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New Housing Supply and Residential Construction Costs in Australia: A Panel ECM Approach

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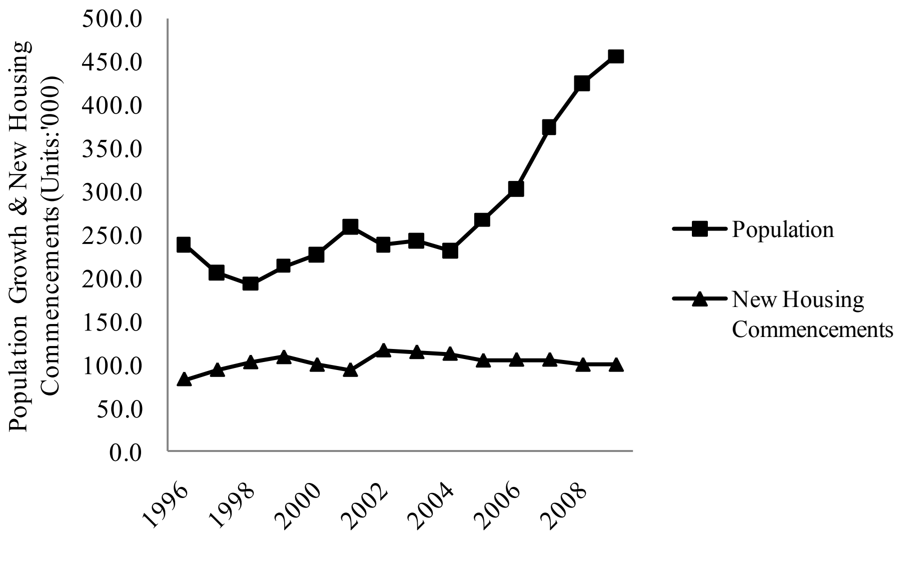
Abstract

The supply of new housing in Australia has been experiencing a low increase rate since the 1990s in conjunction with an increasingly strong housing demand. On the contrary, residential construction costs across Australia's states maintained dramatic increases simultaneously. Economic theory suggests that new housing supply is correlated to the costs of residential constructions. However, few empirical studies have focused on examining this relationship for Australian housing markets. To comprehensively investigate the relationship between the supply of new housing and residential construction costs a function for new housing supply considering the effects of regional heterogeneities is introduced in this study. By estimating a panel error correction model (ECM) applicable for quantifying the correlation with regional heterogeneities, this research identifies that a causal link and a strong correlation exist in between new housing supply and residential construction costs in Australia.

Keywords: new housing supply, residential construction costs, panel error correction model

Introduction

New housing supply in Australia has been experiencing a low increase rate since the 1990s, during which Australian urban population increased dramatically. Figure 1 illustrates the moving trends of annual urban population growth and new housing commencements in Australia between 1996 and 2009. Urban economic theory suggests that population growth is an indicator of the increase in housing demand and there should be a steady equilibrium relationship (convergence) between total housing stock and urban population (DiPasquale, 1999). Nevertheless, it can be identified from Figure 1 that annual urban population growth in Australia maintained a dramatic upward trend from 1996 to 2009 while the number of new housings started for construction were highly stable. In other words, a divergence between housing supply and urban population has gradually occurred in Australia.



Source: Australian Bureau of Statistics (ABS), 2010a

Figure 1: Population growth and new housing commencements in Australia

Another statistic regarding *Housing Finance* indicates that the annual number of the housing mortgage for the purchases of owner-occupied dwellings in Australia increased from 405,531 to 660,426 with an increase rate of 62.9% during the period of 1996-2009 (ABS, 2010c). These data explicitly further reveal that the demand for housing in Australia is increasingly strong. Owing to the strong housing demand and the inadequate housing supply, Australia is currently suffering a severe problem in housing shortage. The annual report from the *Housing Industry Association* (HIA) supported this perspective and claimed that a housing shortage of approximately 110,000 has emerged in Australia in 2009 and this problem will be exacerbated in the future (HIA, 2010).

An interesting situation accompanies the low increase rate of new housing supply in Australia is the input producer price indexes (PPIs) of housing construction on average increased by more than 40% across the states of Australia (ABS, 2010b). The input PPIs is a measure of the changes in the prices of goods and services purchased by domestic producers for intermediate inputs of products (International Monetary Fund, 2004). Hence the input PPIs relative to housing construction is viewed as a measure for the changes in the input cost level of housing production. Urban economics has long suggested that the supply of new housing and the input costs of constructions are interrelated, and the increases in input construction costs reduce new housing output level (Somerville, 1999). Despite the existence of this correlation, few empirical studies have been launched to investigate whether or not the dramatic increases in residential construction costs causally and negatively affect the supply of new housing in Australia. This empirical study aims to identify the natures of these relationships with regional heterogeneities. A methodology which is able to meet this research aim is the panel error correction model (ECM). The importance for addressing regional heterogeneity and the applicability of the use of the panel ECM in this study can be referred to the sections of the *Conceptual Model* and the *Methodology*.

This paper is structured by first establishing the context of this research with the existing literature, presenting the previous studies on new housing supply integrated with construction costs. Secondly, a new housing supply function contributed by the outcomes of the literature review will be introduced and developed in the section of conceptual model, and then the methodology and the data description will be presented. Finally, a panel ECM with the tests of panel unit root and panel cointegration will be utilised for analysis and discussion.

Literature Review

The studies on the supply of new housing can be dated back to the 1960s. Of these studies, the early research focused on the detection for price elasticity of new housing supply relying on the reduced-form estimation. Generally speaking, the reduce-form method in previous empirical research on new housing supply is defined as a simple regression approach where house price is a function of supply and demand factors.

The early reduced-form study, commenced by Muth's (1960) in the 1960s, examined the relationship between new housing outputs and house prices in the US using a regression model and national data. This empirical study suggested that there was no statistical relationship between new housing outputs and house prices. However, this result was contradictory to the economic theory that the outputs of new housing are sensitive to the changes in house prices. Follain (1979) tested the price elasticity of long-run new housing construction by applying Muth's (1960) regression model with national data as well. He yielded a result similar to Muth's (1960) findings, thus confirming that new housing starts were totally price inelastic. Nevertheless, it was not reliable to conclude depending on these two studies that the supply of new housing was price inelastic because Muth (1960) and Follain (1979) used national data which had potential problems in aggregation bias (Stover, 1986). To solve this problem, a function adopting cross-sectional data across 61 US metropolitan areas was estimated by Stover (1986). The results successfully identified that the supply of new housing in the US was significantly related to house prices.

Since the 1980s, there have been some empirical studies attempting to explore innovative approaches to model the supply of new housing directly. The approaches employed in such research focused on a structural method, in which construction or aggregate supply was viewed as a function of prices and cost shifters (DiPasquale, 1999). The theory underpinning this type of study was derived from the investment literature and urban spatial theory.

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 in 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) and real construction wages], was launched by Poterba (1984) in 1984 to test a shock of the user cost on the steady state (long-run equilibrium) of the housing market. The results of this research indicated that house price was a major determinant of the construction of new housing, and an increase in the price of non-residential construction initially triggered a decrease in residential construction level. However, there was no significant relationship between construction costs and new housing outputs (Poterba, 1984).

The model of Poterba (1984) pursued the long-run equilibrium relationships among new housing supply, house price and cost factors, but he ignored the relationship within a short-run context. The study by Topel and Rosen (1988) identified this issue and examined whether or not current asset prices are 'sufficient' for housing investment decisions. In Topel and Rosen's (1988) research, new housing supply is a function of real house prices and a vector of cost factors. The findings indicated that the long-run supply elasticity of price was approximately 3.0 and the short-run elasticity was about 1.0. In short, the supply of new housing in the US was price elastic. Nevertheless, Topel and Rosen's (1988) model produced a result similar to Poterba's (1984) findings in regard to cost factors, which indicated that construction costs had no significant impact on new housing supply.

Although the investment-based models of Poterba (1984) and Topel and Rosen (1988) had contributed to the housing supply literature, advocates of urban-spatial theory still criticised their studies because all of them ignored a highly important issue – the input of land, which is the most unique element of housing. In reality, Poterba (1984) acknowledged the importance of land in housing supply research and he omitted it in his model just because of a lack in data. The urban spatial theory is a theoretic system which assumes that total housing stock equals to the urban population and land is an input in new housing production (DiPasquale, 1999).

One valuable piece of work based on the urban spatial theory for new housing supply arose in the 1990s and it is a simple supply model proposed by DiPasquale and Wheaton (1994) depending upon a spatially based definition of the equilibrium housing stock. This model yielded a construction equation where new housing construction is a function of house price levels, cost factors (land prices and construction costs) and lagged housing stock. By estimating this supply model, the price elasticity of stock and price elasticity of new construction ranged from 1.2 to 1.4 and 1.0 to 1.2 respectively. Although these price elasticities suggested that new house constructions were highly related to house price fluctuations, there was still no significant relationship identified between construction costs and the level of new housing construction in this study (DiPasquale & Wheaton, 1994).

As indicated previously, much of the empirical work on new housing supply shared a problem in poor performance of various measures of construction costs. Somerville (1999) first identified this interesting point and claimed that empirical studies always failed to discover a consistent relationship between construction costs and housing outputs although economic theory had suggested that the increases in the costs of construction should reduce the supply of new housing. Thus, a hedonic construction cost series with an entirely new set of micro-data on housing construction was developed by Somerville (1999) to examine the relationship between new housing outputs and residential construction costs across the metropolitan areas in the US. The empirical results suggested that in the US housing starts were quite cost elastic and construction costs were endogenous in the new housing supply function. The possible causation for poor performance of the housing supply studies on the relationship between housing starts and construction costs was an existence of bias in the commercial cost indexes used by prior research (Somerville, 1999).

In summary, the literature review demonstrated that a number of empirical studies (Poterba, 1984; Topel and Rosen, 1988; and DiPasquale & Wheaton, 1994) attempted to study the relationship between new housing supply and residential construction costs. Nevertheless, all of these researchers claimed that there was no significant linkage between these two variables.

In 1999, a study undertaken by Somerville (1999) successfully identified this correlation and produced a result which was consistent with the justification of standard economic theory that new housing supply is negatively affected by construction costs. Based on this literature review, it is noted that the research on the relationship between new housing supply and the price or cost factors (house prices, land prices and construction costs) has been well established. However, all of them did not considered the effects of regional heterogeneities. The conceptual model will now be presented to address it.

Conceptual Model

The literature review of this study with regard to new housing supply suggested that house prices, land prices and construction costs are three key endogenous variables in new housing supply function. Consequently, the function of new housing supply can be summarised.

$$Q^s = f(HP, LP, Cost) \tag{1}$$

where Q^s is the quantity of new housing supply; *HP* is the house prices; *LP* stands for the land prices; and *Cost* represents the input costs of housing production.

Housing markets on sub-national or regional level can be influenced by a series of intangible variables other than prices and cost factors, such as the impacts of regional heterogeneities caused by the variations of local political and demographic factors, including policies and regulations, culture, race, education and even gender composition of local population (Tu, 2003). Although the majority of these factors that lead to regional disparities is difficult for observation, they can stay constant over time and effectively affect the demand and supply sides of the housing market (Bebee, 1972; Reed, 2001). Thus, the function displayed in Eq. (1) does not comprehensively model new housing supply, particularly in the case of the sub-national or regional markets that have the nature of segmentation and are strongly determined by local elements. Therefore, a new function for the supply of new housing is developed as follows.

$$SQ^s = f[HP, LP, Cost, (V_{RH})] \tag{2}$$

where SQ^s stands for the quantity of the supply of new housing in the sub-national or regional housing markets with the nature of segmentation; *HP* denotes the house price; *LP* is the prices of land input. *Cost* represents the input costs in house production; and the V_{RH} is a vector of regional heterogeneities which are the effects of important unobservable variables varied by regions. As discussed previously, these unobservable variables are able to maintain constant over time to significantly influence the supply side of the housing market.

The study conducted by Tu (2000) argued that the sub-national housing markets in Australia are segmented and they are the individual markets mainly determined by local factors varied by regions rather than an integrated entity. In short, heterogeneities across regions play an active role in the developments of Australian sub-national housing markets. As a result, it is not rational to estimate the relationship between new housing supply and any price or cost factor on sub-national level in Australia without considering regional heterogeneities.

It is knowledge that house prices, land prices and construction costs are the economic variables that change significantly over time. To uncover the relationship between new housing supply and these variables, the approaches used in previous studies were based on the time-series econometric models. Nevertheless, the time-series techniques completely ignored the effects specific to the disparities within a cross-sectional unit across periods (Greene, 2000). Thereby, a model with multi-estimation on time-series and cross-sectional effects must be required for new function [Eq. (2)] estimation. Theoretically, the econometric methods on the basis of the panel data are an applicable choice to fulfill this requirement since the entity fixed-effects models within the framework of panel econometric techniques not only model the time effects but also allow for 'the effects of those omitted variables that are specific to individual cross-sectional units but stay constant over time' (Hsiao, 2003, p. 30).

Methodology

The primary aim of this research is to estimate the causal relationship as well as correlation with regional heterogeneity between new housing supply and residential construction costs in Australia. Suggested by the conceptual model, the panel econometric approach is an ideal technique to satisfy this requirement. Thus, in this research, a panel error correction model will be employed. The ECM is a regression model incorporating cointegration and the error correction term and it is useful for identifying the Granger causality and statistic relationship between variables (Dinda & Coondoo, 2006; Luo *et al.*, 2007). Two prerequisite tests must be undertaken before constructing the panel ECM, the first is the panel unit root test and the second is the panel cointegration test.

Panel Unit Root Tests: IPS test

The panel unit root test used in this study was the IPS test proposed by Im *et al.* (Im, Pesaran and Shin) (1997; 2003). It is an extension of the LLC framework developed by Levin *et al.* (Levin, Lin and Chu) (1992; 2002) and allows for heterogeneity in the value of δ_i under the alternative hypothesis. The main equation of the IPS test is expressed in Eq. (3).

$$\Delta y_{i,t} = \delta_i y_{i,t-1} + \alpha_i + \varepsilon_{i,t}, (i = 1,2,\cdots,N; t = 1,2,\cdots,T) \tag{3}$$

The null and alternative hypotheses of the IPS test are defined as:

$$H_0 : \delta_i = 0 \;\; (i = 1,2,\cdots,N)$$

$$H_1 : \delta_i < 0 \;\; (i = 1,2,\cdots,N), \;\; \delta_i = 0 \;\; (i = N_1 + 1, \;\; N_1 + 2,\cdots,N) \tag{4}$$

The $\varepsilon_{i,t}$ are serially auto-correlated with different serial correlation properties across units. A group-mean Lagrange multiplier (LM) statistic was used by Im *et al.* (1997) to test the null hypothesis in Eq. (4). This LM-statistic was computed by the regression shown as follows:

$$\Delta y_{i,t} = \delta_i y_{i,t-1} + \sum_{L=1}^{p_i} \theta_{i,L} y_{i,t-L} + \alpha_i + \varepsilon_{i,t}, \quad t=1,2,...T. \tag{5}$$

Im *et al.* (1997) defined

$$\overline{LM}_{N,T} = N^{-1} \sum_{i=1}^{N} LM_{iT}(p_i, \theta_i) \tag{6}$$

Then the values of $E[\overline{LM}_{i,t}(p_i,0)|\delta_i=0]$ and $Var[\overline{LM}_{i,t}(p_i,0)|\delta_i=0]$ were obtained by Im *et al.* (1997). Under these assumptions, Im *et al.* (1997) concluded that:

$$\Psi_{\overline{LM}} \Rightarrow N(0,1) \tag{7}$$

Im *et al.* (1997) also used a group-mean t-bar statistic to test the unit root of the panel data. Applying a Monte Carlo Study, Im *et al.* (1997) demonstrated the finite sample property of the IPS test and identified that the performance of the IPS test under the small sample is better than the LLC test.

Cointegraton Test for Panel Data

The panel cointegration test in this paper relies on Pedroni's (1999) approach. It is an EG-based (Engle-Granger) cointegration test, in which the following models of cointegrated regressions are considered.

$$y_{i,t}=\alpha_i+\delta_i t+x_{i,t}^{'}\beta_i+\mu_{i,t}, \quad (i=1,...,N,\ t=1,...,T) \tag{8}$$

where $\beta_i=(\beta_{1i},\beta_{2i},...,\beta_{Mi})$ and $x_{i,t}=(x_{1i,t},x_{2i,t},...,x_{Mi,t})$. The system expressed as Eq. (8) allows for heterogeneity in the panel. As a result, heterogeneous coefficients, fixed effects and individual specific deterministic trends were all permitted. Furthermore, $y_{i,t}$ and $x_{i,t}$ are integrated process of order one for all i.

Pedroni (1999) then set up a H_0 hypothesis, defining $z_{i,t}=(y_{i,t},x_{i,t}^{'})$, $\xi_{i,t}^{'}=(\xi_{i,t}^{y},\xi_{i,t}^{x})$, and $z_{i,t}=z_{i,t-1}+\xi_{i,t}$, in which the process $\xi_{i,t}^{'}$ satisfies

$$\frac{1}{\sqrt{T}}\sum_{t=1}^{Tr}\xi_{i,t} \Rightarrow B_i(\Omega_i) \text{ for all } i \text{ as T}\to\infty. \tag{9}$$

where $B_i(\Omega_i)$ is a vector Brownian motion with asymptotic covariance Ω_i where Ω_{22} is non-singular. The $B_i(\Omega_i)$ is utilised to be defined on the same probability space for all i and $E(\xi_{i,t},\xi_{j,s}^{'})=0$ for all $i\neq j$ and then for all s,t.

Pedroni (1999) assumed that the specification of the process for $\xi_{i,t}$ imposes cross-sectional independence without any common aggregate disturbance but allows for a wide range of temporal dependence in the data. Based on these assumptions, seven panel cointegration statistics were derived by Pedroni (1999), of which four tests belong to the first categories that are defined as within-dimension-based statistics. In the first category, the four tests depend on a variance ration statistic, a non-parametric Philips and Perron type $\rho - statistic$, a non-parametric Philips and Perron type $t - statistic$ and a parametric ADF-based test respectively. Regarding the second category, which is defined as the between-dimension-based statistics, two of the three tests are non-parametric corrections while the third is a test of the ADF. The tests in the second category are based on a group mean approach (Pedroni, 1999).

Panel Error Correction Model

Once the pairwise cointegration has been identified between two panel variables, the next step in the Engle-Granger methodology is to model the short-run variations of the variables, which can be done by estimating the ECM (Dinda & Coondoo, 2006). The error correction model was first introduced by Sargan (1964) in the 1960s and systematically developed by Davidson *et al.* (1978) in the 1970s. However, the ECM was widely promoted by Engle and Granger (1987) in the 1980s. According to the ECM methodology, the panel ECM can be written:

$$\Delta Y_{i,t} = \mu_i + \beta_i \Delta X_{i,t} + \phi_i ecm_{i,t-1}, (i=1,2,3...,N; t=1,2,3...,T) \tag{10}$$

$$ecm_{i,t-1} = Y_{i,t-1} - \alpha_0 - \alpha_1 X_{i,t-1} \tag{11}$$

where $\Delta Y_{i,t}$ and $\Delta X_{i,t}$ represents the data panel $Y_{i,t}$ and $X_{i,t}$ at the first difference; μ_i & β_i denote regression parameters; the symbol ϕ_i stands for the rapidity of adjusting to equilibrium status and they are expected to have negative values; and the $ecm_{i,t-1}$ represents the error correction term, in which the α_0 is the constant item and the α_1 stands for the long-term elasticity. The error correction term can be derived from the residual generated by a simple regression of two variables.

Data Collection and Description

For the purpose of estimating model, the number of new housing commencements (NHC) and the input producer price indexes (IPPI) of housing construction across Australian six states (excluding Australian Capital Territory and Northern Territory) will be utilised for this study. The data on the number of new housing commencements are published in the section of *Building Activity Australia* in the ABS, measuring the number of new housings commenced for construction (ABS, 2010b). The input PPIs of housing construction is one type of producer price indexes used to measure the prices of goods or services purchased by domestic producers for intermediate inputs of housing construction (ABS, 2010c). The reason for excluding the data on two territories is due to a lack in their input PPIs of housing construction within the ABS's publications. The report of the ABS for *Australian Social Trends* claimed that the data for national total on the input PPIs of house construction are a weighted average of six states (ABS, 2010b). Therefore, modelling new housing supply and residential construction costs for Australia without the data on two territories is acceptable.

As described above, the data imported for the panel ECM is the panel data, which are generally defined as a multi-dimensional data set with a given sample of individuals over time (Hsiao, 2003). Table 1 and Table 2 display the panel data on the number of new housing commencements and the input PPIs of housing construction across Australia's six states over 1996 to 2009.

	1996	1997	…	2004	…	2009
New South Wales	22858	24949	…	22223	…	15111
Victoria	27067	22865	…	32320	…	33868
Queensland	22893	23254	…	27339	…	20657
South Australia	4741	5633	…	8297	…	8680
Western Australia	11415	13844	…	18489	…	17167
Tasmania	1705	1413	…	2514	…	2503

Source: ABS, 2010b

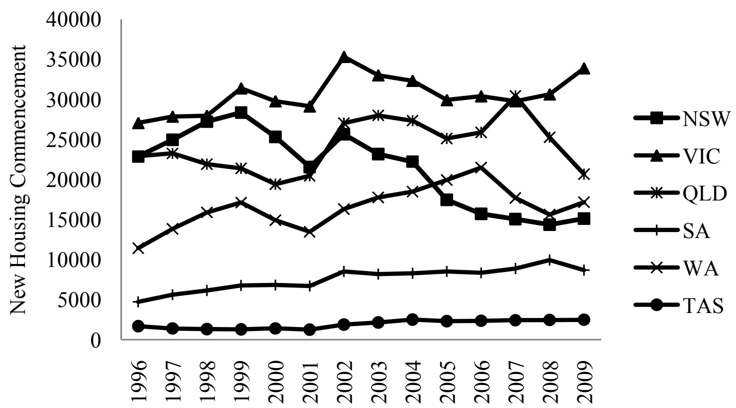
Table 1: The number of new house commencements in six states of Australia

	1996	1997	…	2004	…	2009
New South Wales	115.9	116.3	…	142.3	…	166.0
Victoria	115.4	115.3	…	131.1	…	154.7
Queensland	115.1	115.3	…	132.1	…	160.6
South Australia	118.2	120.6	…	138.4	…	168.8
Western Australia	114.8	115.3	…	125.8	…	163.0
Tasmania	120.7	120.1	…	139.4	…	175.0

Source: ABS, 2010a

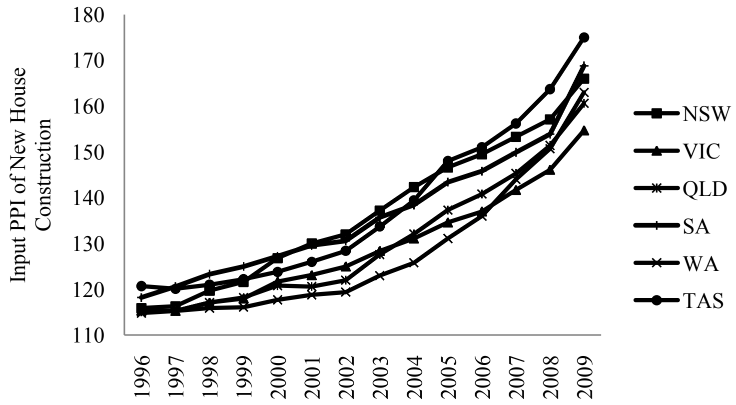
Table 2: The input PPIs of house construction in six states of Australia

In addition, Figure 2 and Figure 3 display the movements in the new house commencements and the input PPIs of house construction in Australia's six states between 1996 and 2009. Figure 2 indicates that the annual number of new housing commencements remained stable in Australia's six states, of which NSW's new housing commencements expressed a dramatic downward trend. However, on the contrary, the input PPIs of housing constructions in six states increased from 115.0 to more than 160.0 during the period of 1996-2009, particularly in New South Wales, South Australia, Tasmania, where the input PPIs of housing construction increased by 166.0, 168.8 and 175.0 respectively. The average increase rates of the input PPIs related to housing construction on state level in Australia achieved 41%.



Source: ABS, 2010b

Figure 2: The number of new housing commencements in six states of Australia



Source: ABS, 2010a

Figure 3: The input PPIs of housing construction in six states of Australia

The low increase rates of the new housing commencements and the dramatic increases in the housing construction input PPIs across six states implies that there should be a correlation between new housing supply and residential construction costs in Australia. In the following analytical section, the panel ECM with the tests for panel unit root and panel cointegration will be constructed to explore the nature of this relationship.

Analysis and Discussion

Likewise the time-series ECM, the prerequisite of the panel ECM is that the data imported must be stationary. Otherwise, a spurious regression will be triggered. Thus, testing the stationarity of the panel data is the first procedure for constructing the panel ECM. Table 3 indicates the results of the IPS test for the number of new housing commencements and the input PPIs of housing construction. The result suggests that these two variables are not stationary at the level form but stationary after the first difference.

Variables	**Level**			**First Difference**			**Results**
	Model Specification (Lags)	Statistics	*P*-value	Model Specification (Lags)	Statistic	*P*-value	
ln(NHC)	Individual Intercept & Trend (1)	-0.9740	0.17	Individual Intercept (1)	-3.0014	0.00	*I* (1)***
ln(IPPI)	Individual Intercept & Trend (1)	-0.7374	0.23	Individual Intercept (1)	-5.8120	0.00	*I* (1)***

Notes: ** and *** denote the 95% and 99% significance level.

Table 3: IPS test results of the panel data on NHC and Input PPI

Having tested the stationarity of the panel data, the second necessary step for building up an error correction model is identifying the cointegration between two variables. As mentioned in the methodology, the Pedroni test has been selected to examine the panel cointegration. Table 4 reports the summary of the Pedroni test results of the panel data on new housing commencement and the input PPIs of housing construction. The results indicate that there is a cointegration relationship between two observed variables.

Variables	**Model Specification (Lags)**	**Panel ADF-Stat.**	***P*-values**	**Weighted Panel ADF-Stat.**	**P-values (weighed)**	**Results**
ln(NHC) (dependent)	Individual Intercept (1)	-1.74	0.04	-1.80	0.04	Y
ln(IPPI) (independent)	Individual Intercept & Trend (1)	-1.58	0.05	-1.78	0.04	Y

Table 4: Summary of the Pedroni test results

Once the data employed are stationary and the variables are co-integrated, the panel ECM can be constructed to explicitly depict the nature of the target relationship. The model expressed as follows is the panel ECM composed of the new housing commencements and the input PPIs of housing construction.

$$\begin{cases} D(NHC_{NSW,t}) = 0.0708 - 0.3785 * D(IPPI_{NSW,t}) - 0.6278 * ecm_{NSW,t-1} + 00472 \\ D(NHC_{VIC,t}) = 0.0507 - 1.9335 * D(IPPI_{VIC,t}) - 0.5179 * ecm_{VIC,t-1} + 0.0472 \\ D(NHC_{QLD,t}) = 0.0196 - 2.8022 * D(IPPI_{QLD,t}) - 0.1623 * ecm_{QLD,t-1} + 0.0472 \\ D(NHC_{SA,t}) = 0.0689 - 2.2466 * D(IPPI_{SA,t}) - 0.4945 * ecm_{SA,t-1} + 0.0472 \\ D(NHC_{WA,t}) = 0.0086 - 0.7591 * D(IPPI_{WA,t}) - 0.4744 * ecm_{WA,t-1} + 0.0472 \\ D(NHC_{TAS,t}) = 0.0771 - 2.3103 * D(IPPI_{TAS,t}) - 0.5081 * ecm_{TAS,t-1} + 0.0472 \end{cases} \quad (12)$$

Based on the cointegration test and the panel ECM shown as Eq. (12), it is reliable to conclude that there is a causal relationship between the new housing commencements and the input PPIs of housing construction across six states in Australia. This is because the Granger causality exists in at least one direction between two variables if they are co-integrated (Johansen, 1988). In the Pedroni test and the panel ECM, the new housing commencement is the dependent variable and the input PPI is the independent variable. Therefore, a causal relationship can be identified within the direction from the input PPIs to the new housing commencements. This implies that the input PPIs Granger causes the output of new housing construction on regional level in Australia. Furthermore, the coefficients of the input PPIs in the panel ECM are all negative, which indicates that the increasing trends of new housing commencements in the residential construction markets of six states were depressed by the dramatic positive movements in the input PPIs of housing construction. These findings are consistent with the justification of economic theory introduced in the literature review.

According to Eq. (12), the coefficients of the input PPIs in Victoria, Queensland, South Australia and Tasmania are larger than 1, indicating that new housing supply in these four states are cost elastic. In other words, the supplies of new housing are sensitive to the changes in residential construction costs in Victoria, Queensland, South Australia and Tasmania. However, regarding NSW and WA, the coefficients of the input PPIs are lower than 1. This means that the correlations between new housing supply and residential construction costs in NSW and WA are not as apparent as that of other states. The possible reason for this situation is that the profit expectations on new housing developments in these two states are still attractive for investors when facing the rises in construction costs. The high expectations on profits will encourage many investors to continue investing on new housing construction in NSW and WA despite the inflation of residential construction costs.

In addition, the first coefficients of the eight equations in Eq. (12) indicate that there are presences of regional heterogeneities across regional housing markets in Australia and they do affect the relationship between Australia's new housing supply and residential construction costs on sub-national level. This empirical evidence supports the assumption on the importance of regional heterogeneity in conceptual model.

Conclusion

This empirical study developed a function to comprehensively model the supply of new housing in the sub-national markets that have the nature of segmentation. Based on this function, a panel error correction model integrated with the tests for panel unit root and panel cointegration has been used to investigate the relationship between new housing supply and residential construction costs in Australia over 1996 to 2009. Benefited by the panel ECM, a causal relationship significantly affected by regional heterogeneities has been identified within the direction from the input PPIs to the new housing supply in Australia. Additionally, the coefficients of the variables in relation to construction costs in the panel ECM are all negative, implying that the increasing trend of new housing supply in Australia has been depressed by the dramatic increase in the costs of residential construction. This finding complies with the economic theory that the output level of new housing is correlated to residential construction costs. The active role of regional heterogeneities and the significant correlations, both of which are identified from the empirical results, validate the reliability of the conceptual model and the panel ECM developed and adapted in this research.

The panel ECM has helped to successfully model the sub-national housing markets within a comprehensive context in this research. Thus, the application of the panel ECM may be useful for policy makers or large companies that conduct property economic research to better understand the nature of the housing markets on regional level. Besides, the development of the new housing supply function and the use of the panel ECM in this study is a contribution to the housing supply modelling within the framework of housing economics.

Future Study

The results of this research indicate that the relationship between new housing supply and residential construction costs in New South Wales and Western Australia are less evident than that of other states. Although the possible reason has been briefly described, the investigation for exact causations related to this situation is a potential area for future study.

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