EXPLORING AUSTRALIAN HOUSING SUPPLY VOLATILITY

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ABSTRACT

This study examines the volatility series of housing supply in Australia. A Generalised Autoregressive Conditional Heteroskedasticity-in-Mean (GARCH-M) model is employed to analyse the volatility series of Australian housing supply over the study period of 1974-2010. The results show the volatility of housing starts is negatively linked to housing starts, suggesting that higher uncertainty does lower housing starts. The results also reveal that the uncertainty of housing starts is also captured by the volatilities of interest rates and construction costs. Therefore policy makers should monitor and attempt to minimise the volatility of housing supply. These steps will enhance housing construction activities and increase the availability of housing supply to potential home buyers.

Keywords: Housing supply, volatility modelling, GARCH-M, Australia

INTRODUCTION

Despite the global financial crisis (GFC), Australian housing prices have increased dramatically in recent years. Over 2002-2010, Australian housing prices have increased by 8.5% per annum (ABS, 2010b). The movements have a significant impact on the welfare of households, since housing is the largest asset for many Australian households. Specifically, housing (either owner-occupied or investment) is an important asset in the broader economy contributing approximately 57% of the total value of Australian household assets (ABS, 2007). More importantly, more than 70% of Australian households have owned a house (ABS, 2008).

Given the significance of the housing sector, extensive studies have examined the volatility pattern of housing prices (Crawford and Fratantoni, 2003, Miller and Peng, 2006, Lee, 2009a). The studies also suggested that both expected housing returns (changes of house prices) and risk (uncertainty)[1] are two important components in housing analysis. But little attention has been placed on the volatility of housing supply. More importantly, the new dwelling supply in Australia has decreased from 33,658 units in Q1:2000 to 27,154 units in Q2:2010 (ABS, 2010a).

Lack of new supply has also been urged as a key variable that contributes to the growth of housing prices (HIA, 2011). Furthermore, a decreased trend of housing affordability is also evident in recent years. The REIA Housing Affordability Index has decreased from 57.4 in 1980:Q1 to 28.9 in 2010:Q2. Importantly, the visual presentation from Figure 1 has also clearly shown that the fluctuation of the housing affordability index is correlated with the movement of housing starts.

Figure 1: Housing start changes and housing affordability index changes in Australia: 1980:Q2-2010:Q2

Sources: ABS(2010) and REIA(2010)

In addition, the housing starts series is very volatile over certain periods, implying that the volatility of housing starts is varying over time. This phenomenon is commonly known as an ARCH or volatility clustering effect in which the volatility of a variable is not constant over time. It is highly volatile in certain periods and high periods of volatility tend to be clustered followed by more tranquil periods of low volatility. The ARCH effect in Figure 1 also suggests that the volatility series of housing supply contains some critical information that should be analysed and considered by housing policy makers and developers for their housing policy and investment decision-making.

[1] Volatility is widely used as an indicator of uncertainty.

This effect also questions the validity of many conventional models with reference to the models assume the variance of the disturbance terms as constant over time. Importantly, the ARCH effect has been widely documented in many property markets. To capture the ARCH effect effectively, a GARCH model has been developed by Bollerslev (1986). Since its introduction, the GARCH model has been widely used to model the volatility of a variable. The model has also been extensively used in the property literature (Stevenson, 2002, Cotter and Stevenson, 2006, Lee, 2009b, Liow et al., 2009).

Moreover, Malpezzi and Wachter (2005) have also shown that housing supply is strongly related to housing speculation and the housing market crashes. Their results reveal that the effect of speculation itself is related to supply conditions. Specifically, speculation would only have a significant impact when housing supply is inelastic. In other words, policies focus on improving the efficiency of housing supply is essential. Therefore, an enhanced understanding of housing supply volatility is critical.

Yet the existing empirical literature has not examined the forward looking volatility of housing development. The only exception is Miles (2009). The study shows that it is important to analyse the volatility series of housing supply in the United States (U.S.) since it would have a negative impact on housing starts. Although Australia is somewhat different from the U.S. as 65% of the Australian population is housed in capital cities, no similar study has been done in the Australian context. Therefore, there are several important research questions: Does the volatility of housing supply contain some important information that has been overlooked by Australian housing developers and policy makers? Will the Australian housing supply be affected by its volatility? What are the important factors in explaining the volatility of Australian housing supply? This study aims to offer some empirical evidence to address these research questions by examining the volatility pattern of Australian housing supply.

The contribution of this study is twofold. Firstly, to the best of our knowledge, this paper is the first study to examine the volatility linkages between housing supply and macroeconomic variables. The important determinants of housing supply volatility are also identified[2]. This is a crucial step in which the volatility of housing supply can be minimised; thereby the housing construction activities can be enhanced and the availability of housing supply to potential home buyers would increase. Secondly, this is probably the first empirical study to examine the volatility pattern of Australian housing supply. The intuition behind this investigation is to determine whether there is the volatility clustering effect in the Australian residential construction industry. The presence of volatility clustering effect suggests the volatility pattern of Australian

[2] In contrast to previous studies, we focus on the volatility linkages between housing supply and macroeconomic variables rather than their relationships in the first moment.

housing development sector contains some important information that should be analysed and considered by builders and urban analysts in their analyses. An enhanced understanding of housing supply volatility will help builders, urban analysts and policy makers to determine whether the uncertainty variable is a crucial variable in estimating the demand of housing investment. Accurate measures of construction demand are required for effective decision-making.

The remainder of this paper is organised as follows. The following section provides a literature review on volatility modelling in housing supply. Data and methodology are discussed in Section 3. Empirical findings are then reported and discussed in Section 4. The final section concludes the paper.

LITERATURE REVIEW

Numerous studies have examined various aspects of housing supply, including housing starts, completions and permits. Although these variables are mainly used to gauge construction activities, they measure different phenomena. Housing permits (or development approvals) provide permission for builders or developers to build. In Australia, a development approval normally must be commenced within a period of 2-5 years in which it varies across different city councils. On the other hand, a building is started when the first physical building activity has been performed on site (ABS, 2010a). A building is only completed when building activity has progressed to the stage where the building can fulfil its intended function.

In the housing literature, Goodman (1986) suggested that house permits can be used to estimate the actual housing starts. DiPasquale and Wheaton (1994) found that new building supply can be explained by fluctuations in interest rates, whereas housing prices is not a significant variable in explaining housing construction. Coulson and Richard (1996) revealed little evidence to support the notion that unseasonable weather has some impact on housing starts in the US, although it is only significant in the North Central region. Coulson (1999) found that housing starts and housing completions are cointegrated, signifying that housing starts do turn into completions. Besides, the results also showed the completion rate is not affected by income, construction costs, interest rates, material prices and housing prices, even though inventories are more influenced by these variables. Somerville (1999) has offered evidence of housing starts are quite cost elastic and higher construction costs do reduce residential construction.

However, empirical work on housing supply outside the US is somewhat limited. Malpezzi and Maclennan (2001) showed that the United Kingdom (UK) market for new housing construction is less elastic compared with the US market. The dissimilarity can be explained by different financial systems and less restrictive planning and regulatory environment in the US. In Netherlands, Vermeulen and Rouwendal (2007) found similar results in which housing supply is inelastic. Tse and Webb (2006) found that house prices and interest rates play a critical role in determining the Hong Kong housing stocks.

Several studies examined the impact of uncertainty on residential construction. Clemhout (1981) utilised the US time series data and exhibited evidence of increased uncertainty will lower capital investment in residential development. Somerville (2001) used a GARCH model to examine whether Canadian builders and developers respond to new information of changing market conditions. The results indicate that new information does affect the timing of housing starts. However, the demand volatility measure is not significant. Interestingly, the insignificance results were attributed to the poor measurement of risk in the analysis. The empirical evidence of Cunningham (2006) showed that uncertainty is an important determinant of construction activities in which one standard derivation in volatility will reduce housing development by 11.3%. Nonetheless, the finding of a subsequent study, Cunningham (2007), demonstrated that the impact of uncertainty has diminished once regulations are controlled. More recently, Bulan et al. (2009) used a GARCH(1,1) model to measure the uncertainty of condominium developments in Vancouver from 1979-1998. Results show that uncertainty (both idiosyncratic and systematic risk) delays condominium construction.

However, Miles (2009) has addressed the deficiencies of standard deviation or variance as a measure of uncertainty that is widely employed by previous studies. Moreover, he also questioned the reliability of using the GARCH model as a measure of uncertainty that was utilised by Somerville (2001) and Bulan et al. (2009) in respect to the model fails to capture the true forward-looking uncertainty of housing supply. To overcome the limitation, he proposed the use of a GARCH-M model in order to investigate the effects of uncertainty on US housing development. His empirical results show that uncertainty has a negative and significant impact on housing starts in the US.

In addition, Miles (2009) only found a volatility clustering effect on house permits and starts. He attributed the results to the concept of real options. Titman (1985) showed that housing developments can also be viewed as real options. Quigg (1993) and Williams (1991) have also offered empirical support to support the view of real estate developments as real options, although Hui and Fung (2009) have identified some technical flaws in their models. Importantly, Somerville (2001) also showed that a housing start is the exercise of a real option. He concluded that developers will obtain housing permits first, but will only exercise them until they are more confident about the future demand. Therefore, housing starts are the most important real estate development indicator. Comparable empirical evidence is also been found by Bulan et al. (2009), confirming “the option to wait” theory for real estate development.

Stevenson and Young (2007) have also illustrated that the profit maximisation behaviour of developers did affect the Irish housing supply level.
Overall, the impact of volatility on housing development has received increasing attention in recent years. However, little study has been done on the impact of housing supply volatility on housing starts, particularly in the Australian context. Besides, housing starts, permits and completions are three common used construction activity proxies in the literature.

DATA AND METHODOLOGY

Data

To assess the impact of uncertainty on housing development, the quarterly data of housing starts, permits and completions over 1974:Q4-2010:Q2 were utilised. The quarterly data was chosen in response to the high level of noise in the monthly data. This is also consistent with Mayer and Somerville (2000) and Miles (2009). The data were obtained from the Australian Bureau of Statistics (ABS). These data are seasonally adjusted. In addition, the data of interest rates, construction costs and housing returns were obtained from the Reverse Bank of Australia, Rawlinsons and ABS respectively. The summary statistics are presented in Table 1.

Table 1: Descriptive Summary

Variable	Starts	Permits	Completions
Mean	24753.94	8637.076	3737144
Standard deviation (%)	3659.130	1462.394	17.725
Skewness	-0.009	0.097	0.781
Kurtosis	2.608	2.785	2.284
Jarque-Bera	0.923	0.509	17.725***

Notes: Standard deviations are expressed in percentage form. The skewness and kurtosis statistics have a value of 0 for a normal distribution. These statistics give a preliminary indication of the normality of these series. The Jarque-Bera test is a formal normality test. * denotes significance at the 10% level; ** represents significance at the 5% level and *** denotes significance at the 1% level

As displayed in Table 1, the standard deviation statistic of housing starts is the highest, suggesting that housing starts are very volatile compared with housing permits and completions. This also implies that an ARCH effect could be found in the housing starts series, although the preliminary results should be confirmed by more rigorous tests in the following section. Additionally, the skewness and kurtosis statistics also show that housing starts and permits are normally distributed. This is further confirmed by the Jarque-Bera statistics. However, no similar evidence is found for housing completions.

Methodology

To ensure a GARCH model is applicable in the housing investment context, the growth rates of housing starts, permits and completions were employed. According to Miles (2009), the growth rates are measured by the differences in the logs of each series. Importantly, this would be a convenient form to interpret the results since the results are in percentage changes. To model the impact of uncertainty on housing development, the growth series of housing starts, permits and completions were firstly used to examine the presence of volatility clustering effects. This can be examined with 1) Ljung-Box test and 2) Engle (1982) LM test for ARCH of order of p tests.

It should be noted that only the series with volatility clustering effect will be used for volatility modelling, since the presence of ARCH effect is required for a GARCH model. To examine the impact of uncertainty on housing supply, a GARCH-in-mean (GARCH-M) model was employed. A GARCH-M model allows the conditional mean to depend on its own conditional variance. Thus, the model has the ability to capture the looking forward uncertainty of a variable (Asteriou and Hall, 2007). The model can be given as follows:

Mean Equation:

$$y_t = a_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=0}^{q} \beta_i \mu_{t-j} + \lambda h_t \qquad (1)$$

where y_t is a development variable (housing starts, permits, completions) at the time t, μ_t is the residual, the estimated coefficient of λ is then tested for significance to determine whether uncertainty affects the dependent variable.

Variance Equation:

$$h_t = \gamma_0 + \sum_{j=1}^{q} \gamma_j \mu_{t-j}^2 + \sum_{i=1}^{p} \delta_i h_{t-i} \qquad (2)$$

where γ_0 is the constant term of variance equation, μ_{t-1}^2 represents the lag of the squared residual from the mean equation, h_{t-i} is the lagged h_t term.

To assess the volatility linkages between housing supply and macroeconomic variables, we introduced three important variables (interest rates, construction costs and housing prices) into our conditional variance equation as follows:

$$h_t = \gamma_0 + \sum_{j=1}^{q} \gamma_j \mu_{t-j} + \sum_{i=1}^{p} \delta_i h_{t-i} + \rho_i Factor_{i,t} \quad (3)$$

where $Factor_{i,t}$ represents a macroeconomic variable (interest rates, construction costs and housing prices).

RESULTS AND DISCUSSION

Volatility clustering

The presence of volatility clustering effect in these series of housing starts, housing permits and housing completions was first examined. GARCH volatility modelling for a series could be a vain exercise if there was no ARCH effect in the series. Hence, the validity of the application of GARCH models in housing development was examined by the Ljung Box test and Engle (1982) LM test. Table 2 displays the empirical results of the Ljung-Box and LM tests for up to sixth order ARCH.

Table 2: LM Tests

Variable	Starts	Permits	Completions
Q(4)	9.692	28.280	5.723
(ρ -value)	(0.046)**	(0.000)***	(0.221)
$Q^2(4)$	16.622	6.242	0.487
(ρ -value)	(0.002)***	(0.182)	(0.975)
LM(4)	14.238	5.834	0.469
(ρ -value)	(0.007)***	(0.212)	(0.976)
Q(6)	17.362	42.521	7.236
(ρ -value)	(0.008)***	(0.000)***	(0.300)
$Q^2(6)$	16.910	8.096	0.611
(ρ -value)	(0.010)***	(0.231)	(0.996)
LM(6)	14.657	6.392	0.587
(ρ -value)	(0.023)**	(0.381)	(0.997)

Notes: This table reports the estimated results from the Ljung-Box and Engle (1982) LM tests. Q(ρ) and Q^2(ρ) are the Ljung-Box tests on standardised residuals and squared standardised residuals respectively. ARCH(ρ) exhibits the LM test on the series up to ρ -order. * denotes significance at the 10% level; ** represents significance at the 5% level and *** denotes significance at the 1% level

Some volatility clustering effect is found by Q(4) and Q(6) statistics for the series of housing permits, whereas no similar evidence is found by $Q^2(4)$, LM(4), $Q^2(6)$ and LM(6) statistics. Therefore, the ARCH effect in the series of housing permits is marginal. Little volatility clustering effect for house permits can be explained by the concept of real options. Once house development permits are granted, developers and builders would have options to wait to develop. Importantly, a real option offers owners or developers the right, but not the obligation, to develop. Thus developers would be less sensitive to changing market conditions when applying housing permits; thereby it is reasonable to find that the volatility series of house permit is relatively stable, suggesting that the series does not contain some important information of the Australian housing development industry. In other words, it is not a good indicator to gauge construction activities.

Table 2 also shows that there is a strong volatility clustering effect in the series of housing starts in light of the coefficients of Q, Q^2 and LM statistics are statistically significant. Comparable results are also documented by Miles (2009). This suggests that periods of high volatility will be concentrated and followed by periods of lower risk. In other words, understanding the conditional volatility of housing starts is essential. The significance of volatility clustering effect in housing starts can be explained by the notion of a housing start is the exercise of a real option. Somerville (2001) has shown that the most important exercise decision occurs by the time a permit is obtained. Specifically, builders and developers do respond to market conditions that occur after permits. In other words, many housing developers would like to defer their housing projects or investments in response to shocks in the market, particularly the negative shocks. Therefore, the economic impact on housing starts will not constant over the market cycle, thereby the series should reveal some volatility clustering effect. In other words, the volatility clustering effects are not only found in housing prices (Miles, 2008, Lee, 2009a), but also in housing starts.

The statistics of Q(4), $Q^2(4)$, LM(4), Q(6), $Q^2(6)$ and LM(6) for housing completions are statistically insignificant, confirming that there is no ARCH effect in the series of housing completions. The results are consistent with the empirical findings of Miles (2009) in which housing completions do not exhibit any ARCH effects. Institutional factors can be a plausible explanation. Somerville (2001) found little evidence to support the view of completion is the exercise of an option. Since housing completion is not a form of exercising an option, the changing market condition will not be very relevant to builders for completing their housing projects. Hence, the shocks or new information of changing market conditions would have marginal impact on housing completions, and then it is reasonable to find the volatility pattern of housing completion is relatively stable. Furthermore, the findings of Coulson (1999) and Somerville (2001) demonstrated that once a housing project is started; virtually the project should be completed in respect to construction activities cannot be reversed. Thus, it is intuitively appealing to find little ARCH effect in the completion series.

Overall, the volatility clustering effect is found for housing starts, signifying that the volatility of housing starts contains some important information that should be analysed and modelled. In other words, housing starts appear as the most important housing development variable compared with housing permits and completions. Thus, the application of GARCH processes (volatility modelling) in housing starts should be carried out.

GARCH-M

Given the preceding results have demonstrated that housing starts exhibit some ARCH effect, we used a GARCH-M model to analyse housing starts. The empirical results of GARCH and GARCH-M are reported in Table 3[3].

Table 3: GARCH and GARCH-M models for housing starts

Model	**I GARCH**	**II GARCH-M**
Panel A: Mean equation		
GARCH-M		-0.041
		(-0.123)
Constant	0.002	0.005
	(1.079)	(0.207)
AR(4)	0.373	0.372
	(3.156)***	(3.149)***
MA(4)	-0.790	-0.789
	(-10.696)***	(-10.685)***
Panel B: Variance equation		
Constant	0.001	0.001
	(1.534)	(1.510)
ARCH(1)	0.406	0.408
	(2.059)**	(2.037)**
GARCH(1)	0.403	0.405
	(2.005)**	(2.007)**
R-squared	0.187	0.187
Log-likelihood	188.723	188.733

Notes: This table reports estimated coefficients for mean and variance equations of GARCH-M(1,1). The model is estimated by:

Mean Equation:

$$y_t = a_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=0}^{q} \beta_i \mu_{t-j} + \lambda h_t$$

Variance Equation:

$$h_t = \gamma_0 + \sum_{j=1}^{q} \gamma_j \mu_{t-j} + \sum_{i=1}^{p} \delta_i h_{t-i}$$

*, **, *** denotes significance at the 10%, 5% and 1% level respectively.

[3] We followed the methodology of Miles (2009) in which an ARMA model of the conditional mean was employed. Besides, various lag lengths for a given series were performed in order to select the most appropriate lag. Importantly, the residual from the selected conditional mean process is uncorrelated.

Model I is a base GARCH model in which it clearly shows that housing starts are successfully fitted into a standard GARCH model. The model effectively achieved convergence with the Macquardt algorithm. Panel B of Model I exhibits the volatility equation of the GARCH model. The significance of ARCH (1) coefficient suggests that there is a strong ARCH effect in the model. A GARCH effect is also evident in the model in respect to the coefficient of GARCH(1) is statistically significant at 1%. In other words, the hypothesis of housing starts is both homoskedastic and time invariant is rejected, indicating that the application of a GARCH model to housing starts is an appropriate model. Besides, the sum of ARCH and GARCH is 0.809, indicating that a shock in the Australian housing development sector on volatility is quite persistent and the response function of volatility decays at a relatively slow rate. This reinforces the notion of analysing the volatility of housing starts. Moreover, the ARCH and GARCH parameters satisfy the specification requirements of non-negativity for housing starts. Both parameters are around 0.4, suggesting that housing developers and builders are equally sensitive to all previous shocks and new information in the Australian housing development sector.

Having estimated the baseline GARCH model, the impact of uncertainty on housing starts is investigated by a GARCH-M model. The results are presented by Model II of Table 3. The coefficient of GARCH-M is negative, demonstrating that uncertainty does somewhat dampen housing starts. In periods of high volatility, we would expect developers and builders to be more prudent and likely to defer their housing projects exposure to market volatility compared with periods of a relatively stable market environment. However, the uncertainty measure is not statistically significant, suggesting that the volatility measure may not be a sufficient measure to capture all the relevant forward looking uncertainty faced by developers and builders. Comparable results are also found by Somerville (2001). In other words, other variables should be introduced into the models in order to capture the remaining volatility of housing starts. Several diagnostic tests for standardised residuals have been performed in order to assess the robustness of our GARCH models. Results confirm that the models have successfully accounted for remaining ARCH effects. The results are depicted in Appendix 1.

In brief, the GARCH-M model has shown that higher uncertainty would have a negative impact on housing starts, although the volatility of housing starts itself has no statistically meaningful effect on housing starts.

Volatility linkages between housing starts and macroeconomic variables

Several macroeconomic variables have also been introduced into our baseline GARCH models in light of the volatility of housing starts itself may not be a sufficient measure for capturing the relevant forward-looking uncertainty. According to Somerville (1999), interest rates, construction costs and housing returns are the common determinants of housing starts. Therefore, we introduced these variables to our baseline models. The results are presented in Table 4.

Table 4: GARCH-M models for housing starts with macroeconomic variables

Model	**I**	**II**	**III**
Panel A: Mean equation			
GARCH-M	-0.479	-0.419	-0.229
	(-1.968)**	(-3.387)***	(-0.854)
Constant	-0.039	-0.035	0.019
	(-2.306)**	(-5.049)***	(0.874)
AR(4)	0.387	0.273	0.471
	(3.142)***	(1.994)**	(4.607)***
MA(4)	-0.790	-0.665	-0.865
	(-10.230)***	(-7.138)***	(-15.849)***
Panel B: Variance equation			
Constant	0.001	0.000	0.001
	(1.601)	(0.106)	(1.024)
ARCH(1)	0.342	0.413	0.440
	(2.138)**	(2.106)**	(1.718)*
GARCH(1)	0.513	0.468	0.472
	(2.656)***	(3.295)***	(1.926)*
Interest Rates	0.012		
	(1.847)*		
Construction Costs		0.069	
		(2.821)***	
Housing Prices			0.003
			(0.139)
LM(24)	17.674	12.208	11.892
	(0.819)	(0.978)	(0.981)
LM(36)	27.766	29.954	16.420
	(0.835)	(0.751)	(0.998)

Notes: This table reports estimated coefficients for mean and variance equations of GARCH-M(1,1). The model is estimated by:

Mean Equation:

$$y_t = a_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=0}^{q} \beta_i \mu_{t-j} + \lambda h_t$$

Variance Equation:

$$h_t = \gamma_0 + \sum_{j=1}^{q} \gamma_j \mu_{t-j} + \sum_{i=1}^{p} \delta_i h_{t-i} + \rho_i Factor_{i,t}$$

*, **, *** denotes significance at the 10%, 5% and 1% level respectively.

Model I of Table 4 shows the results of GARCH-M with the inclusion of interest rates. The GARCH-M coefficient is negative and statistically significant at 5%, reflecting that there is a negative connection among housing starts and its uncertainty. This reinforces the baseline results in which housing starts uncertainty will affect the timing of housing starts. More specifically, it offers empirical evidence to support the view of Miles (2009) and Somerville (2001) that housing development is a form of irreversible investment and housing developers and builders do respond to new information of changing market conditions. In fact, they would defer the starts of their housing projects in response to higher uncertainty. Compared with the baseline results, higher significance level of housing starts volatility in Model I of Table 4 could be attributed to the uncertainty of housing starts is better captured in this model. The coefficient of interest rates in Panel B is negative and statistically significant at 1%, indicating that interest rate volatility would increase the uncertainty of housing starts. In other words, the volatility of interest rate is an important determinant and will be transmitted to housing starts volatility.

Nevertheless, the economic value of housing starts volatility (GARCH-M coefficient) is not very significant. Similarly to Miles (2009), the standard deviation of GARCH process was employed in this model. Therefore, the economic value of the GARCH-M coefficient of -0.479 can be interpreted as follows. The standard deviation of the GARCH is 0.089 in which it is around 0.1 time of the average of the GARCH variance. Thus the economic significance of the GARCH-M coefficient is only 1/10 of the coefficient. In other words, an increase in uncertainty of one unit would lower the change in housing starts by 0.04. Compared to the finding of Miles (2009) in the U.S. market (about 0.5), its impact is much weaker in the Australian market. The differences between Miles (2009) and this study could be attributed to different markets, highlighting international evidence on the impact of uncertainty on housing starts should be provided. Another reason may simply be the relatively lower risk of the Australian housing market. The lower risk can be attributed to the extremely low residential vacancy rate in Australia, which the national average vacancy rate was around 3.2% from 1980 to 2010 (REIA, 2010).

Model II examines the linkages between housing starts and construction costs. Strong volatility spillover effect is also evident between construction costs and housing commences. Specifically, construction costs volatility is positively and significantly linked to housing starts volatility. In other words, higher construction costs volatility would increase the uncertainty of housing construction. Given the significant volatility spillover effect, the true forward looking uncertainty faced by builders and developers has been better captured in this model. Thus it is sensible to find a negative and statistically significant GARCH-M coefficient, indicating that there is an inverse relationship between uncertainty and housing starts. However, the economic value of uncertainty is not very significant in which one unit of increase in housing starts uncertainty will decrease the change in starts by 0.04. The results are comparable to the results from Model I. In short, higher construction costs volatility will make builders less likely to begin construction. Similar results are also found by Somerville (1999).

The volatility linkages between housing prices and housing starts are presented in Model III. The insignificant of housing prices coefficient suggests that there is little volatility linkage between housing prices and housing starts. In other words, higher housing price volatility will not necessarily have an effect on the volatility of housing starts. In other words, housing price volatility contains little information of housing starts uncertainty. Coincidently, the GARCH-M coefficient is statistically insignificant, confirming that housing price volatility does not capture the true-forward uncertainty of housing starts.

Overall, this section has clearly shown that interest rates and construction costs are important determinants of the volatility of Australian housing starts. Therefore, these variables should be introduced in our models in estimating the true-looking forward uncertainty of housing starts. Importantly, these results also strongly reinforce the notion that housing starts are negatively linked to housing starts uncertainty.

CONCLUSIONS AND POLICY IMPLICATIONS

In recent years, the volatility of housing supply has received increasing attention in the property literature as housing development is a critical determinant of the economic growth for a country. However, little study attempts to capture the forward-looking uncertainty of housing supply. Therefore, this study aims to investigate the volatility pattern of housing supply by using a GARCH-M model.

There are several important findings from this study. Firstly, the results show that there is a volatility clustering (ARCH) effect in housing starts, whereas no comparable result is evident in housing permits and completions. In other words, the volatility of housing starts series is not constant over time. More importantly, the finding indicates that housing starts are the most important housing development variable compared with housing permits and completions. It contains some important information of the Australian housing development industry. This could be attributed to institutional factors since many developers and builders view a housing start as the exercise of a real option. Secondly, the empirical results from the GARCH-M models have also shown that uncertainty is negatively linked to housing developments, reflecting that higher uncertainty does lower housing starts. Therefore, housing investment is a form of irreversible investment. However, the uncertainty of housing starts is also captured by the volatilities of interest rates and construction costs in respect to both are important determinants of housing starts volatility. All of these have provided additional insights into the volatility modelling of housing construction activity.

These findings have some important practical implications to housing builders and developers, urban analysts and policy makers. The finding of ARCH effect in the series of housing starts suggests that policy makers and urban analysts should incorporate the volatility pattern of housing starts in their analyses in the light of it contains some important information of the residential development industry. Moreover, housing builders and developers should include the uncertainty variable in their housing demand forecasting models since uncertainty does dampen housing starts. Besides, policy makers should monitor the movements of interest rates and construction costs constantly in which the fluctuations would increase the volatility of housing supply; eventually reduce the availability of housing supply. Most importantly, macroeconomic policy makers should study the impact of interest rates comprehensively. Although increasing interest rates could be an effective policy to discourage housing speculation activities, higher interest rate would also have some negative impacts on housing starts. Hence it might exacerbate the issue of housing shortages and undermine housing affordability in the long run.

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Appendix 1: Diagnostic tests for the GARCH and GARCH-M models

Model	**I** **GARCH**	**II** **GARCH-M**
$Q^2(24)$	11.731	11.665
(ρ -value)	(0.963)	(0.964)
LM(24)	10.867	10.794
(ρ -value)	(0.990)	(0.990)
$Q^2(36)$	17.747	19.019
(ρ -value)	(0.990)	(0.982)
LM(36)	16.595	16.428
(ρ -value)	(0.998)	(0.998)

Notes: This table reports the estimated results from the Ljung-Box and Engle (1982) LM tests. $Q^2(\rho)$ are the Ljung-Box tests on standardised residuals and squared standardised residuals respectively. ARCH(ρ) exhibits the LM test on the series up to ρ -order. * denotes significance at the 10% level; ** represents significance at the 5% level and *** denotes significance at the 1% level

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