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MODELLING HOUSING SUPPLY AND MONETARY POLICY WITHIN THE CONTEXT OF GLOBAL ECONOMIC TURBULENCE

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ABSTRACT. Housing supply is an essential component of the property sector. Compared with an increasingly strong housing demand, the growth rates of total housing stock in Australia have exhibited a downward trend since the end of the 1990s. Over the same period, the significant adjustments in the Australian monetary policy were being implemented under a turbulent global economic climate. This research aims to identify the relationship between housing supply and monetary policy within the context of global economic turbulence by a vector error correction model with a dummy variable. The empirical evidence indicates that the monetary policy changes and global economic turmoil can significantly affect the supply side of the housing sector in Australia. The models developed in this study assist policy makers in estimating the political impacts in the global context.

KEYWORDS: Housing supply; Monetary policy; Global economic turbulence; Vector error correction model

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1. INTRODUCTION

Housing supply is undoubtedly significant to the property sector. However, the Australian housing sector's capacity to supply has already reached a crisis point since the 1990s whilst the housing demand across Australia was increasingly strong. Figure 1 illustrates that the growth rates of total housing stock exhibited a downward trend with a dramatic urban population growth in Australia over the past decade. Urban economic theory claims that the growth of urban population is an indicator of housing demand, and a convergence exists in between the total housing stock and urban population (DiPasquale, 1999). Nevertheless, it can be perceived from Figure 1 that a divergence between housing supply and urban population has occurred in Australia.

The statistics regarding housing finance also indicate that the annual number of housing mortgage for the purchase of owner-occupied dwelling in Australia increased by more than 90% during the period of 1997-2008 (ABS, 2009c). These data further reflect the strong demand for housing in Australia. Owing to the increasing housing demand and the inadequate housing supply, a shortage of approximately

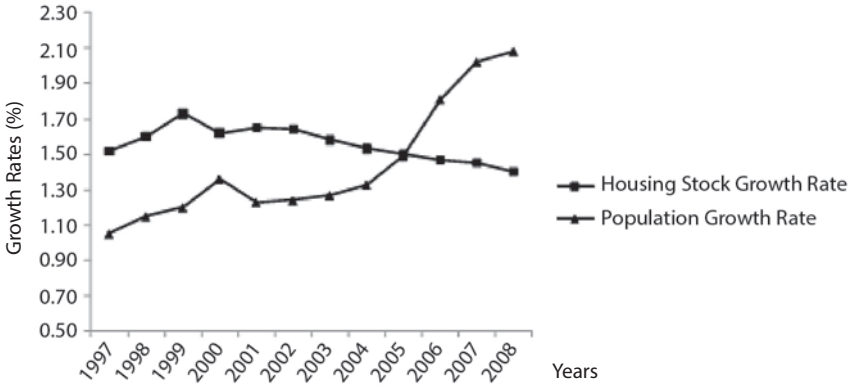


Figure 1. Growth rates of urban population and housing stock in Australia (Australian Bureau of Statistics (ABS), 2009a)

110,000 dwellings has emerged across Australia in 2008 (HIA, 2009*)*. In simple terms, recently, Australia's supply of housing can not keep pace with the increase in housing demand.

According to the data provided by the Reserve Bank of Australia (RBA), from 1997 to 2008, the growth rates of Australia's money supply had decreased and there had been a corresponding rise in interest rates (RBA, 2009). An increase in interest rates as well as a decrease in the money supply growth rates implies that the Australian monetary policy was changed significantly in 12 years. RBA's (1999) announcement supported this perspective and 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.

Monetary policy is generally defined as a process by which the central bank of a country adjusts interest rates to a target level in money market (McTaggart et al., 2003; RBA, 2007a). It is an essential tool for policy makers to regulate economic activities. More importantly, interest rates determined by monetary policy play an important role in the changes in the residential construction costs, which can significantly affect housing supply level (Windapo and Iyagba, 2007). Thus, there might be an indirect relationship between interest rates or monetary policy and the supply of housing (Bourne, 1981). However, in the housing literature, many researchers have investigated how monetary policy affects housing demand while few of them have focused on comprehensively estimating the linkage between housing supply and monetary policy. Furthermore, during the recent decade, the global economic condition was turbulent as a consequence of some special events (RBA, 2001b; 2008). Nevertheless, little work has been done to include the issues of global economic turmoil in the housing supply modelling. Therefore, a research question, 'What is the interrelationship between housing supply and monetary policy within the context of global economic turbulence?', has been raised. The aim of this study is to contribute to the literature by empirically investigating the relationship between housing supply and monetary policy under the global economic disturbance.

The rest of this paper is laid out as follows. Next section will review the literature regarding the relationship between monetary policy and the housing sector. Then, the *Conceptual Model* followed by the *Methodology* and *Data Collection* will be introduced. Finally, the empirical results yielded by the selected econometric techniques will be used for analysis and discussion.

2. LITERATURE REVIEW

Monetary policy maintains an active role in the governmental interventions on economy. It is considered to be an activator that bridges policy makers to various economic sectors. Theoretically, monetary policy is able to affect '*both the supply of and demand for housing*' (Elbourne, 2008, p. 68).

The responsiveness of the housing sector to the shocks of monetary policy has been well considered in numerous studies. The econometric techniques employed for these studies is either the reduced-form vector autoregression (VAR) model or other sophisticated VAR [e.g. structural VAR (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 study by Baffoe-Bonnie (1998), in which a reduced-form VAR was applied to interpret the dynamic effects of monetary policy on house prices and the number of houses sold at national and regional levels in the US. The quarterly data on money supply, mortgage rates, house prices and the number of houses sold were used for modelling. The estimates suggested that monetary policy had a strong impact on mortgage rates, which in turn triggered immediate responses of house prices and the number of houses sold in the US housing markets (Baffoe-Bonnie, 1998).

Likewise, in 2004, Edelstein and Lum (2004) studied the relationships among monetary policy, house prices, wealth effect and macroeconomic situations in Singapore by a reduced-form VAR. By using the data on the disposable incomes, interbank rates, real private and public house prices, transaction volume and real public housing wealth measure, the empirical evidence indicated that a shock of the interbank rates negatively affected the disposable incomes, private and public house prices and public housing wealth in Singapore (Edelstein and Lum, 2004).

Some past research demonstrated that the model misspecification is easily caused in the reduced-from VAR (Bernanke and Blinder, 1992; Sims, 1992). To avoid this problem, more and more studies in the recent decade identified the effects of monetary policy on the housing sector by the SVAR or VECM. The research by Lastrapes (2002), for instance, examined the impact of monetary policy using the SVAR. The primary aim of Lastrapes (2002) was to estimate the response of the prices of owner-occupied housing to the shock of money supply across the metropolitan regions in the US. The results indicated that both real house prices and house sales were driven up in a short-run period in response to the positive shock of money supply (Lastrapes, 2002).

It is noted that Lastrapes (2002) work concentrated on the influence of monetary policy on house prices at the regional level. However, Aoki et al. (2002) investigated this issue within the national context under the SVAR as well. The research by Aoki et al. (2002) sought to explore the linkages among monetary policy, house prices and consumption level in the UK. It was identified that 0.8% decrease in house prices in the UK was triggered after the 50 basis point shock of interest rates in five quarters (Aoki et al., 2002).

In addition to Aoki et al. (2002), Iacoviello (2005) and Iacoviello and Minetti (2008) tested monetary policy impacts in conjunction with the housing sector at the national level by means of the SVAR and VECM respectively. In Iacoviello's (2005) research, six European countries (i.e. France, Germany, Italy, Spain, Sweden and UK) were viewed as an integrated entity to examine the role of monetary policy in the inflation of house prices. Under the identification scheme of King et al. (1991), the results yielded by the SVAR suggested that house prices decreased by 1.5% in response to a tightening of monetary policy. On the other hand, Iacoviello and Minetti (2008) contributed to the literature by uncovering the credit

channels of the monetary policies of such four European countries as Germany, Finland, Norway and UK. The results generated by the VECM showed that an approximately 0.25% fall in the GDP and 1% drop in house prices were produced by a shock of interest rates (Iacoviello and Minetti, 2008).

Recently, the research by Elbourne (2008) emerged to clarify the relationships between house prices and the transmission mechanisms of monetary policy, which include commodity prices, interbank rates, retail sales, price level, money supply and nominal exchange rates. Empirical evidence from the SVAR assisted Elbourne (2008) to discover that the retail sales fell by 0.4% after receiving a positive shock of the interbank rates while house prices decreased up to 0.75% in response to 15% of the consumption drop caused by the monetary contraction.

The research in relation to the effect of monetary policy on the housing sector in the Australian context is sparse. The study by Liu and Liu (2010) investigated the relationship between monetary policy and housing affordability across eight state capital cities in Australia using the SVAR. The shocks of monetary policy in this study were measured by the interbank rates and money supply, and housing affordability was associated with house prices. The results indicated that the interbank rates triggered -1.28% effects on house prices in Australia's eight state capital cities while money supply positively affected house prices by 1.08%.

It is clear from the prior literature review that the past studies on the linkage between monetary policy and the housing sector are primarily concerned with the impacts of monetary policy on house prices, GDP and disposable incomes. These variables are the components of the housing demand function (Quigley, 1999; Hui and Yue, 2006). In short, while there is extensive empirical literature on the relationship between monetary policy and the demand for housing, far less has been written about housing supply.

The research on the influence of monetary policy on housing supply can be dated back to the 1970s. An early study is that undertaken by Bebee (1972), which divided the Canadian housing markets into five regional markets and analysed the effects of interregional population flows, interest rates and the household number on housing starts by a simple multivariate regression model. The empirical results suggested that monetary policy and population growth significantly affected the housing starts in all regional markets in Canada (Bebee, 1972). In 2008, the research by Vargas-Silva (2008) explored the effect of monetary policy on the US housing starts and residential investment employing the SVAR. According to the results of the impulse response function, Vargas-Silva (2008, p. 977) identified that '*housing starts and residential investment response negatively to contractionary monetary policy shocks*'.

This literature review has demonstrated that a number of empirical studies tested the relationship between monetary policy and the housing sector within the VAR system. The majority of them, however, focused on housing demand rather than the supply of housing. Of the past housing supply research, Bebee (1972) and Vargas-Silva (2008) did not examine the linkage between the supply of housing and monetary policy in the comprehensive context, but discussed this issue from a singular perspective related to housing starts. Since the 2000s, particularly in the post-GFC (global financial crisis) era, little attention has been paid to empirically incorporate the global economic disturbance into the housing supply studies. The current limited research scope provides this paper with an opportunity for the further investigation.

3. RESEARCH DESIGN

To ascertain the effects of monetary policy on housing supply, the first step in this study is to develop the functions of monetary policy and housing supply that incorporate the indicators of monetary policy and housing supply. This research strategy complies with the studies by Hwang and Quigley (2006) and Liu and London (2011a), both of which estimate housing supply and monetary policy respectively through a series of relevant economic variables.

Monetary Policy Indicators

Monetary policy, in Australia, is determined by the RBA in accordance with the *Reserve Bank Act 1959*, aiming to control inflation, stabilize currency, improve full employment and maintain economic prosperity and people's welfare (RBA, 2007b). The RBA (2007a) stated that an inflation target is the centrepiece of the Australian monetary policy.

The adjustment in interest rates is a major instrument for the country in which the inflation-targeting monetary policy is operated (McTaggart et al., 2003). Thus, interest rates are an indicator of the Australian monetary policy. However, money supply will also be introduced for modelling in this study because interest rates and money supply are inextricably interrelated. In Australia, a single tool left for the RBA after the removal of all direct controls on the financial markets in the 1980s to achieve its objective is an open market operation (OMO). The OMO is a method used to adjust interest rates by changing money supply. As a result, employing money supply for the analysis relevant to Australia's monetary policy is rational (Liu and Liu, 2010; Liu and London, 2011b). The function of the Australian monetary policy can be written as Eq. (1).

$$MP_{AUS} = f(INT, MS) \tag{1}$$

where: INT denotes interest rates; and MS represents money supply.

Housing Supply Indicators

Quigley (1999) summarised that the supply of housing depends on the prices of house, vacancy rates and new housing construction activities, thus housing supply is a function of house prices, vacancy and new housing construction. Hui and Yue (2006) adopted Quigley's (1999) perspectives to study the housing price bubbles and their empirical results validated Quigley's (1999) housing supply function.

Although the reliability of Quigley's (1999) conceptual model has been supported by Hui and Yue (2006), this function does not include the variable of construction costs. Somerville (1999) argued that construction costs are one endogenous variable of the housing supply function. Liu and London (2011a) further proved that construction costs and housing supply in Australia are interconnected. Hence, construction costs should be incorporated in the housing supply function. More importantly, in some western countries (e.g. Australia, UK and US), new housing construction involves the completely new dwelling construction and the addition as well as conversion to the established house. As claimed by Baer (1986), the addition and conversion of existing housing stock are the significant dynamics on the supply side of the housing sector. Therefore, a new housing supply function on the basis of Quigley's (1999) perspective can be developed as Eq. (2).

$$H^s = f(HP, VAC, Cost, Const^T) \tag{2}$$

where: HP stands for house prices; VAC denotes vacancy rates; $Cost$ represents residential construction costs; and $Const^T$ is the construction of completely new dwelling and the addition and conversion to the established house.

In summary, the analysis on the linkage among the endogenous variables in Eq. (1) and (2) can assist to identify the interrelationship between housing supply and monetary

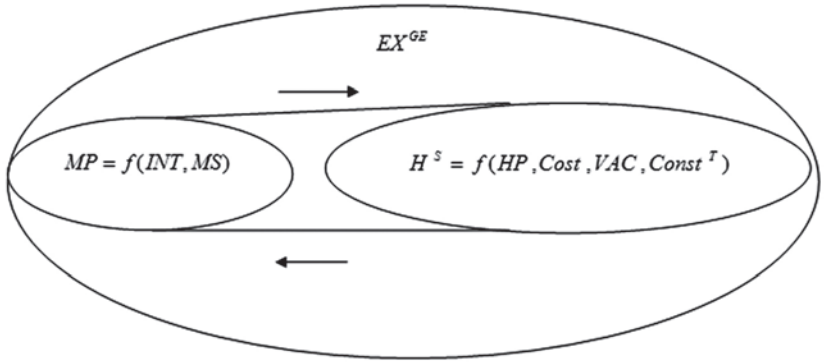


Figure 2. Conceptual model for estimating the relationship between housing supply and monetary policy under the global economic turbulence

policy. The interrelationship defined in this study is the causal links and dynamic interactions between the variables. Furthermore, to capture the impacts of global economic turmoil triggered by some special events on the supply side of the housing sector, an exogenous variable EX^{GE} isolated from Eq. (1) and (2) must be established. The specification on the EX^{GE} will be described in the *Methodology* and *Analysis and Discussion*. Figure 2 simply illustrates the conceptual model developed in this section.

4. METHODOLOGY

The econometric model used to estimate the conceptual model is a vector error correction model (VECM). The VECM is suited for identifying the causal links and dynamic interactions between the variables (Dinda and Coondoo, 2006; Liu and London, 2010; and Luo et al., 2007). Constructing the VECM is preceded by two tests, one is the unit root test and the other is the cointegration test.

The VECM was proposed by Engle and Granger (1987) through integrating the autoregressive and error correction representations into the co-integrated systems. It is a VAR model with the co-integrated restriction and error correction term. The advantage of recognising the cointegration in the VAR framework is the improvement in modelling performance (Engle and Yoo, 1987). The form of the VECM (p) can be represented as Eq. (3) and (4).

$$\Delta Y_t = C + \alpha\beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{3}$$

$$\Delta Y_t = C + \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{4}$$

where: ΔY_t is a k-dimension vector in difference; $ecm_{t-1} = \beta' Y_{t-1}$ is the error correction term; Γ_i is the coefficient matrices; C is the intercept; and ε_t is a vector of error term.

It is known that an exogenous variable has been built to capture the effects of global economic turmoil. Thereby, a dummy variable will be imposed into the VECM in this research. Statistically, dummy variable takes the values 1 or 0 to indicate the occurrences of special events, such as the GFC and war. If a special event occurs in the i-th period, the values of this period will be represented as 1 and otherwise 0. As a result, a VEC-D model (a VECM with a dummy variable) can be written as Eq. (5).

$$\Delta Y_t = C + \alpha ecm_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \delta D_t + \varepsilon_t \quad (5)$$

where: ΔY_t represents the parameter in the difference level; ecm_{t-1} is the error correction term; D_t denotes the dummy variables; C is the intercept; and ε_t is a vector of error term. The use of the dummy variable in the econometric models can always increase the model fit (Crane and Nourzad, 1998; Fan et al., 2009). Based on Eq. (1) and (2), Eq. (5) is able to be rewritten as follows.

$$\Delta HP_t = C + \alpha ecm_{t-1} + \sum_{i=1}^{p} \Gamma_{1,i} \Delta INT_{t-i} + \sum_{i=1}^{p} \Gamma_{2,i} \Delta MS_{t-i} + \sum_{i=1}^{p} \Gamma_{3,i} \Delta HP_{t-i} + \sum_{i=1}^{p} \Gamma_{5,i} \Delta Cost_{t-i} + \sum_{i=1}^{p} \Gamma_{6,i} \Delta Const_{t-i}^{T} + \delta EX_t^{GE} + \varepsilon_t \quad (6)$$

$$\Delta Cost_t = C + \alpha ecm_{t-1} + \sum_{i=1}^{p} \Gamma_{1,i} \Delta INT_{t-i} + \sum_{i=1}^{p} \Gamma_{2,i} \Delta MS_{t-i} + \sum_{i=1}^{p} \Gamma_{3,i} \Delta HP_{t-i} + \sum_{i=1}^{p} \Gamma_{5,i} \Delta Cost_{t-i} + \sum_{i=1}^{p} \Gamma_{6,i} \Delta Const_{t-i}^{T} + \delta EX_t^{GE} + \varepsilon_t \quad (7)$$

$$\Delta MS_t = C + \alpha ecm_{t-1} + \sum_{i=1}^{p} \Gamma_{1,i} \Delta INT_{t-i} + \sum_{i=1}^{p} \Gamma_{2,i} \Delta MS_{t-i} + \sum_{i=1}^{p} \Gamma_{3,i} \Delta HP_{t-i} + \sum_{i=1}^{p} \Gamma_{5,i} \Delta Cost_{t-i} + \sum_{i=1}^{p} \Gamma_{6,i} \Delta Const_{t-i}^{T} + \delta EX_t^{GE} + \varepsilon_t \quad (8)$$

where: C is the intercept; α is the adjustment coefficient; ecm_{t-1} stands for the error correction term; and ε_t denotes the error term. At time t, INT_t is interest rate; MS_t is money supply; HP_t is house price; $Cost_t$ is the residential construction cost, $Const_t^T$ is new housing construction, and EX_t^{GE} represents the global economic turbulence.

The causal links and dynamic interactions among variables can be detected by the Granger causality test and generalized impulse response function under the VECM. The Granger causality is a concept proposed by Granger (1969) in the 1960s and Sims (1972) developed a test for this causality depending on the VAR. The Granger causality test is utilised to examine whether or not the lagged values of a variable X have explanatory power to the other variable Y. If the changes in the Y can be explained by the lagged values of X, it is concluded that 'X Granger-cause Y'.

The impulse response function (IRF) is a technique used to trace the dynamic effect of a shock of the error term of an endogenous variable to other endogenous variables in the VAR or VECM. Koop et al. (1996) developed the traditional IRF and devised a unified method to the impulse response analysis that is applicable for both linear and nonlinear models. This approach proposed is the generalized impulse response function (GIRF).

5. DATA COLLECTION AND DESCRIPTION

Data Collection

For the purpose of estimating a model, data were extracted from several reliable sources. These series of data cover from the first quarter of 1997 (1997Q1) to the fourth quarter of 2009 (2009Q4). Firstly, house prices employed in this study are the median house prices, which are published by the Real Estate Institute of Australia (REIA, 2010).

Secondly, the output producer price indexes (PPI) of housing construction will be used as

a proxy for the residential construction costs. The output PPI is an index issued by the ABS measuring the rates of changes in the costs (labour input costs, plant and material input costs) throughout the procedure of housing production (ABS, 2005; 2010c; 2010d), and it includes the information with regard to the construction of completely new dwelling and the addition and conversion to the established house (ABS, 2010c). Moreover, new housing construction activities will be measured by housing approvals published by the ABS (2010a). Housing approvals reflect the total number of dwelling (house and other residential buildings) approved for construction in the given periods (ABS, 2010b). In previous research, housing starts are normally selected to measure the flow of new housing construction. However, in Australia, the data on housing starts do not accurately reflect the number of the residential units produced by the addition and conversion to the existing housing. On the contrary, housing approvals reveal not only the number of completely new housing construction but also the addition and conversion to the existing housing (ABS, 2010b).

Finally, the interbank rates and the M1 provided by the RBA are the ideal data for examining the shocks of monetary policy (Elbourne, 2008; Liu and Liu, 2010). The interbank rates are the operation target for RBA's monetary policy, and the M1 is the total amount of currency and current deposits of private non-bank sector in commercial banks (RBA, 2001a; 2010a; 2010b). The reason for selecting the M1 as the proxy for money supply is that the M1 is a leading economic indicator in realistic economic system and there is a significant interrelationship between the M1 and housing sector (Elbourne, 2008; Iacoviello, 2005; Lastrapes, 2002; and Liu and Liu, 2010).

The vacancy rates will be omitted in modelling in this research due to a lack of data on the vacancy rates or total number of vacant dwellings in the whole housing market at both regional and national levels in Australia (Zochling, 2010). Hui and Yue (2006) claimed that the variable with respect to the vacancy is for measuring the balance between the demand and supply in the housing market. However, the primary aim of this study is to test the impact of monetary policy on the development of the supply side of the housing sector. 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 adequately efficient to reflect the movement in the supply side of the housing sector. Additionally, the house prices selected for estimation contain the information of the vacant and occupied housings (REIA, 2009). Excluding the total vacant housing from modelling would not bias the results.

Data Description

In the light of the statistics from the REIA (2010) and the ABS (2010c), house prices and output PPI in Australia have increased dramatically since the 1990s. Figure 3 displays the changes in house prices and output PPI between 1997Q1 and 2009Q4 in Australia's housing sector. It can be identified from the figure that the output PPI of housing construction corresponding to the left-hand vertical axis increased from 94.6 to 152.6 with an increase rate of 58% during the period under study. Simultaneously, the Australian house prices, which are articulated by the right-hand vertical axis, maintained an increasing trend as well. Figure 3 indicates that the median house prices in Australia kept increasing and achieved AUD 471,200 in 2007Q4. Then, Australia's house prices began to move down and decreased to AUD 403,500 in 2009Q1. Since 2009Q2, the house prices in Australia had risen again and reached AUD 477,000 in 2009Q4. On the other hand, Figure 4 illustrates 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 2009.

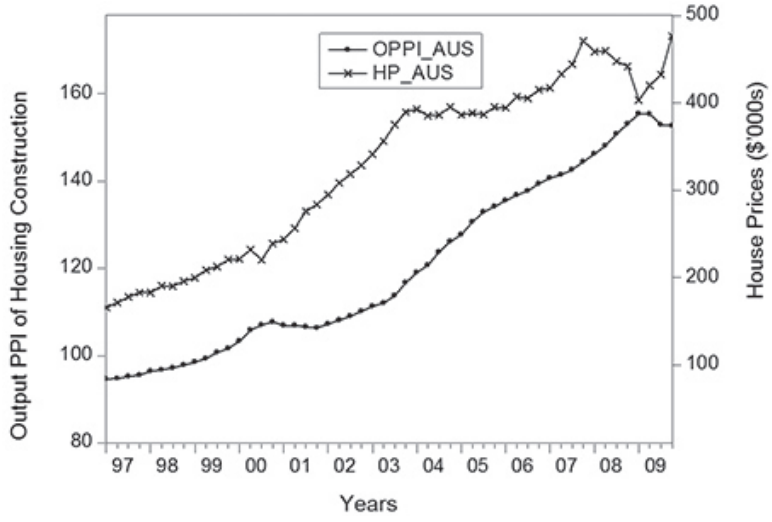


Figure 3. House prices and output PPI in Australia (ABS, 2010d; REIA, 2010)

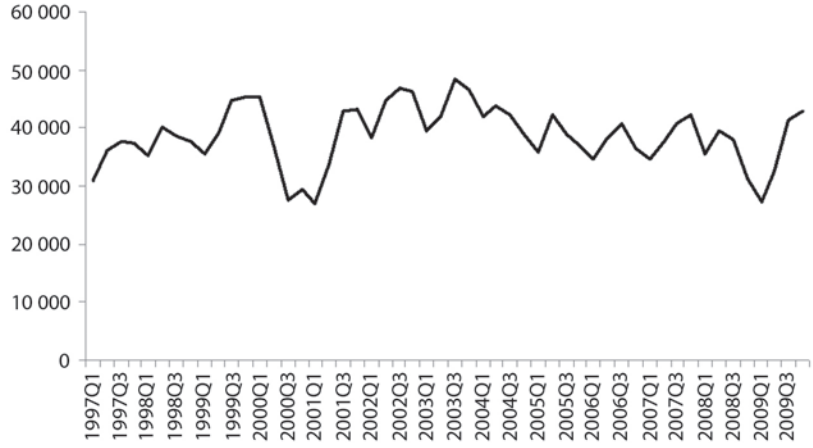


Figure 4. Number of housing approvals in Australia (ABS, 2010a)

The Australian interbank rates and money supply (M1) referred from RBA's (2010a) statistics expressed significant changes. Figure 5 shows 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 3.48% in 2009Q4. Conversely, M1 moved more smoothly than that of interbank rates, rising from 93.8 billion dollars to 251.3 billion dollars in 13 years.

The data described previously reflect that Australia's housing sector was exposed to a dramatic shift of monetary policy from 1997 to 2009. Therefore, the question with regard to the relationship between monetary policy and the supply side of the housing sector was addressed again. This question will be answered in accordance with the results generated by the VECM in next section.

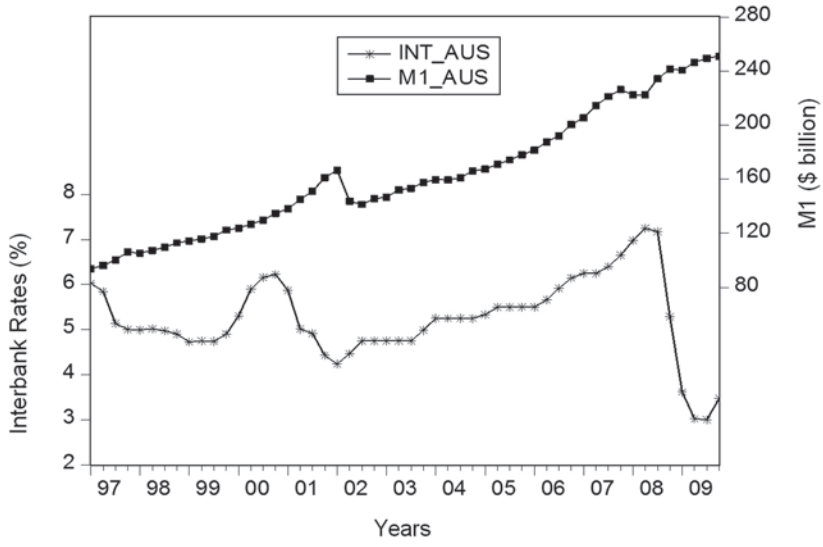


Figure 5. Interbank rates and M1 in Australia (RBA, 2010a; 2010b)

6. ANALYSIS AND DISCUSSION

Unit Root Tests and Cointegration Tests

In time-series modelling, data imported must be stationary. Otherwise, a spurious regression will occur (Granger and Newbold, 1974). Therefore, the unit root tests will be the first test conducted in this study. Table 1 reports the results of the PP unit root tests proposed by Phillips and Perron (1988) for the selected variables [house price (HP), output PPI (OPPI), housing approvals (HA), interbank rates (INT) and M1]. Based on this table, all data employed are integrated of the order one, i.e. I (1).

The cointegration test is the second necessary step for constructing the VECM. The approach developed by Johansen and Juselius (1990) (known as the JJ test) will be carried out after the PP tests. Suggested by the AIC and SC, one lagged term has been selected. Although there are five models in the JJ test, this study is concerned with the Model 3 and Model 4 (Model 3 has a linear data trend but no trend in the cointegration equation; and Model 4 has a linear data trend with both an intercept and a trend in the cointegration equation) because the majority of the data in this paper appears to be trending series. Table 2 summarises the results of the JJ tests, which suggest that one long-run equilibrium relationship exists in the observed variables.

In Table 2, one cointegration vector has been identified by both Model 3 and Model 4 under the Trace test and the Max-eigenvalue test. However, Krol and Ohanian (1990) claimed that there is a stationary deterministic trend in money supply. Hence, one cointegration vector of Model 4 will be utilised as Model 4 is suitable for the situation that some of the series are trend stationary.

Dummy Variable Specification

With the globalization, Australia's economic sectors are undoubtedly impacted by the global economic climate. Over the recent decade, the global economic turmoil was ascribed to some special events. To quantify the influences of these events on the Australian housing sector, a dummy variable has been imposed into Eq. (5).

Table 1. Summary of the PP test results

Variables	Level		First difference		Results
	Model specification (lags)	PP Test Statistics (5%, 1% sig. level)	Model specification (lags)	PP Test Statistics (5%, 1% sig. level)	
ln(HP)	Trend & Intercept (2)	–0.24 (–4.17, –3.51)	None (2)	–4.66 (–2.62, –1.95)	*I* (1)***
ln(OPPI)	Trend & Intercept (2)	–2.67 (–4.17, –3.51)	None (2)	–3.65 (–2.62, –1.95)	*I* (1)***
ln(HA)	Trend & Intercept (2)	–3.32 (–4.17, –3.51)	None (2)	–6.24 (–2.62, –1.95)	*I* (1)***
ln(INT)	Trend & Intercept (2)	–2.76 (–4.17, –3.51)	None (2)	–2.59 (–2.62, –1.95)	*I* (1)**
ln(M1)	Trend & Intercept (2)	–2.49 (–4.17, –3.51)	None (2)	–4.29 (–2.62, –1.95)	*I* (1)***

Notes: The PP Test, which is the unit root test similar to the ADF Test, contains three kinds of model specification: only intercept, trend and intercept, and no trend and no intercept. *** & ** denote the 1% and 5% significance levels.

Table 2. Summary of the JJ cointegration test results

Variables	Lagged difference	Model specification	Results (Trace test)	Results (Max-eigenvalue test)
ln(HP), ln(OPPI), ln(HA), ln(INT), ln(M1)	1	Model 3	1	1
		Model 4	1	1

The challenging issue of establishing the dummy variables is to identify the event window length. Huang and Liu (2010) argued that the announcements of the RBA 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 were reduced from 5.0% to 4.25% between September 2001 and March 2002 (RBA, 2001b; 2002). RBA (2002) claimed that the economic weakness emerged at the end of 2001 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 the GFC took place. The RBA and Australian commonwealth government announced to ground an economic stimulus package in September 2008 to circumvent the rapid spread of the crisis (RBA, 2008; Australian Treasury, 2009). These announcements denote that the 2008 GFC began to influence Australia in 2008Q3. Influenced by the responses of the Australian government to the financial crisis, the cash rates in Australia dropped to 3.0% from 7.25% between September 2008 and September 2009 (RBA, 2010a). In October 2009, an increase in the cash rates had been decided by the RBA because of the resuming growth of global and

Australia's economy (RBA, 2009). This change implies that the impacts of the GFC on Australia finished in 2009Q4. Therefore, the values of 2008Q3, 2008Q4, 2009Q1, 2009Q2 and 2009Q3 will be set as 1 as well. Overall, during the period under study, the special event windows are: 2001Q3, 2001Q4, 2002Q1, 2008Q3, 2008Q4, 2009Q1, 2009Q2 and 2009Q3. Summarily, the dummy variable in the VECM contains the information of two special events, the 2001 terrorist attack and the 2008 GFC. The values of the event windows in this dummy series are 1 and 0 of others.

Analytical Discussion

As the cointegration relationship was found, a VECM with one dummy variable (VEC-D) is constructed. Table 3 summarises the estimates of the VEC-D model. The implication of the coefficients and *t*-statistics of dummy variable is that the supply side of the Australian housing sector received significant negative impacts from the observed global special events (the 2001 terrorist attack to the US and 2008 global financial crisis). The statistics issued by the ABS (2009c) supported this finding and indicate that the number of new housing approvals in Australia decreased by 12% between 2001Q3 and 2002Q1, and dropped approximately 25% in the period of 2008Q3-2009Q3.

The Granger causality test and generalized impulse response function are able to be carried out under the VEC-D model. Applying the Wald tests and joint *F*-tests, the null hypothesis that the independent variables do not Granger-cause the dependent variables is rejected at the 5% and 1% significance levels. Table 4 shows the results of the Granger causality tests.

According to Table 4, a transmission pattern illustrated as Figure 6 can be identified. This pattern not only confirms the interrelationship between housing supply and monetary policy, but also depicts how monetary policy and the supply side of the housing sector interact with each other.

The transmission pattern first suggests a one-way causality relationship between money supply and the interbank rates. This finding complies with the reality that the central bank of Australia affects the interbank rates by changing the supply of money in realistic economic system.

Table 3. Estimates of the VEC-D model

Variables	$\Delta\ln(HP)$	$\Delta\ln(OPPI)$	$\Delta\ln(HA)$	$\Delta\ln(INT)$	$\Delta\ln(M1)$
$\Delta\ln(INT)_{t-1}$	–0.32 (–3.41***)	1.45 (3.75***)	–0.54 (–1.52)	0.22 (1.18)	–0.09 (–1.09)
$\Delta\ln(M1)_{t-1}$	–0.16 (–1.19)	0.06 (1.46)	0.36 (2.27**)	–0.12 (–0.29)	0.60 (1.90**)
$\Delta\ln(HP)_{t-1}$	0.40 (2.38**)	0.06 (1.46)	0.36 (2.27**)	–0.12 (–0.29)	0.60 (1.90**)
$\Delta\ln(OPPI)_{t-1}$	0.84 (1.28)	0.54 (3.61***)	1.48 (1.73**)	1.94 (1.52)	–0.43 (–0.75)
$\Delta\ln(HA)_{t-1}$	0.07 (1.66)	0.02 (2.16**)	0.13 (1.73**)	0.08 (0.78)	–0.10 (2.51**)
Dummy	–0.03 (–2.60***)	–0.01 (–1.94**)	–0.12 (–2.07**)	–0.11 (–3.42***)	0.04 (2.74**)

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 1%, and 5% levels.

Table 4. Summary of the Granger causality test results

Dependent variables	Directions	Chi-square	*P* values	Results
ln(INT)	ln(M1) → ln(INT)	4.75	0.03	Y
	ln(HP) → ln(INT)	1.07	0.99	N
	ln(OPPI) → ln(INT)	0.19	0.66	N
	ln(HA) → ln(INT)	3.26	0.07	N
ln(M1)	ln(INT) → ln(M1)	1.44	0.23	N
	ln(HP) → ln(M1)	5.86	0.02	Y
	ln(OPPI) → ln(M1)	0.49	0.48	N
	ln(HA)→ ln(M1)	10.05	0.00	Y
ln(HP)	ln(INT) → ln(HP)	5.52	0.02	Y
	ln(M1) → ln(HP)	0.37	0.55	N
	ln(OPPI) → ln(HP)	0.67	0.41	N
	ln(HA) → ln(HP)	1.55	0.21	N
ln(OPPI)	ln(INT) → ln(OPPI)	5.27	0.02	Y
	ln(M1) → ln(OPPI)	0.82	0.37	N
	ln(HP) → ln(OPPI)	1.59	0.21	N
	ln(HA) → ln(OPPI)	0.89	0.35	N
ln(HA)	ln(INT) → ln(HA)	2.52	0.11	N
	ln(M1) → ln(HA)	0.78	0.38	N
	ln(HP) → ln(HA)	9.22	0.00	Y
	ln(OPPI) → ln(HA)	13.09	0.00	Y

Figure 6 further illustrates that the interbank rates Granger-cause house prices and the output PPI, both of which Granger-cause housing approvals. However, no causal relationship was identified from the interbank rates and money supply to housing approvals, implying that house prices and construction costs perform as the transmission mechanisms of the impacts of the monetary policy shocks on new housing construction activities. In short, there is a 'ripple effect' among the observed variables, and monetary policy affects new housing construction via house prices and residential construction costs.

The discussions aforementioned focused on the causal links within the direction from monetary policy to housing supply. However, the results indicate that house prices and housing approvals Granger-cause money supply without a feedback. Macroeconomic theory argues that the developments of important economic sectors are a factor considered in monetary policy makings. Hence, the changes in the housing sector can induce the monetary regime shifts.

The Granger causality test identifies the causal links, but it is not able to explore the dynamic interactions among the endogenous variable. Thus, the GIRF will be applied in the following analysis and Figure 7 illustrates the results.

Firstly, there are dramatic effects produced by the interbank rates on house prices. It is noted that the maximum values of the response of house prices to the standard deviation of the interbank rates reach –1.15%.

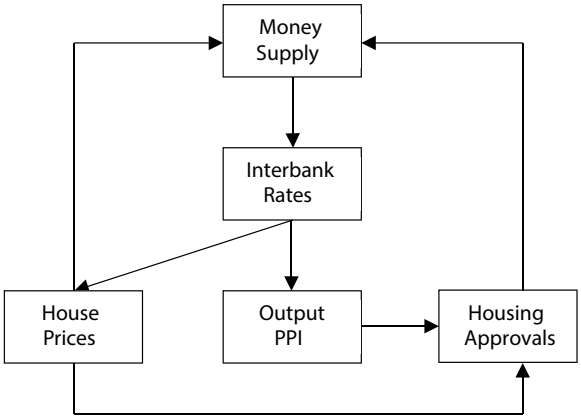


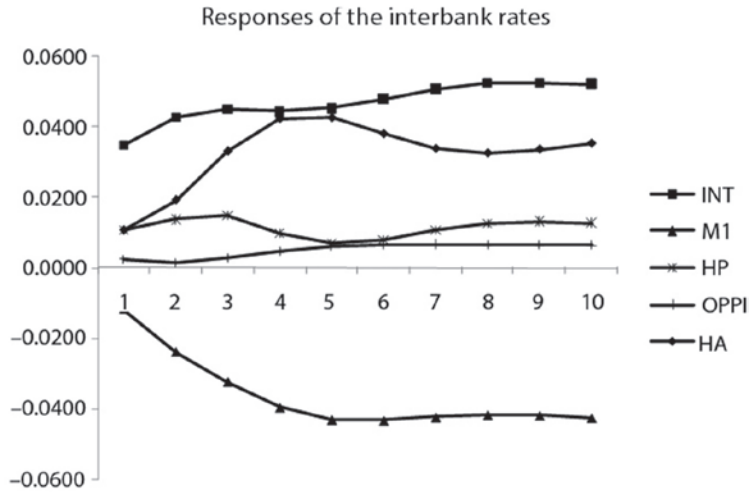
Figure 6. Transmission pattern between monetary policy and housing supply

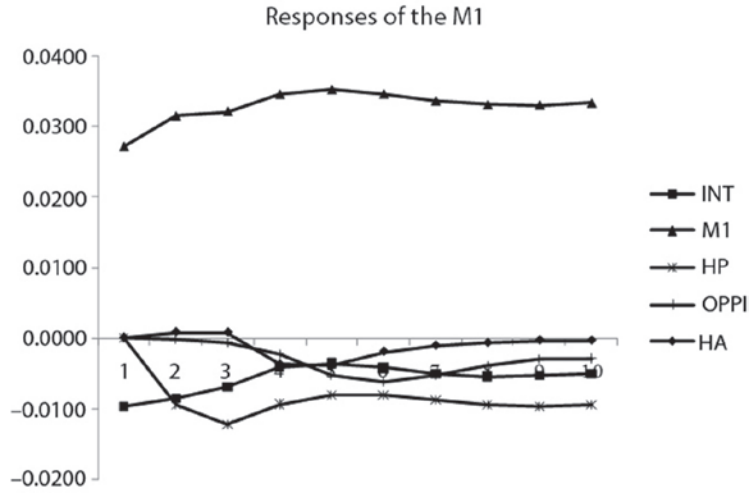
The negative values here indicate that the increasing trend of house prices across Australia had been dramatically depressed by the increase in the interbank rates during the period under study. On the contrary, the response of output PPI to the interbank rates is positive. Specifically, a total of 0.43% dynamics on the output PPI is yielded by the interbank rates, suggesting that an increase in construction costs was strengthened by a rise in the interbank rates. It is acknowledged that an inflation of the interbank rates increases the payments on interests, which represent a major part of the costs of the construction projects financed by the loans of banks or other financial institutions. The ABS (2009c) reports that an approximately 50% of housing construction projects in Australia is under the loans. Thereby, the construction costs in Australia can be easily affected by interest rates.

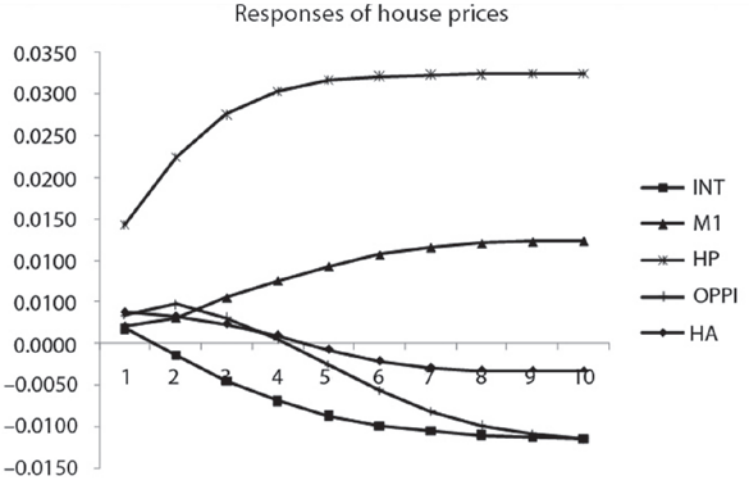
Compared with the interbank rates, house prices and the output PPI are less sensitive to the movement in money supply. The empirical evidence indicates that the standard deviation of the M1 produces less effect on house prices and the output PPI than that of the interbank rates, 1.07% and –0.25% respectively in five quarters. These two values mean that house prices are positively related to the M1 and there is an inverse relationship between the output PPI and money supply.

Secondly, new housing construction activities measured by housing approvals are sensitive to the changes in house prices and construction costs. Overall, house prices have a positive effect on new housing construction while an increase in the output PPI reduces new housing output level. Based on Figure 7, the responsive values of housing approvals to the standard deviations of house prices and the output PPI achieve 1.82% and –4.42% respectively in five quarters. In addition, the impacts of monetary policy shocks on housing approvals are apparent. The housing approvals are decreased by 1.60% on average within three quarters in response to the shocks of the positive changes in the interbank rates and the negative movements in the M1.

Finally, the influence of the supply side of the housing sector on monetary policy makings should not be ignored. The empirical results suggest that the responses of the interbank rates and the M1 to the impulses of house prices, output PPI and housing approvals are: 1.49% and –1.08%, 0.67% and –0.61%, and 4.26% and –0.40% respectively. It is inferred from these values that the Australian central bank will decrease money supply to increase the interbank rates when facing an overheating investment in the housing sector. Conversely, if a shrinking occurred in the supply side of the housing market, the central bank will lower interest rates to stimulate the housing investments. These findings are consistent with the conventional economic theory, thus the developed VEC-D model is reliable.


Responses of the interbank rates
0.0600
0.0400
0.0200
0.0000
–0.0200
–0.0400
–0.0600
1 2 3 4 5 6 7 8 9 10
INT
M1
HP
OPPI
HA


Responses of the M1
0.0400
0.0300
0.0200
0.0100
0.0000
–0.0100
–0.0200
1 2 3
INT
M1
HP
OPPI
HA


Responses of house prices
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0100
0.0000
–0.0050
–0.0100
–0.0150
1 2 3 4 5 6 7 8 9 10
INT
M1
HP
OPPI
HA

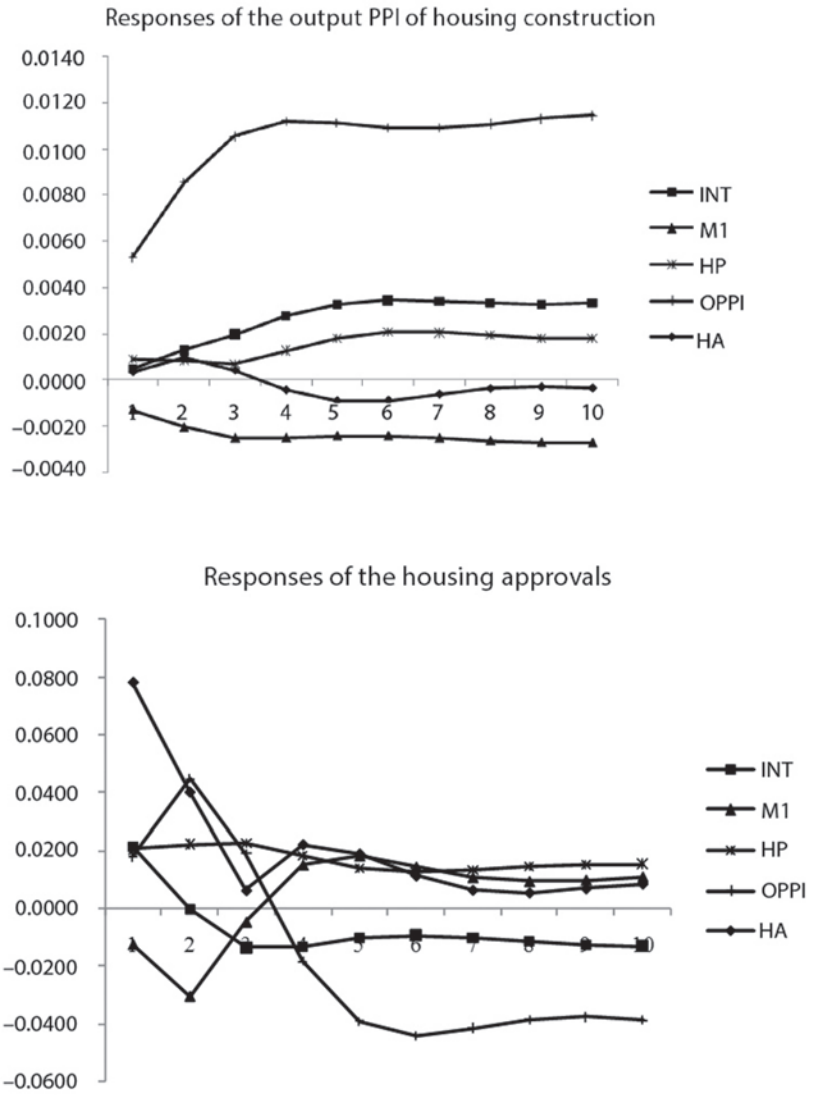


Figure 7. Results of the generalized impulse response function

Finding Implications

The empirical evidence yielded by the GIRF explicitly suggests that the effect of monetary policy is a significant driving force of the supply side of the housing sector. If a slowdown of expansionary monetary policy (it targets to reduce the growth rates of money supply and raise the interbank rates) occurs, the increasing trend of house prices will be depressed while the residential construction costs will be driven up. Then the level of new housing outputs will be negatively affected. This finding helps to identify that the adjustments in the Australian monetary policy between 1997 and 2008 had been the negative gearing of the whole supply side of the housing sector in Australia. Over the same period, Australia's housing affordability has consecutively fallen

in spite of sustained economic growth in the national economy (REIA, 2009). Berry (2003) and Wulff et al. (2011) argued that the consistent fall in the Australian housing affordability during the past decade was interconnected to the undersupply of housing, particularly the affordable dwelling shortage. Hence, monetary policy should be a determinant of Australia's housing affordability and its impact should be addressed in the implementation of housing affordability policy in Australia.

7. CONCLUSION

This study has investigated the interrelationship between housing supply and monetary policy within the context of global economic turbulence by a VEC-D model. The empirical evidence, firstly, indicated that the global economic disturbances triggered by the 2001 terrorist attack to the US and the 2008 GFC created significant negative repercussion of the supply side of the housing sector in Australia. Secondly, depending upon the Granger causality tests, a transmission pattern associated with housing supply and monetary policy has been outlined. The pattern illustrated that the interbank rates serve as an activator that transfers monetary policy makers' interventions to the supply side of the housing sector, and house prices and construction costs are two transmission mechanisms of the impact of monetary policy shocks on new housing construction activities. Finally, according to the results of the generalized impulse response function, it can be concluded that the supply side of the housing sector is dynamically sensitive to the monetary policy shocks.

The overall outcomes of this research have drawn out an implication with regard to housing affordability for policy makers in the Australian context. Therefore, the developed models in this study are useful for governments to perform well in the strategic planning for the residential construction industry within the changing global environment. However, the responses of the supply side of the housing sector to the shocks of monetary policy may vary by regions owing to different bureaucratic procedures. This paper does not discuss this issue and it is a research limitation. Therefore, a comparative study between Australia and other countries (e.g. UK, US and Europe) regarding monetary policy and the supply of housing should be a promising topic in the future research.

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