Investigating Housing Supply and Monetary Policy under Global Economic Turbulence

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Author’s Publications


Liu, J. & Liu, C. 2011, Investigating the housing market under an expansionary monetary policy in Australia, Pacific Rim Property Research Journal, in press. (ERA: B)


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List of Abbreviations

1. GDP: Gross Domestic Product
2. VEC-D: Vector Error Correction Model with Dummy Variables
3. ABS: Australian Bureau of Statistics
4. HIA: Housing Industry Association
5. RBA: Reserve Bank of Australia
6. OLS: Ordinary Least Squares
7. MSAs: Metropolitan Statistics Areas
8. ML: Maximum Likelihood
9. QTM: Quantity Theory of Money
10. (S)VAR: (Structural) Vector Autoregression
11. CPI: Consumer Price Index
12. (G)IRF: (Generalized) Impulse Response Function
13. FAVAR: Factor-augmented Vector Autoregression
14. (V)ECM: (Vector) Error Correction Model
15. OPEC: Organisation of the Petroleum Exporting Countries
16. CGS: Commonwealth Government Securities
17. ESF: Exchange Settlement Funds
18. OMO: Open Market Operations
19. (A)DF Test: (Augmented) Dickey-Fuller (Unit Root) Test
20. PP Test: Phillips-Perron (Unit Root) Test
21. JJ Test: Johansen-Juselius (Cointegration) Test
22. CE: Cointegration Equation
23. REIA: Real Estate Institute of Australia
24. HP: House Prices
25. (O)PPIs: (Output) Producer Price Indexes
26. HA: Housing (Building) Approvals
27. INT: Interest (Interbank) Rates
28. M1: (Narrow) Money Supply
ABSTRACT

The housing sector is essential to the macroeconomy across the world, regardless of whether it is a developed or a developing country. The development of the housing sector depends upon housing demand and housing supply. In housing economics, the supply of and the demand for housing can be influenced by a variety of economic and demographic factors, such as the gross domestic product (GDP), disposable income, urban population, interest rates, culture and even education. Compared with the studies on housing demand, the research on housing supply is less common. However, housing supply is undoubtedly a critical component that is not able to be ignored.

Since the end of the 1990s, Australia has been experiencing a challenge from a housing shortage accompanying an increase in housing demand. From 1997 to 2008, the growth rates of total housing stock in Australia have exhibited a downward trend while the urban population and the number of the mortgage for the purchase of owner-occupied housing increased dramatically. Over the same period, the significant adjustments in the Australian monetary policy were being implemented under a turbulent global economic climate, which was triggered by such special events as the 2001 terrorist attack to the US and the 2008 global financial crisis. According to the perspective of macroeconomic theory, monetary policy maintains an important role in regulating the activities of various economic sectors, involving manufacturing, construction and property sector. In addition, it has been acknowledged that the turbulence of global economic environment had resulted in severe impacts on Australia’s economy since the 2000s. Nevertheless, few empirical studies have focused on exploring the influences of monetary policy and global economic disturbance on the supply of housing in Australia. This research aims to investigate the nature of these relationships.

In order to study the relationship between monetary policy and the supply side of
the housing sector in conjunction with the effects of global economic turmoil, a conceptual model comprised of the endogenous variables of housing supply and monetary policy and the exogenous variable of global economic turbulence will be proposed. Then, a vector error correction model integrated with a dummy variable (VEC-D model) will be developed to estimate the conceptual model. Constructing the VEC-D model is preceded by two tests, one is the unit root test and the other is the cointegration test. As the VEC-D model was formulated, the Granger causality tests and the generalized impulse response function are conducted to investigate the causal link and dynamic interaction between housing supply and monetary policy.

It is first discovered from the empirical evidence that the supply side of the housing sector in Australia received significant impacts from the global economic turmoil caused by the 2001 terrorist attack to the US and the 2008 global financial crisis. Secondly, according to the Granger causality tests, a transmission pattern within the framework of housing supply and monetary policy can be identified. It suggests that house prices and residential construction costs are two transmission mechanisms of the shocks of monetary policy to new housing construction activities. Finally, the results of the generalized impulse response function indicate that housing supply had been significantly depressed by the changes in monetary policy in Australia. The overall outcomes of this research is useful and valuable for policy makers to better estimate the supply side of the housing sector in the context of monetary policy shifts and global economic turbulence, and enact appropriate policies to improve Australia’s housing supply as well as consecutive declining housing affordability.
CHAPTER 1 INTRODUCTION
1.1 Chapter Introduction

Property research has been well considered in literature for a long time. Empirical studies on housing are one of the most attractive areas for both the global and the Australian academic research communities. As the first chapter, the Introduction holds two responsibilities: presenting the industrial problem as well as the research question and launching an overview for the structure of this thesis. Thus, the major issues of this chapter will be described in the following three sections: Problem Statement, Research Aim and Objectives and Thesis Overview.

1.2 Problem Statement

Housing supply is an essential component of the property sector. It is known that the development of the housing sector depends on the demand for and the supply of housing. However, the capacity of the Australian housing sector to supply has already reached a crisis point since the 1990s, during which the urban population across Australia increased dramatically. Urban economic theory has suggested that the growth of urban population is an important indicator of the increasing housing demand (Glaeser et al., 2005b) and there should be a long-run equilibrium relationship (convergence) between the total housing stock and urban population (DiPasquale, 1999).

According to the statistics issued by the Australian Bureau of Statistics (ABS), the growth rates of total housing stock in Australia have been experiencing an identifiable downward trend accompanying the dramatic population growth since the end of the 1990s. The movements in Australia’s growth rates of total housing stock and urban population are illustrated by Figure 1-1. One perspective demonstrated in the housing supply literature is that new housing supply is a leading source of the increase in total housing stock. In Figure 1-2, compared with the dramatic population growth, the annual number of new housing completions in Australia exhibited a stable moving trend. It is inferred from Figure 1-1 and
Figure 1-2 that a divergence between housing supply and urban population has occurred in Australia. In simple terms, the supply of housing currently can not keep pace with the increase in housing demand across Australia.

Measurement unit: percentage (%)  

Source: ABS, 2009a

Figure 1-1: Urban population growth rates and housing stock in Australia

Measurement unit: number  

Source: ABS, 2009a; 2009b

Figure 1-2: Population growth and new housing completions

Another statistics regarding Australia’s housing finance further indicated that the annual quantities of the housing mortgage for the purchases of owner occupied
dwellings in Australia increased by 99.42% on average during the period of 1997-2008 (ABS, 2009e). This rate implies that the demand for housing in Australia is increasingly strong. Owing to the strong housing demand and inadequate housing supply, Australia is now suffering a severe problem in housing shortage. The annual report from the Housing Industry Association (HIA) in 2009 supported this perspective and argued that a shortage of approximately 110,000 dwellings emerged in Australia in 2008 and this problem will be exacerbated in the future if the situations in the supply side of the housing sector are not able to be improved (HIA, 2009).

Based on the data of the Reserve Bank of Australia (RBA), from the end of 1996 to year 2008, the growth rates of money supply in Australia have been decreasing and there has been a corresponding rise in interest rates (RBA, 2009a; 2009b). The increase in interest rates as well as the decrease in the money supply growth rates suggests that there is a significant adjustment in monetary policy in Australia. This assumption can be supported by the announcement of the RBA, which stated that the expansionary monetary policy that had been implemented in Australia for a couple of years would be gradually slowed down in the upcoming periods (RBA, 1999). The expansionary monetary policy defined in economics is the monetary policy that aims to increase the size of money supply, targeting a decline in the interbank rates and other real interest rates (McTaggart et al., 2003).

The macroeconomic theory generally defines monetary policy as a process by which the central bank or national monetary authority of a country controls and adjusts the cash rates to a target level in money market to influence other real interest rates in the realistic economy (RBA, 2007a). It is a key tool for public governors to regulate economic activities. The changes in monetary policy can bring significant effects on various economic sectors, such as manufacturing, construction and property (McTaggart et al., 2003). Exploring the existing housing literature suggests that many researchers have focused on investigating
how monetary policy affects housing demand and few empirical studies were concerned with the comprehensive relationship between monetary policy and the supply of housing. In addition, during the recent decade, the global economic conditions are turbulent due to some special events (RBA, 2001b; 2008). However, little has been done to empirically include the global economic disturbance into the housing supply studies. Thus, a question, 'Do the slowdown of expansionary monetary policy and global economic turmoil significantly influence the supply of housing in Australia?', has been raised. More importantly, the Australian housing market changed markedly in last ten years, but it receives little attention in terms of its responses to the shocks of monetary policy in comparison with the US and European markets. Therefore, a macroeconomic study related to housing and monetary policy in the Australian context is required. This study will provide policy makers with the insights to not only the pattern of the response of the housing market to the political and global economic shocks, but also the issues of housing affordability in Australia.

1.3 Research Aim and Objectives

To answer the question presented in Section 1.2, this research aims to investigate the relationship between housing supply and the changes in monetary policy and the global economic atmosphere. As a result, five research objectives must be achieved in this thesis, involving

- Identifying a research strategy that allows this study to model housing supply within the context of monetary policy changes and global economic turmoil through a series of relevant economic variables.
- Developing a conceptual model comprised of the indicators of housing supply, monetary policy and global economic turbulence.
- Developing a vector error correction model with a dummy variable (VEC-D model) to estimate the conceptual model.
- Identifying the impact of global economic turmoil on the supply side of the housing sector by the coefficients and the t-statistics of the dummy
variable in the VEC-D model.

• Applying the Granger causality tests and generalized impulse response function under the VEC-D model to examine the relationships amongst the indicators of Australia's housing supply and monetary policy.

In summary, the aim of this thesis is to investigating the linkage between housing supply and monetary policy with the disturbance of global economy in the Australian context by a VEC-D model. This empirical study will extend the research scope of the literature in relation to housing supply.

1.4 Thesis Overview

This thesis is structured by six chapters, including Introduction, Literature Review, Conceptual Model, Methodology and Data Collection, Analysis and Discussion and Conclusions. The summary for the contents of these six chapters is as follows.

Chapter 1 Introduction – As the first chapter of this thesis, Chapter 1 starts by presenting the industrial problem in terms of the slowdown of expansionary monetary policy in conjunction with an inadequate housing supply in Australia and the disturbance of global economic climate. Then, the research question with regard to the relationship between housing supply and monetary policy under the global economic turbulence was emerged. To solve this question, the research aim and objectives of this thesis have been introduced.

Chapter 2 Literature Review – In this chapter, a theoretical context of the empirical research on the topic under study will be discussed. The existing literature is reviewed in relation to housing supply as well as the relationship between monetary policy and the property sector. In the housing supply literature, three research themes are identified, involving the supply of new housing, addition and conversion to established housing and housing supply and policies. In addition, the previous studies on monetary policy and the property sector are
organised into two sections, one is the prior research on monetary policy and macroeconomy, and the other is the work related to the linkage between monetary policy and the housing sector. Furthermore, the research theme that aims to quantify the impacts of special events on economy will also be introduced. The literature review set up a theoretical foundation and identified the research gap on the comprehensive interrelationship between housing supply and monetary policy within the context of global economic turbulence.

Chapter 3 Conceptual Model – This chapter will propose a conceptual model composed of the monetary policy function and the housing supply function, which incorporate the variables of interest rates, money supply, house prices, residential construction costs and new dwelling construction, for further empirical analysis. Moreover, a general concept of the systematic methodology in regard to the time-series analysis under the vector error correction model will be provided to establish a background for Chapter 4 Methodology and Data Collection.

Chapter 4 Methodology and Data Collection – This chapter will design the methodology and the data used in this research. In this chapter, firstly, two prerequisite tests (unit root tests and cointegration test) for the formulation of the vector error correction model will be presented. Secondly, a simple vector error correction model will be described in the sections following the introductions on the unit root tests and the cointegration test. Secondly, a dummy variable that can capture the impacts of global special events on the Australian economy will be devised. Thirdly, the Granger causality test and the generalized impulse response function will be outlined in the methodology section. Finally, the data sources and the data employed to measure the variables demonstrated in the conceptual model will be discussed in the last two sections of this chapter.

Chapter 5 Analysis and Discussion – This chapter will empirically investigate housing supply within the framework of monetary policy changes and global
economic turbulence. By using the unit root tests and the cointegration tests, a simple vector error correction model will be constructed in this chapter. Then, a dummy variable will be imposed into the simple VECM to construct the VEC-D model. Depending upon the VEC-D model, the coefficients and the $t$-statistics of dummy variable will be first used to analyse whether the global economic turmoil can bring significant impacts on the supply of housing in Australia. Secondly, the Granger causality tests will be carried out to analyse the causal relationships between the variables associated with housing supply and monetary policy. The results of the Granger causality tests provide information to depict a transmission pattern, which is a map specific to the ripple effects in relation to the indicators of housing supply and monetary policy. Finally, the generalized impulse response function will be utilised to explore the dynamic interactions between housing supply and monetary policy. Benefited by the econometric techniques, the research questions addressed in Chapter 1 Introduction and Chapter 2 Literature Review, and the reliability of the functions developed in Chapter 3 Conceptual Model can be answered and validated respectively. In summary, the influences of the changes in monetary policy and the global economic climate on Australia’s housing supply are significant.

**Chapter 6 Conclusions** – This is the final chapter of the thesis and it will summarise the findings and research outcomes of this study. Overall, according to the empirical results presented in Chapter 5 Analysis and Discussion, it can be concluded that that monetary policy and the global economic turbulence had significantly affected the supply of housing in Australia over the past decade. In the final sections, the implication of findings for policy makers and the research limitations as well as the possibilities for future study will be specified.
1.5 Chapter Summary

Chapter 1 has been developed as an overview for this thesis. In the first section, a background and a statement on the industrial problem with respect to Australia’s inadequate housing supply in conjunction with the slowdown of expansionary monetary policy and the global economic turmoil has been outlined to build up a context to raise the research question. On the basis of the industrial problem and research question, secondly, one research aim and five research objectives have been identified in the section following the problem background, targeting to explore the impact of global economic turbulence on the supply side of the housing sector and uncover the casual link as well as dynamic interaction between housing supply and monetary policy by a VEC-D model. Finally, Thesis Overview was designed to provide an insight to the overall structure of this thesis and summarise the key issues of every chapter.
CHAPTER 2 LITERATURE REVIEW
2.1 Chapter Introduction

Macroeconomics claims that the economic markets, such as financial market, manufacturing market, housing market and construction market, can be influenced by government’s regulations and policies. Of a series of governmental policies, monetary policy is one of the essential tools for the decision makers in the public sectors to adjust economy. Based on the description in Chapter 1 Introduction regarding an inadequate housing supply within the context of monetary policy adjustments and global economic turmoil, the aim of this literature review is to present the theoretical foundation underpinning the interrelationship between housing supply and monetary policy, and the disturbance of global special events on the economic sectors. There are three parts of existing literature to be reviewed in this chapter: the research on housing supply, the study on the impact of monetary policy on economy as well as housing supply and the investigation on the effects of global special events.

Firstly, the review on housing supply has been organised into three sections: the previous studies on the supply of new housing, prior research on the addition and conversion to established housing and previous academic work in regard to housing supply and policies. Secondly, the literature relative to monetary policy is also organised in two parts: the studies with respect to the relationship between monetary policy and macroeconomy and the research focusing on the linkages between monetary policy and housing supply. One of the major issues identified in the review on housing supply was a lack of past work on exploring a comprehensive relationship between the issues of housing supply and monetary policy. Finally, a research theme in terms of the study on the global special events will be introduced. In this section, the econometric technique and the research gap regarding the impacts of global special events on the supply side of the housing sector will be highlighted. The literature review of this research provides a context for the development of a conceptual model and methodology in Chapter 3.
2.2 Housing Supply

While there is extensive empirical literature on the demand for housing, far less has been written about housing supply. Although more and more scholars have begun to explore the supply of housing recently, the empirical evidence in the supply of housing is still far less than that of housing demand. This literature review identified three empirical research themes of housing supply, including *Supply of New Housing, Addition and Conversion to Established Housing*, and *Housing Supply and Policies*.

In this section, the previous studies in relation to housing supply will be critically reviewed and Figure 2-1 maps the chronological progress of the research on the supply of housing. It is not difficult to identify from this figure that the empirical studies on the relationship between housing supply and policies have been well considered since the 1990s and this empirical research will also focus on the issues in this field. Nevertheless, the research scope of the existing housing supply literature is narrow because the research community has largely concentrated on land policies, tax policies and housing affordability policies. In the realistic economic system, many other policies, like monetary policy, also maintained an active and significant role in the development of the supply side of the housing sector. However, less attention has been paid in estimating the interrelationship between housing supply and monetary policy.
Figure 2-1: Chronological map of the research on housing supply
2.2.1 Supply of New Housing

*Reduced-form Estimation*

The empirical research on new housing supply can be traced back to the 1960s. The early research primarily focused on the estimation on the supply elasticity relying on the reduced-form method. The reduced-form technique used before is a simple regression approach where house price is a function of the supply and demand factors.

The first step in understanding the literature of new housing supply is to present a definition of two important terms, 'housing starts' and 'price elasticity of supply'. According to the description of the United States Census Bureau, the definition of 'housing starts' can be summarised as the number of private-owned new houses that have been started for construction in a given period (US Census Bureau, 2000). On the other hand, 'price elasticity of supply' is 'the percentage change in the quantity supplied of a good divided by the percentage change in its price' (McTaggart et al., 2003, p. 88). In economics, the 'price elasticity of supply' is normally represented by $\eta_s$. If $\eta_s = 0$, it indicates that the observed commodity is perfectly inelastic supply; if $0 < \eta_s < 1$, it denotes that the observed commodity is price inelastic; if $\eta_s = 1$, this elasticity is unit elasticity; and if $\eta_s > 1$, it represents that the commodity is price elastic.

The early study under the reduced-form model, commenced by Muth (1960) in the 1960s, examined the relationship between house prices and housing output in the US using the national data. The results indicated that there was no correlation between house prices and housing starts. This result was contradictory to the economic theory that the outputs of new housing are sensitive to the changes in house prices (Quigley, 1999). Follain (1979) tested the price elasticity of long-run new housing construction by applying Muth's (1960) model with more updated national data in the 1970s. The results were similar to Muth's (1960) findings,
thus Follain (1979) claimed that new housing starts were totally price inelastic. However, it was not reliable to conclude depending upon these two studies that the supply of new housing is not related to house prices as Muth (1960) and Follain (1979) utilised the national data that had potential problems in aggregation bias (Stover, 1986). To solve this problem, a function with the cross-sectional data across 61 US metropolitan areas was estimated by Stover’s (1986) study, in which new housing supply is significantly related to house prices.

In addition to the research by Muth (1960), Follain (1979) and Stover (1986), some empirical studies based on the reduced-form estimation during the period of the 1970s and the 1980s contributed to literature by studying new housing supply within the context of rental market. For example, the study by DeLeeuw and Ekanem (1971) estimated a reduced-form equation that explained the variation in the BLS (Bureau of Labour Statistics) quality controlled rent index across 39 metropolitan areas in the US. The findings indicated that the price elasticity of rental housing services ranged from 0.3 to 0.7. Nevertheless, this reduced-form regression equation, in which price was allocated as the dependent variable and output quantity as well as input prices were selected as explanatory variables, was a misspecification (Olsen, 1987) because the primary interest of the research by DeLeeuw and Ekanem (1971) was testing the relationship between long-run supply output for rent and price level. Consequently, the output prices and input prices should not be both included in estimation. In other words, the dependent variable of the equation ought to be either output prices or input prices but not both of them. In reality, this problem also existed in other reduced-form studies, such as Muth (1960) and Follain (1979).

Since the 1980s, there have been more and more studies attempting to explore innovative approaches to model new housing supply directly. The approaches employed in such research focused on a more structural method, in which new housing construction or aggregate supply of new housing was estimated directly
as a function of price and cost factors. The theory underpinning this type of study was derived from the investment literature and urban spatial theory. The major difference between investment-based theory and urban spatial theory is whether or not to consider the issues of land as an input in new housing production.

**Investment-based Theory**

Within the framework of the investment literature, a demand for investment on housing is assumed to be the demand for new construction (Montgomery, 1992). Thus, the empirical studies related to the supply of new housing underpinned by the investment literature defined the construction of new housing as a net investment on physical structure. Based on this theoretical perspective, an asset market approach, which viewed physical structure investment as a function of a series of economic factors [real house prices, the price of output alternative (non-residential deflator), real construction wages, and credit availability], was launched by Poterba (1984) to investigate the impacts of the user costs on the steady state (long-run equilibrium) of the housing market. Apart from the basic hypothesis, three more specific assumptions were simultaneously set up for Poterba’s (1984) study: (1) housing building industry is composed of competitive firms and the industry’s output is dependent of its real price of housing structure; (2) there are limits to materials of housing production; (3) increases in demand for construction lead to a growth in equilibrium price structure. The results of this research indicated that house prices performed as a major determinant of the construction for new housing – the estimated price elasticity of new housing supply (construction) stayed in the interval between 0.5 and 2.3. Besides, an increase in the price of non-residential construction initially resulted in a decrease in residential construction level while a positive change in credit availability drove up the residential-building construction investment. However, there was no statistical relationship identified between construction costs and housing construction outputs.
Poterba’s (1984) overall results suggested that new housing supply is price elastic in the US. This conclusion was supported and restated by a later study by Blackley (1999), in which the long-run elasticity of new housing supply was estimated by using the US annual data over 1950 to 1994. The basic model of this empirical work complied with the recommendations advised by Olsen (1987) and deemed new residential construction as a linear function of new house prices and construction input prices. The long-run elasticity of new housing supply yielded by this function varied from 1.6 to 3.7, implying that the supply of new housing in the US during the sample period was price elastic. After obtaining the supply elasticity, a modified model, where new housing construction is a function of the changes in prices rather than their levels, was formulated to test the supply elasticity again. Nevertheless, this model yielded a lower supply elasticity of around 0.8. Overall, the US price elasticity of new housing supply estimated by Blackley’s (1999) two models ranged from 0.8 to 3.7, which were quite close to the findings of Poterba (1984).

The models of Poterba (1984) and Blackley (1999) had pursued the long-run equilibrium relationships among new housing supply, house prices and other cost factors. However, they ignored the relationship amongst these variables in the short-run context. The study undertaken by Topel and Rosen (1988) identified this issue and detected whether or not the current asset prices are ‘sufficient’ for housing investment decisions. One principal assumption of Topel and Rosen’s (1988) study was that the decision in the investment on new housing construction was determined by the comparison between current asset (house) prices and current marginal costs of production. In Topel and Rosen’s (1988) study, new housing supply (measured by housing starts) is a function of real house prices and a vector (it is defined as a list of numbers in mathematics) of cost factors. Accordingly, a myopic model and a model composed of economic expectations (measured by interest rates, inflation rates and their lag values), internal symmetric adjustment costs and the number of months from start to sales were
constructed with quarterly data from 1963Q1 to 1983Q4. The findings indicated that the long-run supply elasticity was about 3.0 and the short-run elasticity was approximately 1.0. Owing to a rapid convergence between such two elasticities in a year, it was concluded by Topel and Rosen (1988) that resources in construction industry were not all that specialised and can be quickly assembled under changing market conditions. Topel and Rosen’s (1988) model produced a result similar to Poterba’s (1984) findings in regard to cost shifters, which suggested that construction costs had no significant impact on new housing supply.

It can be noted that Topel and Rosen’s (1988) model did not pay attention to the problem that occurs when the costs of construction are not symmetric. Actually, this issue was briefly mentioned by Topel and Rosen (1988) in the footnote of their paper, but they did not provide any further discussion for it. However, due to this problem, an asymmetric and non-linear equilibrium correction model was devised by Kenny (2003) to study the potential effects of asymmetric adjustment costs on the dynamics of new housing supply in Ireland. The Irish quarterly data during the period of 1978Q4 to 1998Q3 was used in Kenny’s (2003) models and the findings successfully uncovered three interesting insights.

Firstly, the Irish housing supply was significantly less elastic than other economic entities like the US. The unit elasticity of long-run housing supply in Ireland implied that restrictions on the supply side of the housing market would possibly appear. Secondly, all results of the empirical models supported the proportion that the adjustment costs relevant to an expansion in housing outputs were greater than the adjustment costs related to a contraction, making the upward trend of housing-output adjustment move slowly when facing a surge of housing demand. Nevertheless, in contrary, the adjustment moved fast during downturn period and this reduced the likelihood that building construction would keep increasing in the context of declining demand. Thirdly, ‘a number of the estimated models support the belief that there are threshold points on the supply side of the housing market:
large deviations from equilibrium appear to be associated with faster adjustment when compared with small deviations from equilibrium. Indeed, over a small interval about the estimated equilibrium, the adjustment of housing supply is not significantly different from zero’ (Kenny, 2003, p. 1109).

Although the investment-based models of Poterba (1984), Topel and Rosen (1988), Blackley (1999) and Kenny (2003) did contribute to the literature of housing supply, advocates of urban spatial theory still criticised their studies because all of them ignored a highly important issue – the influence of land, which is the most unique element of housing production. In reality, Poterba (1984) and Kenny (2003) acknowledged the importance of land in housing supply research. Poterba (1984) omitted this variable in his model because of a lack of data and Kenny (2003) installed a deterministic trend in his model to be a proxy for the impacts of exogenous factors, such as the land input increases and the changes in technology.

**Urban Spatial Theory**

The urban spatial theory claimed that land prices depends more on housing stock than the level of construction activity. Basically, an increase in house prices leads to abnormal returns but just can temporarily raise construction to a level slightly higher than the standard. This is because the inflation of house prices results in the growth of housing stock and then the rise in land prices. The increases in land prices will absorb the abnormal returns generated by the rising house prices and make the construction decline to its normal level. The basic hypothesis of the models in urban spatial theory is that there is a long-run equilibrium relationship between the stock of housing and urban population (DiPasquale, 1999).

One valuable piece of work based on the urban spatial theory arose in the 1990s and it involved a supply model developed by DiPasquale and Wheaton (1994), incorporating a stock adjustment process with a long-run spatially based definition of the equilibrium housing stock. This model produced a construction equation in
which new housing construction is viewed as a function of house price levels, cost shifters and lagged stock. To estimate the model, new single-family housing starts, real short-term interest rates, land costs, construction costs and stock of housing in previous period were identified as the core variables for modelling. The results indicate that the price elasticity of stock and price elasticity of construction ranged from 1.2 to 1.4 and 1.0 to 1.2 respectively. These findings implied that it was highly slow for housing stock to adjust to its new long-run equilibrium via new construction, around 2% per year. This percentage also implied that it would take at least 35 years to achieve a new equilibrium between population and the total housing stocks. Moreover, a significant negative impact on the housing starts was triggered as a consequence of the changes in real short-term interest rates, however, land costs had no identifiable effects on housing construction (supply). An interesting result emerged from the study by DiPasquale and Wheaton (1994) was that there is still no relationship existing in between construction costs and housing construction level. The limitation of DiPasquale and Wheaton’s (1994) model is that they used farmland prices instead of residential lot prices.

Likewise the research by DiPasquale and Wheaton (1994), the study associated with a simultaneous equation model proposed by Pryce (1999) also investigated the supply of new housing combining the land issues. This model, estimated by the variable elasticity approach, provided a tool and conceptual framework to examine and compare the supply elasticity of new housing. The data on the basis of two cross-sectional periods (1988 and 1992) involved real house prices, land stock for private housing, private housing starts, percentage economically active in social classes I and II in England, percentage of residential development on land, and estimated costs of rebuilding standard house at English local authority district level. The structural equations were specified and two-state least squares procedure was implemented in this model to overcome simultaneous problems. Additionally, Pryce (1999) followed Olsen’s (1987) recommendations and cancelled the input costs from the supply function to avoid misspecification. The
results of the model helped to identify an evidence of a structural break between the housing boom (1988) and slump period (1992). During the boom period, the average elasticity of housing supply was 0.58, which was smaller than the one of the burst period (1.03). However, the land supply elasticity was more stable, as much as 0.75 in 1988 and 0.71 in 1992.

In 2000, a residential construction model similar to DiPasquale and Wheaton (1994) was developed by Mayer and Somerville (2000b). However, in this model, housing supply is considered to be a function of the changes in house prices and costs rather than a function of the levels of such variables. Specifically, the single-family housing starts were a function of current price changes and lagged price changes and of current cost changes and lagged cost changes. The theoretical fundamental of this formulation is that the flowing nature of housing starts encourages itself to be a function of other flow variables (Mayer & Somerville, 2000b). As this model was based on the urban land development theory, it was estimated by a time-series method with a dynamic adjustment process used to measure the time for going through the land development process. The empirical results suggested that ‘a 10% rise in real house price led to a 0.8% increase in the housing stock, which was accomplished by a temporary 60% increase in the annual number of starts, spread over four quarters’ during the period of 1975 to 1994 in the US’ (Mayer & Somerville, 2000b, p. 85). According to this model, time to sales had significant impacts on single-family housing construction as well.

Apart from modelling new housing supply in the homogenous time series, the empirical research by Malpezzi and Maclennan (2001) studied new housing supply under the urban spatial theory in the heterogenous period. They estimated the long-run price elasticity of the supply of new housing in the UK and the US within a period with a global special event – the World War II. The empirical evidence yielded by a multivariate regression model indicated that price elasticity
with respect to housing supply in the UK during pre-war period was between 1 and 4, but in the post-war the values decreased to the interval between 0 and 4.0. Simultaneously in the US, the supply elasticity was much higher, achieving the level from 4.0 to 10.0 and 6.0 to 13.0 respectively. In other words, under the regime changes, the housing construction market in the US was more price elastic than that of the UK.

The most recent urban spatial literature related to new housing supply is the study conducted by Grimes and Aitken (2010). This research created a calibrated model which was based on a hypothesis that housing developers are price-taking and profit-seeking agents. This model consisted of a number of components, such as the housing stock, developers’ total costs (e.g. land costs, building costs and financing costs), rates of new housing permits, and sales prices of houses. By employing quarterly data set covering New Zealand’s 73 Territorial Authorities over 1991Q1-2004Q2, the calibrated model generated a series of empirical results, which proved that housing supply and house price dynamics were interconnected, and the impacts of the rise in land on house prices and other costs was moderate while the response of new housing supply would be lessened when land prices increased. Suggested by a regional equation system, the research by Grimes and Aikten (2010) also indicated that the dynamics of regional house prices are a function of region’s supply elasticity.

As indicated previously, much of the empirical work on housing supply share a poor performance of the various measures of construction costs. Somerville (1999) identified this challenging point and claimed that empirical studies always failed to discover a consistent relationship between construction costs and housing outputs although economic theory had long suggested that an increase in the costs of residential construction should reduce the level of housing output. Therefore, a quality-controlled and hedonic construction cost series with an entirely new set of micro-data on housing construction were proposed by Somerville (1999) at the
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end of the 1990s to examine the interrelationship between housing outputs and construction costs in the US metropolitan areas. The empirical results of this study suggested that in the US metropolitan areas housing starts were quite cost elastic and construction costs were endogenous in the housing supply function. The reason for the poor performance of the prior studies on the relationship between housing starts of new single-family residence and construction costs was the bias in the commercial cost indexes used by the researchers (Somerville, 1999).

In addition, the empirical study by Liu and London (2011a; 2011b) focused on estimating the linkage between housing supply and residential construction costs with the regional heterogeneities. In their research, a conceptual model as well as a panel error correction model (ECM), both of which addressed the impacts of regional heterogeneities, had been developed to identify the correlation between new housing supply and the costs triggered in the procedure of housing production across Australia’s states. Suggested by the results of the panel ECM, it is noted that new housing outputs are significantly correlated to residential construction costs in the Australian states, in which the new housing supply of Queensland and Tasmania are highly sensitive to the increases in construction costs (Liu & London, 2011a; 2011b). This research supports the argument of Somerville (1999) that residential construction costs are one endogenous variable of the housing supply function.

In summary, the early empirical studies with respect to new housing supply (DeLeeuw & Ekanem, 1971; Follain, 1979; Muth, 1960; and Stover, 1986) concentrated on the estimation on supply elasticity applying the reduced-form regression technique. Since the 1980s, two schools of housing scholars have begun to model the supply of new housing with more structural approaches. The research by Blackley (1999), Kenny (2003), Poterba (1984) and Topel and Rosen (1988) explored new housing construction in accordance with the investment theory that explains the supply of housing without considering the land inputs. On
the other hand, the advocates of urban spatial theory integrated the issues of land into the modelling in terms of new housing supply (DiPasquale & Wheaton, 1994; Grimes & Aitken, 2010; Malpeuzzi & MacInnan, 2001; Mayer & Somerville, 2000b; and Pryce, 1999). Owing to the failure in identifying the correlation between new housing outputs and residential construction costs in past research, Liu & London (2011a; 2011b) and Somerville (1999) were concerned with this relationship and successfully found this correlation.

2.2.2 Addition and Conversion to Established Housing

Housing is the asset with durable characteristics which lead to that housing supply is determined by not only new housing construction but also the addition and conversion to established housing. Owners of houses or other residential buildings can convert a large single-family house into several small flats or units for sales or rents, or do addition to their small houses. Because of the addition and conversion, the flow of housing services in the supply side of the housing market will be changed. Although the leading source of the increase in the total housing stock is still new house construction, the growth in the housing stock via the extension of existing housing stock is also significant (Baer, 1996).

The literature in relation to the addition or conversion of existing housing stock is limited however, there are two branches in this kind of research, first the conversion of the house for rent, and second, the decision for improvements or moving. The research by Rydell (1982) regarding the price elasticity of the supply of rental housing services was the first study related to this field. The supply of rental housing services can be altered in three different ways: upgrading existing housing by repairs, developing existing residential land more or less intensively, and changing the occupancy rates (Rydell, 1988). From the data panel of the Experimental Housing Allowance Program Supply Experiment, Rydell (1988) found that the repair elasticity (the repair response of the owners of rental housing to the changes in rents) in Brown County, Wisconsin, St. Joseph County, and
Indiana in the US was 0.2, which implied that the rental house owners’ responses of housing maintenance to the changes in rents was inelastic across the US.

The decision on making improvements or moving has been first empirically analysed by the two-equation simple model of Poteban (1989) in the 1980s. This model was developed to examine the influences of the changes in interest rates and growth of income level on the choices between maintenance and moving, utilising the cross-sectional data of the year 1979. The estimated outcomes suggested that the possibility of making home improvements was positively related to the increases in current interest rates if house owners are holding a fixed rate mortgage. In summary, 2% to 6% increases in interest rates raised the possibility of choosing home improvements from 34% to 41%. In contrast, the attractiveness for repairs was negatively affected by the growth of income – a growth of personal income from $10,000 to $40,000 depressed the possibility of moving to 32% from 36% (Poteban, 1989).

The findings produced by Poteban (1989) were not complete because he did not take into account one of the important potential choices of house owners – they do ‘nothing’ for their properties (Montgomery, 1992). In Poteban’s (1989) model, owners who do ‘nothing’ have been considered as the movers in the first equation and even they had been entirely ignored. To solve this problem, Montgomery (1992) proposed an ordered probit model in which households’ choices are classified as: consuming less housing, doing nothing, and consuming more housing in quality and/or quantity. Then this model was estimated using the data on owner-occupied and single-family detached houses from the 1985 American Housing Survey. The results indicated that the households with high income preferred to conduct improvements or maintenance rather than do nothing, and they spent more on such activities than the low-income families. Due to an increase in incomes, households were more likely to move than improve their houses. One interesting finding from Montgomery (1992) was that the possibility
and expenditure in terms of improvements in the community of older households or the groups who had stayed in the residential unit for a long time were much lower than others. In a flourishing market, households’ willingness for improvements was stronger and they would pay more on these kinds of consumptions owing to an expectation on house value appreciations. Montgomery (1992) further discovered that old-house occupants expressed a strong tendency towards the maintenance and improvements of existing housing.

2.2.3 Housing Supply and Policies

It has been acknowledged that governmental policies bring a myriad of influences on both the demand and the supply sides of the housing markets (Reed, 2001). Since the 1990s, many empirical studies have investigated the supply of housing integrating political impacts or regulated differences varied by local governments rather than only cost factors (Anderson, 1999; Bramley & Leishman, 2005; Fingleton, 2007; Glaeser et al., 2005a; 2005b; Green et al., 2005; Mayer & Somerville, 2000a; Mayo & Sheppard, 1996; and Peng & Wheaton, 1994).

Housing Supply and Land Policy

A review of key empirical research in regard to the impact of governmental policies or regulated differences on the supply of housing suggests that land policy is an important theme. To take the multi-equation aggregate housing model proposed by Peng and Wheaton (1994) as an example, they analysed how sudden political restrictions on the supply of developable land for residential buildings affected house prices and new housing supply in the Hong Kong housing market. This model was estimated by the time-series data on the house prices, housing stock, housing completions and government’s land sales between 1965 and 1990. The results indicated that the sudden governmental constraints on the land supply for residential buildings in Hong Kong resulted in higher house prices but did not lower housing completions. ‘The higher price resulted directly from the capitalization of expected higher rents, and they encouraged capital land
substitution in housing production' (Peng & Wheaton, 1994, p.263). Accordingly, Peng and Wheaton (1994) claimed that a shortage of land supply would not cause a reduction of the supply of housing units but a higher house price if the Hong Kong government insisted on restricting new land supply and allowed for flexibility of building density in the future.

An empirical study launched by Mayo and Sheppard (1996) also contributed to the theoretical system in terms of the effects of land constraints on the supply of housing in three countries, including Malaysia, Thailand and Korea. This study was underpinned by a similar approach to that of Follain (1979) which depended on the reduced-form regression technique. The data, on the basis of house prices, household incomes, prices of input in housing production and the prices of other goods relevant to consumer, have been selected. The findings advised that the price elasticities of housing supply in Malaysia and Korea ranged from -0.18 to 0.44 as well as -0.2 to 0.4 by the Ordinary Least Squares (OLS) and from -0.32 to 0.16 as well as -0.32 to 0.17 respectively by the autoregressive least-squares. However, in Thailand, the price elasticity was much higher, ranging from 3.26 to 7.31 by the OLS and 4.25 to 9.31 by the autoregressive estimates. Thus, those countries with more restrictive land planning systems have smaller values of the price elasticities of housing supply, particularly in Malaysia, where a dramatic reduction in the housing supply elasticity occurred during the period after a more restrictive system was introduced (Mayo & Sheppard, 1996). Additionally, a stochastic development control by government may alter the structure of housing supply and then depress house prices.

With the purpose similar to Peng and Wheaton (1994) and Mayo and Sheppard (1996), the impact of land-use regulations on residential construction starts was studied by Mayer and Somerville (2000a) depending on a theoretical framework that assumes that the effects on new construction vary by types of regulations. This study started by classifying regulations as adding explicit costs, uncertainty
or delays to the development process, and then created a regression model with the data on the quarterly percentage change in real house prices, mean number of new single-family building permits issued on quarterly basis, number of months to approve subdivision, number of ways growth management introduced, and land development fees across 44 US metropolitan statistics areas (MSAs) during the period of 1985 to 1996. From the model, land use regulation lowered the level of the steady state of new construction. The results showed that the housing starts in the metropolitan areas of the US with extensive land regulations were fewer, up to 45% than that in the regions with a less-regulated climate. Moreover, the elasticities of housing starts in the markets with little regulatory delay ranged from 15 to 18 while the start elasticities in the more-regulated regions were 14 – approximately 20% less than the less-regulated markets. However, Mayer and Somerville (2000a) argued that it is hardly to identify the impact of development fees on new construction; nevertheless, the regulations that restricted new development or lengthened the development process significantly affected the housing starts in the 44 MSAs in the US.

Few econometric models have been formulated to measure and model the impact of the well-known land-use planning system of the UK on the supply of housing in the British housing market before 2005 even though the political effects of this system had been long recognised by scholars. In order to study this field and explore the differences in behavioural supply responses between the markets in ‘high’ and ‘low’ demand states, a supply-and-demand modelling framework with a wider and more balanced range of dataset and the components that denote the flow of new planning permissions and the stock of existing planning permissions were constructed by Bramley and Leishman (2005). Simulations based on this model were used in this study to identify the impact of land-use policies in different regions on market outcomes. The estimates of the modelling framework indicated that urban conditions had more negative effects on prices in low demand areas than that of high demand areas. Furthermore, new private housing
construction that attracted more in-migration in intermediate areas was able to depress prices more in low demand areas and the sub-regions of high demand areas than the central high-demand region. Moreover, climate, urban conditions, new housing output and migration have more influences on the vacancies in low demand areas as well than that of high-demand districts. As indicated by the simulations, a 39% increase in housing supply would reduce up to 1.1% of house prices, and the policies that could reduce housing supply in low demand areas would induce 10% rises in house prices. The overall results allowed Bramley and Leishman (2005) to conclude that housing output is more sensitive than house prices to the shocks of land-use planning policies, thus both the demand and supply sides policies (e.g. economic, labour, land and social housing) should be considered to balance the housing markets across UK’s different regions.

**Housing Supply and Housing Affordability Policy**

Housing affordability policy, other than land policy, has been an important field for housing economists since the rapid inflation of house prices across the world (Liu & Liu, 2010). As a key component of the housing sector, the supply side of the housing market is the target of the policies relative to housing affordability. With this interrelationship, the empirical study by Fingleton (2007) developed two econometric models to examine the potential effect of the housing affordability policy concerning increasing housing supply in the greater South East of England. As housing affordability is measured by house prices and wage level in this study, a house price model comprised of a demand and a supply function was estimated first by the OLS, ML (maximum likelihood) and two-stage least squares, using the data on the average house selling prices of the year 2001, the wage and employment level of local and commuting distant areas, the number of square km per household, the number of owner-occupied households (total housing stock), the level of education attainment and the square of the distance of the area from London. The empirical evidence suggested that the real house prices in the South East of England was significantly enhanced by the increases in wage and
employment level within commuting distance; however, they were lowered by the growth of housing stock during the observed period. In addition, house prices dramatically increased in the areas with better education level, where there is more space per household and the distance to London is less. After estimating the house price model, Fingleton (2007) introduced the other model, namely wage model, where labour costs is the only input of housing construction outputs. The estimates by the ML indicated that the estimated supply elasticity of employment was 1 and the increase in the housing stock raised wage level by 2.8%. Based on such results, the expansion in housing supply may be accompanied with a boom in employment, which will also increase housing demand and then impel up house prices again. Thus, the housing affordability policies advocated by the UK aiming to increase housing supply will possibly cause a situation worse than before in some areas of England (Fingleton, 2007).

Housing affordability is an attractive topic associated with various backgrounds. For example, Berry (2003, p.413) studied it in the Australian context and outlined that ‘housing affordability has fallen in Australia over the past decade, in spite of sustained economic growth in the national economy.’ According to Berry’s (2003) point of view, the inadequate supply of affordable housing in rental market for the low-income households is an essential determinant of the declining housing affordability across Australia. The research report conducted by Wulff et al. (2011) supported Berry’s (2003) argument and maintained that the consistent fall in the Australian housing affordability is related to a shortage of affordable housing for rents. As a consequence, both Berry (2003) and Wulff et al. (2011) argued that attracting more private investment into the affordable end of the housing market should be a promising solution. The papers written by Berry (2003) and Wulff et al. (2011) imply that the study related to housing supply may contribute to the field of housing affordability.
Housing Supply and Tax Policy

In addition to land and housing affordability policies, the influence of tax policy is a field of concern by researchers in the housing supply studies as tax payments are a significant part of the costs of business operations and transactions. Baser (1975), Bourassa (1995) and Bourassa and Grigsby (2000) maintained that tax is a negative gearing for the housing sector because of its significant impact on the user costs. It is also realised by economists that the conventional property tax causes the housing stock to be smaller than it would be in the existence of a non-distortionary taxation. As a result, some empirical work has been undertaken to investigate the effect of property tax on housing supply. The study by Anderson (1999) in the 1990s examined the effect of a transfer from single-rate property tax to two-rate property tax on the optimal timing and capital intensity of residential land development, which is a crucial factor related to the housing stock under the urban spatial theory. The economic model suggested that the move to two-rate property tax would increase the timing and capital intensity of urban land development for residential purpose. However, due to a lack in the knowledge of the relationship between the timing of development and its capital intensity in the developer’s profit function, it is impossible to accurately predict whether or not the property tax would increase housing supply (Anderson, 1999).

The most recent empirical studies on the effect of property taxes on housing supply was the model proposed by Green et al. (2005), which estimates the elasticity of housing supply for 45 metropolitan areas in the US. This model was derived from embellishing the residential construction model of Mayer and Somerville (2000b) by adding the variables of property taxes and incomes. The estimates in this study were divided into two stages: the first stage is a time-series regression based on the revised residential construction model for the housing supply elasticities of 45 MSAs from 1979 to 1996, and the second one is a cross-sectional regression analysis, in which the supply elasticities obtained at the first stage were allocated as the dependent variable. The first regression results
indicated that the supply elasticities were larger than zero in 43 of 45 cities, where 14 cities’ elasticities were over 10 and 12 cities’ elasticities were less than 3. In conclusion, the metropolitan areas heavily regulated by tax policies exhibited low supply elasticities while the areas that were lightly regulated had high elasticities (Green et al., 2005). From the second regression equation, it can be identified that the regulatory climate is one of major determinants of supply elasticity.

**Housing Supply and Regulatory Environment**

As suggested by Green et al. (2005), the regulatory climate is significant to the housing supply elasticity. Therefore, unlike the research specific to the policies of land, housing affordability and tax, Glaser et al. (2005a) studied the impact of the changes in the whole regulatory environment in the US on the housing sector. A simple model of the regulatory approval that explains the changing judicial tastes and decreasing ability to bribe regulators had been presented by Glaser et al. (2005a). The overall findings suggested that it is the local government regulation that limits the increase in housing supply and leads to a higher house prices at the equilibrium. Over the same period, Glaser et al. (2005b) undertook a research specific to the housing market of Manhattan in the New York city on the basis of the study by Glaser et al. (2005a). According to the empirical results, it is known that the regulatory climate has constrained the supply of housing in Manhattan as well as a large number of other housing markets across the US (Glaser et al., 2005a). Influenced by such a regulatory background, Glaser et al. (2005, p. 331) claimed that ‘increases in demand have led not to more housing units but to higher prices’. In reality, one small section of the study by Green et al. (2005) had launched a conclusion similar to Glaser et al. (2005a; 200b) that the regulatory climate essentially determined the supply of housing across the US.

**Summary**

The review of the literature related to the relationship between housing supply and policies suggested that the changes in policies are the issues of concern by
researchers. Of these studies, the work of Bramley and Leishman (2005), Mayo and Sheppard (1996), Mayer and Somerville (2000a) and Peng and Wheaton (1994) had concentrated on land policies or regulations, and Anderson (1999) and Green et al. (2005) focused on property taxes. Because of the rapid inflation of house prices in the world, Fingleton (2007) was concerned with the relationship between housing supply and housing affordability. Unlike other studies, Glaser et al. (2005a; 2005b) explored the effect of the whole regulatory climate rather than a specific policy on housing supply. In addition to the research discussed in Section 2.2.3, the literature regarding monetary policy and the housing sector will be discussed in the following sections.

2.3 Impact of Monetary Policy on Economy

2.3.1 Monetary Policy and Macroeconomy

Monetary policy is generally defined as a process by which the central bank or monetary authority of a country controls the supply of money or the cash rates in money market to affect a series of real interest rates in economy (RBA, 2007a). This definition demonstrates that the controls of money supply and interest rates are normally the major instruments of monetary policy. Therefore, the first issue that arises is how the money can be supplied to economic agencies. To understand the ground for latter discussion, the quantity theory of money (QTM) must be briefly considered. The QTM assumes that money supply has a direct and positive relationship with the price level (Dalziel, 2002). The QTM dates back to the 16th century and was influentially restated by the literature of Friedman (1956) in the 1950s. It is noted however the question about the channel which bridges money and economic sectors was still unanswered. The answer emerged in the research by Brunner and Meltzer (1963; 1972) that defined a non-goods market, namely credit market, where the quantities of bonds are traded at the market rate of interest. Benefited by the credit market, the monetary authorities or central banks introduce money into economy by the purchase of bonds. In either case, 'under
modern conditions, the quantity of money is determined by government authorities' (Friedman, 1974, p. 23).

In macroeconomics, monetary policy performs as an adjuster that helps to transfer governmental interventions, in terms of the real growth of economy, unemployment, and price inflation, to economic activities. The literature that first systemically describes the role of monetary policy appeared at the end of the 1960s and was an academic article written by Friedman (1968) that sought to summarise the role of monetary policy in economy. This article provided an overview of the valuable contribution of monetary policy to macroeconomy, and it demonstrated that monetary policy is an essential component of policy. Monetary policy can prevent money being a source of economic disturbance and build up a stable background for economy by providing producers, consumers, employers and employees with confidences that the average level of prices will behave in a known or predicative way in the future. Again, monetary policy is also able to offset major disturbance arising from other economic sources (Friedman, 1968).

During the period of the 1960s to the 1970s, the academic literature about monetary policy emphasised identifying the instruments and intermediate target variable of monetary policy (Friedman, 1975, 1977; Kareken, 1970; Parkin, 1973; Poole, 1970; and Shupp, 1972). The core issue clarified from these studies is that interest rates and aggregates of money supply are the instrument variables in the procedure of monetary policy. In particular, Friedman (1975; 1977) claimed that the intermediate variable should be bank credit and overall evidence indicated that the choice amongst instrument variables to be used in controlling the economic aggregate was either the interbank rates or the reserves of money (money supply) in accordance with the economic environment. The aim of the response mechanism for instrument adjustment should focus on medium-term control of the economic aggregates (Friedman, 1977).
Chapter 2: Literature Review

The principal target of monetary policy is underpinned by the assumption that an inextricable linkage between the economic sectors and monetary policy exists in society. Thus, there has been over the past two decades a considerable interest in the identification of monetary policy shocks and measurements of their effects on macroeconomy. Extensive theoretical and empirical literature, which studies the effects of monetary policy on real economic aggregates and prices, has been presented in academic research community. Since the critique of Sims (1980) on excess restrictions of large structural models and the lack of consensus structural models, the majority of empirical studies identifying the shocks of monetary policy to economic activities have applied the vector autoregression (VAR) models. As argued by Cochrane (1998), the VAR can trace the history of economic variables in response to the shocks of monetary policy.

Of the early VAR analysis for monetary policy, examining the responses of prices and economic output by the reduced-form VAR models was a popular topic. Economic theory suggests that the consumer price level and output such as GDP would decline temporarily after a monetary contraction. However, with regards to prices, a number of studies presented a puzzling result that price level is not correlated to interest rates. This result violates the justification of conventional economic theory and thereafter was labelled as the ‘price puzzle’ in the studies by Benanke and Blinder (1992) and Sims (1992). The literature typically argued that the ‘price puzzle’ is a consequence of some model misspecifications (Giordani, 2004). Hence, a number of approaches dealing with model misspecification in relation to monetary policy shocks have been developed in literature, such as the study by Brissimis & Magginas (2006). The researchers claimed that adding a forward-looking variable like the federal funds futures into the reduced-from VAR is a feasible way to obtain the macroeconomic variables because the federal funds futures contain market expectations on prospective monetary policy actions.

In reality, a perspective similar to Brissimis and Magginas’s (2006) argument had
been mentioned by Sims (1992) at the beginning of the 1990s, and claimed that the model misspecification of the VAR relative to the ‘price puzzle’ might be generated by an absence of information that can capture the expectation on future inflation. Thus, Sims (1992) proposed a solution by including the commodity price index in the VAR. The rationale to this method is that the commodity price index seems to capture enough additional information about future inflation (Sims, 1992). Due to this assumption, a six-variable reduced-form VAR [short interest rates, monetary aggregate-M1, consumer price index (CPI), industrial production index, exchange rates, and commodity price index] was constructed by Sims (1992) to investigate the impact of monetary policy on the macroeconomy of five industrial countries (France, Germany, Japan, UK and US). The results of the impulse response function (IRF) of Sims’s (1992) model indicated that the VAR with commodity price index was able to be specified and the ‘price puzzle’ had largely disappeared.

The approach used by Sims (1992) was empirically supported again by a later discussion by Christiano et al. (1996), in which a VAR model depending on the data on commodity prices was established to analyse the impact of contractionary monetary policy on the US economy during the period of 1960Q1 to 1992Q4. The contractionary monetary policy defined by Christiano et al. (1996) was associated with a fall in various monetary aggregates, a rise in the federal fund rates, declines in different measures of activity and commodity prices, and a delayed decrease in the GDP price deflator. The estimates of the impulse response function of the VAR models indicated that the net funds increased by the business sector rises in approximately one year following a negative shock of contractionary monetary policy. In the recession period induced by monetary political effect, a converse result was discovered: the net funds were driven up via the decline in the business sectors. The overall outcomes suggested that the ‘price puzzle’ disappeared in the VAR estimation (Christiano et al., 1996).
Although the results yielded by Sims (1992) and Christiano et al. (1996) generally complied with economic theory, the perspective that the model misspecification can be resolved by integrating commodity prices was questioned by Hanson (2000) and Barth and Ramey (2001). Both these studies were not able to identify the ability of commodity prices in mitigating the ‘price puzzle’. Giordani (2004) argued that the commodity price index resolves the model misspecification not because of its capability in future inflation predication, but its’ inclusion of information regarding the output gap. In 2008, a methodology using the forecasts of market participants and of policy makers was developed by Thaper (2008) to estimate how monetary policy affects the economic output as well as inflation. This methodology incorporates the VAR models and the data (1975 – 2000) on the 3-month Treasury bill and the GB forecasts of Federal Reserve Board instead of the interbank rates and real GDP. The results of the estimation of Thaper’s (2008) creative VAR model reported that the ‘price puzzle’ still remained even taking into account the Federal Reserve Board’s forecast to control for the monetary policy maker’s information set. As a result, the study by Thaper (2008) undermined the justification that incorporating an index of commodity price in the VAR can resolve the model misspecification.

In the academic research community, the structural vector autoregression (SVAR) models appear to be the method that can contribute to a solution towards the VAR model misspecification. The SVAR is helpful for separating out the effects of economically unrelated influences in the VAR and addresses the contemporaneous relationships among the variables. In 1997, a SVAR model for an interpretation of Canada’s small open economy was constructed by Cushman and Zha (1997). This approach relied on the restrictions of ‘block exogeneity’ (reducing the number of parameters) rather than the reduced-form equation and Choleski techniques. The estimates from the SVAR depending upon the monthly data from 1974 to 1993 suggested that a sharp decline in the money supply triggered a significant appreciation of the exchange rate of the Canadian dollar. The responses of other
Canadian macroeconomic variables to the shocks of contractionary monetary policy complied with the specification of standard economics about the responses of the macroeconomy facing a monetary contraction (Cushman & Zha, 1997).

Since the research by Cushman and Zha (1997) in the 1990s, the SVAR has been an important tool for the empirical studies on the interrelationships between monetary policy and macroeconomy, due to the appropriate identification of variables. A popular identifying assumption in the SVAR studies was that there were no contemporaneous responses of macroeconomic variables to the shocks of monetary policy (Carlstrom et al., 2009). In recent studies, scholars preferred to focus on the effects of monetary policy on the economic output or inflation by means of the SVAR, such as Uhlig (2005) and Borys et al. (2009), both of whom mainly investigated the impact of monetary policy on the GDP and commodity price level. In Uhlig’s (2005) study, a SVAR was constructed to explore the effects of monetary policy shocks on the economic output (GDP), imposing sign restrictions on the impulse response associated with prices, non-borrowed reserves and federal fund rates, but no restriction has been imputed to the response of real GDP. By estimating this SVAR using annual data of the US over 1965 to 2005, it was identified by Uhlig (2005) that the shocks of contractionary monetary policy had no clear impact on real GDP even though the general price level moved gradually in one year. Moreover, the GDP price deflator decreased slightly and slowly following a shock of monetary contraction. These findings indicated that ‘contractionary monetary policy shocks do not necessarily seem to have contractionary effects on real GDP’ (Uhlig, 2005, p. 406).

Unlike Uhlig’s (2005) study on a large economic system, the study by Borys et al. (2009) focused on the monetary policy shocks in a small open economy – Czech Republic. This study depended on the models within the reduced-form VAR and a more sophisticated SVAR that was estimated by a Bayesian method with the restrictions proposed by Uhlig (2005). The estimation of the model using the
monthly data (nominal exchange rate, 3-month interbank rate, GDP, real-time output gap, net price index, tradable price index, non-tradable price index and commodity price index) issued by the Czech National Bank, firstly, helped Borys et al. (2009) discover that the shocks of contractionary monetary policy had a negative effect on the degree of economic activity and the price level, both of which expressed a peak response in one year. Secondly, the results indicated that the persistent appreciation and gradual depreciation of domestic currency would occur one after another in response to the shocks of tightened monetary policy.

Some studies within the framework of the literature in relation to monetary policy are associated with the bond market other than the economic output. For example, the study conducted by Kuttner (2001) examined the impact of monetary policy on bills, note and bond yields utilising the data on the Federal Funds Rates (interbank rates) in relation to the US future market. The changes in target fund rates in this study were separated into anticipated and unanticipated parts and the findings indicated that the response of real interest rates to the changes in anticipated target rates was small while it responded significantly to the shocks of unanticipated target rates. Furthermore, Kahn et al. (2002) employed a recursive VAR model (a special form of the SVAR model) to assess the effects of monetary policy on real interest rates in bond market and inflation expectations by taking advantage of the Israeli data on the nominal and indexed bonds. The IRF results suggested that the shocks of monetary policy by means of raising the overnight rates drove up real interest rates but lowered inflation expectations.

Indeed, the SVAR models are still criticised despite their positive role in model identification. The criticisms for the SVAR mainly centre on the small amount information utilised by the VAR system. The SVAR and the reduced-form VAR rarely employ more than six to eight variables so that the models can avoid the problem in the lost of the degree of freedom (Leeper et al., 1996). In reality, macroeconomy and even price level are affected by a large number of complicated
endogenous and exogenous factors. The small number of the variables in the VAR is unlikely to accurately capture the relationships between macroeconomic variables (Bernanke et al., 2005). Thus, expanding the information set of the VAR should be an appropriate way to offset the model misspecification (Romer & Romer, 2004). Over the last decade, a relevant stream of research has attempted to explore the models specifically designed for the analysis with a large amount of information (Forni et al., 2000; 2005; Forni and Lippi, 2001; Stock & Watson, 2002a; 2002b; and Bai and Ng, 2002). These studies have contributed to the development of Factor-augmented VAR (FAVAR) models. The name FAVAR is somewhat misleading because it is essentially a SVAR model with observable factors (Forni & Gambetti, 2010).

Although sparse, there has been some literature designed to extend the scope of VAR studies on monetary policy via the FAVAR since the year 2000. To take the empirical study by Bernanke et al. (2005) as an example, in this paper, a FAVAR model with a broad range of information summarised by a small number of factors was proposed to examine the impact of monetary policy measured by the changes in the interbank rates on the US economy. The results of the FAVAR presented a reasonable response of target variables to a shock of monetary policy. The findings of the study by Bernanke et al. (2005) indicated that exploiting more information in empirical modelling for macroeconomy is reliable and valuable. Furthermore, Forni and Gambetti (2010) studied the monetary policy effects depending upon the FAVAR. This FAVAR was equipped with the data of 112 US monthly macroeconomic series and the monetary shocks were identified by a recursive scheme in which the impact of monetary policy on industrial production and prices were treated as zero. The findings suggested that monetary policy had a sizeable effect on real and nominal variables and the prices declined under a monetary contraction shock. These results yielded by Forni and Gambetti (2010) are consistent with the economic justification that price is negatively influenced by the contractionary monetary policy.
Chapter 2: Literature Review

As discussed previously, the model misspecification has been considered to be a dominating explanation for the 'price puzzle' in the research community. However, Coricelli et al. (2006) insisted that the 'price puzzle' may not be a result of the VAR model misspecification but is a consequence of the adjustments caused by the supply side of the market. For instance, if a firm has to acquire financing for its production, interest rates surely will enter into its cost function. As a result, the firm's costs should be enhanced under a tightened monetary policy. To hedge the risk in losing profits, the firm may react by increasing the prices of its products. Consequently, the price will still rise when a contractionary monetary policy is being operated (Coricelli et al., 2006).

The literature concerning the interrelationships between monetary policy and macroeconomy demonstrated that monetary policy maintains an active role in macroeconomic adjustment and regulation, in which money supply and the interbank rates are two primary instrumental and intermediate variables (Brunner & Meltzer, 1963; 1972; Friedman, 1956; 1968; Friedman, 1975; 1977; 1974; Kareken, 1970; Parkin, 1973; Shupp, 1972; and Poole, 1970). Since the proposition and development initiated by Sims (1982), the VAR model integrated with the impulse response function has gradually become a dominating tool for identifying the impact of monetary policy on the macroeconomic variables [e.g. GDP, CPI and real interest rates]. Overall, the VAR is now an essential technique for the research articulating monetary policy and it can also contribute to this type of study within the context of the housing sector.

2.3.2 Monetary Policy and Housing Sector

The previous section with regard to monetary policy and macroeconomy has demonstrated the interdependence between monetary policy and economic activities. Owing to this relationship, macroeconomic theory has claimed that the changes in monetary policy will bring identifiable effects on various economic sectors, such as manufacturing, construction and property. In housing and real
estate economics, theoretically, monetary policy can affect ‘both the supply of (construction) and demand for houses’ (Elbourne, 2008, p. 68).

The housing and real estate economic theories justified that house prices are correlated to the increases in the cash rates or the decreases in money supply. Firstly, the negative changes in money supply or increases in the cash rates will trigger a positive movement in real interest rates, leading to an increase in the payment for interest that represents a major part of the costs of property purchase (Elbourne, 2008). As a result, a drop in the demand for housing would be caused, which in turn depreciates house prices and vice versa. Secondly, house prices are sensitive to the return available on other financial assets. Housing markets could be taken as a substitute for other markets of financial assets (Hui & Yue, 2006). If the return available from other financial assets increases owing to a rise in interest rates, asset holders will transfer their investment portfolio from the assets of housing into other increasingly profitable assets. This behaviour will lower house prices until the return from holding the different asset classes is equalised.

The specification related to the theoretical relationship between monetary policy and housing demonstrates that monetary policy influences the housing sector via house prices. This justification can be empirically supported by a study conducted by Giuliodori (2005), in which a discussion in terms of the housing market channel of monetary transmission mechanism was provided. From a case study on nine European housing and mortgage markets, a number of vector autoregressive models had been used by Giuliodori (2005) to estimate the individual response of each target housing market to the shocks of monetary policies. The results helped to conclude that house prices are the transmission mechanism of monetary policy in the countries where the housing markets are competitive (Giuliodori, 2005).

Theoretically, house price is an indicator of the supply side and the demand side of the housing sector. Quigley (1999) claimed that housing demand is a function
of house prices and personal income, and housing supply is a function of house prices and vacant new dwellings. In other words, house price is a variable that includes the information on housing demand and housing supply. Thus, the studies on the interrelationship between monetary policy and the housing sector primarily focus on the monetary effects on house prices or the integrated variable set with house price and its relevant factors, such as GDP and disposable income.

The responsiveness of the housing sector to the shocks of monetary policy has been described in numerous past studies since the 1990s (Aoki et al., 2002; 2004; Baffoe-Bonnie, 1998; Bebee, 1972; Costello, 2003; Edelstein & Sau, 2004; Elbourne, 2008; Hwang & Quigley, 2006; Iacoviello, 2002; 2005; Iacoviello & Minetti, 2008; Lasfrance, 2002; Liu & Liu, 2010; Vargas-Silva, 2008; Wolff, 1957; and Wong et al., 2003). The possible reason for the increasing interest in monetary policy and housing is the dramatic inflation of house prices in many developed countries in the 1990s. The major econometric technique selected by these studies is either the reduced-form VAR model or the sophisticated VAR models [e.g. SVAR and vector error correction model (VECM)].

The early research relevant to the effects of monetary policy on the housing sector in the 1990s is the empirical study undertaken by Baffoe-Bonnie (1998), in which a reduced-form VAR model was constructed to interpret the dynamic impact of monetary policy and macroeconomic aggregates on housing prices and the number of houses sold on a national and regional level. For this purpose, the U.S. quarterly data over 1974Q1 to 1994Q4 on money supply, mortgage rates and the house prices and the number of houses sold on both national and regional levels were identified for observation. The estimates of the impulse response function suggested that monetary policy had a strong impact on mortgage rates, which in turn triggered immediate responses of housing prices and the number of houses sold in the national and regional housing markets (Baffoe-Bonnie, 1998).
Likewise, Edelstein and Sau (2004) studied house prices, wealth effect and the macroeconomy in Singapore integrated with the external influence of monetary policy through a VARX (a reduced-form VAR with an exogenous variable). Using the data on consumption (CPI), real disposable income, interbank rates, real private and public housing prices, transaction volume and real public housing wealth measure, the results indicated that the shocks of interbank rates negatively affected the consumption, disposable income, private and public house prices and public housing wealth in Singapore (Edelstein & Sau, 2004).

The previous section demonstrated that the model misspecification is more easily triggered in the reduced-from VAR models. To avoid this problem, more and more studies in the recent decade have identified the shocks of monetary policy on the housing sectors by the SVAR or VECM. Take the research initiated by Lastrappe (2002) as an example, this study attempted to test the effect of monetary policy applying the SVAR. The primary interest of Lastrappe (2002) was to estimate the response of the aggregate prices of owner-occupied housing to money supply shock across the metropolitan regions in the US. Consequently, a SVAR model with the restrictions that are consistent with a wide range of theoretical model was applied. The results of the impulse response function suggested that both real housing prices and housing sales were driven up within a short-run period in response to the positive shock of money supply in the US. These responses generally complied with the conventional economic theory (Lastrappe, 2002).

It is noted that Lastrappe's (2002) work concentrated on monetary impact on house prices on a regional level taking advantage of the SVAR. However, Aoki et al. (2002) studied this field within the national context utilising the SVAR as well. Specifically, the research conducted by Aoki et al. (2002) sought to examine the relationship between monetary policy and house prices as well as the consumption level in the UK. In order to fulfil this research requirement, a SVAR using the data on house prices and money supply as well as a short-term interest rate was set up.
for estimation. From the impulse response function generated by the SVAR model, it was reported that house prices responded negatively to an unexpected monetary tightening and 0.8% decrease in house prices was triggered after 50 basis point shock of interest rates within five quarters in the UK (Aoki et al., 2002). Under the monetary contraction, Aoki et al. (2002) claimed that housing investment were more sensitive to the shocks of monetary policy than house prices because the peak negative response occurred in the second quarter.

In addition to the empirical work undertaken by Aoki et al. (2002), Iacoviello’s (2002; 2005) and Iacoviello and Minetti’s (2008) research investigated monetary policy and the housing sector on a national level through the SVAR and VECM respectively. Iacoviello’s (2002; 2005) study on six European countries, involving France, Germany, Italy, Spain, Sweden and the UK, examined the role of monetary policy in the inflation of house prices. Under the identification scheme of King et al. (1991), the results produced by the impulse response function indicated that house prices decreased by 1.5% following a 50 basis point tightening of monetary policies in the European countries under study. On the other hand, the research by Iacoviello and Minetti (2008) uncovered the credit channel of monetary policy of four European countries (e.g. Germany, Finland, Norway and UK). The empirical evidence put forward by Iacoviello and Minetti’s (2008) VECM indicated that 70 basis point interest rate shocks led to an approximately 0.25% fall of economic output (GDP) and 0.7-1% drop of house prices. Accordingly, it can be concluded that there is a bank-lending channel existing in these four European countries.

Recently, a research theme emerged to comprehensively clarify the relationships between the housing market and the transmission mechanisms of monetary policy. For instance, in 2008, an eight-variable SVAR model was established by Elbourne (2008) for the purpose of investigating house prices and a series of monetary transmission mechanisms, such as commodity prices, interbank rates, retail sales,
price level, narrow money supply, nominal market exchange rates and money demand. Evidence from the structural decomposition of the impulse response function indicated that retail sale fell by 0.4% after being influenced by a temporary positive 100 basis shock of short-term interest rates while real house prices fell by 0.75% in response to 12-15% of the drop in consumption following a contractionary monetary policy.

In Australia, the research on the effect of monetary policy on the housing sector is sparse. The Australian studies within the context of this topic arose after the year 2000, involving the research by Costello (2003) and Liu and Liu (2010). The key aim of Costello’s (2003) study was to test house price changes and informational efficiency in Perth’s housing market. However, in this research, a derivative conclusion had been described that the changes in housing loan interest rates appeared to negatively affect the house prices for up to two years in Perth (Costello, 2003). It is known that housing loan interest rates in financial market are strongly influenced by the cash rates controlled by the monetary authority. Hence, the study by Costello (2003) indirectly proved the relationship between monetary policy and the housing sector in Australia.

In 2010, the empirical study undertaken by Liu and Liu (2010) directly studied the interrelationship between monetary policy and the Australian housing sector. This paper investigated the impact of monetary policy on housing affordability in Australia’s eight state capital cities by using the three-variable SVAR models. The shocks of monetary policy in Liu and Liu’s (2010) research were measured by the interbank rates and money supply. The housing affordability was associated with the level of the house prices of eight capital cities. For the purpose of constructing the SVAR, three restrictions in accordance with three hypotheses that are derived from the economic theory were imposed into the model. The empirical results generated by the structural decomposition of impulse response function indicated that an increase in the interbank rates depressed house prices by an average of
1.28% in Australia’s eight state capital cities while the positive changes in money supply resulted in approximately 1.08% increases in house prices. The empirical evidence suggested that there is a strong relationship between monetary policy and the housing sector across the metropolitan areas in Australia (Liu & Liu, 2010). The studies by Costello (2003) and Liu and Liu (2010) suggested the importance of monetary policy in affecting the Australian housing sector.

The existing literature suggests that the VAR models and the impulse response function are the main technique for researchers to empirically identify the impact of the variables (e.g. money supply and interest rates) associated with monetary policy, however a small group of scholars have used other econometric techniques to test the relationship between monetary policy and the housing market (Aoki et al., 2004; Wong et al., 2003). In the research by Aoki et al. (2004), a general equilibrium model rather than a VAR was considered and developed to estimate the relationships amongst monetary policy, house prices and housing investment in the UK from 1970 to 2000. This research was based on a background related to the mortgage market deregulation caused by the British expansionary monetary policy. Benefited from the deregulation, it is much easier and cheaper for customers to gain access to home equity, leading to an increase in the borrowing against housing. This increase not only stimulated the house prices in the British housing market, but also positively influenced the housing investments. Aoki et al. (2004) concluded that the response of housing investment is more sensitive than that of house prices under the British expansionary monetary policy. Moreover, a later study, conducted by Wong et al. (2003), uncovered the role of nominal interest rates in the influence of house prices on the Hong Kong housing market. One of the major differences between this study and those mentioned previously is the introduction of the Granger causality test for modelling. Under the quarterly data on house prices and interest rates over 1981 to 2001, the empirical results indicated that ‘interaction between interest rates and expectations of capital gain or losses play a critical role in the short-run housing prices fluctuations in Hong
It is clear from the literature review related to the interrelationship between monetary policy and the housing sector that the academic studies are basically concerned with the effect of monetary policy on house prices with such variables as GDP and disposable income. These variables are the components of the housing demand function (Quigley, 1999; Hui & Yue, 2006). The research on the linkage between monetary policy and the variables in relation to the supply side of the housing sector is sparse.

The history of the research on the linkage between housing supply and monetary policy can be dated back to the 1950s. An early study by Wolff (1957) aimed to detect the effects of the variation caused by economic characteristics of different regions on the post-war housing market in the US. The focus of this study was on the economic disparities rather than monetary policy, however Wolff (1957) briefly mentioned that the new housing construction in the South and West regions of the US were more sensitive to monetary policy than the remaining US regions, such as Northeast and North Central. In the 1970s, the research by Bebee (1972) divided the Canadian housing markets into five regional markets and analysed the impact of economic disparities measured by the factors, including inter-regional population flows, interest rates, private and public credit costs and availability and the number of households, on the volume of dwelling unit started for construction. According to the results of a simple regression model, it was argued by Bebee (1972) that monetary policies and population growth had significant influences on housing starts in all regional markets in Canada. Furthermore, the research conducted by Vargas-Silva (2008) empirically estimated the impact of monetary policy shocks on the US supply side of the housing market by the SVAR models that follow the identification procedure suggested by Uhlig (2005). The results encouraged Vargas-Silva (2008) to discover that a negative response of housing starts was caused by the shocks of contractionary monetary policy in the US.
Compared with the research on the impacts of monetary variables on housing starts (Bebee, 1972; Vargas-Silva, 2008; and Wolff, 1957), Hwang and Quigley (2006) investigated housing supply with the monetary influences through several relevant variables (e.g. vacancies, house prices and residential construction activities) by a three-equation model. By using the annual data on single-family house over 1975 to 2000, the empirical evidence has suggested the importance of local regulation, such as the regulatory climate in relation to land use and monetary policy targeting the cash rates and mortgage rates, in affecting the supply side of the housing sector (Hwang & Quigley, 2006).

In summary, the studies with respect to the relationship between monetary policy and the housing sector have been well considered under the autoregressive models (e.g. reduced-form VAR, SVAR and VECM). Figure 2-2 illustrates the progress of the research on monetary policy in the context of the housing sector. However, the majority of these studies were concerned with the impact of monetary policy on the variables of the demand side of the housing market (Aoki et al., 2002; 2004; Baffoe-Bonnie, 1998; Costello, 2003; Edelstein & Sau, 2004; Elbourne, 2008; Lastrappe, 2002; Liu & Liu, 2010; Iacoviello, 2002; 2003; Iacoviello & Minetti, 2008; and Wong et al., 2003), while the research in regard to monetary policy as well as housing supply (Bebee, 1972; Hwang & Quigley, 2006; Vargas-Silva, 2008; and Wolff, 1957) is less common. Of the prior papers, Bebee (1972), Vargas-Silva (2008) and Wolff (1957) had just focused on the linkage between monetary policy and housing starts, and Hwang and Quigley (2006) ignored some essential information in the modelling, such as the shock of money supply, the response of other residential dwelling in addition to single-family house and the issues related to the addition and conversion to established housing. Overall, the existing studies (Bebee, 1972; Hwang & Quigley, 2006; Vargas-Silva, 2008; and Wolff, 1957) did not discuss the interrelationship between housing supply and monetary policy within the comprehensive context. The current limited research scope provides this thesis with an opportunity to undertake a further investigation.
Figure 2-2: Map of key research on monetary policy and the housing sector
2.4 Global Event Study

It has been acknowledged that the macroeconomic research on individual regions or countries cannot ignore the impacts of the changes in the global economic climate since the globalization in economy and culture (Joshi, 2009; Sklair, 2002; and Wolf, 2004). Consequently, some empirical research has been developed to estimate the influences of special global events on economic sectors within the context of specific regions since the year 2000.

The studies on the special global event effects primarily used a dummy variable to capture the influences of the observed special events. For example, an empirical work, commenced by Goh (2005), examined the relationship between the Asian financial crisis and construction demand in Singapore. This research installed a dummy variable into the autoregressive moving average model to quantify the dynamic effects of the Asian financial crisis. The empirical results suggested that the repercussion of the construction industry in Singapore to the disturbance of the Asian financial crisis is dramatic and ‘a logical adjustment to fiscal policy would be to increase public spending on construction’ (Goh, 2005, p. 275).

Likewise, Bina and Vo (2007) adopted a Generalized Autoregressive Conditional Heteroskedasticity with a dummy variable to test whether or not the decisions of the OPEC ( Organisation of the Petroleum Exporting Countries) are able to send a shockwave to the global oil market. The overall coefficients of this study identified that the activities and decisions of the OPEC are significant to the fluctuation of global oil prices (Bina & Vo, 2007).

Within the framework of the autoregressive model, a study conducted by Fan et al. (2009) sought to uncover the dynamic linkage between China’s financial sector and international stock markets. To look at the impact of the special events in regard to the international market on the movements in China’s financial market,
a dummy variable was imposed into a vector error correction model. The results suggested that China can be dramatically affected by the international main stock markets in a short-term period (Fan et al., 2009).

In addition to the autoregressive models, the research by Yap and Allen (2010) investigated the leading factors that can influence the Australian domestic tourism demand through a dynamic panel model. A dummy variable had been employed in this study to quantify the effects of the one-off events (e.g. the Bali bombings in 2005 and the Sydney Olympic Games in 2000) on the Australian tourism industry. The $t$-statistics of the dummy variable in the panel model showed that the Bali bombings and Sydney Olympic Games are the identifiable dynamics which had contributed to the domestic tourism demand in Australia (Yap & Allen, 2010).

The implication of this section is that the research in relation to the global event influences has been an emerging theme in the research community. In Chapter 1 Introduction, it was suggested that a global economic disturbance had been caused by some special events over the past decade and the Reserve Bank of Australia had implemented the corresponding monetary policies to deal with the negative impacts of these special events on the Australian economy (RBA, 2001b; 2002; 2008) (The detailed information of global economic turbulence and the responses of Australia’s governmental departments will be specified in Chapter 5 Analysis and Discussion). However, there is a lack of empirical research to detect the relationship between the special events that disturbed the global economic climate and the supply side of the housing sector, particularly in the Australian context.
2.5 Chapter Summary

This chapter has presented a review of the literature associated with the studies that provide this thesis with a theoretical context. In this literature review, three research themes have been explored, including the studies on housing supply, the research relevant to the relationship between monetary policy and housing, and the detection on the disturbances of global special events to economic sectors.

The review of the prior research on housing supply explicitly revealed that the studies regarding the supply of housing are not sufficient in literature. It can be summarised that the early research published in the field of housing supply primarily focused on the linkages between housing starts and the price or cost factors. Since the end of the 1990s, more and more scholars have begun to test the impacts of policies on housing supply. However, the majority of them were concerned with land policies, tax policies and housing affordability policies, but few in relation to monetary policy. This finding is also supported by the critical review of the monetary policy literature. The studies on monetary policy and the housing sector focused on the issues in the housing demand dimension, but less attention has been paid in identifying the comprehensive relationship between the supply side of the housing sector and the adjustments in monetary policy. In addition, the final section of the review of literature further discovered a research gap related to the impacts of global special events on Australia’s housing supply. Thus, there is a lack of the literature that analyses the housing supply changes within the context of monetary policy shifts and global economic turmoil. As a result, a research question:

- What is the interrelationship between housing supply and monetary policy within the context of global economic turbulence?

has been addressed from this literature review.
CHAPTER 3 CONCEPTUAL MODEL
3.1 Chapter Introduction

To comprehensively explore the interrelationship between housing supply and monetary policy within the context of global economic turmoil, one of the key steps proposed in this thesis is to develop a conceptual model relating the monetary policy function and housing supply function. These two functions will allow housing supply and monetary policy to be investigated through a series of relevant economic variables. In simple terms, the economic variables displayed in the functions will be selected as the indicators that represent the changes in monetary policy and the supply of housing. The linkage between monetary policy and housing supply is then able to be observed by modelling and identifying the interactions amongst the indicators. Figure 3-1 illustrates this research strategy in a simplified manner.

![Figure 3-1: Strategy of the study on housing supply and monetary policy](image)

This chapter will be divided into the following three sections: 1) *Indicators of Monetary Policy in Australia*; 2) *Indicators of Housing Supply*; and 3) *Econometric Principles*. The discussion of this chapter assists in establishing a conceptual foundation for the further empirical modelling undertaken in *Chapter 5 Analysis and Discussion*. 
3.2 Indicators of Monetary Policy in Australia

Monetary policy, as discussed previously, is an important tool that bridges government and economic sectors. It is generally defined as a process by which the central bank or monetary authority of a country controls inflation and moderates the business cycle by changing the quantity of money in circulation and adjusting interest rates (McTaggart et al., 2003). In Australia, monetary policy is determined and implemented by the Reserve Bank of Australia in accordance with the Reserve Bank Act 1959, Bank Act 1959 and Financial Corporations Act 1974, aiming to control inflation, stable currency, improve full employment and then maintain economic prosperity and people’s welfare (RBA, 2007c). The Reserve Bank of Australia is Australia’s central bank that is a public authority responsible for regulating and controlling monetary and financial institutions and markets in Australia. There are several monetary policies around the world, including inflation targeting, price level targeting, monetary aggregate, exchange rate targeting, and mixed policies. According to the statement of the RBA (2007a), an inflation target is the centerpiece of the Australian monetary policy framework.

As a country where the inflation-targeting monetary policy is implemented, the adjustment in the cash rates for money market is a key instrument for policy makers. The cash rate is the ‘interest rate that brings the supply and demand for overnight funds or exchange settlement funds into equilibrium and since 1990 the Reserve Bank has announced the desired stance on monetary policy by announcing the target it wants to achieve for the cash rate’ (McTaggart et al., 2003, p. 587). If a tightening monetary policy will be operated, the RBA announces a higher cash rate, and a lower cash rate is announced if a looser monetary policy will be conducted. Influenced by this type of government’s regulatory behaviour, real interest rates in capital market will be changed. Figure 3-2 depicts the transmission of monetary policy to economy. The changes in the cash rates, which can be controlled under the monetary authorities, will be
transited quickly to other real interest rates in capital markets, including money market rates and bond yields. The movement in real interest rates will affect various economic activities, such as saving and investment behaviour, the households’ consuming behaviour, the supply of credit and asset prices, all of which bring impacts on the aggregate of demand associated with various economic activities and price expectations. In turn, the changes in the demand aggregates, integrated with supply aggregate development, will positively or negatively affect the price level in the economy and then the development of a variety of economic sectors (RBA, 2007a).

![Diagram of monetary policy transmission](source: RBA, 2007a)

Figure 3-2: Transmissions of monetary policy

Although Australia is a country with the inflation-targeting monetary policy, the money supply will also be introduced as an estimated variable into the model of this study because interest rates and money supply are inextricably interrelated. There is a significant effect of money supply on macroeconomy and the housing sector, all of which have been discussed in the literature review in Chapter 2. In Australia, a single tool left for the RBA after the removal of all direct controls on financial markets in the 1980s to achieve its objective is an open market operation (OMO). The OMO is a method used to change interest rates through the purchase or sale of Commonwealth government securities (CGS – Treasury bills and bonds) issued by the Treasury. The Reserve Bank operates the CGS transactions utilising the exchange settlement funds (ESF), by which banks settle transactions among themselves (RBA, 2010). The ESF are held in the ES accounts at the RBA by commercial banks and other financial institutions. When selling the CGS, the Reserve Bank is ultimately paid by the deposits of commercial banks in the ES
account, leading to a decrease in commercial banks’ reserves (money aggregates). Then, a tighter monetary and credit condition will be triggered and banks will cut their lending. Thus, interest rates will be driven up. Conversely, when the RBA buys the CGS, the balances of the ES account of banks will be raised by the payments from the central bank. As a result, interest rates will be lowered. As stated by McTaggart et al. (2003, p. 587), ‘open market operations are undertaken by the RBA to control or influence interest rates’. The description on the OMO reflects that money supply plays an active role in the operations of monetary policy in Australia.

The claim that money supply has an essential role in the implementation of monetary policy can be further supported by the empirical research by Koenig (1990), Meltzer (2001) and Nelson (2002; 2003). These studies argued that real base money growth is a significant determinant of economic output and the control towards real interest rates. Hence, it is rational to introduce money supply into the analysis on the impact of monetary policy on the housing sector (Liu & Liu, 2010). To conclude, the function of the Australian monetary policy can be expressed as Eq. (1).

\[ MP_{AUS} = f(IN, MS) \]  

(1)

where \( IN \) represents interest rates; and \( MS \) stands for money supply. In summary, the monetary function shown in Eq. (1) can be viewed as a monetary entity in Australia. This function has been empirically validated by Liu and Liu’s (2010) study for the impact of monetary policy on housing affordability in Australia. The results of Liu and Liu (2010) are consistent with the justification of conventional macroeconomic theory regarding the monetary policy impact. Therefore, studying Australia’s monetary policy by Eq. (1) is reliable.

### 3.3 Indicators of Housing Supply

A fundamental principle in economics argues that the movements in market
fundamentals in a competitive market, such as prices, are stimulated by the change in the equilibrium of the supply of and demand for specific commodities (Smith, 1976; Gans et al., 2003). This theory can be characterised by:

\[ P_u = f(Q_u^d, Q_u^s) \]  

(2)

where \( P_u \) represents the prices of specific commodity; \( Q_u^d \) and \( Q_u^s \) are the quantities of the commodity that are demanded and supplied. Similarly, in housing markets, housing supply and housing demand are two important dynamics.

Mankiw and Weil (1989) first forecasted the house prices of the U.S. by a model which viewed the impacts of several demographic fundamentals as the effects of the supply of and demand for houses. Depending on Mankiw and Weil's (1989) models, it was claimed that the turning point of house prices in metropolitan areas of the US would come up in 2007. Since Mankiw and Weil's (1989) research, more and more studies (Case and Mayer, 1995; Clapp and Giaccoto, 1994; Dua et al., 1999; and Smith and Ho, 1995) have concentrated on using economic variables other than demographic variables to predict the changes in house prices in different regions.

During 1997, the study by Quigley and Redfearn (1997) established a quantitative description on the economic conditions for the housing markets across 41 U.S. metropolitan areas over a fifteen-year period. The data Quigley and Redfearn (1997) gathered from a variety of sources incorporated population, employment, income, housing starts, vacancy rates, and mortgage activities. Based on this study, Quigley (1999) eventually summarised that housing demand is able to be viewed as a function composed of house prices, income, population growth rates and aggregate employment, and the total housing supply is a function of house prices, total stock of vacant dwellings in the housing market (or vacancy rates) and new housing construction flow. These two functions can be written as Eq. (3) and (4).

\[ Q_u^d = f(HP, INC, POP, EMP) \]

(3)
\[ Q^d_{it} = f(HP, VAC, Const) \]  \hspace{1cm} (4)

Here \( Q^d_{it} \) and \( Q^s_{it} \) denote the quantities of housing that are demanded and supplied respectively; \( HP \) is house prices; \( VAC \) is vacancy rates or vacant dwellings available in housing market; and \( Const \) represents new housing construction. The Eq. (3) will not be included for modelling in the analytical sections as this thesis will focus on housing supply, rather than housing demand.

Hui and Yue (2006) adapted Quigley’s (1999) two functions and estimated four vector error correction models and a multiple regression model to examine the real estate bubbles in Hong Kong, Shanghai and Beijing between 1990 and 2003. According to the empirical results of the Granger causality tests as well as the generalized impulse response and the comparison between actual house prices and predicted house prices, Hui and Yue (2006) identified that the sustainable bubbles of real estate markets existed in Hong Kong and Shanghai and there was no bubble in Beijing. As a real housing bubble emerged and burst in Hong Kong during the period under study, the reliability of their econometric models and Quigley’s (1999) conceptual model with regard to the indicators of housing supply and housing demand have been empirically supported.

The housing supply function proposed by Quigley (1999) has been tested by Hui and Yue (2006), however it does not mention the variable of residential construction costs. Somerville (1999) maintained that housing supply and residential construction costs are inextricably interrelated, and the costs of residential construction are the endogenous variables of the housing supply function. Furthermore, Liu and London (2011) proved that there is a strong relationship between housing supply and residential construction costs in Australia. Therefore, residential construction costs should be included in the housing supply function. Although the construction of completely new dwellings is the leading source of the increase of total housing stock, the conversion and
addition to established housing are also an important dynamic on the supply side of the housing sector in some countries, such as Australia, UK and US (Baer, 1986). However, this issue has not been addressed in the previous housing supply modelling either. Thus, the function of housing supply should be rewritten

$$Q_{it} = f(HP, Cost, VAC, Const^T)$$  \hspace{1cm} (5)

Herein Cost is the construction costs triggered in housing production; and Const$^T$ denotes the flow of new housing construction, including the completely new dwellings and the residential units produced from the addition and conversion of established housing.

The discussions in Section 3.2 and 3.3 demonstrated that the impact of monetary policy can be rationally identified by estimating the effects of interest rates and money supply; and house prices, vacancy, residential construction costs and new housing construction are four indicators of the supply side of the housing sector. As a result, the relationship between housing supply and monetary policy can be derived by investigating the interactions among the variables in Eq. (1) and (5). Besides, to quantify the impact of global economic turmoil caused by some special events on the supply side of the housing sector, an exogenous variable EX$^{GE}$ isolated from the endogenous variables in the functions shown as Eq. (1) and (5) will be developed. The specification on this exogenous variable will be described in Chapter 4 Methodology and Data Collection and Chapter 5 Analysis and Discussion. Figure 3-3 explicitly illustrates the conceptual mode developed in this chapter.
3.4 Econometric Principles

Using econometric modelling to study the housing sector is a well accepted approach and there are numerous empirical studies to support this idea. To understand and analyse housing supply over a period, econometric time-series technique is quite a common practice. Consequently, the time-series models are the technique employed in this study. Some conceptual principles associated with the time-series econometric modelling will be presented in the following parts of this section, involving the stationarity, vector autoregression model, cointegration, Granger causality and impulse response function. Figure 3-4 explains the basic procedure of the vector autoregressive analysis.
3.4.1 Stationarity of Time-Series Economic Variables

Stationarity is an important concept for the time-series estimation. This is because the stationarity of data is highly related to the reliability of regression outcomes in various empirical studies. Granger and Newbold (1974) and Phillips (1987b) claimed that there is a possibility of spurious regression if the data used are not stationary. The condition of stationarity indicates that the mean value, the variance
and the auto covariance at different lags of each single data series are invariant over time. However, in reality, the majority of the economic time-series data are non-stationary in the level form and their variances change over time (Nelson & Plosser, 1982; Meese & Singleton, 1983; DeJong & Whiteman, 1991).

Owing to the presence of a large number of non-stationary data in real economic system, many researchers other than Granger and Newbold (1974) and Phillips (1987b) have provided insight into the implications of the situation of non-stationarity (Engle and Granger, 1987; Fuller, 1976; Granger, 1981; Hendry, 1986; Nelson and Kang, 1982; Phillips, 1987a; Phillips and Perron, 1988 and Sargan and Bhargava, 1983). Depending upon these studies, the non-stationary data can be defined as a high level of the series correlation. It has been argued that the non-stationary data are able to result in misleading outcomes because of a lack in finite definition on the restricting distribution of the asymptotic variance of the parameter estimations (Fuller, 1985; Hendry, 1986).

The stationarity of the data can be detected and identified by the unit root test, which is the first step for the time-series econometric modelling. Theoretically, if the underlying data series have at least one unit root, then this data series will be viewed as a non-stationary time series. Conversely, a data series can be treated as the stationary data if no unit root exists in the series. Numerous studies have contributed to the development of unit root tests (Dickey, 1976; Dickey and Fuller, 1979; 1981; and Phillips & Perron, 1988). Then, the Dickey-Fuller (DF) test, Augmented Dickey-Fuller (ADF) test and the Phillips-Perron test (known as the PP test) were formulated and these tests are widely applied in current empirical research. According to the overview on these three unit root tests, the PP non-parametric test method expresses a better performance than the DF and ADF tests because the Dickey-Fuller system is based on a limited hypothesis that error process is independent and identically distributed (iid) when the underlying data series presents heteroscedasticity and non-normality in the original data. As
discussed previously, the studies on macroeconomy usually face non-stationary variables, such as prices, costs, incomes, consumptions, money supply and trade flows. Thus, a practical solution for the empirical research in relation to economic data is making a first differenced regression because most of non-stationary raw economic data can be stationary after taking the first difference (Greene, 2000). In mathematics, the relationships between the data on level can be derived after the first difference.

3.4.2 Vector Autoregression and Cointegration

Using differencing is one of the appropriate ways to manipulate the data series that are non-stationary. If two or more variables are non-stationary in level but both stationary in the first difference form, it can be expressed that these variables are \( I(1) \). After taking the first difference, the vector autoregression (VAR) model as well as cointegration can be applied for further analysis.

Figure 3-3 explicitly reveals that the Granger causality test and the impulse response function are two core components of the vector autoregressive systems. In addition, the literature review has clearly demonstrated that the VAR models are a widely-used approach to empirically identify the shocks of monetary policy. Thus, applying the VAR technique is an ideal way to meet the primary research aim of this thesis. Since the development by Sims (1980) in the 1980s, VAR models have been primarily used in the macroeconomic research. It was argued by Sims (1980) and Litterman (1986) that the forecasting performances of the VAR are superior to that of the large structural equation model (models built on a theoretical foundation) which was widely utilised during the period of the 1950s and the 1960s. In reality, this type of simultaneous equations model had to run a large number of equations with plenty of restrictions, resulting in the difficulties in interpretation. However, the principal assumption of the VAR methodology claims that the behaviour of a macroeconomic variable relies on the information inside the data series rather than the prior theoretical framework. Therefore, 'one
of the virtues of the VAR is that it obviates a decision as to what contemporaneous variables are exogenous; it has only lagged (predetermined) variables on the right-hand side, and all variables are endogenous’ (Greene, 2000, p. 741). In short, the principles of the VAR methodology do not comprise a priori endogenous or exogenous, zero restrictions and strict economic theory (Charemza & Deadman, 1997). Sargent (1979) considered the VAR to be a practical alternative for the structural economic models because the exclusion of some redundant restrictions in traditional simultaneous equations model would remediate the problems that some restrictions may not be an accurate outcome from the right economic theories.

According to Figure 3-3, the Granger causality test and the impulse response function are able to be operated in both the reduced-form VAR and the vector error correction model. The VECM is a VAR model incorporating cointegration and error correction term (Engle & Granger, 1987), and one of the purported advantages of recognising cointegration in the autoregressive system is the improvement in forecasting performance (Engle & Yoo, 1987). Within the framework of econometrics, cointegration, which was first proposed by Granger (1981), is another important way to analyse the relationship amongst non-stationary variables other than the VAR. As claimed by Granger (1981), a linear combination of two or more non-stationary series may be stationary. Cointegration implies two or more non-stationary variable share a common moving trend within a long-term period. It is a concept reflecting the long-run equilibrium relationship between the observed variables. In econometrics, cointegration can be detected by two types of tests, one is the test based on the methodology of Engle and Granger (1987) and the other is the test proposed by Johansen (1988) and systemically developed by Johansen and Juselius (1990). The methodology of Johansen and Juselius (1990) was constructed on the basis of the vector autoregressive models. The approach of Engle and Granger (1987) is normally called Engle-Granger’s two step method in the academic community,
which depends on the unit root tests for the residuals generated by the ordinary least squares regression on two level-form variables. If the residuals yielded by the common regression are stationary in level after running the ADF test or PP test, it is reliable to conclude that these two variables are co-integrated. In reality, the EG approach is a pairwise cointegration test. On the contrary, Johansen and Juselius’s (1990) method, known as the JJ test, is a multivariate cointegration test depending upon the outcomes of the VAR model. There are five models in the JJ test: Model 1 represents no deterministic trend and no intercept as well as no trend in the cointegration equation (CE); Model 2 assumes no deterministic trend but has an intercept (no trend) in the CE; Model 3 has a linear data trend with an intercept but no trend in the CE; Model 4 has a linear data trend with both an intercept and a trend in the CE; Model 5 allows for quadratic deterministic trend with both an intercept and a trend in the CE.

3.4.3 Granger Causality Test and Impulse Response Function

The Granger causality test and the impulse response function are two key techniques for exploring the causal relationships and dynamic interactions among variables. Firstly, Granger causality is a statistic concept proposed by Granger (1969) in the 1960s and it is entirely based on the predictability of $X$. The basic definition of Granger causality depends on a simple assumption. Suppose that there are three terms, $X_i$, $Y_i$ and $W_i$ ($W_i$ is a vector of possible explanatory variable), and that Granger (1969) first attempted to forecast $Y_i$ taking advantage of the lagged terms of $Y_{t-1}$ and $W_{t-1}$. After obtaining the result, the forecast of $Y_i$ was run again by using the lagged terms of $Y_{t-1}$, $X_{t-1}$ and $W_{t-1}$. If the second forecast with an extra lagged value of $X_{t-1}$ exhibits a better predictable performance than the first forecast that incorporates only $Y_{t-1}$ and $W_{t-1}$ in accordance with the standard cost function, the lagged term $X_{t-1}$ appears to contain valuable information helping in forecasting $Y_i$ which is not included in $Y_{t-1}$ and $W_{t-1}$. Once the condition presented as the second forecast were fulfilled, it is concluded that $X_{t-1}$ Granger causes $Y_i$. 
The definition of the Granger causality entirely relies on the perspective that the causation $X$ occurs before the predictable variable of $Y$. As a result, the Granger causality test is a statistic technique developed to examine whether or not the lagged values of a time-series variable $X$ have explanatory power to the movement in the other time-series $Y$. In the 1970s, Sims (1972) integrated the Granger causality test into the vector autoregressive framework. Hence, the test for the Granger causality has been able to be implemented in the VAR and it has been applied widely in the macroeconomic research. However, the causal relationships would be misspecified by the reduced-form VAR if the observed variables are co-integrated (Engle & Granger, 1987; Hui & Yue, 2006). As pointed out by Engle and Granger (1987), the test for Granger causality between co-integrated variables should be carried out with the vector error correction system to avoid the misspecification. With the practicability of Granger causality in the VAR, the application of it has become popular since the 1980s. The details of the statistical test for the Granger causality under the VECM will be described in Chapter 4 Methodology and Data Collection.

As mentioned in Section 3.5.2, one of the masterpieces of the VAR model is the estimation based on the impulse response function. Econometric theory suggests that the vector autoregressive framework is one type of the models without strict theoretical or priori restrictions. Thus, in practice, the analysis for the VAR models should not focus on examining or investigating the effects of the changes in one variable on other variables, but be concerned with the responses of the system to a shock triggered by changing one of the error terms for one period (Greene, 2000). To fulfil this analytical strategy, the impulse response function (IRF) has been created and applied widely. ‘An impulse response function traces the effect of one standard deviation shock to one of the innovation on current and future values of the endogenous variables in a VAR (VEC) model’ (Hui & Yue, 2006, p. 311). The principle of the impulse response function describes that a shock towards the $i$-th variable in a VAR can not only directly influence the $i$-th
variable itself, but also be transited immediately to all other endogenous variables within this VAR via the dynamic structure of the system. Summarily, 'an impulse response function measures the time profile of the effect of a shock on the behaviour of a series' (Koop et al, 1996, p. 120). Accordingly, the impulse response function is normally applied to trace the dynamic interactions between the endogenous variables in theVAR.

3.5 Chapter Summary

The purpose of this chapter was to develop a conceptual model to investigate the impacts of monetary policy as well as global economic vibrations on the supply of housing in Australia. As a result, an analytical strategy was developed for this research to demonstrate that the empirical research in relation to the interrelationship between housing supply and monetary policy in Australia can be achieved by examining and identifying the causal and dynamic links between the relevant economic variables within the framework of the housing and money market. Within this strategy, two functions were developed in this chapter: one is the monetary policy function that comprises interest rates and money supply, and the other is the function of housing supply composed of house price, residential construction costs, vacant dwellings available in housing market and new housing construction. Furthermore, an exogenous variable will also be established to capture the influence of global economic turmoil on housing supply in Australia.

In the final section of this chapter, due to the key role of time-series econometric methods in this research, a series of conceptual principles associated with econometric modelling, including the stationarity, vector autoregression, cointegration, Granger causality and impulse response function, have been introduced. All of these components of the conceptual methodology underpinning the VAR analysis have been summarised in the econometric flow chart in this chapter. The following chapter will specify the mathematical formulations of the techniques used in this research in detail.
CHAPTER 4 METHODOLOGY AND DATA COLLECTION
4.1 Chapter Introduction

The fundamentals of the econometric approach used in this research have been introduced conceptually in Chapter 3 Conceptual Model. In this chapter, the mathematical formulations of these techniques, including the ADF and the PP unit root tests, the multivariate cointegration test, the vector error correction model, the Granger causality test, and the generalized impulse response function, will be specified in detail. As the important prerequisites of the construction of the vector error correction model and the core role in analysis, the descriptions on the cointegration test, the Granger causality test and the generalized impulse response function under the vector error correction model will be more detailed.

After introducing the econometric techniques that will be adopted in this study, this chapter will continue describing the data which must be imported for modelling. The specification and discussion on the data will be divided into two parts, the first one is the data collection and the second one is the data description. Data collection is an important part that articulates what data will be selected for modelling, the characteristics of the data and where the data are available in Australia. In the section on data description, the changes and moving trends of the observed variables during the sample period will be specified in details. From the data description, the nature of the data selected can be identified.

4.2 Unit Root Tests – the ADF Test and the PP Test

According to Figure 3-3 in Chapter 3 Conceptual Model, the stationarity of the time-series data utilised is significant to vector autoregressive analysis. If the data imported are non-stationary, the results generated by the regressive model will be not reliable due to a possibility of spurious regression (Engle & Newbold, 1974; Phillips, 1987a). However, econometric modelling based on the time-series approaches for the realistic economic variables always face a challenge from non-stationary data. Thereby, such studies as Dickey (1976), Dickey and Fuller...
(1979) and Phillips and Perron (1988), which have been mentioned in Chapter 3 Conceptual Model, focused on how to test the stationarity of time-series data and have contributed to the establishment and application of three well-known unit root tests – the DF test, the ADF test and the PP test.

In statistics, the time-series data stationarity can be identified through examining whether the underlying series has a unit root. Although the DF test, ADF test and PP test are all the methods for testing the unit roots, this thesis will rely on the ADF test and the PP test because of their higher performances than the DF test in practice (Dickey & Fuller, 1979; Phillips & Perron, 1988). As proposed by Dickey and Fuller (1979), firstly, there are three forms of ADF test, which are expressed from Eq. (6) to (8).

\[ \Delta Y_t = \delta Y_{t-1} + \sum_{j=1}^r \beta_j \Delta Y_{t-j} + \epsilon_t, \]  
\[ \Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{j=1}^r \beta_j \Delta Y_{t-j} + \epsilon_t, \]  
\[ \Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + \sum_{j=1}^r \beta_j \Delta Y_{t-j} + \epsilon_t. \]  

Secondly, similar to the ADF test, the PP test has three forms as well which can be written as the following equations from Eq. (9) to (11) (Phillips & Perron, 1988).

\[ \Delta Y_t = \delta Y_{t-1} + \mu_t, \]  
\[ \Delta Y_t = \alpha + \delta Y_{t-1} + \mu_t, \]  
\[ \Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + \mu_t, \]

where \( Y_t \) is a time series and \( \Delta Y_t \) is the data series \( Y_t \) in the difference form; \( i \) is the lagged term of each variable, and \( Y_{t-i} \) denotes the \( i \)-th lagged term corresponding to the \( Y_t \); \( \epsilon_t \) and \( \mu_t \) represent the residual series of ADF and PP unit root test models respectively; \( \alpha \) stands for a non-zero drift; and \( \beta^*t \) are a deterministic trend.

The hypothetical tests for the ADF test and the PP test are similar and shown as
$H_0 : \delta = 0$

$H_1 : \delta < 0$ \hfill (12)

Here $H_0$ is the null hypothesis which assumes that the time series under study contains a unit root, and the $H_1$ is the alternative hypothesis indicating that there is no unit root in the time series. Under this hypothesis test, Eq. (6) and (9) contain no intercept and trend and both of them imply that $Y$ is a stationary time series with non-zero mean if the null hypothesis is rejected. Similarly, Eq. (7) and (10) comprise a non-zero drift but no trend, which means that $Y$ is a stationary time series with non-zero mean if the null hypothesis is rejected. Finally, Eq. (8) and (11) include non-zero drift and deterministic trend. Thus, in Eq. (8) and (11), $Y$ is a stationary time series with non-zero mean and a deterministic trend if the null hypothesis is rejected.

4.3 Multivariate Cointegration Test – the JJ Test

Johansen and Juselius’s (1990) methodology is a multivariate cointegration test first proposed by Johansen (1988) in the 1980s. It takes a starting point in a VAR with $p$ order expressed by:

$$ y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + \Theta D_t + \varepsilon_t, (t=1,2,\ldots,T) $$ \hfill (13)

where $y_t$ is a $k$-dimensional vector of non-stationary variable that is integrated at the first difference level $I(1)$; $\Theta D_t$ is a $k$-dimensional exogenous vector; and $\varepsilon_t$ denotes a vector of error innovations with $k$ dimensions as well. Then, this VAR can be rewritten as a vector error correction form of Eq. (14).

$$ \Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Theta D_t + \varepsilon_t $$ \hfill (14)

where

$$ \Pi = \sum_{i=1}^{p} A_i - I \quad \text{and} \quad \Gamma_i = - \sum_{j=1}^{i} A_j $$ \hfill (15)

Johansen (1988) claimed that the coefficient matrix $\Pi$ contains reduced rank $r$ and $r < k$. Then, there are presences of two $k \times r$ matrices $\alpha$ and $\beta$, both of which has rank $r$ fulfilling the conditions that $\Pi = \alpha \beta^T$ and $\beta' y_t$ is stationary.
Here $r$ is the number of cointegration relationship; $\alpha$ is viewed as the adjustment parameters in the VECM; and assuming $r(\alpha) = r$ and $r(\beta) = r$.

Thereby, the Eq. (15) was rewritten by Johansen (1988) as follows.

$$\Delta y_t = \alpha \beta y_{t-1} + \sum_{i=r+1}^{\infty} \Gamma_i \Delta y_{t-i} + \Theta D_t + \epsilon_t$$

(16)

where each column of $\beta$ is a cointegration vector. With the given $r$, the maximum likelihood estimator of $\beta$ determines the combination of $y_{t-1}$ that produces $r$ largest canonical correlations of $\Delta y_t$ and $y_{t-1}$ after correcting for the lagged differences and deterministic variables. According to the outcomes above, two types of likelihood ratio tests for the significances of these canonical correlations were proposed and developed by Johansen (1988) and Johansen and Juseliu (1990): the trace test and the maximum eigenvalue test. They are given by

$$J_{tr} = -T \sum_{i=r+1}^{\infty} \ln(1 - \hat{\lambda}_i)$$

(17)

$$J_{max} = -T \ln(1 - \hat{\lambda}_{r+1})$$

(18)

where $T$ is the sample size and $\hat{\lambda}_i$ is the $i$-th largest canonical correlation. The trace test, firstly, examines the null hypothesis of $r$ cointegrating vectors as well as the alternative hypothesis in relation to $n$ cointegrating vectors. Secondly, the maximum eigenvalue test examines the null hypothesis of $r$ cointegrating vectors with the alternative hypothesis of $r+1$ cointegrating vectors. As mentioned in Chapter 3 Conceptual Model, there are five models for the JJ test. They are:

1. The $y_t$ has no trend and no intercept as well as no trend in the CE:

$$\Pi y_{t-1} + \mu = \alpha \beta y_{t-1}$$

(19)

2. The $y_t$ has no trend and the CE has no trend but an intercept:

$$\Pi y_{t-1} + \mu = \alpha (\beta' y_{t-1} + \rho_s)$$

(20)

3. The $y_t$ has linear trend and the CE has an intercept but no trend:
\[ \Pi y_{t+1} + \mu = \alpha (\beta y_{t-1} + \rho_o) + \alpha \perp \gamma_o \]  
(21)

(4) the \( y_{t} \) has linear trend and there is an intercept and trend in the CE:

\[ \Pi y_{t+1} + \mu = \alpha (\beta y_{t-1} + \rho_o + \rho_t) + \alpha \perp \gamma_o \]  
(22)

(5) the \( y_{t} \) has quadratic trend and there is only trend in the CE:

\[ \Pi y_{t+1} + \mu = \alpha (\beta y_{t-1} + \rho_o + \rho_t) + \alpha \perp (\gamma_0 + \gamma_t) \]  
(23)

### 4.4 Vector Error Correction Model

The vector error correction model, known as the VECM, is an econometric model proposed by Engle and Granger (1987) which involves the integration of the autoregressive and error correction representations into the co-integrated systems. In summary, the VECM is a vector autoregressive model with the co-integrated restriction and the error correction term. In Chapter 3 Conceptual Model, it was explained that the advantage of recognising cointegration into the autoregressive system is the improvement in forecasting performance and the avoidance of misspecification on the results (Engle & Yoo, 1987). The form of the VECM (\( p \)) can be written as follows.

\[ \Delta Y_t = \alpha \beta' Y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-i} + \epsilon_t \]  
(24)

\[ \Delta Y_t = \alpha ecm_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta Y_{t-i} + \epsilon_t \]  
(25)

Here \( \Delta Y_t \) stands for a vector in difference level with \( k \) dimensions; \( ecm_{t-1} = \beta' Y_{t-1} \) denotes the error correction term, which represents the long-run equilibrium relationship between variables; \( \Gamma_i \) is the coefficient matrices; and \( \epsilon_t \) is a \( k \)-dimensional vector of error term. The VECM is a model applicable for identifying the causal links and dynamic interactions between variables by the Granger causality test and the impulse response function (Liu & London, 2010).

In this research, a dummy variable will be imposed as an exogenous variable to the VECM to capture the effect of the exogenous variable of \( EX^{GE} \) in the
conceptual model. Statistically, the dummy variable is a variable that takes the values 1 or 0 to indicate the occurrence of special events, such as the Olympic Game, global financial crisis and war and so on. If a special event occurs in the $i$-th period, the values of this period will be represented as 1 and otherwise 0. Then, a VEC-D model (a VECM with a dummy variable) can be represented as Eq. (26). The use of dummy variable can increase the model fit. The VEC-D model has been previously adopted for analyzing the financial sector (Fan et al., 2009) and now it shall be borrowed and applied in the housing research.

$$\Delta Y_i = \alpha \text{ecm}_{t-1} + \sum_{i=1}^{m_i} \gamma_i \Delta Y_{i-i} + \delta D_i + \epsilon_i$$  \hspace{1cm} (26)$$

where $\Delta Y_i$ is a vector of parameters in difference level, and it is related to interest rates, money supply, house prices, residential construction costs and new housing construction in this study; $\text{ecm}$ is the error correction term; $\epsilon_i$ stands for a vector of error term; $D_i$ represents a dummy variable; and $\delta$ is the coefficient of dummy variable. The importance for imposing a dummy variable and the detailed formulation of the dummy variable installed into the VECM will be explained in next chapter.

4.5 Granger Causality Test under Vector Autoregression

The Granger causality is a concept proposed by Granger (1969) in the 1960s and Sims (1972) developed the test for this type of causality under the vector autoregressive framework. Generally, the Granger causality test is used to examine whether or not lagged values of a time-series variable $X$ have explanatory power for the movement in the other time-series variable $Y$. If the changes in the $Y$ can be explained by the lagged information of $X$, it is concluded that $X$ Granger causes $Y$. For example, the Granger causality test could be used to examine whether the monetary policy variables Granger cause the changes in the housing supply indicators in Australia over a specific period.

The test of Granger causality developed by Sims (1972) is based on simple $F$-tests
in the VAR models. To illustrate this test, a bivariate reduced-form VAR (p) should be built up and displayed as Eq. (27) (Gao, 2009; Greene, 2000).

\[
\begin{pmatrix}
Y_t \\
X_t
\end{pmatrix} = \begin{pmatrix}
a_0 \\
0
\end{pmatrix} + \begin{pmatrix}
a_{11}^{(0)} & a_{12}^{(0)} \\
a_{11}^{(q)} & a_{12}^{(q)}
\end{pmatrix} \begin{pmatrix}
Y_{t-q} \\
X_{t-q}
\end{pmatrix} + \cdots + \begin{pmatrix}
a_{11}^{(r)} & a_{12}^{(r)} \\
a_{11}^{(r)} & a_{12}^{(r)}
\end{pmatrix} \begin{pmatrix}
Y_{t-r} \\
X_{t-r}
\end{pmatrix} + \begin{pmatrix}
\epsilon_v \\
\epsilon_u
\end{pmatrix}
\]  

(27)

If and only if coefficient \( a_{12}^{(q)} = 0 \) in the coefficient matrices, the lagged values of variable \( X \) have no explanatory power for \( Y \). This implies that \( X \) can not Granger cause \( Y \) and it is exogenous to the system. Accordingly, the most appropriate solution for estimating the Granger causation is applying the \( F \)-test to examine the following joint hypothetical test.

\[ H_0: a_{12}^{(q)} = 0, \quad q = 1, 2, \ldots, p \quad (X \text{ do not Granger cause } Y) \]

\[ H_1: \text{There is at least one } q \text{ in the system causing } a_{12}^{(q)} \neq 0 \]

The statistics of the test is indicated as follows

\[
S_i = \frac{(RSS_i - RSS_o)}{RSS_o / (T - 2p - 1)} \sim F(p, T - 2p - 1)
\]

(28)

where \( S_i \) follows the \( F \)-distribution; \( RSS_i \) stands for the residual sum of the squares of the \( Y \) equation in Eq. (27); and \( RSS_o \) denotes the residual sum of the squares of the \( Y \) equation without variable \( X \). The \( RSS_i \) and \( RSS_o \) can be rewritten by

\[
RSS_i = \sum \hat{\epsilon}_i^2
\]

(29)

\[
RSS_o = \sum \hat{\epsilon}_o^2
\]

(30)

If \( S_i \) is larger than the critical values of \( F \)-distribution, the null hypothesis (\( H_o \)) of the joint hypothetical test above will be rejected, implying that \( X \) Granger cause \( Y \). Otherwise, the null hypothesis will be accepted.

Since the 1990s, some research attempted to test the Granger causality within a vector autoregressive system with the cointegration because there is an existence of misspecifications of the reduced-form VARs when the observed variables are
co-integrated (Toda and Yamamoto, 1995; Yamamoto and Kurozumi, 2006; and Rajaguru and Abeyesinghe, 2008). Thus, the Granger causality test aforementioned is able to be carried out under the framework of the VECM.

4.6 Generalized Impulse Response Function

The impulse response function is utilised to trace out the systematically dynamic effect of a shock of the error term of an endogenous variable to other variables in the VAR or VECM. The conceptual model has demonstrated that the IRF is one of the core analytical components of vector autoregressive systems. Koop et al. (1996) developed the traditional IRF and created a unified approach to impulse response analysis which is applicable to both linear and nonlinear models. This is the generalized impulse response function (GIRF). A summary of key equation of the GIRF is now explained. To understand the GIRF, a VAR \((p)\) must be first presented.

\[
X_t = \Phi D_t + \sum_{i=1}^{p} \Pi_i X_{t-i} + \varepsilon_t, \quad t = 1, \ldots, T,
\]

where \(X_t\) stands for a vector with \(p\) dimensions; \(D_t\) is a vector with deterministic variables; \(\varepsilon_t\) denotes a vector of error term with \(p\) dimensions and it is assumed to be independent and identically distributed with zero mean and positive definite covariance matrices \(\Omega\).

The \(h\)-steps ahead forecast error for \(X_t\) is written by Koop et al. (1996) as

\[
X_{t+h} - E[X_{t+h} | \Pi] = \sum_{j=0}^{h} C_j \varepsilon_{t+h-j}
\]

Here \(\Pi_t\) is a set of information, which incorporates all lagged values as well as the \(i\)-period values of \(X_t\) and the entire time path for \(D_t\). The \(C_j\) is the \(p \times p\) matrices with a condition that \(C_0 = I_p\). Therefore,

\[
C_j = \sum_{i=1}^{\min(k,j)} \Pi_i C_{j-i}, \quad j \geq 1
\]

As a result, all \(C_j\) matrices are able to be determined by the matrices \(\Pi_{ij}\). The GIRF, therefore, can be defined as:
\[ GI,(h,\hat{\delta},\Pi_{r-1}) = E[X_{n+1} | \varepsilon_i = \hat{\delta}, \Pi_{r-1}] - E[X_{n+1} | \Pi_{r-1}] \]  \hspace{1cm} (34) 

where \( \delta \) represents a some known vector, implying that:

\[ GI,(h,\hat{\delta},\Pi_{r-1}) = C_{\delta} \]  \hspace{1cm} (35) 

Based upon Eq. (35), it can be summarised that \( \delta \) is a key issue for determining the time for any GIRF. In order to simplify the calculation of the function, shocking one element \( (\varepsilon_j = \hat{\delta}_j) \) instead of shocking all components of \( \varepsilon_i \) is an appropriate alternative. Hence the GIRF can be redefined by:

\[ GI,(h,\hat{\delta},\Pi_{r-1}) = E[X_{n+1} | \varepsilon_i = \delta_j \Pi_{r-1}] - E[X_{n+1} | \Pi_{r-1}] \]  \hspace{1cm} (36) 

Assuming that \( \delta_j = \sqrt{w_{jj}} \), \( \varepsilon_j \) is a standard deviation and \( \varepsilon_i \) follows Gaussian distribution. Then,

\[ E[\varepsilon_i | \varepsilon_j = \sqrt{w_{jj}}] = \Omega \varepsilon_j w_j^{-1/2} \]  \hspace{1cm} (37) 

where \( \varepsilon_j \) stands for the \( j \)-th column of \( I_p \). Therefore, the generalized impulse response function can be viewed as follows.

\[ GI,(h,\sqrt{w_{jj}},\Pi_{r-1}) = C_{\delta} \Omega \varepsilon_j w_j^{-1/2} \]  \hspace{1cm} (38) 

The equation above measures the response of \( X_{t+h} \) to a standard deviation of \( \varepsilon_j \). In this type of response, the correlation between \( \varepsilon_j \) and \( \varepsilon_i \) has been considered. Then, Koop et al. (1996) defined the diagonal \( p \times p \) matrix \( \Sigma \) as:

\[
\Sigma = \begin{bmatrix}
(e_1^2 \Omega e_1)^{-1/2} \\
(e_2^2 \Omega e_2)^{-1/2} \\
\vdots \\
(e_p^2 \Omega e_p)^{-1/2}
\end{bmatrix}
\]  \hspace{1cm} (39) 

Thereby, the generalized impulse response function can be expressed in the following matrix form.

\[ GI,(h,\sqrt{w_{11}},...,\sqrt{w_{pp}},\Pi_{r-1}) = C_{\delta} \Omega \Sigma = C_{\delta} B = A_h \]  \hspace{1cm} (40) 

where column \( j \) is given by \( GI,(h,\sqrt{w_{11}},...,\sqrt{w_{pp}},\Pi_{r-1}) \); \( \Omega \) represents the diagonal. If \( B = \Omega^{1/2} = \Sigma^{-1} \), a diagonal matrix with standard deviations encloses the diagonal.
The methodology that will be applied in this research has been established. The following two sections will now describe the issues relating to the data that will be used and where it will be sourced from.

4.7 Data Collection

The conceptual model has discussed that the analytical strategic of this study focuses on examining the relationships between the indicators in housing supply function and the Australian monetary policy function. According to the housing supply function developed previously, house prices, residential construction costs, vacancy rates and new housing construction are the four housing supply indicators selected for research, and the series of data used to measure the indicators cover from the first quarter of 1997 (1997Q1) to the fourth quarter of 2008 (2008Q4).

Firstly, in Australia, the data on house prices are mainly published by the Australian Bureau of Statistics (ABS) and the Real Estate Institute of Australia (REIA). ABS is the official statistical organisation for the commonwealth as well as state and territory governments. However, the ABS data on house prices are not the actual prices of housing but the house price indexes. Although house price indexes can reflect approximately the moving trends of house prices in certain regions within a given period, some useful and valuable information included in actual prices would be missed and ignored during the index compilations. As a result, the data on the house prices utilised in this study will be the Australian quarterly median house prices calculated and published by the REIA on a national level. The REIA is the national professional association for the Australian real estate sector. Established in 1924, ‘REIA is a political non-aligned organization that provides research and well-informed advice to the federal government, opposition, professional members of the real estate sector, media and the public on a range of issues affecting the property market’ (REIA, 2011).

Secondly, the output producer price indexes (PPIs) of housing construction will be
selected as a proxy for residential construction costs. The output PPIs of housing construction are compiled and issued by the ABS in the section of *Producer Price Indexes Australia*, and it is the price index that reflects the rates of changes in the prices of buildings sold as they leave the production procedure (ABS, 2005; 2010a). The output producer price indexes for every region are collected by consulting quantity surveyors and this type of index reflects not only the labour input costs, plant and material input costs, but also the margin of subcontractors. It is viewed as an index measuring the changes in the total costs excluding the GST and the costs of site works (e.g. demolition, land clearance and water and electricity connections) throughout the procedure of housing production. One key issue of output PPIs is that these data include the information about both the construction for completely new housing and addition as well as conversion to established house.

Thirdly, the variable of new dwelling added to housing market will be measured by the number of housing approvals in Australia. This statistics are also published by the ABS in the section *Building Approvals Australia*. In summary, housing approvals are the data on the total number of dwelling units (house and other residential buildings) that have been approved for construction. Thus, it is able to measure the number of new dwellings brought to Australia’s housing markets. In previous research, housing starts are normally used to measure the flow of new housing construction. However, in Australia, the data on housing commencements (starts) can not accurately reflect the number of the residential units produced by the addition and conversion to the existing housing stock. On the contrary, housing approvals have the ability in fulfilling this requirement and they reveal the number associated with completely new housing construction and the addition as well as conversion of existing dwelling (ABS, 2009d). The literature review demonstrated that the addition and conversion of existing housing stock are the dynamics that should not be ignored in the housing supply modelling. In addition, some other studies analysing new housing supply (e.g. Driemand & Follain, 2003;
Glaeser, 2005b; Mayer & Somerville, 2000a; and Poterba, 1991) also rely upon housing approvals. Thereby, using the data on output PPIs and housing approvals assists to more comprehensively identify the nature of the target interrelationship.

An important point which must be mentioned here is that the indicator in regard to the total vacant dwellings available in the housing market will not be included for modelling in the following analytical chapter. The reason for omitting the total vacant dwellings is due to a lack of the data on the vacancy rates or total number of vacant dwelling in the whole housing market at both a regional and national level in Australia (Zochling, 2010). According to Hui and Yue (2006), the variable with respect to the vacancy is for measuring the balance between demand and supply in housing market. Nevertheless, the primary aim of this research is to estimate the impact of monetary policy on the development of the supply side of the housing sector in Australia. As suggested by Quigley (1999) and DiPasquale (1999), housing supply in any period depends on new housing construction activities. Accordingly, the data on new housing construction are enough to reflect the movement in the supply side of the housing sector. In addition, the actual median house prices used in this research has already contained the information of both the vacant and occupied housings (REIA, 2009). Thus, excluding the variable of total vacant housing would not result in a bias of the modelling results. In other words, estimating the relationship between housing supply and monetary policy without the vacancy rates within the context of this research is acceptable.

Finally, in the monetary policy function, interest rates and money supply are two core endogenous variables. In reality, central banks or monetary authorities influence real interest rates via the adjustments in the cash rates. So the interbank rates and money aggregates from the RBA statistics will be the ideal data for this study. The interbank rate is the rate of interest charged on short-term loan made between banks and it is the operation target for RBA's open market operations. RBA (2001a) stated that the interbank rates are the weighted average interest rates
reported by the surveyed banks. On the other hand, the data for measuring money supply in this thesis is the narrow money supply, the Australian M1. In Australia, M1 is the total amount of currency and current deposits of private non-bank sector in commercial banks (currency + current deposits of private non-bank sectors). The currency defined here comprises holdings of notes and coins by the private non-bank sector. Therefore, M1 can more effectively reflect the total amount of money that is able to be transited quickly and flexibly throughout the whole economic system than the broad money supply. It has been acknowledged and proved that M1 is a leading economic indicator and there is a strong relationship between M1 and the housing sector (Elbourne, 2008; Lastepe, 2002; Iacoviello, 2005; and Liu & Liu, 2010). However, employing M1 as a proxy for money supply leads to a research limitation that some amount of money circulated in economy will be missed, e.g. the deposits of public non-bank sectors.

The sources of the data used and the rationale for selecting this data have been described. Table 4-1 summarises the major issues of this section and it explicitly displays the key points of the data selection for this empirical study.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Data Selections</th>
<th>Data Sources</th>
<th>Rationales for selecting these data</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Prices</td>
<td>House Prices</td>
<td>REIA</td>
<td>These data are the actual median housing prices.</td>
</tr>
<tr>
<td>Construction Costs</td>
<td>Output PPIs</td>
<td>ABS</td>
<td>These indexes reflect the costs in housing production.</td>
</tr>
<tr>
<td>New Housing Construction</td>
<td>Housing Approvals</td>
<td>ABS</td>
<td>The data include the information on completely new housing construction and established dwelling addition and conversion.</td>
</tr>
<tr>
<td>Interest Rates</td>
<td>Interbank Rates</td>
<td>RBA</td>
<td>The interbank rates are RBA’s operation target.</td>
</tr>
<tr>
<td>Money Supply</td>
<td>M1</td>
<td>RBA</td>
<td>These data measure the total amount of money that can be transited flexibly throughout economy.</td>
</tr>
</tbody>
</table>

Table 4-1: Data source selection and characteristics for this research study
4.8 Data Description

According to the statistics from the REIA (2009) as well as the ABS (2009a), house prices and output PPIs in Australia have increased dramatically since the 1990s. Figure 4-1 displays the changes in house prices and output PPIs between 1997Q1 and 2008Q4 in the Australian housing and construction markets. It can be identified from the figure that the output PPIs of housing construction corresponding to the left-hand vertical axis increased from approximately 96.4 to 152.3 with an increase rate of 58% during the period of 1997Q1-2008Q4. Simultaneously, the Australian house prices, which are articulated by the right-hand vertical axis, maintained a significant increasing trend between 1997Q1 and 2008Q4 as well. Figure 4-1 indicates that the national median house prices in Australia kept increasing and achieved a peak of AUD 471,200 in 2007Q4. Then, the quarterly house prices began to move down and decreased to AUD 442,000 in 2008Q4.

![House prices and output PPIs in Australia](image)

Source: ABS, 2010b; REIA, 2009

Figure 4-1: House prices and output PPIs in Australia

As mentioned previously, the data on the number of housing approvals have been selected to measure new housing construction activities. Figure 4-2 indicates that
the movement of housing approvals was stable, and the average quarterly number of new dwellings approved for construction was approximately 38,000 between 1997 and 2008.

![Graph of housing approvals in Australia](image)

Measurement unit: number

Source: ABS, 2009c

Figure 4-2: Housing approvals in Australia

The Australian interbank rates and money supply (M1) referred from RBA’s (2009) statistics also expressed identifiable changes during the period under study. Figure 4-3 illustrates that the interbank rates in Australia fluctuated upwards in the long-run context and climbed to a peak of 7.25% in 2008Q2, from which the interbank rates suddenly declined to approximately 5.0% in 2008Q4. Conversely, M1 exhibited a smooth trend, rising from 93.8 billion dollars to 234.4 billion dollars in twelve years. Although the total amount of money supply in Australia has an upward trend, as first suggested in Chapter 1 Introduction, the growth rates of money supply had displayed a decreasing trend since the end of 1996 (RBA, 2009b). Thereby, it is noted that a slowdown of expansionary monetary policy had been implemented in Australia between 1997Q1 and 2008Q4.
The data utilised reflect that the Australian housing sector during the period of 1997Q1-2008Q4 was exposed to a slowdown of expansionary monetary policy. As mentioned in Chapter 2 and Chapter 3, theoretically, the deceleration in monetary expansion can bring a significant negative effect on the macroeconomy as well as the property sector. Thus, the question in regard to the interrelationship between monetary policy and the supply side of the housing sector in Australia is valuable for study. This question will be answered in accordance with the results of the VECM in next chapter. All the data imported into the VECM in Chapter 5 Analysis and Discussion will be transformed to natural logarithms.

4.9 Chapter Summary

There are two major components described in this chapter, one is the methodology section and the other is the data collection and description. Firstly, this chapter has introduced the econometric techniques that will be applied in Chapter 5 Analysis and Discussion. The primary interest of this study is to investigate the causal relationship and dynamic interaction between housing supply and monetary policy in Australia in the context of global economic turmoil. As a result, the Granger causality test and the generalized impulse response function based on the vector
error correction model with a dummy variable will be used to achieve the research aim. In addition, the data stationarity and the cointegration are two prerequisites of the time-series econometric modelling within the framework of vector error correction model. Therefore, the ADF unit root test, the PP unit root test and the JJ multivariate cointegration test have also been outlined before the vector error correction model.

Secondly, this chapter has described the major sources of the data that will be used for empirical analysis in this research. In summary, the data from two reliable sources, the REIA and the ABS, both of which are the professional institutions for statistics in relation to real estate and building construction in Australia. After introducing the data sources, this chapter individually described the data imported into the vector error correction model. Owing to the analytical strategy proposed in the chapter of conceptual model, five endogenous variables associated with the functions of housing supply and monetary policy have be considered, incorporating house prices, residential construction costs, new housing construction, interest rates and money supply.

To better study the relationship between housing supply and monetary policy in Australia, the quarterly median actual house price issued by the REIA will be the data selected for the empirical analysis. Moreover, the output producer price indexes and the number of housing approvals, both of which are published by the ABS, will be utilised to measure the residential construction costs and new dwellings added to Australia’s housing market. All of these data aforementioned include the information about both completely new housing construction and the residential units produced by the addition and conversion of established dwellings. Furthermore, because of the nature of the Australian monetary policy, the data on the interbank rates and money supply (M1) provided by the RBA has been selected for identifying the shocks of monetary policy in Australia. These two data explicitly illustrate the shifts of monetary policy in Australia.
CHAPTER 5 ANALYSIS AND DISCUSSION
5.1 Chapter Introduction

The empirical results will be presented in four sections in this chapter. Following the flow chart of time-series econometric modelling (Figure 3-3) in Chapter 3 Conceptual Model, firstly, this chapter will test the stationarity of the selected data series (e.g. house prices, output PPIs, the number of housing approvals, interbank rates and money supply). The testing for the data stationarity will rely on two unit root tests – the ADF test and the PP test, both of which have been introduced in Chapter 4 Methodology and Data Collection. Secondly, the test for the cointegration must be conducted before formulating the vector error correction model. In this study, the multivariate cointegration test is the single test used to identify the cointegration relationship among the selected variables. Thirdly, as the tests for the unit roots and the cointegration have been completed, the VEC model with a dummy variable (VEC-D model) will be constructed for further empirical analysis. Depending upon the VEC-D model, in Section 5.4, the Granger causality tests will be applied to uncover the causal relationships between the variables associated with housing supply and monetary policy in Australia. Then, a transmission pattern amongst the variables will be identified. Finally, to trace the dynamic interactions between the observed variables, the generalized impulse response function will be adopted. The core issues of this chapter can be summarised as follows:

- Testing unit roots and cointegration for the selected variables.
- Building a dummy variable that can quantify the impacts of global economic turbulence caused by special events.
- Constructing the VEC-D model and applying the Granger causality tests and the generalized impulse response function to analyse the causal link and dynamic interaction between housing supply and monetary policy.
5.2 Empirical Analysis

5.2.1 Testing the Stationarity for the Selected Data

As mentioned in Chapter 3 Conceptual model, the first step for the time-series econometric modelling is to identify whether the data imported are stationary, otherwise, a spurious regression will be triggered. To avoid the spurious regression, two unit root tests (ADF test and PP test) are conducted. The null hypothesis that the data employed are non-stationary is rejected at the 5% and 1% significance levels. Table 5-1 and Table 5-2 report the results of the ADF tests and the PP tests for five selected variables, including house prices (HP), output PPIs (OPPIs), housing approvals (HA), interbank rates (INT) and money supply (M1). The observed period of this analysis will focus on the interval between 1997Q1 and 2008Q4. In summary, all data used for modelling are non-stationary in the level form, but stationary after taking the first difference. These results indicated that the data utilised are \( I(1) \), denoting that the time series integrated at the first difference. Therefore, the econometric modelling in this research will rely on the data that have been taken the first difference so as to deal with the possibility of spurious regression.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Level</th>
<th>Model specification (lags)</th>
<th>ADF Test Statistics (5%, 1% sig. level)</th>
<th>First Difference Model specification (lags)</th>
<th>ADF Test Statistics (5%, 1% sig. level)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(HP)</td>
<td>Trend &amp; Intercept (1)</td>
<td>-0.12 (-4.18, -3.51)</td>
<td>None (1)</td>
<td>-1.96 (-2.62, -1.95)</td>
<td>( I(1)** )</td>
<td></td>
</tr>
<tr>
<td>ln(OPPIs)</td>
<td>Trend &amp; Intercept (1)</td>
<td>-2.99 (-4.18, -3.51)</td>
<td>None (1)</td>
<td>-2.34 (-2.62, -1.95)</td>
<td>( I(1)** )</td>
<td></td>
</tr>
<tr>
<td>ln(HA)</td>
<td>Trend &amp; Intercept (1)</td>
<td>-3.39 (-4.18, -3.51)</td>
<td>None (1)</td>
<td>-5.91 (-2.62, -1.95)</td>
<td>( I(1)*** )</td>
<td></td>
</tr>
<tr>
<td>ln(INT)</td>
<td>Trend &amp; Intercept (1)</td>
<td>-2.92 (-4.18, -3.51)</td>
<td>None (1)</td>
<td>-4.06 (-2.62, -1.95)</td>
<td>( I(1)*** )</td>
<td></td>
</tr>
<tr>
<td>ln(M1)</td>
<td>Trend &amp; Intercept (1)</td>
<td>-2.79 (-4.18, -3.51)</td>
<td>None (1)</td>
<td>-3.59 (-2.62, -1.95)</td>
<td>( I(1)*** )</td>
<td></td>
</tr>
</tbody>
</table>

Note: ** and *** denote the 5% and 1% significance levels.

Table 5-1: Summary of the ADF test results
## Table 5-2: Summary of the PP test results

### 5.2.2 Testing the Cointegration for the Selected Data

One of the challenges other than the stationary test in the VECM modelling is that the variables employed must be co-integrated. It has been described in the conceptual model and the methodology that the multivariate cointegration test is the most appropriate method to identify this long-run equilibrium relationship. It is known that the multivariate cointegration test mentioned in previous chapters is a technique that depends on the vector autoregression model. As a result, selecting the optimal lag length is a common practical problem in this test. The simple method in the optimal lag length selection is to launch a VAR model first for the observed variables and then reduce a large lag term until 0. There are five criteria in the lag length judgement, involving Sequential modified likelihood ratio test statistics (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn information criterion (HQ). The optimal lag length can be mainly determined by comparing the AIC and the SC. The smallest values of the AIC and the SC are normally used to indicate the optimal lag. Table 5-3 summarises the results of the lag order selection based on the reduced-form VAR.
Table 5-3: VAR lag order selection criteria

The econometric theory about the VAR models claims that the long lag length will distort the data and will cause a decrease in power. Therefore, suggested by the criterion in Table 5-3, particularly the AIC and the SC, one lagged term is the optimal lag order and thus it has been selected for the following cointegration test. Although there are five models in the multivariate cointegration test, this research will be concerned with the Model 3 and Model 4, which are displayed as Eq. (22) and (23) in Section 4.3 in Chapter 3 Methodology and Data Collection. The reason for focusing on the Model 3 and Model 4 is that the description on the data (e.g. house prices, output PPIs and money supply) has reflected that the majority of the data used in this research appears to be trending series. Table 5-4 shows the summary of the cointegration test results in relation to five observed variables. It is noted that there is a long-run equilibrium relationship among house prices, output PPIs, housing approvals, interbank rates and money supply.

<table>
<thead>
<tr>
<th>Lag</th>
<th>LR</th>
<th>FPE</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NA</td>
<td>2.10e-11</td>
<td>-10.3966</td>
<td>-10.1938</td>
<td>-10.3214</td>
</tr>
<tr>
<td>1</td>
<td>497.7884</td>
<td>1.35e-16</td>
<td>-22.9142*</td>
<td>-21.1434*</td>
<td>-21.9088*</td>
</tr>
<tr>
<td>2</td>
<td>49.3897*</td>
<td>9.86e-16</td>
<td>-22.3599</td>
<td>-20.4900</td>
<td>-21.8931</td>
</tr>
<tr>
<td>3</td>
<td>37.2484</td>
<td>9.16e-17*</td>
<td>-22.7202</td>
<td>-19.6702</td>
<td>-21.7111</td>
</tr>
</tbody>
</table>

Table 5-4: Summary of the cointegration test results

The key issue identified in Table 5-4 is that one co-integrated vector exists among the selected variables in both Model 3 and Model 4 under the Trace test and the Max-eigenvalue test. However, according to the study by Krol and Ohanian (1990), a stationary deterministic trend has been discovered in money supply across money markets. Hence, one cointegration vector in conjunction with the
Model 4 will be the result utilised for the following VECM analysis because the Model 4 is suitable for the situation that some of the series are trend stationary.

5.2.3 Dummy Variable Specification

With the rapid globalization, Australia’s domestic economic development is undoubtedly impacted by the global economic climate. During the recent decade, the global economic turmoil had been caused by some special events. To quantify the influences of these events on the supply side of the Australian housing sector, a dummy variable will be set up. The establishment of dummy variable in the VECM can not only increase the model fit, but also quantitatively capture the responses of economic activities within a ‘real world’ context. The challenging issue of building a dummy variable is to identify the event window length. Huang and Liu (2010) argued that the announcements of the Reserve Bank of Australia are an ideal indicator to uncover this point because the central bank is sensitive to the changes in the domestic and global economic environment.

Since the third quarter of 2001, Australia’s domestic economic condition had been weakened and this situation continued in 2001Q4 and 2002Q1, thus the Australian cash rates had been reduced from 5.0% to 4.25% between September 2001 and March 2002 (RBA, 2001b; 2002). RBA (2002) claimed that the economic weakness that had emerged in September 2008 was originated from the expansion of the short-term US economic decline caused by the terrorist attack on 11 September 2001. In April 2002, the economic climate in Australia had improved markedly and the RBA decided to increase the cash rates up to 4.50%, implying that the impact of the terrorist attack had passed (RBA, 2002). Accordingly, the values of such periods as 2001Q3, 2001Q4 and 2002Q1 will be represented as 1 because of the occurrence of terrorist attack.

In 2008, the US financial crisis sent shockwaves throughout the world and a global financial crisis was triggered. As a result, the Reserve Bank of Australia
and the Australian commonwealth government announced the implementation of a significant economic stimulus package from September to December in 2008 to circumvent the rapid spread of the crisis (RBA, 2008; Australian Treasury, 2009). These announcements clearly denote that the 2008 global financial crisis began to influence Australia in 2008Q3 and this impact deepened in 2008Q4. Influenced by the responses of the Australian government to the financial crisis, the cash rates in Australia dramatically dropped to 4.35% from 7.25% between September and December in 2008. Therefore, the values of 2008Q3 and 2008Q4 will be also set as 1. Overall, during the period under study, the special event windows are: 2001Q3, 2001Q4, 2002Q1, 2008Q3 and 2008Q4. Summarily, the dummy variable in the VEC-D model contains the information of two special events (the 2001 terrorist attack to the US and the 2008 global financial crisis), and the values of the quarters previously mentioned in this dummy variable are 1 and 0 of others.

5.2.4 Impacts of Global Economic Turbulence on Australia’s Housing Supply

After conducting the unit root tests as well as the cointegration test and formulating a dummy variable, the VEC-D model (a vector error correction model with a dummy variable) can be constructed. Table 5-5 reports the estimates of the VEC-D model. The coefficients and t-statistics of the dummy variable indicate that the supply side of the housing sector in Australia received significant negative impacts from the observed global special events. In other words, a dramatic recession of the supply side of the housing sector in Australia had taken place during the period of global economic disturbance, which was caused by the shocks of the 2001 terrorist attack to the US and the 2008 global financial crisis. The movements of housing approvals, shown as Figure 4-2, support this argument. Figure 4-2 illustrates that the number of new housing approvals in Australia decreased by 12% from 2001Q3 to 2002Q1, and dropped down up to 21% in the period of 2008Q3-2008Q4.
### Table 5-5: Estimates of the VEC-D model

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\Delta \ln(HP)$</th>
<th>$\Delta \ln(OPPI)$</th>
<th>$\Delta \ln(HA)$</th>
<th>$\Delta \ln(INT)$</th>
<th>$\Delta \ln(M1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \ln(INT)_{t-1}$</td>
<td>-0.32 (-3.41***)</td>
<td>1.45 (3.75***)</td>
<td>-0.54 (-1.52*)</td>
<td>0.22 (1.18*)</td>
<td>-0.09 (-1.09*)</td>
</tr>
<tr>
<td>$\Delta \ln(M1)_{t-1}$</td>
<td>-0.16 (-1.19*)</td>
<td>-0.02 (-0.05)</td>
<td>-1.10 (-1.92***)</td>
<td>-0.31 (-3.19***)</td>
<td>0.24 (1.96**)</td>
</tr>
<tr>
<td>$\Delta \ln(HP)_{t-1}$</td>
<td>0.40 (2.38***)</td>
<td>0.06 (1.46*)</td>
<td>0.36 (2.27**)</td>
<td>-0.12 (-0.29)</td>
<td>0.60 (1.90**)</td>
</tr>
<tr>
<td>$\Delta \ln(OPPI)_{t-1}$</td>
<td>0.84 (1.28)</td>
<td>0.54 (3.61***)</td>
<td>1.48 (1.73***)</td>
<td>1.94 (1.52)</td>
<td>-0.43 (-0.75)</td>
</tr>
<tr>
<td>$\Delta \ln(HA)_{t-1}$</td>
<td>0.07 (1.66*)</td>
<td>0.02 (2.16**)</td>
<td>0.13 (1.73***)</td>
<td>0.08 (0.78)</td>
<td>-0.10 (2.51**)</td>
</tr>
<tr>
<td>Dummy</td>
<td>-0.03 (-2.60***)</td>
<td>-0.01 (-1.94**)</td>
<td>-0.12 (-2.07**)</td>
<td>-0.11 (-3.42***)</td>
<td>0.04 (2.74**)</td>
</tr>
</tbody>
</table>

R-squared: 0.5139;  Sum sq. resides: 0.0461  
S.E. equation: 0.0503;  Log likelihood: 176.6652

Note: ** and *** denote the t-statistic significant at 5% and 1% significance levels.

#### 5.2.5 Causal Relationships between the Selected Variables

Under the VEC-D model, the Granger causality test and the generalized impulse response function can be carried out. The Granger causality tests in this chapter will be performed at the 5% and 1% significance levels. Chapter 4 Methodology introduced that the null hypothesis of the Granger causality test in the VAR system is that there is no Granger causality between the observed variables. Table 5-6 indicates the Granger causality test results generated from the VEC-D model. In this table, the $P$-value<0.05 means that the null hypothesis will be rejected as the test is operated under the 5% and 1% significance levels.
<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Directions</th>
<th>Chi-square</th>
<th>P values</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(INT)</td>
<td>ln(M1) → ln(INT)</td>
<td>4.75</td>
<td>0.03</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>ln(HP) → ln(INT)</td>
<td>1.07</td>
<td>0.99</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(OPPis) → ln(INT)</td>
<td>0.19</td>
<td>0.66</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HA) → ln(INT)</td>
<td>3.26</td>
<td>0.07</td>
<td>N</td>
</tr>
<tr>
<td>ln(M1)</td>
<td>ln(INT) → ln(M1)</td>
<td>1.44</td>
<td>0.23</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HP) → ln(M1)</td>
<td>5.86</td>
<td>0.02</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>ln(OPPis) → ln(M1)</td>
<td>0.49</td>
<td>0.48</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HA) → ln(M1)</td>
<td>10.05</td>
<td>0.00</td>
<td>Y</td>
</tr>
<tr>
<td>ln(HP)</td>
<td>ln(INT) → ln(HP)</td>
<td>5.49</td>
<td>0.02</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>ln(M1) → ln(HP)</td>
<td>0.37</td>
<td>0.55</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(OPPis) → ln(HP)</td>
<td>0.67</td>
<td>0.41</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HA) → ln(HP)</td>
<td>1.55</td>
<td>0.21</td>
<td>N</td>
</tr>
<tr>
<td>ln(OPPis)</td>
<td>ln(INT) → ln(OPPis)</td>
<td>5.27</td>
<td>0.02</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>ln(M1) → ln(OPPis)</td>
<td>0.82</td>
<td>0.37</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HP) → ln(OPPis)</td>
<td>1.59</td>
<td>0.21</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HA) → ln(OPPis)</td>
<td>0.89</td>
<td>0.35</td>
<td>N</td>
</tr>
<tr>
<td>ln(HA)</td>
<td>ln(INT) → ln(HA)</td>
<td>2.52</td>
<td>0.11</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(M1) → ln(HA)</td>
<td>0.78</td>
<td>0.38</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>ln(HP) → ln(HA)</td>
<td>9.22</td>
<td>0.00</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>ln(OPPis) → ln(HA)</td>
<td>13.09</td>
<td>0.00</td>
<td>Y</td>
</tr>
</tbody>
</table>

Table 5-6: Summary of the Granger causality test results

Based on the results in Table 5-6, a transmission pattern within the framework that consists of the variables of monetary policy and house supply in Australia can be identified as Figure 5-1. This transmission pattern not only confirms the interrelationship between monetary policy and the supply side of the housing market, but also comprehensively depicts how monetary policy and the housing supply sector interact with each other. Generally speaking, there is a significant interrelation amongst the indicators of monetary policy as well as housing supply.
Figure 5-1 summarises the results listed in Table 5-6 and the arrows in this figure illustrate the directions of the causal relationships between every two variables. The transmission pattern in relation to monetary policy and housing supply first indicates that the changes in the supply of money Granger cause the movements in the interbank rate without a feedback in Australia. This finding is consistent with the reality that the Australian central bank (Reserve Bank of Australia) adjusts the cash rates to a target level by means of the open market operations. Influenced by RBA’s behaviour in the open market, the total amount of money circulated in the national economic system can be increased or decreased and then a series of interest rates (e.g. interbank rates and other real interest rates) will be significantly affected. This is the reason why the changes in money supply Granger cause the fluctuations in the interbank rates.

Additionally, in Figure 5-1, the changes in the interbank rate Granger cause the appreciations or depreciations of house prices and output producer prices in Australia. These two results suggest that political behaviour such as the central bank’s adjustments in monetary policy influence the indicators of the supply side of the housing sector directly in the national context. However, no causal link has
been identified in the direction from money supply to any housing supply indicator. This empirical evidence implies that monetary policy makers deliver their interventions to the housing supply sector via the interbank rates. Moreover, in Australia’s housing sector, both of house prices and output PPIs Granger cause the changes in new housing construction (housing approvals) and the two monetary policy indicators can not causally trigger the changes in housing approvals. Thus, monetary policy affects the supply of new housing in Australia via house price and the costs triggered in housing production. There are two findings that can be summarised in this paragraph: firstly, the interbank rate is an activator that bridges monetary policy to the supply side of the housing sector; secondly, house prices and residential construction costs (the output PPI is a proxy for residential construction costs) are two transmission mechanisms of monetary policy shocks to the supply of new housing in the Australian housing sector.

The previous discussion has focused on the analysis with respect to the impact of monetary policy on the supply of housing. However, the transmission pattern exhibited in Figure 5-1 illustrates that monetary policy and the supply side of the housing market can interact with each other. Regarding the effects of housing supply indicators on monetary policy, it was discovered that house prices and housing approvals Granger cause money supply in economic system without receiving a feedback in Australia. It is acknowledged that the property sector is significant to Australia’s economy and the governmental interventions to the macroeconomy are primarily achieved by a series of economic policies and regulations (e.g. monetary policy, land policy and construction policy). For these reasons, policy makers may implement the monetary targets in consideration of the situation of the important economic sectors, such as the housing sector. In Australia, the cash rate is an instrument for the commonwealth government to control the property sector and the adjustments for it can only be achieved by changing money supply. Therefore, the changes in house prices and new housing construction will directly affect monetary policy makers’ decisions in regard to the
amount of money in the circulation in economy. This explains why house prices and housing approvals causally affect the supply of money.

5.2.6 Dynamic Interactions between the Selected Variables

The Granger causality test identifies the causal relationships between the observed variables, however it is not able to uncover the dynamic response of each variable to the shocks of other endogenous variables in the VECM. Thus, the generalized impulse response function (GIRF) will be adapted in the following analysis. The results of the GIRF will provide valuable information to understand how the slowdown of expansionary monetary policy dynamically affects housing supply.

The GIRF traces the dynamic effects among the endogenous variables in a VAR system. Figure 5-2 to Figure 5-6 illustrates the results of the generalized impulse response function of five selected variables. In these five figures, the vertical axis represents the level of the responses of the endogenous variables to the shocks of other endogenous variables in the VEC-D model, and the horizontal axis stands for lag period. Based on the relationship identified in Figure 5-1, firstly, money supply (M1) negatively influences the interbank rates in Australia (Figure 5-2). Specifically, a standard deviation of money supply brings -4.33% effects on the interbank rates in the 5th quarter. This responsive value indicates that there is an inverse relationship between the interbank rates and money supply. Owing to the decreasing trends of the growth rates of money supply, this GIRF result implies that the interbank rates in Australia had been significantly increased by the M1.

Secondly, there are dramatic negative influences caused by the positive changes in the interbank rates on the Australian house prices. Figure 5-4 illustrates that the maximum values of the responses of house prices to the standard deviation of interbank rates reaches -1.15%. Herein the negative values indicate that the increasing trends of house prices on a national level in Australia had been dramatically depressed by the increases in the interbank rates during the period.
under study. Conversely, suggested by Figure 5-5, the values of the response of output PPIs to the standard deviation of interbank rates are positive. A total of 0.71% dynamics on the output PPIs were produced by the standard deviation of interbank rates on a national level within six quarters. These results suggest that the increasing trend of residential construction costs were strengthened by an increase in the interbank rates in Australia between 1997 and 2008. This is due to a situation that a rise in the interbank rate increases the payments on real interests, which represent a major part of the costs of the construction projects that are financed by the loans of commercial banks or other financial institutions. In Australia, according to the statistics of ABS’s *Housing Finance* (ABS, 2010), approximately 50% of construction projects are under the loans from financial institutions. Therefore, the residential construction costs in Australia are easily enhanced by the rises in the interbank rates.

Compared with the impact of interbank rates, house prices and output PPIs are less sensitive to the changes in money supply. Overall, the standard deviation yielded by the M1 produced less effect on house prices and output PPIs, achieving 1.24% and -0.25% respectively. The ‘positive’ and ‘negative’ values here imply that house prices are positively related to the M1 while there is an inverse relationship between output PPIs and money supply. In previous chapters, it has been described that the growth rates of money supply in Australia between 1997 and 2008 had exhibited a downward trend. Thus, the slowdown of expansionary monetary policy in Australia from 1997 to 2008 had weakened the increasing trend of house prices but dramatically increased residential construction costs.

Thirdly, new dwelling construction measured by the number of housing approvals is sensitive to the changes in house prices and residential construction costs. Figure 5-6 suggests that in Australia the increases in house prices positively affect new housing constructions while a rise in output PPIs will depress the number of new dwelling construction. According to Figure 5-6, the maximum values of the
responses of housing approvals to the standard deviation of output PPIs are highly sensitive, as much as -4.42% in six quarters. On the other hand, the standard deviation originated from house prices can produce a total of 1.82% dynamics on housing approvals in five quarters. These results indicate that an inflation of house prices can positively influence new dwelling construction and the increases in construction costs will reduce the level of housing output.

As discussed previously, monetary policy affects new housing construction via house prices and residential construction costs. From 1997 to 2008, the increasing trend of house prices in Australia was depressed by an inflation of interbank rates, and residential construction costs had been conversely increased by the adjustments in monetary policy. Due to the close relationship amongst house prices, construction costs and new housing outputs, the influences triggered by monetary policy on house prices and residential construction costs surely will reduce new housing construction level. This conclusion can be further supported by the results of the generalized impulse function shown in Figure 5-6. Although there is no causal link between any indicator of monetary policy and housing approvals, the responses of housing approvals to the standard deviations of Australia’s interbank rates and M1 are still apparent in the sample period, during which the increasing trend of new housing construction is decreased by averagely 1.60% in three quarters after receiving the shocks of monetary policy. These findings empirically prove that the slowdown of expansionary monetary policy is able to negatively affect the construction of new dwelling and the addition as well as conversion to established housing, all of which are significant to the growth of total housing stock.

One issue related to the strength of the impact from money supply to housing approvals must be concerned with in this section, especially when it takes 3-lag time for such impact to be effective. There will be 3 lags in-between money supply and housing approvals, during which period money supply constantly
changes. Before the impact of money supply that happened 3-lag time ago affects housing approvals, new information of money supply changes the interbank rates again. This may be one of the reasons why money supply does not direct affect housing approvals through the Granger causality findings (Figure 5-1).

Finally, the shocks of the supply side of the housing sector to monetary policy can not be ignored. The empirical evidence of Figure 5-3 indicates that the responses of interbank rates and M1 to one standard deviation of house prices are also evident, as much as 1.49% and -1.08% in the third quarter. Furthermore, a total of response of interbank rates and money supply to the impulse of new housing construction (housing approvals) achieves 4.26% and -0.40% in the 5th quarter. The responsiveness of money supply to the impulse of residential construction costs is also identifiable. The maximum values of the response of interbank rates and M1 to the output PPIs standard deviation are 0.67% and -0.61% in the 6th quarter.

![Graph showing responses of interbank rates](image)

Figure 5-2: Responses of interbank rates
Figure 5-3: Responses of M1

Figure 5-4: Responses of house prices

Figure 5-5: Responses of the output PPIs
This section has analysed the results yielded by the generalized impulse response function and Figure 5-2 to 5-6 illustrate the dynamic interactions amongst the five selected variables [e.g. interbank rates (INT), money supply (M1), house prices (HP), output producer price indexes (OPPIs) and housing approvals (HA)]. In next section, a critical discussion on the empirical evidence will be presented.

5.3 Critical Discussion on the Empirical Evidence

The section of empirical analysis explains the results produced by the VEC-D model. According to the coefficients and t-statistics of dummy variable, firstly, it has been identified that the repercussion of the supply side of the housing sector in Australia is significantly negative after receiving the shocks of global economic turmoils triggered by the 2001 terrorist attack to the US and the 2008 global financial crisis.

Secondly, the empirical evidence from the Granger causality tests depicts a transmission pattern within the framework of monetary policy and housing supply. Depending upon this pattern, the interbank rate is an activator that transits monetary policy makers’ interventions to the housing sector, and Australia’s monetary policy does not causally affect the level of new housing construction but directly causes the changes in house prices and construction costs. In short, house
prices and residential construction costs perform as two transmission mechanisms of the shocks of monetary policy. Owing to the Granger causality identified from house prices and housing approvals to money supply, one implication is able to be traced that the development of the supply side of the housing sector would affect monetary policy makers’ decisions on money supply level.

In order to deeply investigate the interactions between housing supply and monetary policy, the generalized impulse response function has also been applied to explore the dynamic responses of endogenous variables. The important findings in the impulse response analysis are that both of house prices and residential construction costs were sensitive to the changes in the interbank rates, and housing approvals can be significantly affected by the changes in house prices and output PPIs. Table 5-7 reports the responses of the housing supply indicators to the impulses of monetary policy in Australia. The ‘negative’ and ‘positive’ shown in Table 5-7 denote the types of the dynamics triggered by monetary policy. It has been introduced in Chapter 1 Introduction that the slowdown of expansionary monetary policy was implemented by the Reserve Bank of Australia between 1997 and 2008. As a result, the ‘negative’ dynamics caused by the interbank rates indicates that the increasing trends of house prices and housing approvals had been depressed by the increases in the interbank rates during the sample period. Similarly, the ‘positive’ denotes that the decelerations of the rise in money supply weakened the increasing trends of Australia’s house prices and housing approvals. Conversely, the ‘positive’ and ‘negative’ in relation to output PPIs means that the residential construction costs in Australia had been significantly increased by the adjustments in money supply and the interbank rates.

Based on the results of the Granger causality tests and the generalized impulse response function, the impact of the slowdown of expansionary monetary policy on three housing supply indicators (house prices, output PPIs and housing approvals) can be summarised (Figure 5-7). Figure 5-7 specifically illustrates that
the deceleration of monetary expansion in Australia between 1997 and 2008 had depressed house prices and increased residential construction costs. It has been demonstrated in Section 5.2.6 that there is a positive relationship between house prices and housing approvals while an inverse linkage exists between construction costs and housing approvals. Hence monetary policy’s pressure on house prices and positive dynamics on construction costs surely can reduce the level of the construction for completely new housing and the addition to established house. The dotted line in Figure 5-7 illustrates the indirect relationship between the slowdown of expansionary monetary policy and new housing approvals in Australia. As suggested by the literature review (section 2.2.1 and section 2.2.2), the construction for new dwellings and the addition and conversion to established housing are two major sources of the increase of housing stock. Therefore, it can be concluded that the slowdown of expansionary monetary policy in Australia is an obvious negative impetus on Australia’s housing supply, and house prices and construction costs serve as the transmission mechanisms of monetary policy.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Interbank Rates</th>
<th>Money Supply (M1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Prices</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Output PPIs of Housing Construction</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Housing Approvals</td>
<td>Negative</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Table 5-7: Summary of the responses of housing supply indicators to the shocks of monetary policy variables
Figure 5-7: Impacts of slowdown of expansionary monetary on the housing supply indicators in Australia

In addition, Table 5-8 displays the responses of interbank rates and money supply to the shocks of house prices, output PPIs and housing approvals. In this table, the ‘negative’ and ‘positive’ dynamics triggered by the indicators of housing supply denotes that the Reserve Bank of Australia would decrease money supply to stimulate the interbank rates when facing a challenge from the overheating investments in the property sector. On the contrary, if a recession occurred in the supply side of the housing sector, a negative pressure will be required for the interbank rates and thus the central bank would adjust money supply to affect the interbank rates. These findings comply with the anticipated points considering the conventional macroeconomic theory (McTaggart et al., 2003; RBA, 2007a).

<table>
<thead>
<tr>
<th>Variables</th>
<th>House Prices</th>
<th>Output PPIs</th>
<th>Housing Approvals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interbank Rates</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Money Supply</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Table 5-8: Summary of the responses of monetary policy variables to the shocks of housing supply indicators

The overall findings produced by the VEC-D model have answered the research
question, ‘What is the interrelationship between housing supply and monetary policy within the context of global economic turbulence?’, which was proposed in Chapter 1 Introduction and Chapter 2 Literature Review. The coefficients as well as the t-statistics of dummy variable and the empirical results from the Granger causality tests and the generalized impulse response function indicated that the global economic turmoil and the slowdown of expansionary monetary policy resulted in a dramatic negative impact on the supply side of the housing sector in Australia. It was also suggested by the empirical evidence that the development of the supply side of the housing sector would influence the central bank’s monetary policy decisions. The results regarding the effect of the housing supply sector on monetary policy comply with the conventional macroeconomic theory. Therefore, the reliability of the conceptual model and the VEC-D model developed in this research has been empirically validated.

5.4 Chapter Summary

This chapter has empirically analysed the interrelationship between housing supply and monetary policy in Australia under an environment of global economic disturbance between 1997Q1 and 2008Q4 using a vector error correction model with a dummy variable. In the VEC-D model, one lag length and one cointegration vector have been selected for modelling.

From the coefficients and t-statistics of the dummy variable in the VEC-D model, it was identified that the global economic disturbances caused by the 2001 terrorist attack to the US and the 2008 global financial crisis created significant negative repercussion of the supply side of the housing sector in Australia. This finding is consistent with Figure 4-2, which indicates that the number of housing approvals did decline significantly during the occurrences of the observed special events. By using the Granger causality tests, a transmission pattern within the framework of housing supply and monetary policy has also been discovered, in which a series of causal links can be uncovered.
Money supply Granger causes the interbank rates without a feedback.

Money supply does not Granger cause housing approvals in Australia. However, the movements in the interbank rates causally trigger the changes in house prices and output PPIs of housing construction.

The changes in house prices and output PPIs Granger cause the number of housing approvals.

No causal relationship has been found between any housing supply indicator and money supply in Australia.

There are only one-way causal links discovered in the direction from house prices and housing approvals to money supply.

The causal relationships identified by the tests for the Granger causality indicate that monetary policy causally affects house prices and residential construction costs but not new housing construction in Australia. In short, monetary policy influences new housing construction activities via the price and cost factors.

As indicated by the generalized impulse response function, several dramatic responses in relation to housing supply and monetary policy have been uncovered.

- The responses of house prices to the standard deviations of interbank rates and money supply are -1.15% and 1.05% respectively.
- The responses of output PPIs to the standard deviations of interbank rates and money supply achieve 0.71% and -0.25%.
- The standard deviations of house prices and output PPIs can bring up to 1.82% and -4.42% dynamics on housing approvals.
- A total of -1.36% dynamics are caused by the slowdown of expansionary monetary policy on housing approvals.

The results of the impulse response function suggested that a positive linkage exists in between house prices and new housing output, and there is a negative relationship between residential construction costs and new housing construction activities. Due to these relationships, it can be identified that the slowdown of expansionary monetary policy did depress the development of the supply side of
the housing sector in Australia. In addition to the impact of monetary policy on housing supply, this chapter also discovered the significantly dynamic response of the monetary policy variables to the shocks of the supply side of the housing sector. This finding is consistent with the conventional macroeconomic theory, implying that the conceptual model and the VEC-D model developed in this study are reliable. In summary, the empirical analysis and the findings in this chapter has uncovered a significant relationship between housing supply and monetary policy within the context of global economic turbulence, which is a research gap addressed in an intensive review of literature in Chapter 2 Literature Review.
CHAPTER 6 CONCLUSIONS
6.1 Conclusion Remarks

This empirical research focused on analysing the interrelationship between housing supply and monetary policy within the context of global economic turbulence. In Chapter 1 Introduction section 1.2 Problem Statement, it was demonstrated that a housing shortage has emerged alongside significant monetary policy adjustments as well as global economic turmoil in Australia since the end of the 1990s. The literature review suggested that the majority of the research on the linkage between housing supply and policies largely concentrated on the impact of such polices as land, tax and housing affordability on housing supply, but few studies were comprehensively concerned with monetary policy that is the decisions in relation to interest rates and the flow of money supply in economy. Moreover, there is also a lack of empirical work for modelling the effect of global economic disturbance on the supply side of the housing sector in Australia.

A conceptual model that incorporates the functions of the Australian monetary policy and housing supply was developed. Detecting the interactions between the endogenous variables in these two functions was the master plan of this research. In addition, an exogenous variable has been established in the conceptual model, which enables this study to quantify the impact of the special events that had affected the global economic climate and Australia’s macroeconomy; namely the terrorist attack to the US in 2001 and the 2008 global financial crisis. For the purpose of estimating the conceptual model, a VEC-D model (vector error correction model with a dummy variable) was developed to explore the relationship between housing supply and monetary policy under the global economic turmoil. By using the data from published sources (e.g. the Australian Bureau of Statistics, Real Estate Institute of Australia and the Reserve Bank of Australia) on median house prices, output producer price indexes, housing approvals, interbank rates and money supply, a series of valuable findings have been identified and discussed in Chapter 5 Analysis and Discussion.
Firstly, the coefficients and $t$-statistics of dummy variable indicate that a recession of the supply side of the housing sector in Australia had taken place because of the global economic disturbances. Secondly, depending upon the Granger causality tests, a transmission pattern across the variables associated with monetary policy and housing supply in Australia has been uncovered. This transmission pattern depicts that there is a causal link found between money supply and the interbank rates in Australia. Additionally, two causal relationships existed in between the interbank rates and house prices as well as residential construction costs. However, no causal link was identified from money supply to the variables relevant to the supply of housing in Australia. This means that the interbank rates serve as an activator which connects monetary policy and the supply side of the housing sector. Furthermore, the changes in house prices and residential construction costs can Granger cause housing approvals, and yet no causal link in the direction from monetary policy indicators to housing approvals has been discovered. These results imply that monetary policy affects the construction of new dwelling via the price and cost factors. In simple terms, house prices and residential construction costs are two transmission mechanisms that transfer the shocks of monetary policy to new housing construction activities.

After exploring the causal links, the generalized impulse response function has been applied to estimate the dynamic interactions between the selected variables. The empirical evidence first suggested that the interbank rates are able to be affected negatively by money supply. It is noted that Australia’s expansionary monetary policy has been slowing down since the end of the 1990s and the growth rates of money supply in Australia has exhibited a downward trend. As a result, it is reliable to conclude that the interbank rates had been increased by the shock of money supply during the period under study. Secondly, suggested by the generalized impulse response function, it is identified that the increasing trend of house prices in Australia was depressed by the slowdown of expansionary monetary policy. On the contrary, residential construction costs were significantly
increased by the monetary policy changes. According to housing economics, house prices are positively interrelated to new housing outputs while there is a correlation between the output level of new housing and the costs of housing construction. Therefore, the results yielded by the generalized impulse function imply that the construction of new dwelling and the addition as well as conversion to established housing will be negatively influenced by the decelerations of monetary expansion in Australia. This conclusion is again supported by the empirical evidence with respect to the values of the responses of housing approvals to the impulses of interbank rates and money supply. Summarily, the standard deviations of interbank rates and money supply triggered a dramatic negative impact on new housing construction activities in Australia.

Finally, an identifiable interaction between monetary policy and the supply side of the housing sector has been discovered, and the changes in house prices and housing approvals causally and dynamically affected the movement in money supply in Australia. The adjustment in money supply is the only way left for the Reserve Bank of Australia to change the cash rates in Australia’s money market. Hence, it is summarised that the development of the supply side of the housing sector will lead to significant effects on the decisions on monetary policy. This outcome is underpinned by the conventional macroeconomic theory, which addresses the reliability of the conceptual model in terms of the functions of monetary policy and housing supply, and thus validates the VEC-D model.

In conclusion, this empirical study successfully identified the negative impact of the slowdown of expansionary monetary policy and global economic turmoil on housing supply in Australia, and it also uncovered that monetary policy influences the supply side of the housing sector by the price (house price) and cost (residential construction cost) factors. Therefore, the research question, ‘What is the interrelationship between housing supply and monetary policy within the context of global economic turbulence?’, has been answered.
Chapter 6: Conclusions

The overall outcomes of this thesis provide policy makers with valuable insights to current policies in relation to housing. The previous section has highlighted that a shortage of housing supply can negatively affect housing affordability. It has also been addressed throughout this research that the changes in the Australian monetary policy over the last decade are the negative gearing of the supply side of Australia’s housing sector. As a result, this thesis has drawn out an implication for policy makers that the current monetary policy should be one of the significant determinants of the consecutive fall in housing affordability across Australia, and the existing housing policies are not effective to offset this declining trend. Therefore, new policies are required in Australia to reduce the severe impact of monetary policy on the housing sector. As suggested by the perspective of policy collaboration, some other policies (e.g. construction policy or taxation policy) related to dwelling construction can be implemented for the construction industry by Australia’s commonwealth or state governments.

6.2 Contributions to Literature

There are three significant contributions of this research to the housing literature. Firstly, this thesis addressed the research gap with regard to the comprehensive interrelationship between housing supply and monetary policy. Secondly, to meet the primary research aim, a more complete and realistic VEC-D model (a vector error correction model with a dummy variable) that reflects ‘real world’ shocks to economic systems has been developed. The development and the use of the VEC-D model allow this research to be the first empirical study on the impacts of the changes in the global economic environment on the supply side of the housing sector, particularly in Australia’s context. Thirdly, unlike prior empirical studies, this research has considered not only the responses of new housing construction to the shocks of monetary policy and global economic turmoil, but also the repercussions of the addition and conversion to established dwelling.
6.3 Research Limitations and Future Study

6.3.1 Research Limitations

Although this research has successfully identified the interrelationship between housing supply and the shocks of monetary policy and global economy, there are some research limitations that have to be concerned. For instance, the empirical analysis of this study on the linkage between housing supply and monetary policy depends upon the data on a national level. In reality, the response of the supply side of the housing sector to the shocks of monetary policy on a regional level can be considered. The reason for omitting the estimation within the regional context in this study is a lack of the data on state-level house prices. Moreover, because of a lack of the longer time-series data and the data on vacancy rates, this research has just employed 12-year data and did not include the vacancy rates in modelling. Finally, the uses of the Australian M1 triggered a limitation that the narrow money supply does not involve the information of public non-bank sector.

6.3.2 Future Study

Owing to the research limitations, collecting and compiling the data on the Australian house prices and vacancy rates on a state level is a promising way for the prospective study. Under the sub-national level, the effects of regional heterogeneities should be included in modelling as the economic environment surrounding each regional or state market are different and these markets can be affected by a variety of unobservable factors, such as culture, race, education and gender composition of local population. Thereby, estimating the interrelationship between housing supply and monetary policy on a state level with the regional heterogeneities will be a positive future topic. In addition, as mentioned in Section 6.1 of this chapter, the topics integrated with other essential policy issues, involving construction policy or tax policy, are also the potential research areas.
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APPENDICES
Appendix 1: Impulse Response Results

*Appendix 1-1: Response of the INT to Generalized S.D. Innovation*

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![Graph showing the response of the HP to Generalized S.D. Innovation]
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