**	-1.0671	.8642	/	-.2392**	/
	(.8288)	(1.4104)	(2.3095)	(1.595)		(.1039)	

Notes: ***, ** and * denote statistically significant at the 1%, 5% and 10% significance level, respectively. ‘Wrongly signed’ coefficients are in bold. Panel B is drawn from Table 3.9 in Chapter 3.

Table 4.10 shows the better alternative models for equation (4.5). Like any previous findings, the fixed parameter regression models report severely from parameter instability and a large number of coefficients are statistically insignificant. Panel A of Table 4.10 reveals that the alternative model for 1968Q2-1982Q4 satisfies all the diagnostic tests; the alternative model for 1983Q1-2007Q4 reports residual autocorrelation; the alternative model for 1968Q2-2007Q4 reports residual non normality and heteroskedasticity at the 5% significance level. The alternative model for 1995Q1-2007Q4 reports residual non normality. Three out of four coefficients for the FPI are statistically insignificant over the samples. Overall, the general findings of panel A and panel B are consistent in terms of parameter instability and poor robustness.

Table 4.10 The Alternative Model for Equation (4.5)

Panel A: Equation with fpi_t								
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m - ph - h)_{t-1} + \alpha_5 \Delta_1(y-h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_{12} \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4643***	5.9492	.5043**	.0259	.0503**	.5261*	.3088	-.6052***
	(.1231)	(9.2073)	(.2001)	(.0199)	(.0228)	(.2680)	(.2369)	(.1977)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.1713	-1.1541	-2.353***	.0035*	-.0731			
	(.2706)	(2.0673)	(.8345)	(.0019)	(.0642)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.6150	-267.2571	.5344	.1740	.3066	.7428	All VIF Values < 10	
	Remark							
	More than half of the coefficients are statistically insignificant at the 5% significance level.							
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1 \Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m - ph - h)_{t-1} + \alpha_5 \Delta_1(y-h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8 \bar{R}^0_{t-3} + \alpha_9 \Delta_1 R^0_{t-1} + \alpha_{10} D^0_1 + \alpha_{11} D^0_2 + \alpha_{12} \Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4256***	8.8752	.1076	.0106	.0820***	.5398**	.4499***	-.4593***
	(.1287)	(13.3612)	(.3811)	(.0124)	(.0222)	(.2324)	(.1184)	(.1278)

	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.7530**	-.3492	1.9168	.0005	-.0325			
	(.3694)	(2.0937)	(1.5832)	(.0025)	(.0659)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.3868	-489.1495	.1035	.5149	.4510	.0383**	All VIF Values < 10	
	Remark							
	More than half of the coefficients are statistically insignificant, and the model reports residual autocorrelation.							
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1(m-ph-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8\bar{R}^0_{t-3} + \alpha_9\Delta_1 R^0_{t-1} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_{12}\Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.1175	16.4531**	.5226***	.0063	.0019	.7119***	.4950***	-.5149***
	(.0817)	(7.4018)	(.1770)	(.0110)	(.0119)	(.1711)	(.1129)	(.1105)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.1263	.2769	.2043	.0036**	-.0080	/	/	/
	(.2388)	(2.2607)	(1.6027)	(.0017)	(.0473)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.3741	-729.9944	.0140**	.0394**	.0661*	.0709*	All VIF Values < 10	
	Remark							
	Half of the coefficients are insignificant, and the model reports residual non-normality and heteroskedasticity at 5% level.							
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_4 ph_t + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1(m-ph-h)_{t-1} + \alpha_5\Delta_2(y-h)_{t-2} + \alpha_6 F_{13}(p)_{t-2} + \alpha_7 F_{13}(m-p)_{t-2} + \alpha_8\Delta_4\bar{R}^0_{t-2} + \alpha_9\Delta_1 R^0_{t-2} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_{12}\Delta_1 fpi_{t-1} + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4424***	28.9437	.1860	.0585*	.0174	1.0633*	.5160*	-.5395
	(.1207)	(37.0105)	(.3902)	(.0325)	(.0391)	(.5655)	(.2687)	(.5958)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-1.0283	-1.4915	-.6400	.0068	-.0019	/	/	/
	(1.1619)	(1.8488)	(1.3184)	(.0064)	(.0120)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.3660	-229.0623	.0215**	.9287	.1832	.3528	All VIF Values < 10	
	Remark							
	Majority of coefficients are insignificant. The residual of this model is non-normality.							
Panel B: Equation without fpi_t								
Hendry's Eq. (18)	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m-ph-h)_{t-1} + \alpha_5(y-h)_{t-1} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8\bar{R}^0_{t-3} + \alpha_9\Delta_1 R^0_{t-1} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	0.22***	14.0***	0.42***	0.178***	0.47***	0.85***	0.54***	-0.22***
	(0.07)	(4.9)	(0.07)	(0.027)	(0.08)	(0.12)	(0.11)	(0.09)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-0.50***	-3.5***	-2.1***		-0.30***			
	(0.20)	(0.4)	(0.3)		(0.05)			
1968Q2-1982Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t) + \alpha_4(m-ph-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8\bar{R}^0_{t-3} + \alpha_9\Delta_1 R^0_{t-1} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4631***	6.2378	.4731**	.0288	.0465*	.4807*	.2928	-.6195***
	(.1262)	(9.435)	(.2043)	(.0204)	(.0233)	(.2734)	(.2426)	(.2024)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.1878	-1.1966	-2.6213***		-.0800			
	(.2772)	(2.1186)	(.8411)		(.0657)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.5956	-265.2553	.6804	.3534	.4975	.3812	All VIF Values <10	

	Remark							
	Half of the coefficients are insignificant.							
1983Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-1} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t) + \alpha_4(m-ph-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-1} + \alpha_6 F_{13}(p)_{t-2} + \alpha_7 F_{13}(m-p)_{t-1} + \alpha_8\bar{R}^0_{t-2} + \alpha_9\Delta_1 R^0_{t-2} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4314***	8.5742	.1195	.0109	.0829***	.5377**	.4501***	-.4569***
	(.1239)	(13.1711)	(.3735)	(.0122)	(.0215)	(.2308)	(.1178)	(.1265)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.7438**	-.3807	1.9497		-.0343			
	(.3640)	(2.0752)	(1.5644)		(.0649)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.3935	-491.1132	.1002	.4303	.4032	.0318**	All VIF Values <10	
	Remark							
	Half of the coefficients are insignificant.							
1968Q2-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_1 ph_{t-2} + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_3(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1(m-ph-h)_{t-1} + \alpha_5\Delta_1(y-h)_{t-2} + \alpha_6 F_{13}(p) + \alpha_7 F_{13}(m-p) + \alpha_8\bar{R}^0_{t-3} + \alpha_9\Delta_1 R^0_{t-1} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.1790**	13.2595*	.6153**	.0653***	.0612***	.5834***	.4577***	-.5364***
	(.0830)	(7.3172)	(.2402)	(.0180)	(.019)	(.0917)	(.0917)	(.1027)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-.2827	.1564	.4372		.0255***			
	(.2376)	(2.2175)	(1.5833)		(.0067)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.4009	-737.673	.3340	.1530	.0001	.2333	All VIF Values <10	
	Remark							
	This model reports residual autocorrelation.							
1995Q1-2007Q4	$\Delta_1 ph_t = \alpha_1\Delta_4 ph_t + \alpha_2(\Delta_1 ph_{t-1})^3 + \alpha_3 A_2(\Delta_1 y_t)_{t-1} + \alpha_4\Delta_1(m-ph-h)_{t-1} + \alpha_5\Delta_2(y-h)_{t-2} + \alpha_6 F_{13}(p)_{t-2} + \alpha_7 F_{13}(m-p)_{t-2} + \alpha_8\Delta_4\bar{R}^0_{t-2} + \alpha_9\Delta_1 R^0_{t-2} + \alpha_{10}D^0_1 + \alpha_{11}D^0_2 + \alpha_0 + \varepsilon_t$							
	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
	.4732***	34.5078	.3084	.0649*	.0311	1.1733**	.5665**	-.4384
	(.1174)	(36.7069)	(.3734)	(.0320)	(.0369)	(.5570)	(.265)	(.5892)
	α_9	α_{10}	α_{11}	α_{12}	α_0	/	/	/
	-1.0393	-1.1899	-.7270		-.0052			
	(1.1639)	(1.8302)	(1.3184)		(.0116)			
	Adj. R^2	AIC	ς_1	ς_2	ς_3	ς_4	Centred VIF Value	
	0.3636	-229.51	.0725*	.9147	.2812	.5094	All VIF Values <10	
	Remark							
	This model is poor. Most of the coefficients are insignificant.							

Notes: The dataset 1995Q1-2007Q4 uses the composite mortgage rate of the Building Societies and Banks, while all the other three datasets use the mortgage rate of the Building Societies. ς_1 denotes the Skewness-Kurtosis Normality Test. ς_2 denotes the Breusch-Pagan Test for Heteroskedasticity. ς_3 denotes Breusch-Godfrey LM Test for Autocorrelation. ς_4 denotes Ramsey RESET Test for Model Specification. (O'Brien, 2007) suggests a variable reports the multicollinearity when the corresponding centred Variance Inflation Factor (VIF) > 10. The figures reported for the diagnostic tests are *p-values*, except for the VIF values. Panel B is drawn from Table 3.10 in Chapter 3.

4.4 Conclusion

This chapter contributes to the housing literature by assessing whether an open economy framework is superior to its closed economy counterpart by incorporating Foreign Portfolio Investment (FPI) into Hendry (1984) in terms of four recent datasets. Firstly, the results indicate that incorporating an exogenous variable such as FPI does not enhance the model's robustness under the fixed parameter regression framework, *ceteris paribus*. Secondly, this chapter suggests that the changes in FPI in general do not statistically significantly drive the house prices after controlling for the effect of other economic variables, which supports Whelan (2010) and Xu and Chen (2012). However, the second findings could be biased conditional on the poor model fitting.

Technically speaking, the classical fixed parameter demand and supply equations are poor in terms of robustness, either in a closed economy or an open economy framework. This is because they all fail to model the effect of people's expectations and/or institutional changes on housing market explicitly. Therefore, the thesis will study the UK house prices by using more sophisticated empirical models in Chapters 5 through to 7 which take account of the expectations and institutional changes specifically.

Chapter 5. Identification of House Price Bubbles using User Cost in a State Space Model

5.1 Introduction

The poor robustness of the classical demand and supply econometric equations in Chapters 3 and 4 prompt this chapter to the application of an asset market approach. This chapter expands Chapters 3 and 4 by addressing two issues specifically.

- Firstly, how much variation in house price results from bubbles?
- Secondly, whether bounded rationality expectation hypothesis best fit into the UK housing market?

A persistent and substantial divergence between market price and its fundamental value is evidence of a bubble. In an efficient market, where the current asset price has fully, instantaneously and correctly reflected all relevant information, there are no speculative bubbles. However, there are a number of papers in the literature (Black *et al.*, 2006; Xiao and Randolph Tan, 2007) suggest the house price may contain a non-fundamental element, or bubble element. The quantification of bubbles in house prices will make market participants aware of the size of their risk exposure and can help them to detect early signals of the possibility of a financial market crash (Reinhart and Rogoff, 2009). These signals drive investors to respond rationally and adjust house prices toward their fair value. Furthermore, policy-makers can use information about the existence and size of bubbles in order to stabilize the market.

Black *et al.* (2006) find that intrinsic bubbles, which depend on the Bounded Rationality Hypothesis, have an important role to play in determining actual house prices in terms of the UK housing data over the periods from 1973Q4 through 2004Q3 by using a Vector Autoregression (VAR) based time-varying risk present value model. The present chapter considers if their result is supported by using a User Cost Framework based State Space model, furthermore, whether the bounded rationality hypothesis fits into the UK housing market in the presence of Subprime Crisis in 2008.

This chapter contributes to the literature from two aspects. Firstly, this chapter proposes a two-step approach of quantifying a bubble in housing by incorporating the present value of housing User Cost into a State Space Model (SSM). The two-step approach bases the estimation of fundamental value on the user cost framework which takes mortgage rates, taxes, rent prices, expected capital gain and people's risk premium into account relative to a simple price-income ratio. Moreover, the unobservable bubble time series is estimated by taking advantages of a Kalman filter. Relative to Black *et al.* (2006)'s time varying present value approach, an absolute valuation approach, the User Cost in a State Space Model is a relative valuation approach. The present value model is extremely sensitive to the quality of inputs, such as the estimate of discount rate. The key advantage of the relative value method, especially when contrasted with the present value approach is based on the assumption that fundamental house purchase prices are not necessarily the summation of discounted future values. Given that a large numbers of investors use market arbitrage opportunities as their activity criterion, the relative valuation approach appears attractive (Poterba, 1984; Case and Shiller, 1989; Himmelberg *et al.*, 2005). Secondly, given the bubble process does not follow an explosive path and has a statistically significant positive correlation with the fundamental price-rent ratio and House Rent Index, our results support the bounded rationality hypothesis. The empirical results indicate that UK house prices were undervalued from 1996Q1 to 2002Q2 and thereafter entered into a bubble by 2011Q1. Although consistent with Black *et al.* (2006) in general, our results provide more recent empirical evidence. The bounded rationality hypothesis argues that people make expectations and decisions to help them satisfice rather than make theoretically optimal decisions. Therefore, people take steps to achieve short-run targets, as long as they assist people toward the ultimately desired target.

Although many papers in the literature agree about the presence of bubbles in housing markets, there are controversies about the features of a bubble. Under the Rational Expectation Hypothesis, Diba and Grossman (1988a,b) suggest rational bubbles have explosive conditional expectations. Therefore, a rational bubble might either increase or decrease into the infinite future. Under the Bounded Rationality Expectation Hypothesis, Black *et al.* (2006) suggest intrinsic bubbles or bounded rational bubbles do not continuously diverge but periodically revert toward their fundamental value and are statistically correlated with fundamental variables. The bounded rationality bubble captures the idea that asset prices overreact to relevant information on fundamentals. Under the Irrational Expectation Hypothesis, Akerlof and Shiller (2010) suggest bubbles reflect are independent of fundamental values.

This chapter identifies a bubble when the following characteristics are met simultaneously. Firstly, there is a persistent and substantial deviation of house prices from their fundamental value. Secondly, such a deviation follows a non-stationary AR(1) random process while the changes in the bubble are stationary. The chapter proposes that the bubble results from people who are willing to purchase an overpriced asset now with the aim of avoiding paying an unreasonably higher price to buy the asset in the future (Shiller, 1990; Froot and Obstfeld, 1991; Wu, 1997; Himmelberg *et al.*, 2005; Black *et al.*, 2006; Xiao and Randolph Tan, 2007; Al-Anaswah and Wilfling, 2011).

In the study of speculative bubbles, there are two broad categories of literature, namely, indirect bubble tests and direct bubble tests. The first category of research attempts to conquer the econometric limitations of standard tests by implementing sophisticated cointegration and unit root tests to relationships such as those between price-dividend and price-income. If one rejects the null hypothesis of market efficiency this, indicates the presence of a bubble (Campbell and Shiller, 1987,1988b,a; Evans, 1991; McMillan, 2007). One essential limitation of the indirect bubble tests is the tests cannot generate a time series of the bubble component. By contrast, direct bubble tests explicitly formulate the presence of a bubble in the alternative hypothesis. These tests typically, identify the deviation of asset prices from the determined fundamental values, and use the discrepancies to generate a bubble time series (Wu, 1997; Himmelberg *et al.*, 2005; Black *et al.*, 2006; Xiao and Randolph Tan, 2007). Given that fundamental value is typically inferred, rather than directly observed, the estimation of bubbles is somewhat dependent on the assumptions of the model used. This chapter follows the direct bubble tests, as we aim to extract a bubble time series and investigate the path of bubble.

The remainder of the chapter is structured as follows. Section 5.2 reviews the literature about bubble quantification. Section 5.3 exhibits the methodology of the State-Space Model within User Cost Framework. Data descriptions are in Section 5.4. Section 5.5 reports the empirical results and discussion. Section 5.6 concludes the chapter.

5.2 Literature Review

This section investigates the evolution of bubble quantification techniques by reviewing the bubble literature into two categories; 5.2.1 simple housing market indicators and 5.2.2 econometric models.

5.2.1 Simple Housing Market Indicators

Price Appreciation Rate

In order to study when house prices are excessive, researchers frequently start by assessing the house price appreciation rate (Hendry, 1984). A bubble is recognized when the price appreciation rate exceeds a predetermined rate (Himmelberg *et al.*, 2005; Finicelli, 2007). Generally speaking, a house provides homeowners with two distinctive benefits: shelter and an investment asset. From the perspective of shelter, the most essential features of housing is that the house be durable but also experience depreciation with the passage of time. From the investment perspective, the total return for a homeowner consists of two components; the rent saved by living in the 'rent-free' house or received from the purchase-to-rent, and the appreciation of house prices. This means a higher house price is compensation for the investor's capital investment and the risk bearing on that investment. Therefore, high price appreciation does not necessarily mean that prices are deviating from underlying value; it may instead be driven by fundamentals such as the risk premium.

House Price-Income Ratio

A second widely used simple indicator is the house price-income ratio, which is the house price divided by income, see equation (5.1). Based on the hypothesis that home prices and incomes share some common trends in the long-term, aggregate demand for a home is proposed to be a stable function of the average income in any particular period. A high price-income ratio indicates the expense of purchasing a house entails devoting a higher percentage of income. A higher home price-income ratio ensures the growth of capital value and investment returns for those who already own a house, whereas, a higher price-income ratio means housing prices are more 'overvalued' (Himmelberg *et al.*, 2005; Girouard *et al.*, 2006; Finicelli, 2007).

$$Price\ Income\ Ratio = \frac{House\ Price}{Income} \qquad 5.1$$

However, the price-income ratio does not consider the value of housing services and ignores mortgage rates. The per-capita income used in many countries is an average evaluation that covers the aggregate population, but the specific groups of sellers and buyers that determine the house prices may have income that is significantly different from the population mean. Furthermore, the price-income ratio measures the local purchasing ability relative to the local housing prices. It does not consider the purchasing power from outside the local statistical area and the availability of mortgages. With the acceleration of globalization, international capital flow and population migration plays a much more important role than ever in the determination of domestic equilibrium house prices. An equilibrium price is set through market competition and refers to a situation where the supply of housing equals demand. When there is huge house demand caused either by speculation with hot money (e.g. Japan's housing appreciation in the early 1990's) or wealth movements from abroad or the rest of country (e.g. London at the metropolitan level; and the UK and the US at the state level (Benson *et al.,* 1997)), domestic equilibrium house prices may be above the price that local people can afford.

House Price-Rent Ratio

A third popular cited ratio used to examine housing prices is the house price-rent ratio, see equation (5.2), this is the house price divided by the house rent. The rationale is that either renting or owning a house provides people with shelter and when the price is high relative to rent, people should rent a house rather than buy one and *vice versa*. In theory, rational people will drive house prices and rents towards their long run equilibrium. A higher price-rent ratio is associated with high house prices and is akin to estimating the price-earnings ratio for shares.

$$Price\ Rent\ Ratio = \frac{House\ Price}{Rent} \qquad 5.2$$

As with the price-income ratio, price-rent ratio ignores the implicit costs such as mortgage interest, tax, and maintenance costs of owning a house.

User Cost Framework

A fourth widely used indicator is the user cost framework. Poterba (1992) and Himmelberg *et al.* (2005) suggest the main problem of the earlier simple market indicators, is that they erroneously view the purchase price of a home as if it were the same as the cost of owning it for a year, and that the yield on the house equal to the capital gain or loss on that home. The user cost of ownership and the implied theoretical price-rent ratio is the most complete framework to assess when home prices are misaligned (Finicelli, 2007) out of those in the simple market indicator group.

The user cost framework suggests that people should be indifferent between renting and purchasing, given the same cost and housing attributes. The user cost of holding a house, in percentage level, is the sum of six components, as shown in equation (5.3).

$$UC_t = R_t^m + PT_t + MC_t + RP_t - MT_t(R_t^m + PT_t) - CG_{t+1} \qquad 5.3$$

R_t^m is the foregone interest rate, PT_t is the property tax rate, MC_t is the depreciation rate of the property or maintenance cost, RP_t is the risk premium for the larger uncertainty of purchasing relative to renting. MT_t is the marginal tax rate for the house buyer, usually considered constant. As nominal mortgage payment and property tax are tax deductable in many tax regimes, they often provide an offsetting benefit to the home owner. CG_{t+1} is the expected capital gain. If the house purchase was equity financed, the foregone interest rate R_t^m should be measured by long-term risk free rate and without the benefit of marginal tax deduction (Himmelberg *et al.*, 2005); if it were debt financed, the interest rate should be the nominal mortgage rate (Finicelli, 2007); if it were financed by a mix of debt and equity, the weighted average cost of capital appears much more appropriate (Hubbard and Mayer, 2009).

In the equilibrium condition, the annual cost of owning a house should equal the average corresponding market rent following the assumption of non-arbitrage, see equation (5.4):

$$HRI_t = HPI_t^f \times UC_t \qquad 5.4$$

HRI_t is actual market rent, HPI_t^f is the theoretical housing price or fundamental housing price. Equation (5.4) implies the fundamental house price-rent ratio is the inverse of user cost, say, $HPI_t^f / HRI_t = 1/UC_t$. Home prices are overvalued if the theoretical price calculated by the user cost framework is less than the market price, and *vice versa*. Equation (5.4) also implies that the user cost should be positive, as neither the theoretical house price nor the actual market rent should be negative. The user cost framework does not have a specific item to represent inflation, although the influence of inflation can be reflected via the changes of expected capital gain and nominal mortgage rate.

Although house prices and rents, and the ratio between them, are frequently indices instead of values, the average of the actual price-rent ratio and the theoretical price-rent ratio should be equal in the long run. For example,

$$\frac{1}{T}\sum_{t=1}^{T}\frac{HPI_t}{HRI_t}=\frac{1}{T}\sum_{t=1}^{T}\frac{HPI_t^f}{HRI_t}=100 \qquad 5.5$$

T is the number of observation, HPI_t is the market house price, HPI_t/HRI_t is the market price-rent ratio, HPI_t^f/HRI_t is the fundamental price-rent ratio. The spread between the real price-rent ratio and the theoretical price-rent ratio at any given time shows the extent of non-fundamentals factors or the size of bubble.

5.2.2 Econometric Models

Dividend-Ratio Model

Campbell and Shiller (1987,1988b,a) propose a dividend-ratio model for stock prices on the basis of a log-linear approximation, as equation (5.6).

$$q_t=\kappa+\psi E_t(sp_{t+1})+(1-\psi)d_t-sp_t \qquad 5.6$$

The lower case letters represent the natural log of the underlying variables. q is the required log gross return rate. κ is a constant and is defined by $\kappa\equiv-log(\psi)-(1-\psi)log(\frac{1}{\psi}-1)$. ψ is the average ratio of the stock price to the sum of the stock price and the dividend, $0<\psi<1$. $E_t(\cdot)$ is the mathematical expectation conditional on information available at time t. $sp_t\equiv log(SP_t)$ is the log stock price at date t. $d_t\equiv log(D_t)$ is the log real dividend paid at date t. In the static situation, the log dividend-price ratio $(d_{t-1}-sp_t)$ is a constant and $(d_t-sp_t)=log(\frac{1}{\psi}-1)$.

When the stock returns and dividend growth rates are time varying, the equation (5.6) does not hold exactly, in which case, a first order Taylor approximation form can be used:

$$q_t=\kappa+log(\frac{1}{\psi}-1)_t-\psi log(\frac{1}{\psi}-1)_{t+1}+\Delta d_t \qquad 5.7$$

If the terminal condition that $\lim_{i\to\infty}\psi^i log(\frac{1}{\psi}-1)_{t+i}=0$ is imposed,

$$d_t - sp_t = \sum_{i=0}^{\infty}\psi^i\,(q_{t+i}-\Delta d_{t+i}) - \frac{\kappa}{1-\psi} \qquad 5.8$$

Equation (5.8) implies that the log dividend-price ratio $(d_t - sp_t)$, can be expressed as a discounted value of all future returns q_{t+i} and dividend growth rate Δd_{t+i}, at the discount rate of $\left(\psi-\frac{\kappa}{1-\psi}\right)$. Campbell and Shiller (1988a) suggest 'the imposition of a condition that $(d_t - sp_t)$ does not explode as i increases'. In order to get an economic model of the dividend-price ratio model, researchers can impose some restriction on the required rate of return q_t.

Given that the house price-rent ratio is similar to the stock price-dividend ratio, the dividend-ratio model has been widely used in the study of house prices. In the housing literature, the dividend-ratio model is also called the present value model, and the dividend-price ratio is often replaced by the price-rent ratio or price-income ratio (Black *et al.*, 2006; Xiao and Randolph Tan, 2007; Man Hui and Gu, 2009).

In the following two subsections, this chapter will briefly review two well-known extensions to the original dividend ratio model in the housing market, respectively state space model and the Vector Autoregressive (VAR) model.

State Space Models

Wu (1997) suggests the unique forward-looking, no bubble solution to equation (5.6) can be denoted by the fundamental price ph_t^f. Moreover, if imposing the transversality condition $\lim_{i\to\infty}\psi^i E_t(p_{t+i})=0$, then

$$ph_t^f = \frac{\kappa-q}{1-\psi} + (1-\psi)\sum_{i=0}^{\infty}\psi^i\,E_t(d_{t+i}) \qquad 5.9$$

In order to apply equation (5.9) to house prices, the log dividend d_t is replaced by the log rentals hri_t. All other letters have clear interpretations in work on house prices.

As market price ph_t may deviate from fundamental value ph_t^f, the general solution to equation (5.9) has the form:

$$ph_t = ph_t^f + b_t \qquad 5.10$$

In equation (5.10), the no-bubble solution ph_t^f only relies on log rents and is named the market fundamental solution. b_t is the non-fundamental element and is frequently termed the speculative bubble.

As the log rents hri_t often contain a unit root, they are approximated by an $ARIMA(p, d, 0)$ process (Wu, 1997; Xiao and Randolph Tan, 2007; Al-Anaswah and Wilfling, 2011). Wu (1997) estimates the stock price bubble by using the following state space model

$$\Delta_1 ph_t = \Delta_1 hri_t + M\Delta_1 Y_t + \Delta_1 b_t \qquad 5.11$$

$$Y_t = U + A\Delta_1 Y_{t-1} + v_t \qquad 5.12$$

$$b_t = \frac{1}{\psi} b_{t-1} + \eta_t \qquad 5.13$$

$Y_t = (\Delta_1 r_t, \Delta_1 r_{t-1}, \cdots \Delta_1 r_{t-h+1})'$, $M = gA(I - A)^{-1}[I - (1 - \psi)(I - \psi A)]^{-1}$, $g = (1,0,0 \cdots ,0)$, $U = (\mu, 0, \cdots ,0)'$, A is an $h \times h\ matrix$, $v_t = (\delta_t, 0, \cdots ,0)'$ are all *h-vectors*.

$\{\eta_t\}$ is an $i.i.d.\ N(0, \sigma_\eta^2)$ error term. η_t is uncorrelated with the dividend innovation, δ. Wu (1997) applies a state space model drawn from equations (5.11) through (5.13) for stock prices. The unobservable bubble process b_t is estimated by standard Kalman filtering techniques.

Contrarily, Xiao and Randolph Tan (2007) estimate the following state space model

$$\begin{pmatrix} \Delta_1 ph_t = \Delta_1 s_t + \beth\Delta_1 hri_t + (1 - \beth)\Delta_1 hri_{t-1} + b_t \\ \Delta_1 d_t = \pi\Delta_1 hri_{t-1} + \aleph_t \end{pmatrix} \qquad 5.14$$

$$\Delta_1 s_t = \beta\Delta_1 s_{t-1} + \zeta_t \qquad 5.15$$

b_t, $\aleph_t$ and ζ_t are the $i.i.d.$ error terms and are uncorrelated with each other. Unlike Wu (1997), Xiao and Randolph Tan (2007) treat the model specification error $\Delta_1 s_t$, as the state variable and then estimate house price bubble b_t as the residual of the first section of equation (5.14). Both Wu (1997) and Xiao and Randolph Tan (2007) use the first log differenced variables in their measurement equations, therefore, what they estimate are the changes in bubble rather than the level of bubble.

Theoretically, any factor that is not in the pricing model will contribute specification errors of that model. Subsequently, a bubble is a part of the specification error. If the goal of the model is to estimate a price bubble, one needs to decompose the error term in two parts, namely, the bubble component and the specification error component. Unfortunately, from a purely statistical point of view, there is no way to do this. Therefore, it is necessary to make an assumption, based on economic intuition, about the distribution of the bubble component and non-bubble component. This chapter defines bubble as a non-stationary random process. In addition, the specification error of a well-defined linear state space model should be an $i.i.d.$ process (Hamilton, 1994; Kim and Nelson, 1999; Durbin and Koopman, 2001).

Departing from Wu (1997) and Kim and Nelson (1999), Al-Anaswah and Wilfling (2011) apply a state-space model with Markov-switching to dividend ratio model (Campbell and Shiller, 1987,1988b,a). Although their approach is well suited to quantifying a stock price bubble, it fails to generate a time series of the bubble.

Vector Autoregressive (VAR) Model

Black *et al.* (2006) transfer the dividend-price ratio in equation (5.8) into the following house price-income ratio:

$$py_t = \frac{\kappa}{1-\psi}\sum_{i=0}^{\infty}\psi^{i+1}\, i_{t+i+1} - \sum_{i=0}^{\infty}\psi^{i+1}\, q_{t+i+1} \qquad 5.\ 16$$

py_t is the log price-income ratio, y_t is the log real disposable income, $py_t = ph_t - y_t$. If $\{y_t\}\sim I(1)$ then $\{\Delta_1 y_t\}\sim I(0)$, and $\{q_t\}\sim I(0)$. As q_t is the required log gross return rate or real discount rate, $py_t\sim I(0)$.

Once the coefficients of their specific 3-variable VAR model are estimated, Black *et al.* (2006) can estimate the fundamental price-income ratio py_t^f. The log of house price is expressed as:

$$ph_t = ph_t^f + b_t + \varepsilon_t = (py_t^f + y_t) + b_t + \varepsilon_t = log\left(\frac{House\ Price_t^f}{Income_t} \times Income_t\right) + b_t + \varepsilon_t \quad 5.\ 17$$

To sum up, among the simple market indicators, the user cost framework is superior as it takes the mortgage rates, risk premium, taxes and expected capital gain into account; and therefore provides a complete asset valuation framework. It seems state space model may outperforms other sophisticated econometric models by estimating the unobservable bubble by taking the advantage of a Kalman filter.

5.3 Empirical Methodology

Departing from equation (5.17), this chapter proposes an approach to quantify the bubble by a combination of existing econometric models and indicators, namely, the User Cost Framework in a State Space Model. As the first step, this chapter uses the enhanced user cost framework to estimate the fundamental house price-rent ratio. In the second, it uses a linear state space model to estimate the unobservable bubble time series. Relative to Black *et al.* (2006)'s time varying present value approach, a typical absolute valuation approach, the User Cost Framework in a State Space Model is a relative valuation approach.

The present value model is extremely sensitive to the quality of inputs, such as the estimate of discount rate. Moreover, the factors, such as supply restrictions, regulations and contractual practices that affect the relationship between house prices and rents are hard to incorporate into the simple asset pricing models. The key advantage of the relative value method, especially when contrasted with the present value approach is based on the assumption that fundamental house purchase prices are not necessarily the summation of discounted future values. Given that large numbers of investors use the market arbitrage opportunity as their activity criterion, the relative valuation approach appears attractive (Poterba, 1984; Case and Shiller, 1989; Himmelberg *et al.*, 2005).

5.3.1 The Enhanced User Cost Step

The main equations for the user cost framework are equation (5.3) and equation (5.4). In literature, Himmelberg *et al.* (2005) assume marginal tax rate $MT_t = 25\%$, maintenance cost $MC_t = 2.5\%$, property tax PT_t and risk premium $RP_t = 2\%$. Finicelli (2007) sets $MT_t = 27.5\%$ and $PT_t = RP_t = MC_t = 2\%$. Quigley and Raphael (2004) suppose $MT_t = 30\%$, $RP_t = 0\%$; $PT_t = MC_t = 2\%$. Girouard *et al.* (2006) employ a varied of parameters for the OECD countries.

This chapter sets the marginal tax rate $MT_t = 25\%$, and the property tax rate and maintenance cost $PT_t = MC_t = 2\%$. Given the real marginal tax rate is very hard to estimate at the macroeconomic level, this chapter also uses $MT_t = 0\%$ for the sake of comparison.

In the literature, risk premium is often set as a constant, for example, 2%. The expected capital gain is often proxied by the past *n*-period moving average of the Consumer Price Index (CPI) and/or forward looking long term CPI. However, people's risk premium is time-varying; and the calculation of CPI does not consider house prices due to the house being regarded as investment goods rather than consumption goods. In fact, the biased estimation of risk premium and expected capital gain are often blamed as the main culprit to the biased user cost (Finicelli, 2007). Unlike the literature, this chapter uses the *ex post* realized annual house price return to proxy the expected annual capital gain, CG_{t+1}.

$$CG_{t+1} = \frac{HPI_{t+1}}{HPI_t} - 1 = \frac{HPI_{t+1} - HPI_t}{HPI_t} \qquad 5.\ 18$$

The rational is when the individual market participant has a perfect forecast (no forecast error) at time *t*, the unbiased annual expected capital gain at any point is the price appreciation over the next year.

Furthermore, the risk premium of owning a house relative to renting RP_t, is calculated as the *ex post* annual house price return minus *ex post* annual rental changes.

$$RP_t = CG_{t+1} - \frac{HRI_{t+1} - HRI_t}{HRI_t} = \frac{HPI_{t+1} - HPI_t}{HPI_t} - \frac{HRI_{t+1} - HRI_t}{HRI_t} \qquad 5.\ 19$$

Given this chapter uses the quarterly time series data, the annual capital gain at any point is calculated as the price appreciation over the next four quarters. In finance, risk premium refers to the amount by which an asset's expected rate of return exceeds the return on a risk free asset. In practice, risk premium is calculated as the difference between the historical mean of risky asset return and the risk free return. When people adjust their annual risk premium on a quarterly basis, equation (5.19) appears appropriate. Here, the market rentals are regarded as 'risk free' relative to house prices. However, this method is redundant when estimating the perfect capital gain and risk premium beyond the end period of the sample data, as it assumes investors are *ex post* rational.

The enhanced user cost time series is calculated by applying equation (5.3) and then the implied fundamental house price-rent ratio is the inverse of user cost, $HPI_t^f/HRI_t = 1/UC_t$. Instead of quantifying the bubble by using equation (5.5), this chapter incorporates the user cost based fundamental house price-rent ratio into the state space model.

The so-called enhanced user cost model is based on some simplified assumptions, such as markets have high liquidity and individual investors are rational all of the time, resulting in misspecification errors.

5.3.2 The State Space Model Step

Before introducing the state space model step, this section briefly illustrates the general state space model and the Kalman filter. State space models were initiated by control engineers (Kalman, 1960), and are effective tools for expressing dynamic systems that involve unobserved state variables. A state space model consists of two equations: a measurement equation (or signal equation) and a state equation (or transition equation). The measurement equation illustrates the relation between observed variables and unobserved state variables. The state equation illustrates the dynamics of the unobserved state variables, normally in the form of an AR(*p*) in the state vector.

Once a model has been expressed in a state space form, some important algorithms can be applied the Kalman filter being central. The Kalman filter is a recursive procedure for estimating the optimal estimator of the state vector at time *t*, based on the information available at time *t*. The Kalman filter assures the estimation of the state vector to be continually updated as new information becomes available. When the disturbance and the initial state vector follow a normal distribution, the likelihood function can be accurately calculated via what is known as the 'prediction error decomposition' (Harvey, 1990; Hamilton, 1994; Kim and Nelson, 1999; Durbin and Koopman, 2001).

Based on the existing literature, in particular equation (5.13) and equation (5.17), this chapter defines the following state space model.

Measurement equation:

$$ph_t = c_1 pr_t^f + c_2 hri_t + b_t + c_3 \quad 5.20$$

ph_t is the log house price, pr_t^f is the log fundamental price-rent ratio which is calculated as $log(1/UC_t)$, hri_t is the log rent, and b_t is level of bubble in log scale.

State equation:

$$b_t = \frac{1}{c_4} b_{t-1} + c_5 \quad 5.21$$

Where,

$$c_3 \sim i.i.d.N(0, R) \quad 5.22$$

$$c_5 \sim i.i.d.N(0, V) \quad 5.23$$

$$E(c_3, c_5') = 0,\ E(c_3, b_0') = 0 \text{ and } E(c_5, b_0') = 0 \quad 5.24$$

c_3 and c_5 are the error terms. To guarantee nonnegative variance estimates, variances are defined as exponential functions of the coefficients c_3 and c_5. More specifically,$var_{c_3} = exp(c_3)$, $var_{c_5} = exp(c_5)$. var_{c_3} and var_{c_5} are the variance for c_3 and c_5. b_0' is the initial state vector. When $0 < c_4 < 1$, it would indicate the bubble has an explosive path.

There are no constants in equation (5.20) and equation (5.21), given that house price is a sum of fundamental value and bubble. The rationale for the AR(1) process in equation (5.21) is based on the assumption that people will naively extrapolate the most recent price deviation level into the next period. Relative to equation (5.17), equation (5.20) replaces the log fundamental price-income ratio and log income with the log fundamental price-rent ratio and log rent, respectively. The rationale for the state space model step is three fold. Firstly, based on equation (5.17), equation (5.25) can be derived.

$$ph_t = log\left(\frac{House\ Price_t^f}{Income_t} \times Income_t\right) + b_t + \varepsilon_t = log\left(\frac{House\ Price_t^f}{Rent_t} \times Rent_t\right) + b_t + \varepsilon_t = pr_t^f + hri_t + b_t + \varepsilon_t \quad 5.25$$

Secondly, the price-rent ratio outperforms price-income ratio in economics theory and practice, to an extent, particularly the fundamental price-rent ratio which is calculated by an enhanced user cost framework. Thirdly, it simplified the model building process relative to Wu (1997) and Black *et al.* (2006) while maintaining the advantages of a state space model. Unlike regular time series regressions, the stationarity of a time series is not required in a state space model (Harvey, 1990; Commandeur and Koopman, 2007).

The two-step state space model has five unknown parameters, $\Psi = (c_1, c_2, c_3, c_4, c_5)'$. Ψ are termed as hyperparameters and are estimated by Maximum Likelihood Estimation (MLE) with Marquardt algorithm, in this chapter. Marquardt algorithm is a modification of the Gauss-Newton algorithm (Commandeur and Koopman, 2007). The initial values for the hyperparameters are those specified in the coefficient vector, which are estimated by EVIEWS 7.

Overall, the proposed state space model within user cost framework typically uses of two steps. Firstly, to calculate the enhanced user cost and the implied fundamental house price-rent ratio and secondly, to put the fundamental price-rent ratio into the linear state space model; and treat the bubble as an unobservable state variable which is estimated by taking the advantages of the Kalman filter.

The two-step user cost framework in a state space model suffers from some fragile assumptions. Firstly, the chapter assumes the bubble follows a linear Gaussian process, which may not be the truth in reality. If the bubble is a nonlinear, non-Gaussian process, the particle filter instead of the Kalman filter appears more suitable (Arulampalam *et al.*, 2002). Secondly, the inputs of the user cost framework could be more realistic such as the time varying tax rates and maintenance costs.

5.4 Data Description

The data included in this study are Department for Communities and Local Government (DCLG) House Price Index (HPI), a House Rent Index (HRI) which is proxied by the CPI component of actual rents for housing, and the composite mortgage rate of banks and building societies from the Bank of England. The quarterly UK time series data are all collected from DataStream with a time span from 1996Q1 to 2011Q1. The start and end dates are chosen by the availability of data from the House Rent Index and composite mortgage rate, respectively. This chapter sets $HPI = HRI = 100$ in 2002Q1. Table 5.1 presents the preliminary statistics about the HPI, HRI and fundamental price-rent ratios.

In Table 5.1, the Jarque-Bera test indicates that the HPI, HRI and fundamental price-rent ratios are normally distributed at the 5% significance level, an ADF unit root test shows that the four variables are nonstationary in levels, and the Johansen Trace test shows that HPI, HRI and the fundamental price-rent ratio (MT=0) are cointegrated at the 5% significance level.

Table 5.1 Descriptive Statistics (1996Q1-2011Q1)

	House Price Index $\boldsymbol{ph_t}$	House Rent Index $\boldsymbol{hri_t}$	F. Price/Rent Ratio $\boldsymbol{pr_t^f}$ (MT=25%)	F. Price/Rent Ratio $\boldsymbol{pr_t^f}$ (MT=0%)
No. of Observations	60	60	60	60
Mean	4.7385	4.6379	2.8896	2.5684
Median	4.8593	4.6357	2.8896	2.5533
Maximum	5.2128	4.8235	3.3647	3.0079
Minimum	4.0236	4.4123	2.6390	2.3169
Standard Deviation	0.3979	0.1204	0.1509	0.1425
Jarque-Bera Test	5.9981	3.4463	10.992	11.604
ADF Unit Root Test	0.2062	0.5371	0.7410	0.5765
Johansen Trace Test	33.273** (29.797)			

Notes: F.Price/Rent Ratio pr_t^f is the fundamental price-rent ratio. MT=25% and MT=0% stand for the fundamental price-rent ratios are estimated based on marginal tax rate $MT_t = 25\%$ and $MT_t = 0\%$, respectively. The null hypothesis of the Jarque-Bera test is that the variable is from a normal distribution. For ADF tests, the values are p-values. Johansen trace test tests the null hypothesis that there is no cointegration against the alternative that there is at most one cointegrating vector. The figure in parenthesis under the trace statistic is the 95% critical value. The Johansen trace test applies to the House Price Index ph_t, House Rent Index hri_t and fundamental price-rent ratio pr_t^f (MT=0). ** stands for statistical significance at the 5% significance level. The lower case letters represent the natural log of the underlying variables.

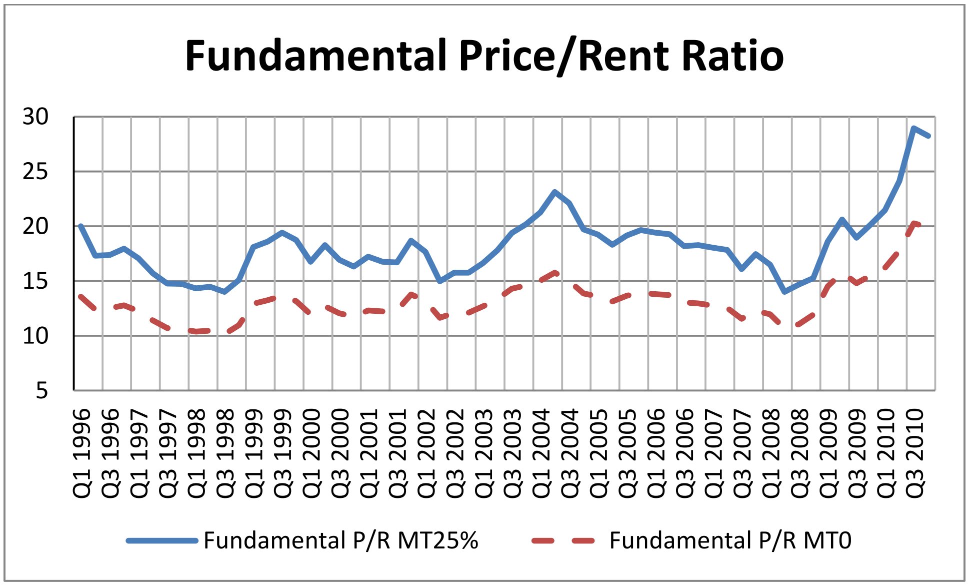
DCLG HPI employs the mix-adjusted method, which is based on weighted averages, using mortgage completion data from a few large lenders. Black *et al.* (2006) use the Nationwide HPI which uses hedonic regression, also known as the characteristics based method, using datasets from Nationwide's mortgage lending. Black *et al.* (2006) deflate all the nominal variables by the Retail Price Index (all items), thus providing prices in real terms. In this chapter, however, all the variables are in nominal terms for two reasons. Firstly, 'there is a great deal of confusion about the role of inflation expectations in the demand for housing' (Schwab, 1982,1983). Some argue that inflation is a major determinant of the demand for housing (Poterba, 1984). Others suggest inflation expectations are independent on the demand for housing; and that only deflated variables are relevant (Arcelus and Meltzer, 1973). Schwab (1982,1983) suggest that the truth lies somewhere between these two extremes. Therefore, it is interesting to study whether the linkages between house prices and its determinants can be replicated in nominal terms. Secondly, bulk of people tend to arbitrage between owning and renting by comparing the cost of holding a home and renting a home per year in nominal terms instead of real terms. Akerlof and Shiller (2010) suggest people often fail to exclude the effect of inflation on their house investments in reality.

5.5 Empirical Results and Discussion

Figure 5.1 plots the fundamental price-rent ratio HPI_t^f/HRI_t, which is the inverse of the enhanced user cost time series. In the case of Marginal Tax rate $MT = 25\%$, the fundamental house price-rent ratio ranges from 14 to 28.9 with a mean of 18.2 and standard deviation of 2.95. Driven by the low interest rates and high expected capital gain, the ratio rebounded sharply from the local bottom of 15 in 2002Q2 to a peak of 28.9 at 2010Q3. This means the implied fundamental price for investors to buy a house on average is approximately 18.2 times the market rent between 1996Q1 and 2009Q3, *ceteris paribus*. In the case of Marginal Tax rate $MT = 0$, the fundamental price-rent ratio ranges from 10.14 to 20.24 with the mean of 13.18 and standard deviation of 2.14. Given the effect of marginal tax rate on user cost is $-MT_t(R_t^m + PT_t)$ and R_t^m is not a constant, so the spread between the two fundamental price-rent ratios varies with the mortgage rate. Considering the real marginal tax rate is an unknown weighted average of $MT_t = 0$ and $MT_t = 25\%$ in the UK[1], the real fundamental price-rent ratio will be bounded by the ratios shown in Figure 5.1.

[1] The chapter assumes that the tax rates imposed on high earners will not have a significant effect on the aggregate tax rate.

Figure 5.1 Fundamental Price-Rent Ratio HPI_t^f/HRI_t (1996Q1-2011Q1)



Notes: $HPI_t^f/HRI_t = 1/UC_t = 1/(R_t^m + PT_t + MC_t + RP_t - MT_t(R_t^m + PT_t) - CG_{t+1})$. HPI_t^f/HRI_t denotes for the fundamental Price-Rent Ratio. UC_t is the User Cost of holding a house per year. R_t^m is the composite mortgage rate from Bank of England. Property Tax rate $PT_t = 2\%$, Maintenance Cost $MC_t = 2\%$, Risk Premium for the larger uncertainty of purchasing relative to renting RP_t is the difference between the house price appreciation and rent appreciation over next four quarters. MT_t is the Marginal Tax rate for the house buyer. Fundamental P/R MT25% and MT0 stand for the fundamental price-rent ratio HPI_t^f/HRI_t are estimated based on marginal tax rate $MT_t = 25\%$ and $MT_t = 0$, respectively. Expected Capital Gain CG_{t+1} is proxied by the real capital gain over next four quarters.

Table 5.2 displays the empirical results of the state space model, equations (5.20) and (5.21). Except for the coefficient of fundamental price-rent ratio c_1 and the residual of the measurement equation c_3, the remainder of the hyperparameters are statistically significant at the 1% level. Given the chapter uses index data instead of actual data to proxy house price and rent, it is not surprising to see the figure of House Rent Index is very close to, if not higher than, the figure of House Price Index, even when the house price is significantly overvalued. For example, both HPI and HRI are 100 in 2002Q1. Therefore, it is quite possible and reasonable for the hyperparameter $c_1 < 0$ and $c_2 > 0$. However, it must be kept in mind that such a condition is only sensible for index data. Given c_4 is slightly above 1 in both cases, so, $0 < 1/c_4 < 1$ which would indicate rejection of hypothesis that the bubble follows an explosive path. This means the process b_t is not a typical rational bubble process (Diba and Grossman, 1988a,b; Black *et al.*, 2006). Furthermore, Table 5.2 suggests the level of marginal tax rate does not substantially affect the fitting of the two-step state space model, given that hyperparameters and/or Akaike Information Criterion (AIC) and Log Likelihood ratios are very close to each other.

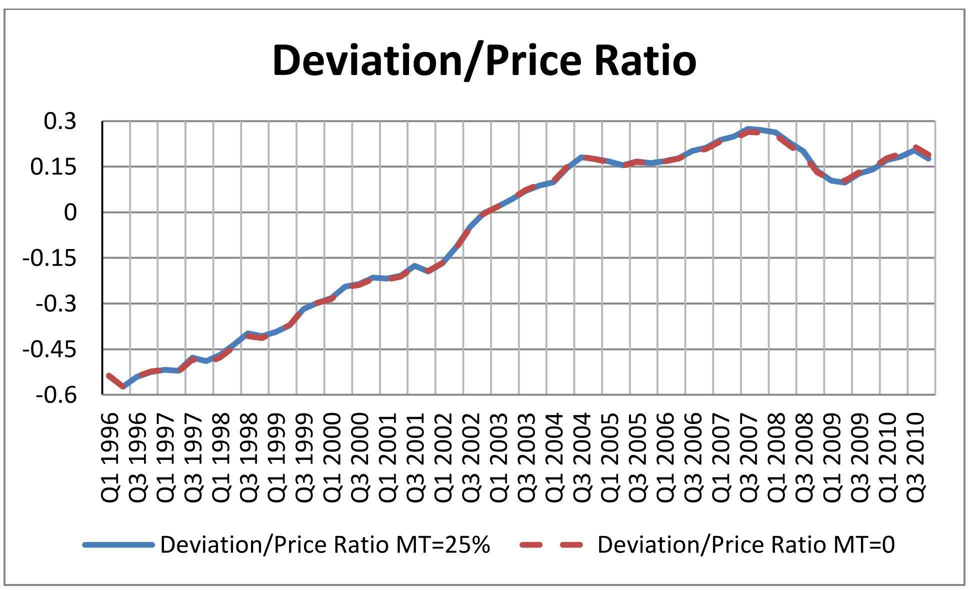
Table 5.2 Maximum Likelihood Estimates of Hyperparameters (1996Q1-2011Q1)

$\boldsymbol{ph_t = c_1 pr_t^f + c_2 hri_t + b_t + c_3}$							Equation (5.20)
$\boldsymbol{b_t = \frac{1}{c_4} b_{t-1} + c_5}$							Equation (5.21)
$\boldsymbol{\Psi}$	c_1	c_2	c_3	c_4	c_5	AIC	Log Likelihood
MT=25%	-0.0398	1.0611***	-29.3038	1.0025***	-7.197***	-4.1039	128.1180
	(0.045)	(0.1544)	(18835056)	(0.0127)	(0.2139)		
MT=0	-0.0840	1.0832***	-26.5544	1.0024***	-7.225***	-4.1309	128.9283
	(0.0529)	(0.1612)	(36050335)	(0.0129)	(0.2451)		

Notes: ph_t is the house price. c_1, c_2 and $1/c_4$ are the coefficients on fundamental price-rent ratio pr_t^f, House Rent Index hri_t and deviation from fundamental value b_t, respectively. c_3 and c_5 are the error terms for the measurement equation and state equation, respectively. See Figure 5.1 for the calculation of fundamental price-rent ratio at the raw data level. AIC refers to the Akaike Information Criterion. MT25% and MT0 stand for the fundamental price-rent ratio HPI_t^f/HRI_t are estimated based on marginal tax rate $MT_t = 25\%$ and $MT_t = 0$, respectively. Standard errors are in parentheses. *** stands for statistical significant at the 1% significance level. The lower case letters represent the natural log of the underlying variables. This chapter uses the Marquardt algorithm to optimize the likelihood function. The initial values for the hyperparameters are those specified in the coefficient vector, which are estimated by EVIEWS 7. $var_{c_3} = exp(c_3)$, $var_{c_5} = exp(c_5)$. var_{c_3} and var_{c_5} are the variances for c_3 and c_5. The $p\text{-}values$ for b_t are 0 in both cases.

In order to identify whether the time series b_t generated by the state space model satisfy the main characteristics of the bubble process, Figure 5.2 plots the deviation from fundamental value b_t. When the price-deviation is above 0 this, indicates the price is above its fundamental value and *vice versa*.

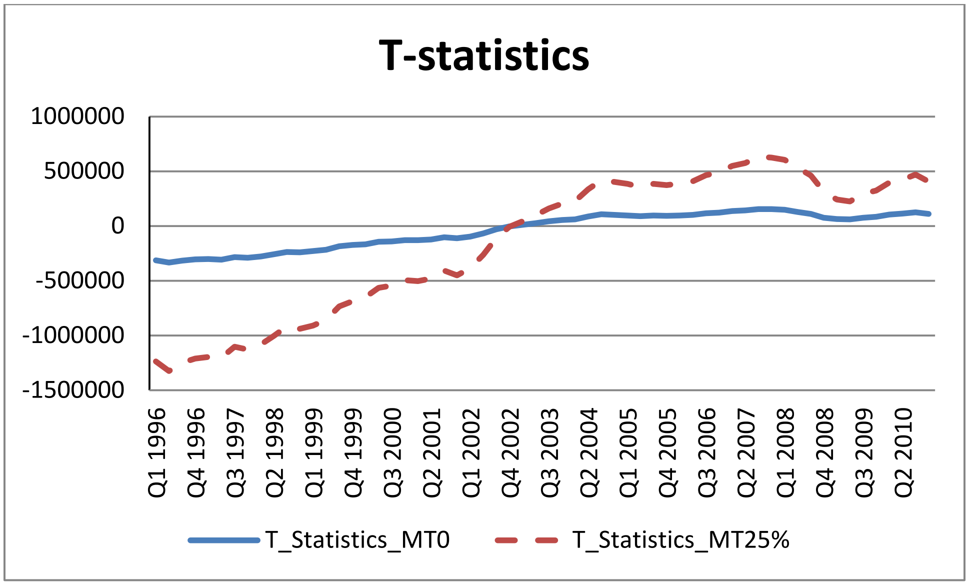
Figure 5.2 Deviation from Fundamental Value b_t (1996Q1-2011Q1)



Notes: See Table 5.2 for the estimation of deviation from fundamental value b_t. Deviation/Price Ratio MT25% stands for the estimation of b_t is based on the marginal tax rate $MT_t = 25\%$. Deviation/Price Ratio MT25% and MT0 stand for the estimation of b_t are based on the marginal tax rate $MT_t = 25\%$ and $MT_t = 0$, respectively.

From Figure 5.2, the two cases of deviation from fundamental values are quite close to each other, even though that which has a 25% Marginal Tax rate is slightly higher. So, the level of tax rates is not of great importance in explaining the deviations from fundamental value. There is a long term increasing trend of deviation from 1996Q1 at -0.54% to 2007Q3, peaking at 27.4%; hit by the Subprime Crisis, the deviation sharply decrease to below 10% by 2009Q2; it stands at 18% by 2010Q4. Additionally, the impressive increase in the deviation seems to result from people's speculative activities and the slowdown of supply, especially from 2000 to 2003. According to the data of the Office of National Statistics (ONS), the quarterly housing completions remain about 36,000 units between 2001 and 2003 which is lower than the historical average. Given the lengthy lag in supply, the resulting effect may cause an increase of price deviation to follow. Figure 5.3 illuminates the quarterly changes in deviations from fundamental values $\Delta_1 b_t$ against the changes in house prices. The two cases of changes in deviations from fundamental values $\Delta_1 b_t$ overlap significantly. Generally, the changes in deviations from fundamental values $\Delta_1 b_t$ show significant ups-and-downs with value ranges from -6% to 7%. When marginal tax rate is 25%, for example, the correlations between house price and deviation are 0.9934 and 0.9399 in log level scale and log difference scale, respectively. In order to investigate whether the deviations from fundamental values $b_t$are statistical different from 0, Figure 5.3 plots the t-*statistics* for b_t over the sample. The chapter does not plot the confidence bands for the b_t primarily because the standard errors for b_t are very tiny and thereby make the confidence bands too tight to understand. Given the absolute values of t-*statistics* for b_t are substantially above 2.33 over the sample, deviations from fundamental values b_t are statistical different from 0 at the 1% significance level.

Figure 5.3 T-statistics for the Deviation from Fundamental Value b_t (1996Q2-2011Q1)

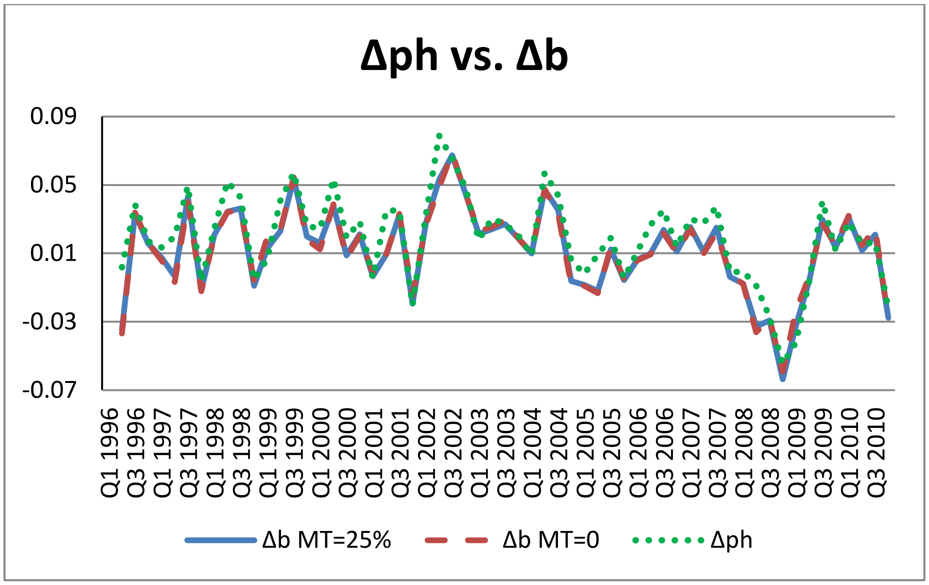


Notes: The null hypothesis for the *t-test* is the deviation from fundamental value $\mathrm{b_t}$ equals 0. *t-statistic*=$b_t/SE(\mathrm{b_t})$. $SE(b_t)$ is the smoothed standard error for b_t. *t-statistic>2.33* or *t-statistic<-2.33* indicates the null hypothesis is rejected at the 1% significance level. MT25% and MT0 stand for the estimation of b_t are based on the marginal tax rate $MT_t = 25\%$ and $MT_t = 0$, respectively.

In Table 5.3, the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests indicate the deviations from fundamental value b_t are non-stationary random processes which indicate b_t are unpredictable, and its mean and variance are time varying. However, the changes in deviation from fundamental value $\Delta_1 b_t$ are stationary that means the $\Delta_1 b_t$ will never goes too far from its mean.

Given that the price deviation from fundamental value b_t simultaneously meets the characteristics of a bubble, the chapter can safely conclude the deviation from fundamental value b_t illustrates the level of biased expectation bubble in log scale. Figure 5.2 and Figure 5.4 reflect the bubble to price ratio and the changes in bubble to price ratio, respectively.

Figure 5.4 Changes in House Price Index $\Delta_1 ph_t$ against Changes in Price Deviation from Fundamental Value $\Delta_1 b_t$ (1996Q2-2011Q1)



Notes: Δ_1 stands for first difference. $\Delta_1 ph_t$ stands for the first natural log difference of House Price Index. $\Delta_1 b_t$ stands for the changes in deviations from fundamental values. See Table 5.2 for the estimation of deviation from fundamental value b_t. $\Delta_1 b_t = b_t - b_{t-1}$. $\Delta_1 b_t$ MT25% and MT0 stand for the estimation of b_t are based on the marginal tax rate $MT_t = 25\%$ and $MT_t = 0$, respectively.

Table 5.3 Unit Root Tests for Price Deviation from Fundamental Value b_t (1996Q1-2011Q1)

Time Series b_t	Unit Root Tests	Marginal Tax (MT) rate = 25%		Marginal Tax (MT) rate = 0	
		ADF	PP	ADF	PP
	With Intercept	0.1839	0.4467	0.1887	0.4968
Log level	With Intercept and Trend	0.9788	0.9870	0.9782	0.9842
	Without Intercept and Trend	0.0126	0.0426	0.0123	0.0509
	With Intercept	0.0001	0.0001	0.0001	0.0001
Log Difference	With Intercept and Trend	0.0001	0.0001	0.0001	0.0001
	Without Intercept and Trend	0.0001	0.0001	0.0001	0.0000

Notes: The optimal lag length for the Augmented Dickey–Fuller (ADF) test is determined by the Schwarz Information Criterion (SIC). The figures presented in this table are *p-values*. PP stands for the Phillips-Perron test.

Froot and Obstfeld (1991) and Black *et al.* (2006) suggest the deviations of prices from fundamental values can be interpreted by the non-linear deterministic functions of the fundamentals of asset value alone. When this is true, then, the deviations of prices from fundamental values are intrinsic bubbles. Intrinsic bubbles depend on bounded rationality hypothesis and self-fulfilling expectations. Intrinsic bubbles do not continuously diverge but periodically revert toward their fundamental value, which is consistent with Table 5.2 and Figure 5.2. The non-linear relation between bubbles and the fundamentals themselves indicate that asset prices overreact to news on fundamentals (Chen and Sauer, 1997; Dissanaike, 1997; Black *et al.*, 2006). When the biased speculative bubbles are not significantly correlated with any fundamental variables, then, the bubbles support the pure irrational expectation hypothesis.

Following Black *et al.* (2006), Table 5.4 illustrates the correlation matrix between the bubble, fundamental price-rent ratio, HRI and HPI in log scale. We find that all the correlations are significantly different from zero depicting a positive relationship, which supports the bounded rationality hypothesis and consistent with Black *et al.* (2006). However, the correlation between bubble and house price is higher than that for bubble and fundamental price-rent ratio and House Rent Index which is contrast to Black *et al.* (2006). While Table 5.4 indicates that bubbles are not driven by purely irrational activities, it does not quantify about the extent to which bubbles are rational, partially due to fundamentals; or irrational, due to pure non-economic behaviour.

Table 5.4 Correlation Matrix (1996Q1-2011Q1)

	Bubble $\boldsymbol{b_t}$	F.Price/Rent Ratio $\boldsymbol{pr_t^f}$	HPI $\boldsymbol{ph_t}$	HRI $\boldsymbol{hri_t}$
Bubble $\boldsymbol{b_t}$	1			
F.Price/Rent Ratio $\boldsymbol{pr_t^f}$	0.4834*** (4.2058)	1		
HPI $\boldsymbol{ph_t}$	0.9934*** (65.9941)	0.4792*** (4.1579)	1	
HRI $\boldsymbol{hri_t}$	0.9337*** (19.8663)	0.5185*** (4.6184)	0.9676*** (29.1727)	1

Notes: F.Price/Rent Ratio pr_t^f is the fundamental price-rent ratio. HPI ph_t is the House Price Index. HRI hri_t is the House Rent Index. The values above the parentheses are the corresponding correlations. The values in the parentheses are the $t\text{-}statistics$. $t\text{-}statistic = (corr \times \sqrt{n-2})/(\sqrt{1-corr^2})$. $corr$ is the correlation coefficient and $corr^2$ is the squared correlation coefficient. The bubble b_t and the fundamental price-rent ratio pr_t^f are estimated based on the Marginal Tax rate MT=0. *** stands for the correlation is statistical significance at 1% level.

5.6 Conclusion

This chapter studies how much variation in house prices results from non-fundamental factors by quantifying the size of housing bubbles. The chapter contributes to the literature both methodologically and empirically. Using the user cost framework in a state space model has clear methodological advantages. In the first step, the fundamental house price-rent ratio is calculated using the enhanced user cost framework which has the benefit compared to many prior papers of incorporating all relevant variables. In the second step, the method can advantageously estimate the level of any bubble by incorporating the fundamental price-rent ratio into a state space model by taking advantage of a Kalman filter.

Our empirical results indicate that UK house prices were undervalued from 1996Q1 to 2002Q4; and thereafter overvalued. As a proportion, the bubble ranges from -52% to 27.4% in log scale, which is indeed a quite substantial range. The magnitude of this range indicates that any modelling of house prices without the consideration of a bubble element, or the non-fundamental components, will be somewhat problematic.

From a theoretical viewpoint our results favour the bounded rationality hypothesis rather than the rational expectation hypothesis and the pure irrational expectation hypothesis. The bounded rationality hypothesis suggest that people's expectations and economic behaviours might be biased due to cognitive and psychology limitations which, in turn, indicates the market might be inefficient at least temporarily. However, people learn from their mistakes and attempt to satisfice by acting as rationally as possible.

From a practical perspective, the quantification of bubbles in house prices can make market participants aware of the size of their risk exposure and can help them to detect early signals of the possibility of a financial market crash (Reinhart and Rogoff, 2009). For financial institutions, periodically assessing the state of the housing market, rational diversification and timely rebalancing of portfolios may help them prevent similar losses to those experienced in the Subprime Crisis. Signals regarding a bubble may drive investors to respond rationally and adjust house prices toward their fair value. Furthermore, policy-makers can use information about the existence and size of bubbles in order set policies to stabilize the market.

There are several avenues for future research in this area. The method can be applied to other markets and time periods and compared to other approaches. Detailed consideration of the various components of the user cost can also give a guide to the relative influences of different factors on house prices and the size of any bubble component. This understanding is potentially very useful for policy formation.

Chapter 6. Investigation of Institutional Changes in the UK Housing Market by Structural Break Tests and Time Varying Parameter Models

6.1 Introduction

This chapter considers whether the effects of institutional changes within the UK housing market are empirically supported, furthermore, whether these institutional changes are short term (less than 1 year) or long term (more than 1 year). If the changes are short term, the best course of action might be to do nothing. However, if the institutional changes are long term, one has to review and adjust his/her investment strategies.

This chapter contributes to the literature from two aspects. Firstly, the dates of structural breaks or fast-moving institutional changes appear to match the unexpected market shocks rather than political events, which provides more recent empirical evidence to support Lucas (1976), Roland (2004) and Culpepper (2005). Culpepper (2005) suggests the sufficient condition for institutional change is the change in ideas, with the process by which people apply triggering events such as the financial crises to coordinate their future anticipations around the new rules of the economy.

Secondly, this chapter expands on the literature by using three novel Kalman filtering based Time Varying Parameter (TVP) models to quantify the slow-moving institutional changes in the UK housing market. The three TVP models are the Time Varying Parameter with Principal Component Analysis (TVP-PCA), Time Varying Parameter with Principal Component Analysis and Bubbles (TVP-PCA-Bubble), and Time Varying Parameter with Error Correction Model (TVP-ECM). Literature often uses TVP-PCA and TVP-ECM in dynamic forecasting (Li *et al.*, 2006; Stock and Watson, 2006). However, the chapter does not find any literature studies institutional changes using the three aforementioned TVP models, especially TVP-PCA-Bubble.

Empirically speaking, statistical significant structural breaks will indicate fast-moving institutional changes. Even though some sophisticated structural break tests may detect all structural break points, they are however, naturally unsuitable to investigate the slow-moving institutional changes. For many purposes, a more natural model is that parameters gradually change over time with small, Gaussian shifts, rather than rare but large 'structural break' shifts. The slow-moving institutional changes are identified to occur if the coefficients in a regression are time varying (Brown *et al.*, 1997; Hansen, 2001; Pesaran and Timmermann, 2002; Gérard, 2004; Baddeley, 2005; Culpepper, 2005; Guirguis *et al.*, 2005). There are three reasons for using the time varying parameter models in economic modelling (Engle and Watson, 1987; Brown *et al.*, 1997; Guirguis *et al.*, 2005). Initially, the Lucas (1976) critique proposes a behavioural motivation for parameter variation. Lucas (1976) suggests people adjust not only their behaviour in response to new policies, but also their expectations of the economic model believed relevant to existing policies. Secondly, changes in the unobservable components of economic variables such as expectations will drive institutional changes in the data generating process. Thirdly, model mis-specification is another source of time varying parameters given it is generally impossible to build a perfect specification of an economic data generating process. The TVP models usually take the state space form and are estimated by the Kalman filter algorithm (Kalman, 1960; Brown *et al.*, 1997; Kim and Nelson, 1999; Guirguis *et al.*, 2005; Li *et al.*, 2006; Zivot and Wang, 2006). Chow *et al.* (2011) suggest the constant coefficient models such as the classical Ordinary Least Squares (OLS) are only plausible for stationary time series. Having constant coefficients is necessary but an insufficient condition for stationary, as some non-stationary processes may have constant coefficients.

The Principal Component Analysis (PCA) investigates the dynamic links among observed, correlated economic variables by using a potentially lower number of unobservable common factors. Relative to the TVP-PCA, the TVP-PCA-Bubble incorporates the housing bubbles as an additional independent variable which controls for people's biased expectations. One of the advantages of the Error Correction Model (ECM) lies in its ability to capture the short-run dynamic self-correcting process of the housing market toward its long-run equilibrium relationship (Li *et al.*, 2006). Moreover, ECM and PCA can eliminate the occurrence of spurious regression and multicollinearity problems, which may otherwise compromise the reliability and accuracy of the applied investigation.

The three TVP models suggest that the effects of fundamental variables such as real household disposable income on housing returns have declined over previous decades. With the effect of people's biased expectations, housing price bubbles are playing a more important role than ever. The empirical findings are generally consistent with Chapters 3 and 4 and literature (Brown *et al.*, 1997; Gérard, 2004; Culpepper, 2005; Guirguis *et al.*, 2005). Additionally, TVP-PCA-Bubble outperforms TVP-PCA and TVP-ECM in terms of model explanation and model fitting.

The empirical findings suggest that the fast-moving (or formal) institutional changes such as significant political reform is often a necessary but insufficient condition for institutional change, given people's shared beliefs can persist even after changing the formal laws. However, the changes in policies would impact the housing market through the slow-moving institutional changes, in particular those relating to people's preferences, technology and expectations over time. Slow-moving institutions must change continuously so that they produce inconsistencies within fast-moving institutions which, in turn, create pressure for changes. Overall, reforms (fast-moving institutions) in a given economy must in part build on their local conditions (slow-moving institutions).

In the remainder of the chapter, Section 6.2 exhibits data description. Section 6.3 displays the Bai and Perron (1998) structural break tests. Section 6.4 presents the three TVP models and the diagnostics tests. Section 6.5 concludes the chapter.

6.2 Data Description

The data included in this study are the Department for Communities and Local Government (DCLG) House Price Index (HPI), Retail Price Index (RPI), House Rent Index (HRI), mortgage rates of Building Societies, composite mortgage rate of Building Societies and Banks (1995Q1-2007Q4 only), aggregate mortgage outstanding, real aggregate household disposable income, house completions, foreign exchange reserves (foreign currency deposits and bonds held by UK monetary authorities only), net exports of good/services and net Foreign Direct Investment (FDI) inflow from the United Kingdom. Except for the composite mortgage rate of Building Societies and Banks, all the quarterly time series data were collected from DataStream covering the period from 1968Q2 to 2007Q4. The starting dates are chosen by the availability of data for the HPI and the end dates are chosen by the availability of data for the house completions. The chapter sets the House Price Index (HPI), House Rent Index (HRI) and the Retail Price Index (RPI) equal to 100 at 2002Q1. Following Martin and Morrison (2008), the chapter calculates the Foreign Portfolio Investment (FPI) by the identity: FPI Inflow = Change in Foreign Exchange Reserves – Net Exports – Net FDI Inflow. Unless specifically mentioned, all the variables are in nominal terms. Throughout this chapter, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts. Δ_1 denotes for the first difference.

In Appendices, Tables A and B illustrate the source and definition of data. Table C exhibits a basic data summary. Table D exhibits the results of Augmented Dickey Fuller (ADF) unit root tests on the level and the first natural log difference for each variable where the appropriate number of lagged difference is identified by the Bayesian Information Criteria (BIC). Table D suggests all the applied variables are nonstationary in log level but stationary after first log difference.

6.3 The Bai and Perron (1998) Structural Break Tests for Fast-moving Institutional Changes

To empirically assess whether the political reforms caused structural breaks immediately after the 1970s, Table 6.1 presents two forms of the Bai and Perron (1998) structural break tests. The univariate test applies to the changes in house prices $\Delta_1 ph_t$ only, for the purpose of detecting the structural breaks in housing prices. The multivariate test applies to house price $\Delta_1 ph_t$ against mortgage outstanding $\Delta_1 m_t$, mortgage rate of Building Societies $\Delta_1 r_t$, house completion $\Delta_1 h_t$, real aggregate household disposable income $\Delta_1 y_t$, foreign portfolio investment $\Delta_1 fpi_t$ and general index of retail price $\Delta_1 p_t$ at the first natural log difference scale. The rationale for the multivariate test is detecting the structural breaks in the housing market which contains a group of economic variables.

Table 6.1 Bai and Perron (1998) Structural Break Tests

Bai and Perron (1998) structural break test for $\Delta_1 ph_t$					
$\boldsymbol{SupF_T(1)}$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(2\|1)$
6.149	25.010***	19.309***	14.644***	12.203***	34.300***
$\boldsymbol{SupF_T(3\|2)}$	$SupF_T(4\|3)$	$SupF_T(5\|4)$	$UDmax$	$WDmax$	/
1.887	3.139	2.019	25.010***	32.064***	/
Number of breaks selected			**Identified break dates**		
Sequential Procedure	LWZ	BIC	/	85th Observation	112th Observation
0	0	2	/	1989Q3	1996Q2
Bai and Perron (1998) structural break test for $\Delta_1 ph_t$ against $\Delta_1 m_t$, $\Delta_1 r_t$, $\Delta_1 h_t$, $\Delta_1 y_t$, $\Delta_1 fpi_t$ and $\Delta_1 p_t$					
$\boldsymbol{SupF_T(1)}$	$SupF_T(2)$	$SupF_T(3)$	$SupF_T(4)$	$SupF_T(5)$	$SupF_T(2\|1)$
1202.66***	547.291***	192781.922 ***	6084796.474***	5267225.103***	62.386***
$\boldsymbol{SupF_T(3\|2)}$	$SupF_T(4\|3)$	$SupF_T(5\|4)$	$UDmax$	$WDmax$	/
58.586***	62.386***	9.641	6084796.474***	8061287.479***	/
Number of breaks selected			**Identified break dates**		
Sequential Procedure	LWZ	BIC	22th Observation	78th Observation	116th Observation
2	0	0	1973Q4	1987Q4	1997Q2

Notes: Δ_1 denotes the first difference. ph_t is house price, m_t means mortgage outstanding, r_t means mortgage rate of Building Societies, h_t means house completion, y_t means real aggregate household disposable income, fpi_t means foreign portfolio investment, and p_t means the general index of retail price. Throughout the thesis, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts. In the Bai and Perron (1998) tests, the chapter sets the maximum number of break points $m = 5$, minimum length of distance equals 23, trimming equals 0.10. The sample size ranges from 1968Q2 to 2007Q4. *** denotes statistical significance at the 1% significance level. The null hypothesis for $SupF_T(m)$ test is there are m statistical structural breaks, where, $1 \le m \le 5$. The null hypothesis for $SupF_T(m+1|m)$ test is there are $m+1$ statistical significant structural breaks conditional on m structural breaks. The null hypothesis for the $UDmax$ test and the $WDmax$ test are there is no structural break. BIC is Bayesian Information Criteria and LWZ is a modified Schwartz's Criteria. Sequential Procedure, LWZ and BIC test for the number of breaks selected, respectively.

From Table 6.1, the $UDmax$ test and the $WDmax$ test consistently reject the null hypotheses that there are no structural breaks. However, there are controversies on the dates of the breaks. In the univariate tests, the $SupF_T(1)$ test, Sequential Procedure test and LWZ test fail to reject the null hypothesis and suggest that there is no structural break. The tests $SupF_T(2)$ through $SupF_T(5)$ are statistically significant and suggests that there are 2 to 5 structural breaks, respectively. The BIC test suggests there are two structural breaks or fast-moving institutional changes at 1989Q3 and 1996Q2. In the multivariate tests, the tests $SupF_T(1)$ through $SupF_T(5)$ suggest there are 5 structural breaks. The tests $SupF_T(2|1)$ through $SupF_T(4|3)$ suggest there are 4 statistical significant structural breaks. The Sequential Procedure test suggests there are 2 statistical significant structural breaks. However, the LWZ and BIC tests suggest there is no statistical significant structural break. For the sake of prudence, this chapter identifies three statistical significant structural breaks at 1973Q4, 1987Q4 and 1997Q2. The first structural break 1973Q4 roughly follows the collapse of the Bretton Woods Agreement in 1971, the 1973 oil crisis, and the Secondary Banking Crisis of 1973-1975. The second structural break, 1987Q4 or

1989Q3, follows the UK Building Societies Act 1986, the Lawson boom from 1986 to 1988, the 'Big Bang' in 1986, the general election in June 1987, and the Black Monday on 19th October 1987. Finally, 1996Q2 or 1997Q2 follows the UK recession in 1992, the US savings and loan crisis in the early 1990s, the 1994 economic crisis in Mexico, the 1997 Asian financial crisis and/or the UK general election in May 1997. The dates of the structural breaks appear to match the unexpected market shocks rather than political events. However, some of the political events would be the real drivers of the market shocks. It seems the unexpected shocks in particular financial crises often drive people to coordinate their future anticipations around the new rules of the economy, and thereby leads to structural break. Table 6.1 empirically supports that the political and/or legal reform is often a necessary but insufficient condition for fast-moving institutional changes, given people's shared beliefs can persist even after changing the formal laws (Gérard, 2004; Culpepper, 2005).

Building on a sample from 1971Q4 to 1989Q2, Brown *et al.* (1997) uses the Chow (1960) structural break test to find that 1983Q2 is a statistically significant structural break in the UK which seems to differ slightly from Table 6.1. Given 1983Q2 is in the middle of the recession of the early 1980s in the UK, the implications of Table 6.1 indeed remain consistent with Brown *et al.* (1997). Guirguis *et al.* (2005) empirically support the coefficient instability of the US housing market by using three statistical tests including, the rolling OLS, the Chow (1960) structural break test and the RESET test. Unfortunately, Guirguis *et al.* (2005) fail to detect the numbers and the possible dates of the structural breaks.

The Chow (1960) test is a linear regression based known break point model, which is essentially a test of parameter constancy or homogeneity. In practice, one has two options: to pick an arbitrary potential break point; or to pick a break point based on some known characteristic of the time series. In the earlier case, the real break point can be missed. In the latter case, the tests can be misleading due to the candidate break points being endogenous. Moreover, people can easily obtain distinctly different results, given the selection of candidate break points are far more art than science. By contrast, the Bai and Perron (1998) test is an unknown break point test. One of the key points of the Bai and Perron (1998) test is how to estimate 'confident intervals' for the break point. The Bai and Perron (1998) break test can extend to more than one break point given the maximum number of possible breakpoints are known. For the Chow (1960) test, one has to split the sample at the estimated break point and test for further breaks on the two subsamples by repeating the Chow (1960) test until there are no further breaks. In recent econometric practice, the unknown break test such as the Bai and Perron (1998) test has replaced the more well-known break tests, in particular the Chow (1960) test, see (Hansen, 2001).

6.4 The Time Varying Parameter Models for Slow-moving Institutional Changes

6.4.1 Time Varying Parameter with Principal Component Analysis (TVP-PCA)

In the first step, the chapter extracts principal components from a number of macroeconomic and fundamental factor variables which are related to the changes in house prices, $\Delta_1 ph_t$. In the second step, the chapter runs the changes in house prices $\Delta_1 ph_t$ against a few of the selected principal components, by using the TVP in the form of a state space model which is in the spirit of Principal Component Regression.

Measurement Equation:

$$\Delta_1 ph_t = sv_{k,t} PC_{k,t} + c_0 + \varepsilon_t \qquad 6.1$$

State Equation with Random Walk Specification:

$$sv_{k,t} = sv_{k,t-1} + u_t \qquad 6.2$$

$$(\varepsilon_t, u_t)' \sim N\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}\sigma^2 & 0\\ 0 & Q\end{pmatrix}\right) \qquad 6.3$$

$sv_{k,t}$ is the time varying coefficient for the k-th independent variable, principal component $PC_{k,t}$ at time t. c_0 is the constant. ε_t and u_t are the temporary and permanent disturbance terms, respectively. ε_t and u_t are Gaussian disturbances, which are serially independent and independent of each other over the sample. Once the TVP models are specified as equations (6.1) through (6.3), the unknown parameters for the disturbance terms and the time varying parameters can be estimated by using maximum likelihood estimation. This chapter uses a Gauss-Newton algorithm, Marquardt, for optimizing the log likelihood function. Here, the log likelihood function refers to the ‘prediction error decomposition’ in Harvey (1990).

In the housing literature, one of the main challenges is the 'curse of dimensionality'. For serially correlated variables, the number of parameters of a model often increases significantly when the order of the model is increased. Multiple variables present similar patterns, implying the existence of common factors among these variables. As a statistical factor model, the aim of a Principal Component Analysis (PCA) is to identify and extract, from a number of possibly related stationary variables, a few uncorrelated stationary factors, named principal components which can attribute to most of the variations in the covariance or correlation matrix of the variables. The first principal component accounts for as much of the variability in the data as possible, the second greatest variability on the second principal components, and so on. See (Jackson, 1993; Zivot and Wang, 2006; Alexander, 2008; Tsay, 2010).

Building on the demand and supply equations in Hendry (1984) and the open economy framework of Mankiw (2011), this chapter runs robust PCA (Verardi and Croux, 2008) to house completion $\Delta_1 h_t$, Retail Price Index (RPI) $\Delta_1 p_t$, real household disposable income $\Delta_1 y_t$, real income per household $\Delta_1(y-h)_t$, house price $\Delta_1 ph_t$, average value of housing per unit income $\Delta_1(ph+h-p-y)_t$, mortgage total outstanding $\Delta_1 m_t$, mortgage rate from Building Societies $\Delta_1 r_t$, ratio of borrowed to own equity $\Delta_1(m-ph-h)_t$, real mortgage value $\Delta_1(m-p)_t$, real value of the mortgage stock $\Delta_1(m-p-h)_t$, ratio of house price to incomes $\Delta_1(ph-p-y)_t$ and foreign portfolio investment $\Delta_1 fpi_t$ at the first log difference scale. Relative to the standard PCA application, Verardi and Croux (2008)'s robust PCA eliminates the outlier effects.

By applying the correlation matrix approach, Table 6.2 shows the results of the robust PCA. Because of collinearity, STATA automatically drops the changes in physical house completion $\Delta_1 h_t$, RPI $\Delta_1 p_t$, real income per household $\Delta_1(y-h)_t$, ratio of borrowed to own equity $\Delta_1(m-ph-h)_t$, real mortgage value $\Delta_1(m-p)_t$ and ratio of house price to incomes $\Delta_1(ph-p-y)_t$. Therefore, the robust PCA actually applies to the real household disposable income $\Delta_1 y_t$, house price $\Delta_1 ph_t$, average value of housing per unit income $\Delta_1(ph+h-p-y)_t$, mortgage total outstanding $\Delta_1 m_t$, mortgage rate from Building Societies $\Delta_1 r_t$, real value of the mortgage stock $\Delta_1(m-p-h)_t$, and foreign portfolio investment $\Delta_1 fpi_t$ at the first log difference scale.

Table 6.2 Results of Robust PCA

Panel A:

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.17894	.661348	0.3113	0.3113
Comp2	1.5176	.360288	0.2168	0.5281
Comp3	1.15731	.122031	0.1653	0.6934
Comp4	1.03528	.274499	0.1479	0.8413
Comp5	.760777	.415837	0.1087	0.9500
Comp6	.34494	.339779	0.0493	0.9993
Comp7	.005161	/	0.0007	1.0000

Panel B: Principal components (Eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Unexplained
$\Delta_1 \boldsymbol{y_t}$	-0.0426	-0.0290	0.1497	***0.9153***	0.3650	0.0201	0.0595	0
$\Delta_1 \boldsymbol{ph_t}$	0.2514	***0.6570***	0.1982	0.0722	-0.1195	-0.6492	-0.1578	0
$\Delta_1 (\boldsymbol{ph + h - p - y})_t$	***0.6611***	-0.0717	-0.0245	-0.0891	0.1907	-0.0428	0.7149	0
$\Delta_1 \boldsymbol{m_t}$	0.2047	0.0246	***0.8030***	0.0155	-0.3600	0.4260	-0.0359	0
$\Delta_1 \boldsymbol{r_t}$	0.1948	0.4566	***-0.5157***	0.2664	-0.4281	0.4826	0.0243	0
$\Delta_1 (\boldsymbol{m - p - h})_t$	***-0.6263***	0.1962	0.1158	0.0318	-0.2885	-0.1166	0.6768	0
$\Delta_1 \boldsymbol{fpi_t}$	-0.1606	***0.5611***	0.1164	-0.2772	***0.6481***	0.3851	0.0244	0

In Table 6.2, panel A shows the figures for the eigenvalues, and the (cumulative) percentage of explained variance. The eigenvalue for a given component measures the variance in all the variables which is accounted for by that component. The sum of all eigenvalues equals the total number of variables. The difference shows the spread between one eigenvalue and the next. The proportion indicates the relative weight of each component in the total variance. The cumulative shows the amount of variance explained by the sum of the first k components. Following Jackson (1993), the chapter identifies the numbers of principal components when the cumulative proportion of variance is above 90%. Therefore, the chapter selects the first five principal components that implies $k = 5$ in equation (6.1). The chapter does not rotate the principal components, primarily as the components rotation does not enhance the interpretation in Table 6.2. The rotated results are available upon request. Given the chapter targets quantifying the dynamic relationships between the changes in house prices against the five principal components or common factors in the UK housing market, instead of identifying the specific characteristics of each component, the chapter names the principal components according to the values of the factor loadings.

In Table 6.2, panel B reports the factor loadings which are the correlation coefficients between the variables (rows) and components (columns). As the first component has a factor loading of

0.66 on the average value of housing per unit income $\Delta_1(ph + h - p - y)_t$, -0.62 on real value of the mortgage stock $\Delta_1(m - p - h)_t$, and quite low loadings on the rest of variables. The first component is named the house value and leverage factor. In the same way, the second principal component is named the house price appreciation factor. The third principal component is the credit availability factor. The fourth and fifth principal component is the personal disposal income factor and the foreign capital factor, respectively. Considering the factors might have substantial factor loadings on some other variables, it is somewhat problematic to assume a specific component has the same characteristics as the underlying variables. For instance, the performance of the fourth principal component might differ significantly from the real household disposable income $\Delta_1 y_t$, simply because the component also has very high loadings on the mortgage rate $\Delta_1 r_t$ (0.27), and these variables have quite different or even opposite characteristics.

Then, the chapter runs changes in house price $\Delta_1 ph_t$ against the five unrotated principal components by using the equations (6.1) and (6.2). Figure 6.1 shows the time varying coefficients $sv_{k,t}$ for the five principal components over the sample 1975Q1-2007Q4. This is because there are spikes in the diagrams which correspond to having an exact fit to the data or at most 1 degree of freedom over the sample 1968Q2-1974Q4, given the TVPs are estimated by recursive process. With the increasing in degrees of freedom, the time varying coefficients tend to be sensible. Throughout the chapter, the notation $sv_{k,t}$ means the time varying coefficients for the k-th independent variable at time t. Throughout the chapter, the time varying coefficients indicates that one unit changes in independent variable could cause about $sv_{k,t}$ unit changes in house prices at time t, *ceteris paribus*.

Figure 6.1 TVP-PCA (1975Q1-2007Q4)

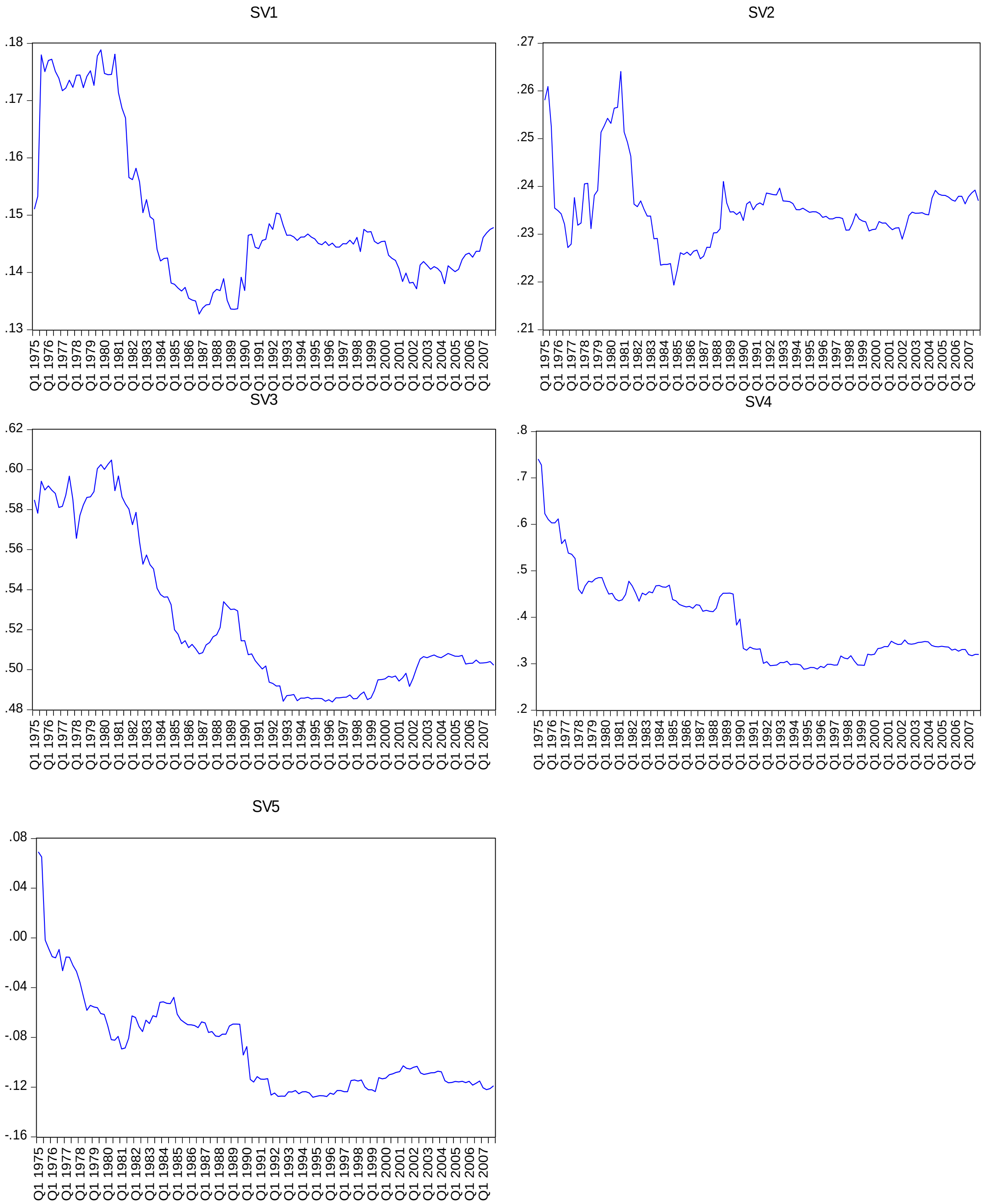


Figure 6.1 suggests all the coefficients are declining between 1975Q1 and 2007Q4 albeit they experience various levels of short-term recoveries. It implies that the five principal components, or common factors in general, play a declining role in driving the changes in house prices over the sample 1975Q1-2007Q4. Apart from the coefficients of the fifth principal component $sv_{5,t}$,

the remainder of the four TVPs remain positive over the sample. The general turning points for these time varying parameters appears in 1980-1983, 1987-1990 and 1996-1998 which are consistent with Table 6.1 and Brown *et al.* (1997).

6.4.2 Time Varying Parameter with Principal Component Analysis and Bubble (TVP-PCA-Bubble)

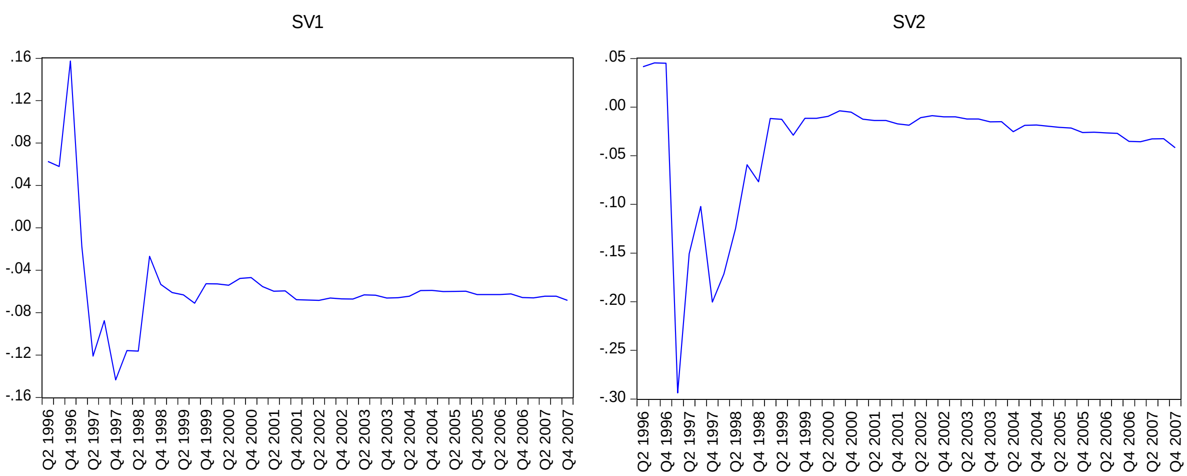
To control the effect of people's biased expectations on the changes in housing prices, equation (6.4) incorporates the changes in housing price bubble $\Delta_1 b_t$ to equation (6.1).

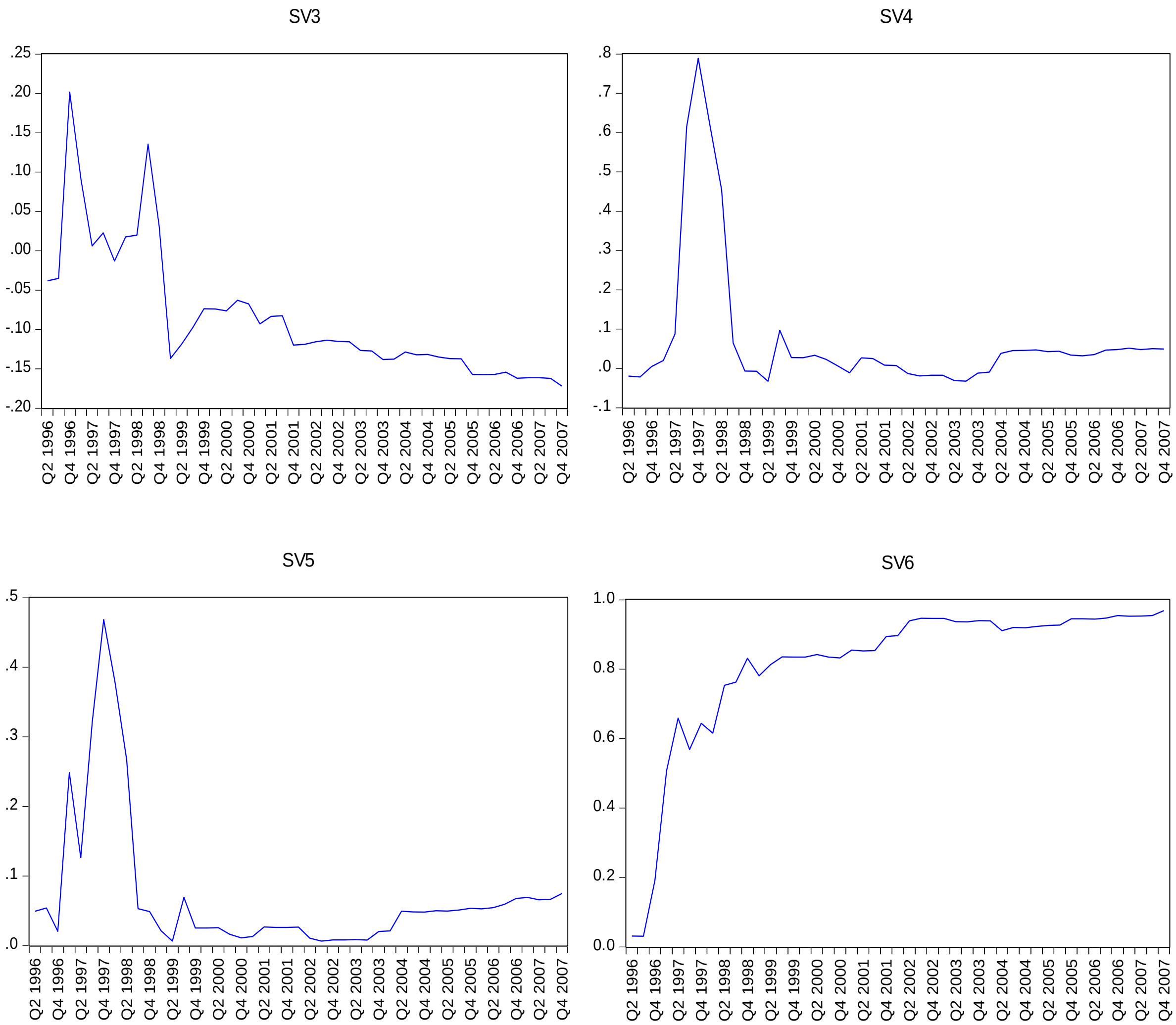
Measurement Equation:

$$\Delta_1 ph_t = sv_{k,t} PC_{k,t} + sv_{k+1,t} \Delta b_t + c_0 + \varepsilon_t \qquad 6.\ 4$$

The remainder of the model specification is same as equations (6.2) and (6.3). As $k = 5$, the time varying coefficients for the changes in bubble Δb_t is labelled as sv_6. The estimation of changes in bubble $\Delta_1 b_t$ is available in Section 7.2.1, in Chapter 7. Figure 6.2 plots the time varying coefficients of the TVP-PCA-Bubble over the sample 1996Q2- 2007Q4 because the starting data for the changes in house price bubble Δb_t are available at 1996Q2.

Figure 6.2 TVP-PCA-Bubble (1996Q2-2007Q4)





In Figure 6.2, the coefficients for the five principal components change signs over time which is a contrast to Figure 6.1. However, the decline of coefficients sv_1 through sv_5 over time and the dramatic volatility between 1996 and 1998 are consistent with Figure 6.1. After controlling for the effect of changes in bubble Δb_t, the coefficients for the five principal commons are smaller than 0.2 in absolute value. The coefficient for the changes in bubble sv_6 increases from 0.05 in 1996 to 0.8 in 1998, and thereafter, it remains stable and approaches 1.0 by 2007Q4. Given bubble is a component of house price, one unit changes in bubble approximately drives one unit changes in house price, after controlling for the effect of the fundamental variables. The small value of sv_6 prior to 1998 is probably due to lack of degree of freedom. When compared to Figure 6.1, Figure 6.2 implies that the effects of common factors on housing prices are substantially dependent on the changes in bubble, or people's biased expectations. It is the build-up of the bubble which is driving the changes in house prices.

Brown *et al.* (1997) study the time varying coefficients for the nominal user cost and the expected capital gains on housing separately. However, this chapter treats expected capital gains as a key driver of the nominal user cost which, in turn, is a main variable in the estimation of bubble, or people's biased expectations. Furthermore, Brown *et al.* (1997) formulate the expected capital gains by using the backward-looking adaptive expectations, while this chapter uses the forward-looking unbiased expectations.

Brown *et al.* (1997) suggest the coefficient for the expected capital gains is likely to increase when the house prices are booming and fall when house prices are in recession periods over the sample 1968Q2-1992Q2. Given the sample 1996Q2-2007Q4 is a typical booming period in the UK housing market, the increase of coefficient for the changes in bubble sv_6 in Figure 6.2 support Brown *et al.* (1997).

6.4.3 Time Varying Parameter with Error Correction Model (TVP-ECM)

Following Li *et al.* (2006), this chapter investigates a two-step TVP-ECM. TVP-ECM accommodates an adjustment process that prevents housing variables from moving too far away from their long-run equilibrium.

Building on the equation (14) of Hendry (1984) and the open economy theory of Mankiw (2011), the first step applies the Johansen cointegration test for house price ph_t, mortgage outstanding m_t, mortgage rate r_t, house completion h_t, real household disposable income y_t, foreign portfolio investment fpi_t and general index of retail price p_t at the natural log scale.

From Table 6.3, both the trace test and the maximum eigenvalue test indicate there are four cointegrations among the seven applied variables at the 5% significance level. It implies there are four linear combinations of these variables which are stationary in level.

Table 6.3 Johansen Cointegration Test

Unrestricted Cointegration Rank Test (Trace)			
No. of Cointegration(s)	Eigenvalue	Trace Statistic	p-value
None	0.4554	266.7334	0.0000***
At most 1	0.3755	171.3211	0.0001***
At most 2	0.2505	97.4002	0.0001***
At most 3	0.1789	52.1197	0.0188**
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
No. of Cointegration(s)	Eigenvalue	Max-Eigen Statistic	p-value
None	0.4554	95.4122	0.0000***
At most 1	0.3755	73.9209	0.0000***
At most 2	0.2505	45.2806	0.0015***
At most 3	0.1789	30.9458	0.0178**

Notes: Johansen cointegration test for house price ph_t, mortgage outstanding m_t, mortgage rate r_t, house completion h_t, real household disposable income y_t, foreign portfolio investment fpi_t and general index of retail price p_t. *** and ** denote for statistical significant at the 1% and 5% significance level, respectively.

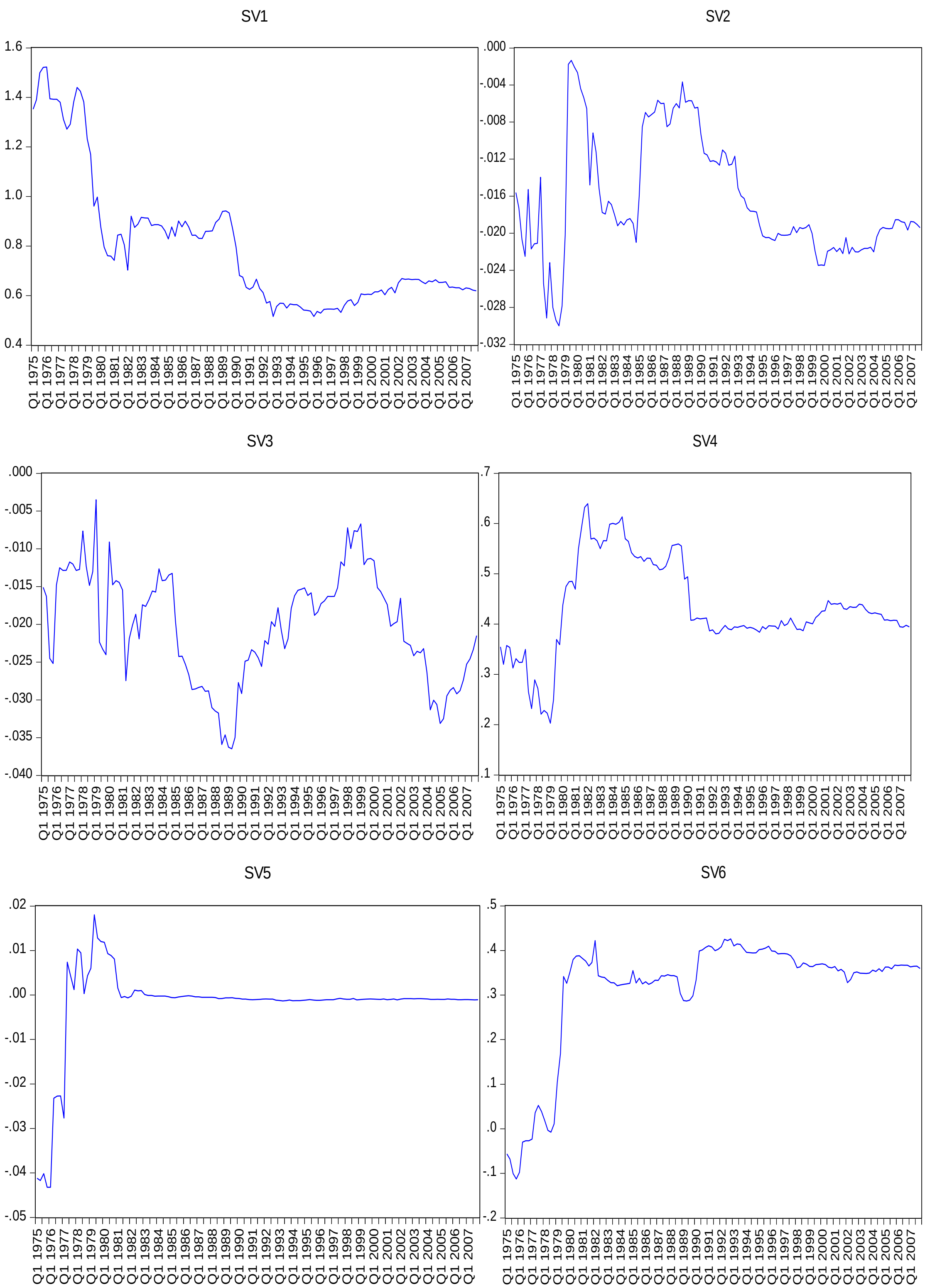
The second step runs the changes in house price $\Delta_1 ph_t$ against the cointegration terms and the mortgage outstanding $\Delta_1 m_t$, mortgage rate $\Delta_1 r_t$, house completion $\Delta_1 h_t$, real household disposable income $\Delta_1 y_t$, foreign portfolio investment $\Delta_1 fpi_t$, general index of retail price $\Delta_1 p_t$ at the first natural log difference scale as equation (6.5).

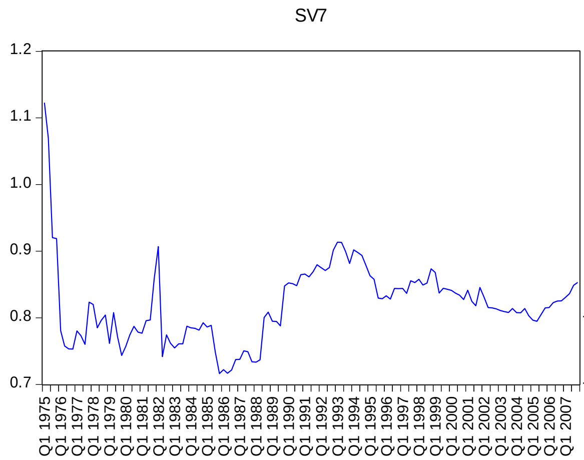
Measurement Equation:

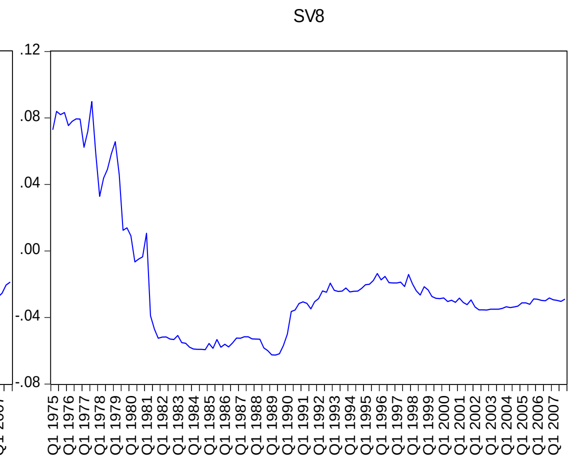
$$\varDelta_1 ph_t = sv_{1,t}\varDelta_1 m_{t-1} + sv_{2,t}\varDelta_1 r_{t-1} + sv_{3,t}\varDelta_1 h_{t-1} + sv_{4,t}\varDelta_1 y_{t-1} + sv_{5,t}\varDelta_1 fpi_{t-1} + sv_{6,t}\varDelta_1 ph_{t-1} + sv_{7,t}\varDelta_1 p_{t-1} + sv_{8,t} cointeg_{1,t-1} + sv_{9,t} cointeg_{2,t-1} + sv_{10,t} cointeg_{3,t-1} + sv_{11,t} cointeg_{4,t-1} + c_0 + \varepsilon_t \qquad 6.5$$

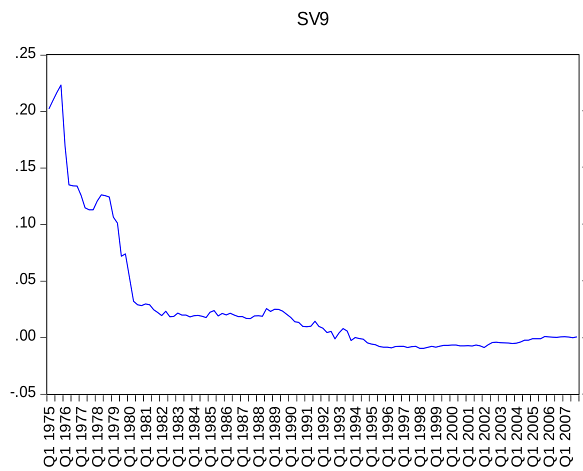
$cointeg_{i,t}$ is the $i\text{-}th$ cointegration term or error correction mechanism. The state equation and the rest of model specifications are same to equations (6.2) and (6.3). Like Figure 6.1, Figure 6.3 shows the time varying coefficients for the TVP-ECM over the sample 1975Q1-2007Q4.

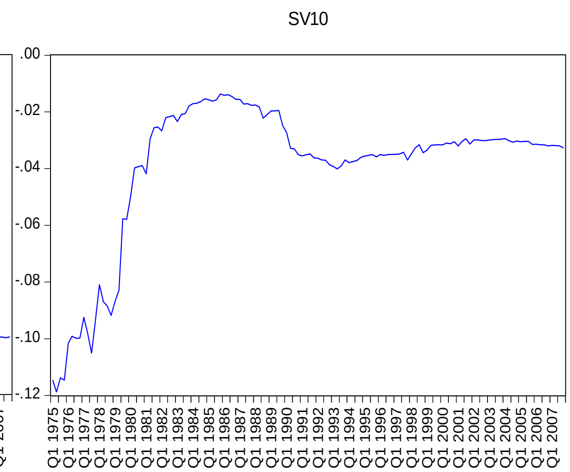
Figure 6.3 TVP-ECM (1975Q1-2007Q4)

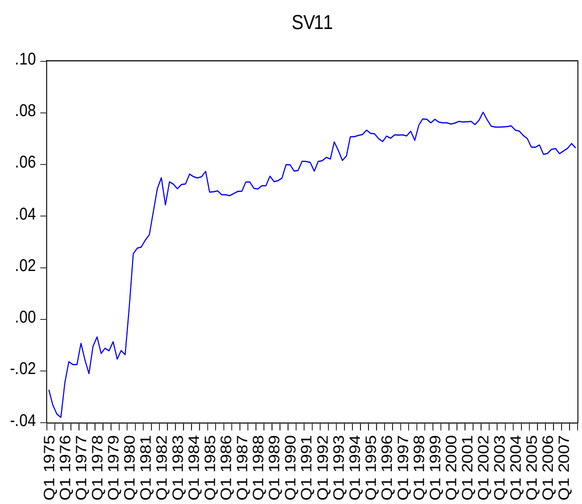












In Figure 6.3, the coefficient for the changes in mortgage outstanding sv_1, declines between 1975 and 1982; remains stable between 1983 and 1989; declines from 1990 to 1997, and then recoveries slightly. The coefficients for changes in mortgage rate from Building Societies sv_2, house completion sv_3 and real household disposable income sv_4 show W-shape volatiles. The coefficient for changes in foreign portfolio investment sv_5 and the lagged changes in house price sv_6 increases from 1975 to 1978; declines between 1979 and 1980. Thereafter, sv_5 remains quite stable. sv_6 exhibits a slight recovery from 1989 to 1990 and then remains stable. The coefficient for changes in RPI sv_7 declines from 1975Q1 at 1.1 to 0.7 at 1996Q1, recoveries of 0.9 at 1993Q1, and then experience long term decline with modest short term recoveries by 2007Q4. The coefficients for the cointegration terms, sv_{10} and sv_{11} are negative but sv_8 and sv_9 are positive with slightly higher values between 1975Q1 and 1982Q2 which implies the cointegration terms in general drive the housing market far away from their equilibrium. From 1982Q3 to 2007Q4, the coefficients sv_8 and sv_{10} remain negative, sv_9 converges to 0, sv_{11} turns to positive; and the overall effect of these four cointegration terms turns to negative which drives the UK housing market to converge on its long run equilibrium. Figure 6.3 suggests the turning points appear in 1980-1982, 1989-1991 and 1995-1998 which are consistent with Table 6.1 and Figures 6.1 and 6.2.

The general declining values of sv_1, sv_4 and sv_7 over the sample indicate that the changes in the mortgage outstanding from Building Societies, real household disposable income and RPI are playing a less important role than they were. The values of sv_2, sv_3 and sv_5 are less than 0.05 in absolute values, suggesting that if one unit changes in each of the mortgage rates from the Building Societies, house completion and foreign portfolio investment cannot substantially drive the movement of house prices, *ceteris paribus*.

Table 6.4 exhibits the hypothesis testing for statistical significance of the TVPs throughout the chapter. The chapter does not display the confidence intervals for the TVPs primarily because the standard errors for the TVPs are generally very small, and thereby make the confidence intervals and the TVPs too tight to distinguish. Except for few exceptional, the majority of TVPs are statistical significant at the 10% significance level. The statistical insignificant TVPs including the coefficient for the fourth principal component in the TVP-PCA-Bubble model; the coefficients for the changes in mortgage rate from Building Societies sv_2, the changes in housing completion sv_3, the changes in foreign portfolio investment sv_5 and the second ECM in the TVP-ECM model. The next two paragraphs present a battery of evidences to support these empirical findings.

Table 6.4 Statistical Significance for the Time Varying Parameters

	Final State	Root MSE	Z-$Statistic$	p-$value$
TVP-PCA:				
$\Delta_1 ph_t = sv_{k,t}PC_{k,t} + c_0 + \varepsilon_t$				**Equation (6.1)**
$sv_{k,t} = sv_{k,t-1} + u_t$				**Equation (6.2)**
$sv_{1,t}$	0.147830	0.018092	8.171039	0.0000
$sv_{2,t}$	0.236976	0.020796	11.39542	0.0000
$sv_{3,t}$	0.502223	0.036696	13.68589	0.0000
$sv_{4,t}$	0.319816	0.103073	3.102803	0.0019
$sv_{5,t}$	-0.118968	0.049496	-2.403569	0.0162
TVP-PCA-Bubble:				
$\Delta_1 ph_t = sv_{k,t}PC_{k,t} + sv_{k+1,t}\Delta b_t + c_0 + \varepsilon_t$				**Equation (6.4)**
$sv_{k,t} = sv_{k,t-1} + u_t$				**Equation (6.2)**
$sv_{1,t}$	-0.068433	0.014462	-4.731877	0.0000
$sv_{2,t}$	-0.041734	0.021256	-1.963376	0.0496
$sv_{3,t}$	-0.171932	0.040672	-4.227262	0.0000
$sv_{4,t}$	0.049494	0.082698	0.598487	0.5495
$sv_{5,t}$	0.074855	0.038897	1.924443	0.0543
$sv_{6,t}$	0.969045	0.053804	18.01080	0.0000
TVP-ECM:				
$\Delta_1 ph_t = sv_{1,t}\Delta_1 m_{t-1} + sv_{2,t}\Delta_1 r_{t-1} + sv_{3,t}\Delta_1 h_{t-1} + sv_{4,t}\Delta_1 y_{t-1} + sv_{5,t}\Delta_1 fpi_{t-1} + sv_{6,t}\Delta_1 ph_{t-1} + sv_{7,t}\Delta_1 p_{t-1} + sv_{8,t}cointeg_{1,t-1} + sv_{9,t}cointeg_{2,t-1} + sv_{10,t}cointeg_{3,t-1} + sv_{11,t}cointeg_{4,t-1} + c_0 + \varepsilon_t$				**Equation (6.5)**
$sv_{k,t} = sv_{k,t-1} + u_t$				**Equation (6.2)**
$sv_{1,t}$	0.619478	0.117573	5.268883	0.0000
$sv_{2,t}$	-0.019398	0.019762	-0.981590	0.3263
$sv_{3,t}$	-0.021493	0.019095	-1.125550	0.2604
$sv_{4,t}$	0.394486	0.113480	3.476249	0.0005
$sv_{5,t}$	-0.001048	0.002083	-0.503042	0.6149
$sv_{6,t}$	0.359820	0.078414	4.588731	0.0000
$sv_{7,t}$	0.853063	0.153488	5.557853	0.0000
$sv_{8,t}$	-0.028909	0.011434	-2.528233	0.0115
$sv_{9,t}$	0.000653	0.014477	0.045105	0.9640
$sv_{10,t}$	-0.032686	0.010400	-3.142964	0.0017
$sv_{11,t}$	0.066366	0.022491	2.950734	0.0032

Notes: $\Delta_1 ph_t$ is the changes in house price. $sv_{k,t}$ is the time varying coefficient for the k-th independent variable, at time t. $PC_{k,t}$ denotes for principal component. c_0 is the constant. ε_t and u_t are the temporary and permanent disturbance terms, respectively. $cointeg_{i,t}$ is the i-th cointegration term or error correction mechanism. Root MSE stands for Root Mean Square Error.

Firstly, Shiwakoti *et al.* (2008) suggest that about 80% of the total assets of Building Societies eventually transfer to the banking sector, since the enactment of the UK Building Societies Act 1986. O'Connor (2010) suggests the proportion of total mortgage outstanding provided by Building Societies dramatically declines from more than 60% in mid-1980s to 14% by 2010. Therefore, the mortgage outstanding and the mortgage rates from the Building Societies play a declining role in driving the UK housing prices. However, the estimation of housing price bubbles in Chapter 5 suggests that the composite mortgage rate of Building Societies and Banks plays an increasing role over previous decades. Secondly, the real disposable income is an average evaluation that covers the aggregate population, but the specific groups of sellers and buyers that determine the house prices may have income that is significantly different from the population mean, which is particularly true in the UK housing market. Thirdly, when people purchase a home, they make their decision based not only on available information such as the lagged changes in RPI, but also their expectations about the future. Fourthly, the house completion is very small in relation to the existing housing stock (Hendry, 1984); and the domestic regulations which could effectively eliminate the impact of foreign portfolio investments (Whelan, 2010; Xu and Chen, 2012). Fifth, the spread of 'short-termism' in the UK since the 1960s is associated with financial innovations and deregulations that drive people to treat housing as a gambling chip, becoming increasingly impatient for a quick return on their investments. Consequently, people's expectations, in particular the expected capital gains on the housing market rather than the traditional economic factors, are playing a far more important role in driving the UK housing prices.

6.4.4 Diagnostic Tests

To assess whether the three two-step TVP models are valid, Table 6.5 tests the residuals of the three TVP models in terms of independence, homoscedasticity and normality, which are listed in a decreasing order of importance according to Commandeur and Koopman (2007). As the measure of the relative quality of a statistical model, Table 6.5 also presents the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Table 6.5 Diagnostic Tests for the TVP Models

	Independence (L-B Test)	**Homoscedasticity** (McLeod-Li Test)	**Normality** (J-B Test)	**AIC**	**BIC**	**Remark**
TVP-PCA	1.4920	No ARCH effect	138744.8***	-4.035	-3.996	Alright.
TVP-PCA-Bubble	20.189	No ARCH effect	2.19841	-4.284	-4.205	Good Model.
TVP-ECM	23.246	No ARCH effect	627.963***	-3.454	-3.415	Alright.

Notes: The null hypothesis for the Ljung-Box (L-B) independence test is the residuals are independent at Q(24). The null hypothesis for the Jarque-Bera (J-B) normality test is the residuals follow a normal distribution. *** represents statistical significant at the 1% significance level.

In Table 6.5, the Ljung-Box (L-B) test fails to reject the residual independence and the McLeod-Li test does not reject the residual homoscedasticity for the TVP-PCA, the TVP-PCA-Bubble and the TVP-ECM; the Jarque-Bera (J-B) test significantly rejects the normality of residuals for the TVP-PCA and the TVP-ECM. The TVP-PCA-Bubble reports the smallest AIC and BIC, while the TVP-ECM exhibits the largest AIC and BIC. Table 6.5 indicates the TVP-PCA-Bubble model satisfies the three assumptions concerning the residuals of the analysis. The TVP-PCA and the TVP-ECM are somewhat problematic but still provide sensible outputs, given the residual normality is the least important assumption. The model fitting of TVP-PCA-Bubble outperforms TVP-PCA which, in turn, is superior to the TVP-ECM. Overall, the findings of the three applied TVP models are valid.

6.5 Conclusion

This chapter investigates the institutional changes in the UK housing market from 1968Q2 to 2007Q4 using two categories of quantitative models. The Bai and Perron (1998) break tests for the fast-moving (or formal) institutional changes, and the Time Varying Parameter (TVP) models for the slow-moving (or informal) institutional changes.

The chapter contributes to the housing literature from two aspects. Firstly, this chapter provides more recent empirical evidence to justify that the fast-moving institutional changes, such as political reforms do not cause statistically significant structural breaks immediately which supports Lucas (1976), Roland (2004) and Culpepper (2005). Political reform is often a necessary but insufficient condition for institutional change, given people's shared beliefs can persist even after changing the formal laws. It seems the unexpected shocks in particular financial crises often drive people to coordinate their future anticipations around the new rules of the economy, and thereby leads to structural break.

Secondly, the chapter investigates three two-step TVP models, namely, TVP-PCA, TVP-PCA-Bubble and TVP-ECM. Although it is getting popular to use TVP-ECM and TVP-PCA in dynamic forecasting, the chapter does not find any one uses these models to quantify the slow-moving institutional changes, let alone the TVP-PCA-Bubble model. The TVP models suggest the changes in policies would impact the housing market through the slow-moving institutional changes in particular those relating to people's preferences, technology and expectations over time. The findings of TVP models support the Lucas (1976), Gérard (2004) and Culpepper

(2005). Therefore, rapidly political and legal interventions may not stabilize the housing market immediately and may risk driving the housing market into further uncertainty in the long run.

From an investment perspective, this chapter finds that the linkages between house prices and fundamental variables are decaying over time. On the contrary, people's biased expectations of housing price bubbles are playing much more of an important role in driving the UK house prices over the booming period 1996Q2-2007Q4, which supports Brown *et al.* (1997). Whether the coefficient for the biased expectations will fall in recession periods needs more recent empirical evidence. Any housing policies and investment strategies would be wise if they take account of people's biased expectations.

Chapter 7. Understanding the Causal Relationship between the Changes in House Prices and Bubbles: Evidence from the UK Regional Panel Data

7.1 Introduction

This chapter aims to test that the findings in Chapters 5 and 6 are robust over time, even in terms of panel data analysis. This chapter considers two issues.

- Firstly, whether the bounded rationality expectation hypothesis best fit into the UK housing market in terms of panel data analysis?
- Secondly, whether the feedback theory (Shiller, 1990,2007) is supported in the UK housing market?

The bounded rationality hypothesis argues that people make expectations and decisions to help them satisfice rather than make theoretically optimal decisions. The bounded rationality expectation captures the idea that asset prices overreact to relevant information on fundamentals, due to cognitive and psychological limitations. However, people learn from their mistakes and attempt to satisfice by acting as rationally as possible.

The feedback theory (Shiller, 1990,2007) suggests that when house prices as a whole appreciate significantly, this generates many investor success stories. These stories entice potential investors, who naively extrapolate that they will achieve the same success if they invest too, and *vice versa*. The repeating of this process drives prices higher and higher and *vice versa*, for a while. The feedback theory implies that there is a positive feedback causal relationship between people's expectations and subsequent house prices, and *vice versa*. The feedback theory appears as a type of adaptive expectation hypothesis which means that people usually form their expectations of an economic variable by taking a weighted mean of past values and an 'error adjustment' term. Mayer (2007) suggests Shiller (2007) overstates the case by ignoring the role of interest rates and using an outdated dataset.

This chapter contributes to the literature from two aspects. Firstly, the chapter empirically indicates that the changes in people's expectations best fit the bounded rationality hypothesis in the context of the panel data analysis. Relative to Shiller (2007), the chapter estimates the regional fundamental value and takes account of mortgage rates, people's risk aversions, taxes and the most recent UK datasets. Relative to Mayer (2007) and Hubbard and Mayer (2009), the study incorporates people's unbiased expected capital gain and the quarterly adjusted risk premium into the estimation of a fundamental house price.

Secondly, the chapter provides the first empirical evidence to justify the statistically significant feedback causality between the changes in bubble and the contemporaneous changes in house prices by using the Fixed Effects Model (FEM). The feedback causality is robust even when taking the mortgage rate and the more recent datasets into account. Therefore, we contribute to the literature on how regional heterogeneity may affect a region's housing market. When some regional heterogeneity is unobservable, a fixed effects model helps to capture the effect of the unobservable variables, and therefore alleviates the endogeneity problem resulting from the omitted variable bias. Additionally, a fixed effects model is unique in that it captures the time series variation (Chi, 2005). In line with earlier chapters, this chapter regards bubbles as the house prices deviation from fundamental values which result from people's biased expectations.

Our findings indicate that as a region increases its house price, people observe a subsequent increase in its bubble, *ceteris paribus*. However, an increase in bubble could cause a subsequent decrease in house price which does not support the feedback theory (Shiller, 1990,2007), *ceteris paribus*. The causality effects are asymmetrical, being more significant from bubble to house price than that from house price to bubble in the presence of the observable and unobservable regional characteristics. Furthermore, there is modest parameter instability over the subsamples. This chapter supports the findings in Chapters 3 through to 6.

There are two broad categories of literature study of house prices using the panel data analysis. The first category focuses on the linkages between some fundamental factors and housing prices. For instance, Holly *et al.* (2010) investigate the determination of real house prices by using a spatio-temporal model in a panel of 49 US states over a period of 29 years. Holly *et al.* (2011) propose a novel way to model the spatial-temporal dispersion of shocks in non-stationary systems in a panel of 11 UK regions. Holly *et al.* (2011) suggest that the effects of a shock decay more slowly along the geographical dimension when compared to the decay along the time dimension. The second category places emphasis on whether the house prices are supported by fundamentals. For example, Cameron *et al.* (2006) examine the bubbles hypothesis using a dynamic panel data model in a panel of the UK regional property prices from 1972 to 2003, but fails to find a bubble. Recent studies (Mikhed and Zemčík, 2009; Clark and Coggin, 2011) suggest there is a house price bubble in the US, according to the univariate and panel unit root and cointegration tests. Unfortunately, it is rare for the literature to quantify the level of housing price bubbles by using the panel data analysis, let alone modelling the direction of causality between the changes in house price and the changes in bubble. This chapter quantifies the regional changes in bubbles using a time series approach, namely, the user cost framework in a state space model.

Relative to the pure aggregate time-series analysis, the panel data analysis using the UK regional data possesses several advantages: (1), panel data normally provides a large number of data points, raising the degrees of freedom and eliminating the multicollinearity among independent variables; (2), controlling for individual heterogeneity; (3), micro panel data collected on individual regions may be more precisely measured than similar variables measured at the macro level; (4) better ability to investigate the dynamics of economic states; (5) panel allows researchers to investigate causality (Hsiao, 2003; Frees, 2004; Wooldridge, 2010).

In the remainder of the chapter Section 7.2 presents the methodology. Section 7.3 is data description. Section 7.4 reports the empirical results and discussion. Section 7.5 is the conclusion.

7.2 Methodology

Section 7.2.1 presents how to estimate the regional changes in bubble using the user cost framework in a state space model, which is a typical two-step time series approach. Section 7.2.2 exhibits the causality tests in the context of the fixed effects model. Throughout this chapter, lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts. Δ_1 denotes for first difference.

7.2.1 Estimation of Changes in Bubble

Given that asset price is a combination of fundamental, non-fundamental or bubble and model misspecification error (Wu, 1997), we can write the changes in house price as

$$\Delta_1 ph_t = \Delta_1 ph_t^f + \Delta_1 b_t + \varepsilon_t \qquad 7.1$$

Where, $\Delta_1 ph_t$ is the changes in house price, $\Delta_1 ph_t^f$ is the changes in fundamental house price, and $\Delta_1 b_t$ is the changes in bubble, ε_t is error term. Because $log(HPI_t^f) = log(HPI_t^f / HRI_t) + log(HRI_t)$, we can rewrite equation (7.1) as

$$\Delta_1 ph_t = \Delta_1 ph_t^f + \Delta_1 b_t + \varepsilon_t = \Delta_1 pr_t^f + \Delta_1 hri_t + \Delta_1 b_t + \varepsilon_t \qquad 7.2$$

$\Delta_1 pr_t^f = \Delta_1 \, log(HPI_t^f / HRI_t)$ is the changes in fundamental price-rent ratio. $\Delta_1 hri_t = \Delta_1 log(HRI_t)$ is the changes in house rent index. In equation (7.2), the changes in fundamental house price-rent ratio $\Delta_1 pr_t^f$ and the changes in bubble $\Delta_1 b_t$ are not directly observable and need some algebra estimations.

In the first step, the chapter estimates the fundamental house price-rent ratio pr_t^f by using the user cost framework. The user cost framework suggests that at the equilibrium house price HPI_t^f, the cost of holding a house per year $UC_t \times HPI_t^f$ equals the cost of renting the house HRI_t for that period, namely,

$$HRI_t = UC_t \times HPI_t^f \qquad 7.3$$

UC_t is the user cost of holding a house per year at the percentage level. Then, the fundamental house price-rent ratio PR_t^f is the inverse of the user cost UC_t.

$$PR_t^f = \frac{HPI_t^f}{HRI_t} = \frac{1}{UC_t} \qquad 7.4$$

At the percentage level:

$$UC_t = R_t^m + PT_t + MC_t + RP_t - MT_t(R_t^m + PT_t) - CG_{t+1} \qquad 7.5$$

Where, R_t^m is the foregone mortgage rate, PT_t is the property tax rate, MC_t is the maintenance cost, RP_t is the risk premium for the larger uncertainty of purchasing relative to renting, MT_t is the marginal tax rate for the house buyer. CG_{t+1} is the expected capital gain over the next year. Equation (7.4) implies that the user cost should be positive, as neither the theoretical house price nor the actual market rent should be negative. This chapter estimates the risk premium RP_t and expected capital gain CG_{t+1} as

$$RP_t = CG_{t+1} - \frac{HRI_{t+1} - HRI_t}{HRI_t} \qquad 7.6$$

$$CG_{t+1} = \frac{HPI_{t+1}}{HPI_t} - 1 = \frac{HPI_{t+1} - HPI_t}{HPI_t} \qquad 7.7$$

Equation (7.6) calculates the risk premium as the difference between the house price appreciation and the rent appreciation over the next year. Equation (7.7) calculates the expected capital gain as the realized capital gain over the next year. Then,

$$RP_t = CG_{t+1} - \frac{HRI_{t+1} - HRI_t}{HRI_t} = \frac{HPI_{t+1} - HPI_t}{HPI_t} - \frac{HRI_{t+1} - HRI_t}{HRI_t} \qquad 7.8$$

Equation (7.8) implies the net effect of risk premium and expected capital gain equals the changes in rent over the next year. Because the chapter uses the quarterly data, the annual changes in rent are the changes in rent over the next four quarters. Following Chapter 5, this chapter sets the property tax rate PT_t = maintenance cost rate $MC_t = 2\%$, and the marginal tax rate $MT_t = 0$. Furthermore, the chapter uses the composite mortgage rates from Building Societies and Banks over the sample 1996Q2-2007Q4 to proxy the R_t^m. Additionally, the chapter assumes the changes in regional rents are identical to the changes in national rents, given the regional rents are not available. Because the quarterly changes in regional house prices are quite huge, a few of the user costs are negative. In such case, the negative user costs are replaced by the previous positive figures.

In the second step, the chapter estimates the changes in bubble $\Delta_1 b_t$ by using a state space modelling.

Measurement equation:

$$\Delta_1 ph_t = c_1 \Delta_1 pr_t^f + c_2 \Delta_1 hri_t + \Delta_1 b_t + c_3 \qquad 7.9$$

State equation:

$$\Delta_1 b_t = \frac{1}{c_4} \Delta_1 b_{t-1} + c_5 \qquad 7.10$$

$$c_3 \sim i.i.d.N(0, R) \qquad 7.11$$

$c_5 \sim i.i.d.N(0, V)$ *7. 12*

$E(c_3, c_5') = 0, E(c_3, b_0') = 0$ and $E(c_5, b_0') = 0$ *7. 13*

c_3 and c_5 are the error terms. b_0' is the initial state vector. The five unknown parameters $(c_1, c_2, c_3, c_4, c_5)'$ are hyperparameters and are estimated by Maximum Likelihood Estimation (MLE) with Marquardt algorithm. The initial values for the hyperparameters are those specified in the coefficient vector, which are estimated by EVIEWS 7.

7.2.2 Panel Data Causality Tests

From the perspective of econometrics, there are four possible causal relationships between the changes in bubble and the changes in house price. (1), changes in bubble drive subsequent changes in house price; (2), changes in house price drive subsequent changes in bubble; (3), feedback effect, the changes in house price affects the changes in bubble, or causality runs both ways; (4), changes in bubble and changes in house price are not directly related, but are spuriously associated through other variables, either observable or unobservable. Technically speaking, situation (3) and situation (4) refer to the endogeneity, which is one of the most significant challenges in applied econometrics. Endogeneity normally arises from three sources: measurement error; simultaneity, as in situation (3); and omitted variable biases, as in situation (4).

The fixed effects model includes all unobserved effects and then provides a good control for endogeneity (Chi, 2005; Schroeder, 2010; Wooldridge, 2010). The key motivation of using a fixed effect model is to alleviate the omitted variable bias, not that the unobservable regional heterogeneity is fixed over time. Alternatively, one could try the instrument variable regression. However, exogenous and strong instruments may be unavailable.

In the spirit of the Granger causality test (Chi, 2005), the chapter sets the following fixed effects models:

$$\Delta_1 ph_{i,t} = \propto_1 + \beta \Delta_1 b_{i,t-1} + \sum_{k=1}^{K} \beta_k C_{k,i,t} + u_i + \varepsilon_{i,t} \qquad 7.\ 14$$

$$\Delta_1 b_{i,t} = \propto_2 + \theta \Delta_1 ph_{i,t-1} + \sum_{k=1}^{K} \theta_k C_{k,i,t} + \mu_i + \epsilon_{i,t} \qquad 7.\ 15$$

Where, $\Delta_1 ph_{i,t}$ is the changes in house price index for region i at time t. $\Delta_1 b_{i,t}$ is the changes in bubble for region i at time t. $\propto_1$ and $\propto_2$ are constants. i denotes different regions, t denotes time, and k the number of Control Variables. For instance, $C_{k,i,t}$ is the k-th control variable for region i at time t. β and θ are the coefficients on the underlying independent variables. u_i and μ_i are the fixed effects, indicating the effects of any and all time-invariant covariates on each variable, along with time-specific error terms ε and ϵ. The fixed effects model controls for the endogeneity by extracting the unobservable regional heterogeneities u_i and μ_i from the error terms ε and ϵ, respectively. It is possible to estimate equations (7.14) and (7.15) simultaneously as in the typical panel data Granger causality tests (Hoffmann *et al.*, 2005; Schroeder, 2010). However, estimating equations (7.14) and (7.15) separately allows for more flexibility in specifying the model.

There are three criteria for inferring causality (Frees, 2004; Chi, 2005). (1), there is a statistically significant relationship. (2), the causal variable must precede the other variable in time. (3), the association between two variables must not be result from another, omitted, variable. Given equations (7.14) and (7.15) control for these observable and unobservable regional heterogeneity (criterion 2 and criterion 3), one can infer the causality effect primarily depends on the significance of the relevant coefficients. More specifically, the statistical significance of β would indicate changes in bubble cause subsequent changes in house price, *ceteris paribus*. The statistical significance of θ indicates changes in house price would cause the changes in bubble, *ceteris paribus*. When β and θ are simultaneously statistically significant, then there are feedback relationships between changes in bubble and changes in house price, *ceteris paribus*. When β and θ are simultaneously statistically insignificant, there are no statistically causal relationships between changes in bubble and changes in house price, *ceteris paribus*.

The Random Effects Model (REM) is another popular panel data model. REM assumes the omitted time-invariant variables are irrelevant with the involved time-varying covariates. REM is often estimated by the Generalized Least Square (GLS) estimator, while FEM is often estimated within the OLS estimator. REM outperforms FEM for its greater efficiency leading to statistical power to detect effects and smaller standard errors. Given that there is almost always some omitted variables bias, FEM appears more suitable than REM from a causal inference perspective.

Both random and fixed effects models have implicit restrictions that are infrequently examined but that if incorrect, could bias the estimated results. For example, both models assume the unexplained variance remains the same over time. Moreover, the autoregressive relations with lagged dependent variables are assumed to be nil. When the lagged dependent variables are included in the Arellano Bond dynamic model, the dataset has to be a large number of regions (N) and short time period (T) (Arellano and Bond, 1991; Bond, 2002). Although the Hausman test is widely used to distinguish between REM and FEM, the choice is never straightforward, and tends to be harder still when the number of observations is small (Hsiao, 2003; Bollen and Brand, 2008,2010).

7.3 Data Description

The dataset in this study covers the twelve regions of the UK regional Halifax seasonal adjusted House Price Indices (HPI), the UK aggregate House Rent Index (HRI) is proxied by the Consumer Price Index (CPI) component of actual rents for housing, and the composite mortgage rate of Building Societies and Banks from the Bank of England. Black *et al.* (2006) suggest the Halifax house price index tracks price changes of a representative house rather than average prices by using the hedonic regression. The price of the representative house is then estimated for each period using the implicit prices of each attribute as extracted from the hedonic regression.

All the quarterly UK time series data are collected from DataStream with a time span from 1996Q1 to 2011Q1. The starting dates are chosen by the availability of data for the House Rent Index. The end dates are chosen by the availability of data for the composite mortgage rate of Building Societies and Banks. All the indices are set to 100 in 2005Q2. The twelve regions of the UK are; Northern Ireland, Scotland, Wales and the nine regions of England, namely, East Anglia, East Midlands, Greater London, North, North West, South East, South West, West Midlands, and Yorkshire and the Humber. The full dataset has long time periods ($T = 60$) with small individuals ($N = 12$) at the first log difference scale. All the variables in this chapter are not adjusted for inflation. Given that 'there is a great deal of confusion about the role of inflation expectations in the demand for housing' (Schwab, 1982,1983), it is interesting to study the linkages between house prices and its determinants in nominal terms.

A preliminary statistics and correlation matrix about the changes in HPI, changes in HRI, changes in fundamental price-rent ratios and changes in bubble are available in Appendix Table E and Table F, respectively.

7.4 Empirical Results and Discussion

7.4.1 Findings from the Full Sample

Table 7.1 displays the results of panel data unit root tests for changes in house price index $\Delta_1 ph_{i,t}$, changes in fundamental house price-rent ratio $\Delta_1 pr_{i,t}^{f}$, changes in house rent index $\Delta_1 hri_{i,t}$ and changes in bubble $\Delta_1 b_{i,t}$. The applied unit root tests are Harris–Tzavalis (HT) test, Levin–Lin–Chu (LLC) test and Im-Pesaran-Shin (IPS) test. The dataset includes all twelve UK regions over 1996Q1 to 2011Q1. As expected, all these variables are stationary at a 1% significance level.

Table 7.1 Panel Data Unit Root Tests

	$\Delta_1 \boldsymbol{ph}_{i,t}$	$\Delta_1 \boldsymbol{pr}_{i,t}^{f}$	$\Delta_1 \boldsymbol{hri}_{i,t}$	$\Delta_1 \boldsymbol{b}_{i,t}$
Harris–Tzavalis (HT) Test	.000	.000	.000	.000
Levin–Lin–Chu (LLC) Test	.000	.000	.000	.0053
Im-Pesaran-Shin (IPS) Test	.000	.000	.000	.0002

Notes: $\Delta_1 ph_{i,t}$ denotes for changes in house price index, $\Delta_1 pr_{i,t}^{f}$ denotes for changes in fundamental house price-rent ratio, $\Delta_1 hri_{i,t}$ is changes in house rent index and $\Delta_1 b_{i,t}$ denotes for changes in bubble. The figures presented in Table 7.1 are $p\text{-}values$.

Figure 7.1 displays the changes in regional bubbles against the changes in regional house prices. In Figure 7.1, the quarterly changes in bubbles report significant regional heterogeneities with values ranging from -8% to 10% which indicate the bubbles do not follow the explosive paths. Therefore, the chapter rejects the rational expectation hypothesis. Apart from few exceptions such as Northern Ireland, the difference between changes in bubble and changes in house price is minute for a given region. The bubbles increases across the UK from 1996 to 2007, given the changes in bubbles $\Delta_1 b_{i,t}$ are positive during most of that time. During the Subprime Crisis, the bubbles decrease significantly thereafter and demonstrate varied recovery after 2009.

Figure 7.1 Changes in Regional House Price Bubble (dlbubble) vs. Regional House Price Index (dlhpi)

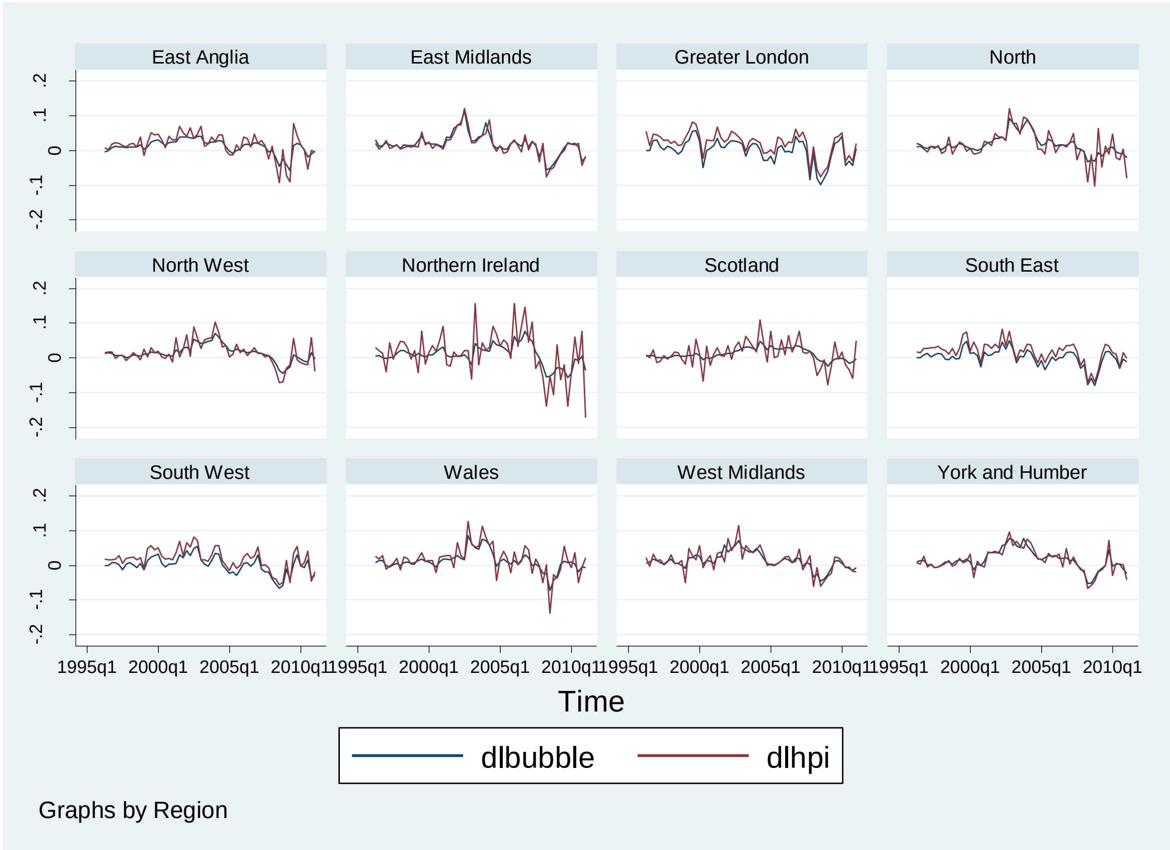


Table 7.2 shows the impact of changes in bubble on changes in housing price in terms of Fixed Effects Model (FEM) and Random Effects Model (REM). Model 1 of each approach regresses the changes in house prices $\Delta_1 ph_{i,t}$ against two control variables, namely, the changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and the changes in rent $\Delta_1 hri_{i,t}$. The coefficients on changes in fundamental price-rent ratios $\Delta_1 pr_{i,t}^f$ are statistically significant with a value of -0.031 in both FEM and REM. So, one unit increases in the changes in fundamental price-rent ratio will significantly cause housing return decreases by 0.031 units and *vice versa*, *ceteris paribus*. The coefficient on changes in rent $\Delta_1 hri_{i,t}$ is -0.167 but insignificant in both of FEM and REM.

In Table 7.2, Model 2 of each approach regresses the changes in house prices $\Delta_1 ph_{i,t}$ against the changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$, the changes in rent $\Delta_1 hri_{i,t}$ and the changes in bubble $\Delta_1 b_{i,t}$. Model 2 suggests after controlling for the changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and the changes in rent $\Delta_1 hri_{i,t}$, the coefficients on changes in bubbles $\Delta_1 b_{i,t}$ are statistically significant with values of 1.209 and 1.124 in the FEM and REM, respectively. Given bubble is a component of house price, one unit changes in bubble approximately drives one unit changes in house price, after controlling for the effect of the fundamental variables. In contrast to Model 1, the coefficients on the changes in rents $\Delta_1 hri_{i,t}$ turn positive but still statistically insignificant.

Relative to Model 2, Model 3 includes the lagged changes in bubble $\Delta_1 b_{i,t-1}$ as another independent variable. The coefficients on the changes in bubbles $\Delta_1 b_{i,t}$ remain significant but more positive in both FEM and REM. The coefficients on the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ are significantly negative with values of -0.434 and -0.484 respectively, which indicates the previous increases in bubbles tend to reduce the subsequent increases in house prices and *vice versa*, *ceteris paribus*. The significant but negative coefficients on the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ do not support the feedback theory (Shiller, 1990,2007). Given the bubbles reflect people's biased expectations and market anomalies, the negative coefficients on lagged changes in bubbles $\Delta_1 b_{i,t-1}$ suggest people learn from their past mistakes and try to adjust the current house prices to converge to their fundamental values which, in turn, justify the arguments of bounded rationality expectation hypothesis. The net effect of changes in bubble $\Delta_1 b_{i,t}$ and lagged changes in bubble $\Delta_1 b_{i,t-1}$is approximately one unit, *ceteris paribus*. Additionally, the coefficients on the changes in rents $\Delta_1 hri_{i,t}$ become more positive and statistically significant.

In Models 4 and 5, the chapter adds two interactive variables, $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^f$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, to control for the interaction effects. $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^f$ is the interaction of changes in bubble and changes in fundamental price-rent ratio. $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ is the interaction of changes in bubble and changes in rent. Throughout the chapter, all the interactive variables are scaled down by multiplying 100. This is because the first log differenced variables, such as $\Delta_1 hri_{i,t}$ and $\Delta_1 pr_{i,t}^f$, represent the continuous compounded returns on the underlying variables. However, the interaction variables represent the multiplying effect of return on return. The scaling only affects the coefficients of scaled variables but does not influence the coefficients of other variables and the fit of the model. The interaction effect of changes in bubble and changes in fundamental price-rent ratio $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^{f}$ are significantly positive with coefficient of 0.2% in FEM and 0.1% in REM, which indicates the effect of changes in bubble on the changes in house price is positively dependent on the changes in the fundamental price-rent ratio. On the contrary, the coefficient on the interaction effect of changes in bubble and changes in rent $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ is significantly negative with a value of -0.104 in FEM and -0.154 in REM, which implies increasing bubbles combined with declining rents making it more attractive to buy than rent because of higher capital gain on ownership, *ceteris paribus*. The coefficients on changes in bubble $\Delta_1 b_{i,t}$ and lagged changes in bubble $\Delta_1 b_{i,t-1}$ remain significant and on their signs, after controlling for the interaction effects.

In general, Table 7.2 shows a series of interesting findings. Firstly, the significantly negative coefficients on changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^{f}$ and the significantly positive coefficients on changes in rent $\Delta_1 hri_{i,t}$ jointly indicates that with the changes in house price, the changes in the fundamental house price are less than the changes in rent, *ceteris paribus*. On one hand, Britain has probably the most liberalised private renting market in the European Union (EU) since 1989. Less security of tenure and the long-term taxation imbalance between the rental and the owned makes it more attractive to rent rather than own than ever before. On the other hand, the structure of the privately rented market has been changed over the past two decades. The typical landlord has treated the buy-to-let as the mainstream for personal investment, and the tenants are now composited by far more immigrations and younger people. Consequently, although changes in rent may be less than the changes in market house price, they can easily exceed the changes in the fundamental house price in the UK, at least in the nominal term.

Secondly, the causality tests reject the null hypothesis of changes in bubbles and lagged changes in bubbles and are jointly insignificant, $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. Therefore, the changes in bubble $\Delta_1 b_{i,t}$ and the lagged changes in bubbles $\Delta_1 b_{i,t-1}$ jointly cause the contemporaneous changes in house prices $\Delta_1 ph_{i,t}$, *ceteris paribus*.

Thirdly, throughout the chapter, the FEMs use regional fixed effects which assume the potential omitted variable bias from variables that vary across regions but are constant over time. The chapter does not exhibit the results of the fixed time effects, primarily because the results of time fixed effects are highly consistent with the results of FEM with regional fixed effects. Furthermore, the chapter does not present the fixed regional and time effect model, given the chapter's dataset is not large enough to end up as a reasonable model fit.

Fourthly, the explanatory power of fundamental factors, in particular the changes in fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and the changes in rent $\Delta_1 hri_{i,t}$, on the changes in house price $\Delta_1 ph_{i,t}$, is quite low as the R^2 is just 0.16 in Model 1. After incorporating the changes in bubbles $\Delta_1 b_{i,t}$, the R^2 dramatically increases to above 0.81 in Model 2 which indicates the changes in bubble can significantly explain the changes in house prices. The marginal effect of lagged changes in bubbles $\Delta_1 b_{i,t-1}$ and interaction effects on changes in house price is quite low as the marginal increase in R^2 is less than 0.05 in Models 2 through to 5.

Finally, the F-tests for the fixed effects are statistically significant in Models 2 through to 5, which indicate the FEMs are superior to the Pooled OLS in these four models. The Lagrange Multiplier (LM) random effects test fails to reject the null hypothesis of variances across individuals as zero in Models 1 through to 5. Therefore, the Pooled OLS outperforms REM in all five models. The Hausman test suggests REM outperforms FEM in Model 1, as the Hausman test fails to reject the null hypothesis of REM is preferred. However, the Hausman tests break down in the remaining four models, given the $\chi^2 < 0$. This is because the model fitted on these data fails to meet the asymptotic assumptions of the Hausman Test. Consequently, Pooled OLS works best in Model 1. FEMs are superior to Pooled OLS and REM in Models 2 through to 5.

For the five FEMs, the LM independence tests indicate the residuals are serially correlated. The Pasaran Cross-Sectional (CD) tests suggest the residuals are correlated across individuals, expect for Model 3. The heteroskedasticity tests reject the null hypothesis of homoskedasticity. Because the diagnostics tests suggest the FEMs violate two or three model assumptions, the findings of FEMs in Table 7.2 might be biased more or less.

Table 7.2 Changes in Bubbles cause Changes in HPIs: Fixed Effects Models vs. Random Effects Models (1996Q2-2011Q1)

Dependent Variable $\Delta_1 \boldsymbol{ph_{i,t}}$	Fixed Effects Models (1996Q2-2011Q1)					Random Effects Models (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 \boldsymbol{pr^f_{i,t}}$	-.031***	-.020***	-.022***	-.026***	-.026***	-.031***	-.021***	-.023***	-.026***	-.026***
	(.003)	(.001)	(.001)	(.001)	(.001)	(.003)	(.001)	(.001)	(.002)	(.002)
$\Delta_1 \boldsymbol{hri_{i,t}}$	-.167	.136	.232**	.232**	.349***	-.167	.115	.224**	.224**	.397***
	(.201)	(.094)	(.095)	(.093)	(.102)	(.200)	(.107)	(.108)	(.107)	(.116)
$\Delta_1 \boldsymbol{b_{i,t}}$		1.209***	1.538***	1.479***	1.557***		1.124***	1.500***	1.455***	1.571***
		(.024)	(.034)	(.035)	(.044)		(.026)	(.038)	(.040)	(.051)
$\Delta_1 \boldsymbol{b_{i,t-1}}$			-.434***	-.395***	-.414***			-.484***	-.456***	-.483***
			(.034)	(.034)	(.035)			(.039)	(.039)	(.040)
$\Delta_1 \boldsymbol{b_{i,t}} * \Delta_1 \boldsymbol{pr^f_{i,t}}$				.002***	.002***				.001***	.001***
				(.0004)	(.0004)				(.0004)	(.0004)
$\Delta_1 \boldsymbol{b_{i,t}} * \Delta_1 \boldsymbol{hri_{i,t}}$					-.104***					-.154***
					(.037)					(.042)
Constant	.017***	.003***	.003***	.004***	.003***	.017***	.004***	.004***	.005***	.003***
	(.002)	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes					
Time Fixed Effects	No	No	No	No	No					
No. Observation	720	720	720	720	720	720	720	720	720	720
Within $\boldsymbol{R^2}$	.160	.818	.853	.858	.860	.160	.817	.851	.857	.858
F-test for Fixed Effect	.997	.000	.000	.000	.000					
LM Random Effect Test						1.000	1.000	1.000	1.000	1.000
Hausman Test	.999	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	.999	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$	$\chi^2 < 0$
LM Independence Test	.000	.000	.000	.000	.000					
Pasaran CD Test	.000	.000	.374	.028	.004					
Heteroskedasticity Test	.000	.000	.000	.000	.000					

Notes: Δ_1 means first difference. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 b_{i,t}$ denotes the changes in bubble. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. $\chi^2 < 0$ means the Hausman test fails as model fitted on these data fails to meet the asymptotic assumptions. The values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. The null hypothesis of LM Independence Test is that residuals across regions are not correlated. The null hypothesis of Pasaran Cross-sectional Dependence (CD) Test is the residuals are not correlated across regions. The null hypothesis of Heteroskedasticity test is homoskedasticity. Coefficient standard deviations are in parentheses. *** and ** stand for statistical significance at 1% and 5% level, respectively.

As a robust check, Table 7.3 displays the findings of the Panel-Corrected Standard Errors (PCSE) with AR(1), and the Feasible Generalized Least Squares (FGLS) with heteroskedasticity. Both approaches correct the panel residuals for groupwise heteroskedasticity, contemporaneous correlation, and serial correlation. PCSE is an alternative to FGLS. When AR(1) is not specified, PCSE produces OLS estimates of the coefficients, while the standard errors are estimated differently. When AR(1) is specified, PCSE estimates the coefficients by the Prais-Winsten regression which is conditional on the estimates of the autocorrelation coefficients. The FGLS estimation is conditional on the estimation of the residual covariance matrix and is conditional on any autocorrelation coefficients that are estimated. Either PCSE or FGLS estimator is consistent when the conditional mean is properly specified. FGLS is more efficient than PCSE, as long as the assumed covariance is correctly structured. However, the full FGLS variance-covariance estimates might be biased when the applied dataset consists of 10-20 regions with 10-40 time periods. The datasets, especially the subsamples, used in this chapter roughly falls into this category. PCSEs are helpful in precisely assessing the variance across regions, as they purport to create higher standard errors in an effort to generate more conservative results.

PCSE with AR(1) and FGLS with heteroskedasticity may provide a better statistical estimation, especially for the standard errors. However, they are unsuitable to control the omitted variable bias as FEM does. In general, the findings of Table 7.3 are highly consistent with Table 7.2. One interesting finding is the standard errors for PCSE with AR(1) are 50%-100% higher than those for the FGLS with the heteroskedasticity model (Beck and Katz, 1995).

Table 7.3 Changes in Bubble cause Changes in HPI: PCSE with AR(1) vs. FGLS with (Heteroskedasticity) (1996Q2-2011Q1)

Dependent Variable $\Delta_1 \boldsymbol{ph}_{i,t}$	PCSE (AR1) (1996Q2-2011Q1)					FGLS (Heteroskedasticity) (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 \boldsymbol{pr}^f_{i,t}$	-.031***	-.023***	-.023***	-.027***	-.027***	-.029***	-.023***	-.026***	-.028***	-.028***
	(.002)	(.001)	(.001)	(.002)	(.002)	(.002)	(.001)	(.001)	(.001)	(.001)
$\Delta_1 \boldsymbol{hri}_{i,t}$	-.012	.133	.214*	.218*	.375***	-.198	.068	.111	.101	.291***
	(.244)	(.119)	(.112)	(.115)	(.132)	(.183)	(.081)	(.079)	(.079)	(.089)
$\Delta_1 \boldsymbol{b}_{i,t}$		1.159***	1.477***	1.409***	1.515***		1.081***	1.560***	1.550***	1.657***
		(.037)	(.042)	(.046)	(.056)		(.020)	(.031)	(.033)	(.040)
$\Delta_1 \boldsymbol{b}_{i,t-1}$			-.463***	-.418***	-.442***			-.516***	-.513***	-.541***
			(.042)	(.044)	(.044)			(.031)	(.033)	(.032)
$\Delta_1 \boldsymbol{b}_{i,t} * \Delta_1 \boldsymbol{pr}^f_{i,t}$				.002***	.002***				.001***	.001**
				(.0004)	(.0004)				(.0003)	(.0003)
$\Delta_1 \boldsymbol{b}_{i,t} * \Delta_1 \boldsymbol{hri}_{i,t}$					-.142***					-.138***
					(.046)					(.032)
Constant	.015***	.003**	.004***	.005***	.004***	.017***	.002***	.002***	.002***	.001
	(.005)	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
No. Observation	720	720	720	720	720	720	720	720	720	720
$\boldsymbol{R^2}$	.328	.737	.791	.793	.797					
$\boldsymbol{Prob > \chi^2}$	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. The null hypothesis of Causality Test is $H_0 : \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. $Prob > \chi^2$ tests for whether all the coefficients in the model are joint significant. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significance at 1%, 5% and 10% level, respectively.

Table 7.4 studies whether the changes in house prices $\Delta_1 ph_{i,t}$cause changes in bubble $\Delta_1 b_{i,t}$ in terms of fixed effects model with robust standard error (White, 1980), and PCSE with AR(1). In Table 7.4, Model 1 regresses changes in bubble $\Delta_1 b_{i,t}$ against changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and changes in rent $\Delta_1 hri_{i,t}$. The coefficient on changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ is significantly negative with a value of -0.008 in FEM and -0.006 in PCSE with AR(1), respectively. The coefficient on changes in rent $\Delta_1 hri_{i,t}$ is significantly negative with a value of -0.251 in FEM; but statistically insignificant in PCSE with AR(1).

After controlling for changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ and changes in rent $\Delta_1 hri_{i,t}$, Model 2 suggests the coefficient on changes in house price $\Delta_1 ph_{i,t}$ is significantly positive with a value of 0.648 in FEM and 0.488 in PCSE with AR(1). Therefore, Model 2 of FEM suggests that one unit changes in house price only drive 0.65 unit changes in bubble. This is because bubbles are primarily driven by people's biased expectations alongside the available information, *ceteris paribus*. Moreover, the coefficient on changes in the fundamental price-rent ratio $\Delta_1 pr_{i,t}^f$ becomes significantly positive, implying the changes in bubble reflect people's biased reaction to the changes in the fundamental. Overall, the results for Model 2 support the bounded rationality hypothesis.

Model 3 adds the lagged changes in house price $\Delta_1 ph_{i,t-1}$ as another independent variable. The coefficient on changes in house price $\Delta_1 ph_{i,t}$ is still significant and positive, *ceteris paribus*. The coefficients on lagged changes in house price $\Delta_1 ph_{i,t-1}$ are significantly positive with a value of approximately 0.2, which indicates the one unit changes in house price will cause about 20% subsequent changes in bubble, *ceteris paribus*. Model 4 and Model 5 include interaction variables, changes in house price and changes in the fundamental price-rent ratio $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^f$, and changes in house price and changes in rent $\Delta_1 \mathrm{b}_{\mathrm{i,t}} * \Delta_1 \mathrm{hri}_{\mathrm{i,t}}$. The interaction variables, $\Delta_1 \mathrm{ph}_{\mathrm{i,t}} * \Delta_1 \mathrm{pr}_{\mathrm{i,t}}^{\mathrm{f}}$ and $\Delta_1 \mathrm{ph}_{\mathrm{i,t}} * \Delta_1 \mathrm{hri}_{\mathrm{i,t}}$, are scaled down by multiplying 100. After controlling for the interaction variables, the coefficient on changes in house price remains significantly positive. The coefficients on $\Delta_1 b_{i,t} * \Delta_1 pr_{i,t}^f$ are insignificant. The coefficients on $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$ are significant and negative, while the figures of coefficients are quite small in both FEM and PCSE with AR(1).

In Table 7.4, the causality test indicates the changes in house price $\Delta_1 ph_{i,t}$ and lagged changes in house price $\Delta_1 ph_{i,t-1}$ are joint significant in driving the changes in bubble $\Delta_1 b_{i,t}$. The LM independence tests indicate the fixed effects models are subject to serial correlations. Pasaran CD tests report cross sectional dependence in Model 1 and Model 2. The robust standard deviations (White, 1980) fail to control for the standard error heteroskedasticities in Models 1 through to 5. Overall, the findings of FEM are highly consistent with PCSE with AR(1), except for a few exceptions.

Tables 7.2 through to 7.4 suggest there are statistically significant feedback effects between the changes in bubble and the changes in contemporaneous house price between 1996Q2 and 2011Q1. However, the effect is asymmetric. After controlling for the fundamental variables, one unit changes in contemporaneous bubble drives approximately one unit changes in house prices, given bubble is a component of house price. One unit changes in house price only cause about 60% units changes in contemporaneous bubble, even controlling for some fundamental variables.

Table 7.4 Changes in HPI cause Changes in Bubble: Fixed Effects Models vs. PCSE (AR1) (1996Q2-2011Q1)

Dependent Variable $\Delta_1 b_{i,t}$	Fixed Effects Models (Robust St. Dev.) (1996Q2-2011Q1)					PCSE (AR1) (1996Q2-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.008***	.011***	.009***	.009***	.012***	-.006***	.009***	.008***	.008***	.011***
	(.003)	(.003)	(.002)	(.002)	(.002)	(.001)	(.001)	(.001)	(.001)	(.001)
$\Delta_1 hri_{i,t}$	-.251**	-.143	-.141	-.140	-.130	-.123	-.134	-.120**	-.129**	-.136**
	(.099)	(.108)	(.104)	(.124)	(.117)	(.126)	(.109)	(.058)	(.063)	(.063)
$\Delta_1 ph_{i,t}$		.648***	.555***	.555***	.580***		.488***	.507***	.504***	.531***
		(.074)	(.064)	(.056)	(.057)		(.021)	(.014)	(.017)	(.018)
$\Delta_1 ph_{i,t-1}$			.237***	.237***	.228***			.194***	.194***	.187***
			(.013)	(.013)	(.014)			(.012)	(.012)	(.012)
$\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$				-.001	-.005				.005	.004
				(.024)	(.021)				(.018)	(.018)
$\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$					-.001***					-.001***
					(.0002)					(.0001)
Constant	.012***	.001	-.002*	-.002*	-.002**	.009*	.003**	-.0003	-.0003	-.001
	(.001)	(.001)	(.001)	(.001)	(.001)	(.005)	(.002)	(.001)	(.001)	(.001)
Causality Test			.000	.000	.000			.000	.000	.000
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes					
Time Fixed Effects	No	No	No	No	No					
No. Observation	720	720	708	708	708	720	720	708	708	708
Within R^2	.029	.790	.889	.889	.893	.072	.615	.723	.725	.731
LM Independence Test	.000	.000	.000	.000	.000					
Pasaran CD Test	.000	.000	.377	.378	.194					
Heteroskedasticity	.000	.000	.000	.000	.000					
$Prob > \chi^2$						.000	.000	.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. The Robust St. Dev. stands for robust standard deviation (White, 1980) which controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are p-$values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. The null hypothesis of LM Independence test is that residuals across regions are not correlated. The null hypothesis of Pasaran Cross-sectional Dependence (CD) test is the residuals are not correlated across regions. The null hypothesis of heteroskedasticity test is homoskedasticity. $Prob > \chi^2$ tests for whether all the coefficients in the model are jointly significant. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significance at 1%, 5% and 10% level, respectively.

7.4.2 Robustness Tests

Following the modelling procedure in Table 7.2, Table 7.5 investigates whether the changes in bubbles cause the changes in house prices in terms of FEM with robust standard errors (White, 1980) for the subsamples 1996Q2-2000Q4, 2001Q1-2006Q4 and 2007Q1-2011Q1. The three subsamples roughly match the recovery, boom and recession of the UK housing market, respectively.

The findings of Table 7.5 are highly consistent with Table 7.2. Broadly speaking, Table 7.2, Table 7.3 and Table 7.5 altogether exhibit parameter instability, which means the coefficient on any given variable changes from model to model and over time. For example, in the subsample 1996Q2-2000Q4, the coefficient on the changes in bubble $\Delta_1 b_{i,t}$ ranges from 0.94 to 1.2 in models 2 through to 5, which is much lower than that for the rest of samples for a given model. But the coefficient on the lagged changes in bubble $\Delta_1 b_{i,t-1}$ ranges from -0.33 to -0.25, which is higher than that of the rest of the samples. Moreover, the coefficients on the changes in rent and the interaction variables experience more changes than that for the rest of the variables, in terms of magnitude and sign.

From an economics perspective, the time varying coefficients reflect the dynamics of the underlying economy and people's economic behaviour, which supports the findings in Chapters 3 through to 6. Given the sample size is relatively small, the changes in coefficient over time is quite modest, even in the presence of the Subprime Crisis between 2007 and 2009.

Following Table 7.4, Table 7.6 studies whether the changes in house price cause the changes in bubble by using FEM with robust standard errors (White, 1980) for the subsamples 1996Q2-2000Q4, 2001Q1-2006Q4 and 2007Q1-2011Q1. The general findings in Table 7.6 are highly consistent with Table 7.4, except for the modest parameter instability.

Table 7.5 Changes in Bubble cause Changes in HPI (Panel A): Fixed Effects Models (1996Q2-2000Q4 vs. 2001Q1-2006Q4)

Dependent Variable $\Delta_1 ph_{i,t}$	Fixed Effects Models (Robust St. Dev.) UK (1996Q2-2000Q4)					Fixed Effects Models (Robust St. Dev.) UK (2001Q1-2006Q4)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.041***	-.031***	-.033***	-.036***	-.037***	-.018***	-.014***	-.018***	-.015**	-.015**
	(.003)	(.005)	(.005)	(.005)	(.005)	(.002)	(.003)	(.005)	(.006)	(.006)
$\Delta_1 hri_{i,t}$	.070	.194*	.266*	.230	.353	-.629***	.189	.159	.152	.623***
	(.077)	(.105)	(.143)	(.136)	(.212)	(.169)	(.128)	(.170)	(.170)	(.174)
$\Delta_1 b_{i,t}$		.941***	1.087***	1.063***	1.203***		1.263***	1.592***	1.610***	1.742***
		(.082)	(.117)	(.125)	(.131)		(.116)	(.261)	(.263)	(.269)
$\Delta_1 b_{i,t-1}$			-.325***	-.254**	-.274***			-.490**	-.504**	-.519**
			(.079)	(.087)	(.080)			(.218)	(.220)	(.219)
$\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$				.004***	.004**				-.0006	-.001
				(.001)	(.002)				(.001)	(.001)
$\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$					-.162					-.202***
					(.146)					(.058)
Constant	.015***	.005***	.007***	.007***	.006***	.038***	.001	.005**	.005**	.001
	(.001)	(.001)	(.001)	(.001)	(.002)	(.001)	(.003)	(.002)	(.002)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No	No	No	No	No	No
No. Observation	228	228	216	216	216	288	288	276	276	276
Within R^2	.539	.794	.824	.834	.836	.107	.759	.806	.806	.814
Causality Test			.000	.000	.000			.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. The robust standard deviation (White, 1980) controls for heteroskedasticity. The interaction variables, $\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. The values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significant at the 1%, 5% and 10% significance level, respectively.

Table 7.5 Changes in Bubble cause Changes in HPI (Panel B): Fixed Effects Models (2007Q1-2011Q1)

Dependent Variable $\Delta_1 ph_{i,t}$	Fixed Effects Models (Robust St. Dev.) UK (2007Q1-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.046***	-.027***	-.027***	-.024***	-.024***
	(.007)	(.007)	(.007)	(.006)	(.006)
$\Delta_1 hri_{i,t}$	-.635*	-.152	.347	.313	.359
	(.312)	(.295)	(.269)	(.249)	(.347)
$\Delta_1 b_{i,t}$		1.146***	1.459***	1.429***	1.406***
		(.105)	(.264)	(.259)	(.278)
$\Delta_1 b_{i,t-1}$			-.469**	-.434*	-.432**
			(.207)	(.199)	(.200)
$\Delta_1 b_{i,t} * \Delta_1 pr^f_{i,t}$				.004***	.004***
				(.001)	(.001)
$\Delta_1 b_{i,t} * \Delta_1 hri_{i,t}$					.031
					(.118)
Constant	-.007***	.003	-.001	.001	.001
	(.002)	(.002)	(.002)	(.001)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No
No. Observation	204	204	192	192	192
Within R^2	.346	.784	.821	.831	.832
Causality Test			.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. The robust standard deviation (White, 1980) controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are p-$values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 b_{i,t}} = \beta_{\Delta_1 b_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significant at the 1%, 5% and 10% significance level, respectively.

Table 7.6 Changes in HPI cause Changes in Bubble (Panel A): Fixed Effects Models (1996Q2-2000Q4 vs. 2001Q1-2006Q4)

Dependent Variable $\Delta_1 b_{i,t}$	Fixed Effects Models (Robust St. Dev.) UK (1996Q2-2000Q4)					Fixed Effects Models (Robust St. Dev.) UK (2001Q1-2006Q4)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.010**	.014***	.014***	.015***	.018***	-.003	.007**	.008**	.008**	.014***
	(.004)	(.003)	(.002)	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.003)
$\Delta_1 hri_{i,t}$	-.132	-.173	-.135	.007	-.059	-.648***	-.284***	-.212**	-.324*	-.290
	(.113)	(.110)	(.109)	(.124)	(.136)	(.115)	(.082)	(.091)	(.169)	(.173)
$\Delta_1 ph_{i,t}$		.586***	.623***	.713***	.698***		.578***	.533***	.512***	.539***
		(.080)	(.073)	(.068)	(.066)		(.083)	(.059)	(.060)	(.060)
$\Delta_1 ph_{i,t-1}$			.203***	.193***	.196***			.230***	.231***	.220***
			(.031)	(.031)	(.022)			(.010)	(.010)	(.010)
$\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$				-.105**	-.059				.035	.022
				(.041)	(.039)				(.041)	(.042)
$\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$					-.001***					-.001***
					(.0004)					(.0003)
Constant	.010***	.002**	-.003***	-.004***	-.004***	.029***	.007**	.001	.002	.0008
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.003)	(.002)	(.002)	(.002)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No	No	No	No	No	No
No. Observation	228	228	216	216	216	288	288	276	276	276
Within R^2	.112	.602	.734	.751	.777	.044	.742	.857	.858	.865
Causality Test			.000	.000	.000			.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. The robust standard deviation (White, 1980) controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are p-$values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significant at the 1%, 5% and 10% significance level, respectively.

Table 7.6 Changes in HPI cause Changes in Bubble (Panel B): Fixed Effects Models (2007Q1-2011Q1)

Dependent Variable $\Delta_1 b_{i,t}$	Fixed Effects Models (Robust St. Dev.) UK (2007Q1-2011Q1)				
Independent Variables	Model 1.	Model 2.	Model 3.	Model 4.	Model 5.
$\Delta_1 pr^f_{i,t}$	-.017***	.010***	.008***	.008***	.008***
	(.004)	(.004)	(.002)	(.002)	(.002)
$\Delta_1 hri_{i,t}$	-.422	-.050	-.181	-.186	-.155
	(.332)	(.228)	(.184)	(.198)	(.182)
$\Delta_1 ph_{i,t}$		.585***	.528***	.530***	.542***
		(.083)	(.081)	(.078)	(.079)
$\Delta_1 ph_{i,t-1}$			.223***	.223***	.216***
			(.012)	(.013)	(.013)
$\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$				-.003	-.0001
				(.031)	(.033)
$\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$					-.0007**
					(.0003)
Constant	-.009***	-.005**	-.003	-.003	-.004***
	(.002)	(.002)	(.002)	(.002)	(.001)
Regional Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	No
No. Obs	204	204	192	192	192
Within R^2	.126	.712	.824	.824	.829
Causality Test			.000	.000	.000

Notes: Δ_1 means first difference. $\Delta_1 b_{i,t}$ denotes the changes in house price bubble. $\Delta_1 pr^f_{i,t}$ denotes the changes in fundamental price-rent ratio. $\Delta_1 hri_{i,t}$ denotes the changes in house rent index. $\Delta_1 ph_{i,t}$ denotes the changes in house price index. The robust standard deviation (White, 1980) controls for heteroskedasticity. The interaction variables, $\Delta_1 ph_{i,t} * \Delta_1 pr^f_{i,t}$ and $\Delta_1 ph_{i,t} * \Delta_1 hri_{i,t}$, are scaled down by multiplying 100. Values presented for the diagnostics tests are $p\text{-}values$. The null hypothesis of Causality Test is $H_0: \beta_{\Delta_1 ph_{i,t}} = \beta_{\Delta_1 ph_{i,t-1}} = 0$. Coefficient standard deviations are in parentheses. ***, ** and * stand for statistical significant at the 1%, 5% and 10% significance level, respectively.

7.5 Conclusion

This chapter supports the bounded rationality hypothesis best fit into the UK housing market. However, the chapter does not support the feedback theory (Shiller, 1990,2007) because an increase in bubble could cause a subsequent decrease in house price, *ceteris paribus*. This chapter demonstrates that the findings in Chapters 5 and 6 are robust over time, even in panel data analysis.

The statistically significant and positive feedback causal relationship between the changes in house price and the contemporaneous changes in bubble are asymmetrical. One unit changes in bubble could approximately drive one unit changes in house price, after controlling for the fundamental variables. Therefore, it is the build-up of bubbles which is driving the changes in house prices over time. By contrast, one unit changes in house price only causes about 60% unit changes in bubble, after controlling for the contemporaneous fundamental variables and the lagged changes in house price.

As the bubbles do not follow an explosive path, the bubbles are not rational bubbles which reject the rational expectation hypothesis. The lagged changes in bubble could significantly cause the subsequent changes in house price in reverse direction, which suggests people learn from their past mistakes and try to adjust the house prices to converge to their fundamental value. However, the adjustment effect is not powerful enough to offset the negative effects of biased expectations at the current period, *ceteris paribus*. The changes in fundamental variables could significantly drive the changes in bubble implying that the bubbles are not dominated by people's purely irrational behaviour, so rejecting the irrational expectation hypothesis. These evidences jointly support the bounded rationality hypothesis and best fit the UK housing market.

Thirdly, the modest time varying coefficients for a given variable indicate there are institutional changes which, in turn, suggest people adjust their behaviours according to the dynamics of the underlying economy.

Chapter 8. Conclusion

This thesis contributes to literature by investigating the underlying valuation drivers of the UK housing prices both methodologically and empirically.

Chapter 2 proposes a three-step theoretical framework for studying the primary drivers of housing prices. The rationale is that people make investment decisions by studying the underlying costs and benefits. Additionally, people respond to expectations under the given behaviour rules, which refer to the institutions in place. Following the three-step framework, Chapter 2 reviews literature from three interrelated aspects:

- Common factors that are specific to the UK housing price in a closed economy and an open economy.
- The implications of four typical expectation hypotheses, namely, Irrational Expectation Hypothesis, Adaptive Expectation Hypothesis, Rational Expectation Hypothesis, and Bounded Rationality Expectation Hypothesis.
- The institutions and the effect of institutional changes on the UK housing prices.

Chapters 3 and 4 suggest the classical fixed parameter models are poor in terms of robustness, especially the regression coefficients changes in both magnitude and sign over samples. Brown *et al.* (1997) suggest that the time varying coefficients indicate the possibility of institutional changes and the changes in the unobservable components of economic variables such as expectations. Some naïve modifications will improve the fit of the underlying equation. However, it is unclear why people should make such a modification.

Chapter 5 proposes a user cost framework in a state space model. The empirical results indicate that UK house prices were undervalued from 1996Q1 to 2002Q4 and thereafter overvalued. As a proportion, the bubble ranges from -52% to 27.4% in log scale, which is indeed quite a substantial range. The chapter supports the bounded rationality hypothesis implying the UK housing bubbles reflect people’s biased expectations.

Chapter 6 empirically suggests that the fast-moving institutional changes are likely to occur at the domestic financial crises by using the structural break tests. This chapter expands literature by using three novel Time Varying Parameter (TVP) models to quantify the slow-moving institutional changes. The TVP models empirically suggest that people's biased expectations are playing a much more important role in driving the UK house prices than ever. However, the effects of fundamental variables on housing prices are decaying over time.

Chapter 7 indicates that the bounded rationality hypothesis best fit into the UK housing market in the context of the panel data analysis. However, the chapter does not support the feedback theory (Shiller, 1990,2007) because an increase in bubble could cause a subsequent decrease in house price, *ceteris paribus*. Furthermore, the chapter provides the first empirical evidence to justify the statistically significant feedback causality between the changes in bubble and the contemporaneous changes in house prices by using the Fixed Effects Model (FEM). Finally, the regression coefficients changes modestly over time indicate there are institutional changes.

Overall, the findings in Chapters 3 through to 7 empirically support the three-step framework. Housing prices are not only determined by fundamental economic variables but also people's expectations, under the given institutions in place. Through a series of institutional changes, people's biased expectations are playing a far more important role in driving the UK house prices than the fundamentals.

The bounded rationality hypothesis suggest that people's expectations and economic behaviours might be biased due to cognitive and psychological limitations which, in turn, indicates the market might be inefficient, at least temporarily. However, people learn from their mistakes and attempt to satisfice by acting as rationally as possible. For policymakers, interest rate is not the only source of housing dynamics. Public policy, e.g. manipulating money supply and interest rates, may fix housing recessions in the short run but run the risk of re-inflating housing bubbles in the future. Furthermore, people's expected capital gain, or people's biased expectations, should be given much more emphasis when stabilizing housing markets. In order to enhance market stability, policymakers may implement counter-cyclical policies, given human nature is inherently pro-cyclical. For markets already in a bubble, releasing the bubble modestly may save more than busting the bubble immediately. For financial institutions, periodically studying the housing market, rational diversification and timely rebalancing portfolios may help them prevent similar losses by those experienced during the Subprime Crisis. A reasonably volatile price not only drives the market price to regress to equilibrium, but also provides informed investors with profit opportunities and *vice versa*.

It would be appreciated if any future studies can fill the gaps of this thesis from the following aspects.

- Firstly, whether the housing price bubbles exists under the assumption that bubbles follow a non-linear non-normal distribution?
- Secondly, whether the bounded rationality hypothesis fit into the other housing markets?
- Thirdly, whether the three-step theoretical analysis framework is supported in the other housing markets and/or stock markets?

Appendices

Table A. Variable Sources

Variable	Definition	Source and Time Period
$\boldsymbol{FDI_t}$	Net FDI Inflow: Gross Earnings	Office for National Statistics
$\boldsymbol{FX_t}$	Foreign Currency Reserves	International Financial Statistics (IMF)
$\boldsymbol{H_t}$	Number of owner occupied houses using data on completions of private sector	Office for National Statistics
$\boldsymbol{M_t}$	Total Mortgage Outstanding	Bank of England
$\boldsymbol{P_t}$	Retail Price Index	Office for National Statistics
$\boldsymbol{Ph_t}$	DCLG house price index	Department of Communities and Local Government
$\mathbf{R}(\boldsymbol{BS})_t$	Interest Rate on New Mortgages to Owners	Building Societies
$\mathbf{R}(\boldsymbol{Comp})_t$	Basic Rate Mortgages: Composite Banks and Building Societies	Office for National Statistics
$\boldsymbol{X_t}$	Net Export Good/Services	Office for National Statistics
$\boldsymbol{Y_t}$	Real Household Disposable Income	Office for National Statistics (ONS)

Source: DataStream

Table B. Variable Definitions and Expressions

Variable	Economic meaning
$A_n(x_t) = \frac{2}{n(n+1)} \sum_{i=0}^{n} (n - i) x_{t-i}$	$A_n(x_t)$ is a restricted Almon polynomial.
$A_2(\Delta_1 y_t) = \frac{1}{3}[2 \times \Delta y_t + \Delta y_{t-1}]$	$A_3(\Delta_1 y_t) = [\frac{1}{2} \times \Delta_1 y_t + \frac{1}{3} \times \Delta_1 y_{t-1} + \frac{1}{6} \times \Delta_1 y_{t-2}]$
C	Rate of completion of new units.
c_a and c_b	Historical means of the feedback.
$D_1^0 = \frac{D_1}{100}$	D_1 is Dummy variable.
E	Excess demand.
$F_{13}(x) = \Delta_1(x_{t-1} + x_{t-3})$	
$F_{13}(p) = \Delta_1(p_{t-1} + p_{t-3})$	$F_{13}(m-p) = \Delta_1[(m-p)_{t-1} + (m-p)_{t-3}]$
$h_t = logH_t$	Physical housing stock.
H^D and H^s	House demand and House supply, respectively.
$\mathrm{hri}_t = logHRI_t$	House rent index.
$m_t = logM_t$	Mortgage total outstanding (£ Million).
$(m-p)_t$	Real mortgage value.
$(m-p-h)_t = \frac{M}{P.H.}$	Real value of the mortgage stock.
$(m-p-y)_t$	Real mortgage value per unit income.
$(m-ph-h)_t = \frac{M}{Ph.H.}$	Ratio of borrowed to own equity.
N_f	Number of families.
$p_t = logRPI_t$	RPI: General Index of retail price.
P_0	Overall house prices.
$ph_t = logHPI = logPh_t$	Ph is the House Price Index (HPI).
$(ph-p)_t$	Real house prices.
$(ph+h-p-y)_t$	Average value of housing per unit income.
$(ph-p-y)_t = \frac{Ph}{P.Y}$	Ratio of house price to incomes.
pr_t^f	Fundamental price-rent ratio.
$py_t = ph_t - y_t$	Price-income ratio.
py_t^f	Fundamental price-income ratio.
$R^* = R_t^m \times (1 - MTR)$	After-tax mortgage rate, MTR is the Marginal Tax Rate.
$r_t = logR_t^m$	Mortgage rate.
$R_t^0 = \frac{R^*}{100}$	
$\overline{R}_{t-3}^0 = \frac{1}{2}(R_{t-3} + R_{t-4})$	
$\overline{x}_t = \frac{1}{2}(x_t + x_{t-1})$	
$y_t = logY_t$	Real household disposable income (£ Million).
$(y-h)_t$	Real income per household.
$(\Delta_1 ph_{t-1})^3$	The cubic effect of changes in lagged house price.

Notes: Lower case letters for time-dependent variables represent the natural logarithm of their capital counterparts.

Table C. Basic Data Summary

Sample 1968Q2-1982Q4	ph_t	p_t	y_t	m_t	h_t	$R^*(BS)_t$	$R^*(Comp)_t$	fpi_t
No. Obs.	59	59	59	59	59	59	/	59
Mean	2.21848	2.99641	3.84312	9.91000	3.66056	9.10487	/	7.8129
St. Dev.	.610414	.538873	.104704	.673727	.198315	2.44502	/	1.34234
Minimum	1.28093	2.25143	3.65686	8.85037	3.27336	5.25	/	0
Maximum	3.10906	3.85942	3.99903	11.1257	4.06389	14.25	/	8.86841
Sample 1983Q1-2007Q4	ph_t	p_t	y_t	m_t	h_t	$R^*(BS)_t$	$R^*(Comp)_t$	fpi_t
No. Obs.	100	100	100	100	100	100	52	100
Mean	4.184753	4.396824	4.383296	12.659	3.675868	7.265625	5.242067	8.957995
St. Dev.	.5591631	.261959	.2184159	.6522185	.1163814	2.402262	.7186375	.8345972
Minimum	3.13983	3.8645	3.9741	11.1779	3.48738	4.125	3.9825	6.405229
Maximum	5.21276	4.79316	4.69691	13.5911	3.95508	12.75	6.6525	10.43494
Sample 1968Q2-2007Q4	ph_t	p_t	y_t	m_t	h_t	$R^*(BS)_t$	$R^*(Comp)_t$	fpi_t
No. Obs.	159	159	159	159	159	159	52	159
Mean	3.455129	3.877173	4.182854	11.63893	3.670186	7.948113	5.242067	8.533085
St. Dev.	1.113863	.7811407	.3200674	1.485917	.1515883	2.569997	.7186375	1.185683
Minimum	1.28093	2.25143	3.65686	8.85037	3.27336	4.125	3.9825	0
Maximum	5.21276	4.79316	4.69691	13.5911	4.06389	14.25	6.6525	10.43494
Sample 19995Q1-2007Q4	ph_t	p_t	y_t	m_t	h_t	$R^*(BS)_t$	$R^*(Comp)_t$	fpi_t
No. Obs.	52	52	52	52	52	52	52	52
Mean	4.588464	4.605609	4.561869	13.15858	3.659145	5.516827	5.242067	9.363086
St. Dev.	.4022786	.097905	.103983	.2716969	.1071827	.8154749	.7186375	.8286384
Minimum	4.00369	4.43593	4.37243	12.7553	3.48738	4.125	3.9825	6.405229
Maximum	5.21276	4.79316	4.69691	13.5911	3.89386	7.125	6.6525	10.43494

Notes: $R^*(BS)_t$ means mortgage rate from Building Societies. $R^*(Comp)_t$ means the composite mortgage rate from Building Societies and Banks.

Table D. ADF Unit Root Test

ADF Unit Root Test for the Sample 1968Q2- 2007Q4							
	ph_t	y_t	m_t	p_t	h_t	$r_t^*(BS)$	fpi_t
Log Level	0.3521	0.9080	0.0507*	0.0143**	0.0645*	0.4371	0.6081
1st Log Difference	0.0008***	0.0000***	0.4746	0.1016*	0.0000***	0.0000***	0.0001

Notes: ph_t is the house price index, y_t represents the real household disposable income, m_t is the mortgage outstanding, p_t is the general index of retail price. h_t is the physical housing stock. $r^*(BS)_t$ is the mortgage rate from Building Societies. The composite mortgage rate from Building Societies and Banks for the sample 1995Q1-2007Q4 are stationary at first natural log difference. The figures shown in the table are $p\text{-}values$. The appropriate number of lagged difference for the ADF unit root test is identified by the Bayesian Information Criteria (BIC).

Table E. Preliminary Statistics (1996Q2-2011Q1)

Variable	Mean	St. Dev.	Minimum	Maximum	No. of Obs.
$\Delta_1 \boldsymbol{ph_{i,t}}$	.016	.037	-.172	.157	60
$\Delta_1 \boldsymbol{hri_{i,t}}$	.007	.006	-.002	.029	60
$\Delta_1 \boldsymbol{pr^f_{i,t}}$	.004	.488	-2.647	2.011	60
$\Delta_1 \boldsymbol{b_{i,t}}$	.010	.026	-.099	.114	60

Notes: $\Delta_1 ph_{i,t}$ is the changes in house price index. $\Delta_1 hri_{i,t}$ is the changes in house rent index. $\Delta_1 pr^f_{i,t}$ is the changes in fundamental price-rent ratio. $\Delta_1 b_{i,t}$ is the changes in bubble.

Table F. Correlation Matrix (1996Q2-2011Q1)

	$\Delta_1 \boldsymbol{ph_{i,t}}$	$\Delta_1 \boldsymbol{hri_{i,t}}$	$\Delta_1 \boldsymbol{pr^f_{i,t}}$	$\Delta_1 \boldsymbol{b_{i,t}}$	$\Delta_1 \boldsymbol{ph_{i,t-1}}$	$\Delta_1 \boldsymbol{b_{i,t-1}}$
$\Delta_1 \boldsymbol{ph_{i,t}}$	1.000					
$\Delta_1 \boldsymbol{hri_{i,t}}$	-.024	1.000				
$\Delta_1 \boldsymbol{pr^f_{i,t}}$	-.397	-.027	1.000			
$\Delta_1 \boldsymbol{b_{i,t}}$	.831	-.058	-.155	1.000		
$\Delta_1 \boldsymbol{ph_{i,t-1}}$	.362	-.009	-.048	.596	1.000	
$\Delta_1 \boldsymbol{b_{i,t-1}}$	.544	.017	-.189	.784	.835	1.000

Notes: $\Delta_1 ph_{i,t}$ is the changes in house price index. $\Delta_1 hri_{i,t}$ is the changes in house rent index. $\Delta_1 pr^f_{i,t}$ is the changes in fundamental price-rent ratio. $\Delta_1 b_{i,t}$ is the changes in bubble.

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