Spatial Linkages among Australian Construction Markets

Heng Jiang and Chunlu Liu, (Deakin University, Australia)

Abstract

The linkages among different construction markets have recently attracted much attention from construction economists. The interactions among regional construction markets have been discussed in a few studies, most of which have been carried out by using input-output methods, and none of them investigated spatial effects on the regional construction markets. This study employed spatial econometric techniques, including spatial autocorrelation and convergence tests, to analyse interactions and linkages among construction price indices in Australian six states and two territories. The empirical results indicate the presence of significant positive spatial correlation among the construction prices in Australian eight construction markets and the degree of dependence decreasing sufficiently quickly as the space between regions increases. The results of convergence test further provide evidence of existence of a ripple effect in construction prices among the Australian regional markets and the changes in construction prices in a state would first positively influence neighbouring states, and then spread out into other non-neighbouring states or territories.

Keywords: Spatial linkages, Construction prices, Regional markets, Autocorrelation, Convergence

Introduction

Construction plays a vital role in many economies not only in generating a conspicuous contribution to economic development, employment and income but also in providing the necessary public infrastructure and private physical structures for government, business, and domestic consumption (Song et al., 2006). The severity of the global economic impact of the recent financial crises has intensified the needs for modelling linkages between different regional construction markets (Jiang et al. 2013). It is important for construction firms, developers and policy makers to understand how specific regional market shocks are transmitted to other regions, because it affects their ability of risk hedging though regional investment.

The linkages among construction markets in different regions has been discussed in previous studies. Song et al. (2006) investigated forward and backward linkages among construction markets in eight OECD countries by using input-output methods. Developing countries generate economic development by rapid investments in construction programs over a short-term period, leading to direct or indirect effects on other regional construction markets (Low, 1991). As a regional dimension was added in the study of the relationship between the construction industry and economic growth in China (Han and Ofori, 2001), the authors found that regional construction markets are strongly interacting due to the spread of civil engineering works and infrastructure projects across all the provinces. Linkages among regional housing and construction markets have been found in the studies of Alexander and Barrow (1994) and Luo et al. (2007). These studies indicated that migration and regional arbitrage activities may be the main reasons that lead to diffusion of regional house prices.

A large volume of empirical literature about the construction markets is focused on the analyses of determinants or formulation of the construction price, demand, supply and activities, e.g. Hassanein and Khalil (2006), Wong and NG (2010) and Jiang and Liu (2011).

With a few notable exceptions, most of these studies have been carried out at the national level. However, an important strand of thought argues that construction markets cannot be considered as a national aggregate, but are better represented as a series of interconnected regional and local markets. There are two aspects of this issue, first, the determinants of construction prices and demand may differ over different socio-economic development levels. Hence, even if the structures of construction markets are identical, there may still be a problem of differences in construction markets from a policy perspective. Secondly, the interactions among regional construction markets could not be ignored. Whether or not spatial effects on regional construction markets need to be considered in the construction price and demand formulation has never been discussed. Recently, spatial autocorrelation has been increasingly used in cross-sectional and panel regression studies, neglecting that spatial autocorrelation in regression models may lead to poor assessment of the estimator (Martellosio, 2011). In this study, the interrelationship of regional construction markets will be investigated by utilising spatial autocorrelation tests among regional construction prices in Australia. Additionally, the converging property of construction price levels of the eight regional markets will be estimated by using spatial convergence tests.

Spatial Linkage Indications

Spatial econometrics, introduced by Paelinck and Klaasen (1979) and Anselin (1988), is a subfield of econometrics that deals with the treatment of spatial interconnections and spatial structures in regression models for cross sectional and panel data. The development of spatial econometrics has been spurred by a new interest in the role of space in regional economic, with a particular emphasis placed on interactions in dependence (autocorrelation) and spatial convergence (Holly et al., 2010).

Spatial dependence in a collection of observations refers to the phenomena that an observation in a location is correlated with the observations in the other locations (LeSage, 1999). The core attention of spatial econometrics is to address the spatial dependence among the observations of interest. In the spatial econometrical regression models, spatial dependence represents the spatial effects and is expressed in the form of spatially lagged dependents or in the form of error structures. The former, which is called spatial lagged model, is used in the following parts of this research. Spatial heterogeneity refers to the distinctions in relationships across regions. In the regression context, the spatial heterogeneity can be carried out by varying parameters, random coefficients and so on (Anselin, 1988). When there is a spatial autocorrelation, the sample variances and correlation coefficients in the conventional statistical models tend to be biased (Griffith and Chun, 2014).

Spatial convergence was first mentioned by Baumol (1986) in analysing of the convergence of national productivity levels. The systematic approach of investigating the regional convergence was introduced in the research which studied the issue whether poor countries should grow faster than rich ones (Barro and Sala-i-Martin, 1992). Based on a neoclassical growth model (Solow, 1956) and under the assumption that the steady states and the relevant factors should be the same over regions, this research provided a way to investigate the convergence across the U.S. states over a certain period. The results suggested that the U.S. regional economies should converge. The regional convergence of German labour markets was investigated by a technique of geographically weighted regression, which allowed a detailed analysis of convergence processes (Eckey et al., 2007). Spatial convergence has also been widely applied to analysis of regional housing markets in many studies, for instance, (Meen, 1996; Cook, 2003; Holly et al., 2011). These authors all supported the existences of both price convergence and strong equilibrating mechanisms in housing markets.

Spatial Effect Originations

Spatial effects in the regional markets have been found in many studies, particular in housing and construction markets. Geographical forces that arise from economic or other activities of the agents in neighbouring regions may come into play in a different region (Deng et al., 2010), Deng et al., (2010) also indicated that if regions in adjacent areas are growing fast, this may generate demand for construction workers and land as many other industries also begin to expand their activity in the region itself. When construction activity is low, competition for projects becomes intense, and construction firms are willing to bid in other regional markets where they do not normally operate (Skitmore et al., 2006). Skitmore (1987) indicated that builders move with the seasons from one region to another to obtain work.

Previous studies have found that spatial effects are statistically significant, but the underlying behavioural explanations for the interactions which lead to the observed pattern of the spatial effects are still not entirely clear. Three possible explanations might be distinguished as Migration, Spatial arbitrage, and Spatial patterns in the determinants of construction prices.

It is possible that States that are contiguous may influence each other's construction prices. High construction prices in one market may persuade people to commute from neighbouring states (Holly et al., 2010). A lower construction price may provide an incentive to migrate and increase the labour mobility. Giussani and Hadjimatheou (1991) indicated that if housing construction prices are high in a south region relative to north region, then households might be expected to migrate to the north region, leading to an equalisation in housing construction prices over time as the ripple effect would suggest. Since the empirical studies typically find that population changes are the key influence factor for construction prices, changes in migration might affect changes in construction prices.

Construction firms, developers and suppliers may enter that market for gaining higher profits when the construction price goes up (Skitmore et al., 2006). If construction markets were fully efficient, arbitrage would take place over space to eliminate any differences in returns. Evidence of spatial arbitrage in regional construction markets has been found of a diffusion process or ripple effect, whereby recent strength in one sub-market feeds gradually into others (Fu and Liu, 2010). These arbitrage activities might be explained as when new information becomes available in one region, this information is transmitted first to nearby regions (Meen, 1999).

Spatial effects as determinants of construction prices have been found in some previous studies, such as Skitmore et al. (2006). The author summarized that a high demand in the northern area of the USA is associated with high construction prices. Changes in demand in one regional construction market would cause changes in demand in nearby markets, hence produce similar shifts in their construction price levels. Meen (1999) claimed that the changes in local income may affect incomes in nearby regions and generate indirect impacts on their construction markets.

Methodology

In this study, spatial autocorrelation and convergence tests are employed to explore the existence of spatial effects on the regional construction prices.

Spatial Autocorrelation Test

Spatial autocorrelation coefficient is a statistic which attempts to measure the interrelationship between construction prices in different states. The coefficient is usually evaluated with respect to distance, contiguity, boundaries and other geographic weighting functions. Spatial weights are often used to quantify the locations of observations. There are various types of spatial weight constructions in spatial econometrics, which can be classified into two ways. One is to construct the spatial weights based on the distance among observations, while the other is to use the contiguity reflecting the position of one observation to the others in the space. In this paper the spatial weight will be constructed based on the position of each regional construction market to others in the space. For example, the (*i*, *j*) elements of a weighting matrix, w_{ij} could take a value of 1 if the *i*th and *j*th regions but are contiguous and zero otherwise. The spatial weight for two regions is defined as the reverse values of the d_{ij}, namely $w_{ij} = \frac{1}{d_{ij}}$.

In that way, the weight matrix *W* is composed by $W = \begin{bmatrix} 0 & w_{12} & \dots & w_{1N} \\ w_{21} & 0 & \dots & w_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ w_{N1} & w_{N2} & \dots & 0 \end{bmatrix}$. It can be found that the geographic weight matrix is symmetric, which means the spatial weight from region *i* to region *j* is the same as that from region *j* to region *i*. Moreover, the spatial matrix is time invariable, indicating the spatial weights will not change over time.

The null hypothesis for testing the presence of spatial autocorrelation is that there is no relation between construction prices in different regions and their relative weights. Moran's *I* statistic (Moran, 1950) is used to calculate the tests in this paper. The calculation of Moran's *I* test mentioned in the work of Aten (1996) was described as

$$I = \frac{N \sum_i \sum_j w_{ij}(p_i - \bar{p})(p_j - \bar{p})}{\sum_i \sum_j w_{ij} \sum_i (p_i - \bar{p})^2} \tag{1}$$

where, *i* and *j* denote the eight different regional construction markets, counted from 1 to 8, *N* denotes the number of regions, (8), w_{ij} is an element of the spatial matrix W, p_i and p_j denote the natural logarithm of the construction price in state *i* and state *j* respectively, and $\bar{p} = \frac{1}{N}\sum_i p_j$ in a certain time. The Moran's *I* values range from -1 to 1. A positive value of Moran's *I* indicates a positive autocorrelation, which is measured as the clustering of similar construction prices, while a negative value indicates a negative autocorrelation, which describes the tendency for dissimilar construction prices to cluster. When the Moran's *I* value close to 0, it is expected that the physical distribution of construction prices should follow a random distribution, which means the lack of spatial autocorrelation.

The z-scores of Moran's *I*, which is computed by $z(I) = \frac{I - E(I)}{\sqrt{Var(I)/N}}$, are often used to determine the significance. $E(I) = \frac{-1}{N-1}$ is the expected value of Moran's *I*, when there is no spatial autocorrelation, while $Var(I)$ is the variance of Moran's *I*. When $z(I)$ is more than $z_{a/2}$, there is a significant positive spatial autocorrelation; when $z(I)$ is less than $-z_{a/2}$, there is a significant negative spatial autocorrelation, where a indicates the critical level of the confidence.

Spatial Convergence Test

Spatial convergence has been considered through co-integration analysis. Suppose, for example that construction price *p* in region *i* and form a co-integration set:

$$p_i = \alpha + \beta p_j + \varepsilon_i \tag{2}$$

If a change in one region is transmitted to all other regions, then there is a stable long-run relationship in construction prices between the regions, and those regions may be considered as open in the long-run. If this does not occur, then there is a suggestion that there are barriers, preventing prices from adjusting. The concept of co-integration was first suggested by Granger (1981). If several non-stationary variables have a co-integration relationship, it indicates that these non-stationary variables own a common trend and there is an equilibrium relationship among them in the long term. There are two popular econometric co-integration test theories employed in this study. They are the Engle-Granger co-integration test and the Johansen co-integration test. The Engle-Granger co-integration test theory was proposed by Engle and Granger (1987). The Engle-Granger co-integration test is good at detecting pairwise co-integration relationship between variables. Once the pairwise co-integration relationships are discovered, then the co-integration equations can be built up on this ground, and the causal links between variables will be explored according to a co-integration model. There are two sorts of Engle-Granger co-integration test used in this study. They are one without deterministic time trend and another one with deterministic time trend.

When the pairwise co-integration relationships are detected by the co-integration test, it does not support the notion that there is a continuous equilibrium relationships between the pairs of variables, and they are because they are probably in disequilibrium in the short term. However, despite this, there may well be a long term equilibrium relationships between the variables. The equilibrium error term was firstly proposed by Sargan (1964), and it is named as 'error correction mechanism'. The notion of error correction mechanism was promoted by Davidson et al. (1987) and combined with co-integration theorem by Engle and Granger (1987). The danger of spurious regression can be eliminated by the analysis of the co-integration relationship, and the error correction models can used to present the causality between the pairs of variables.

The error correction model is expressed as:

$$\Delta Y_t = \alpha_0 \Delta X_t + \emptyset ecm_{t-1} + \mu_t \tag{3}$$
$$ecm_{t-1} = Y_{t-1} - \beta_0 - \beta_1 X_{t-1} \tag{4}$$

where ΔY_t represents the data series derived from the first difference of the time series Y_t and ΔX_t denotes the data series X_t at the first difference level, t=1, 2, 3, …, n and n is dimension of the vector variable. The time series of Y_t and X_t are both hypothesized as $I(1)$, which indicates that they are both integrated at the first difference level. The symbol α_0 denotes the short term elasticity, and the symbol $\emptyset$ represents the rapidity of adjustment back to equilibrium status and the item of μ_t denotes the residual value of the ECM. The item of ecm_{t-1} denotes the error correction term, and in the expression of ecm_{t-1}, the symbol β_0 is the constant item and the symbol β_1 represents the long term elasticity. The ecm_{t-1} is derived as the residual value of the co-integration regression equation.

Australian Construction Markets

The data used in this study is adopted from the Australian Bureau of Statistics. The coverage of collections and datasets processed by the Australian Bureau of Statistics is widely spread over Australian social and economic activities, such as research and development, manufacturing, energy, mining, retail and wholesale trade establishments, interstate trade, tourist accommodation, the census of population and housing, education, health, welfare, justice and other social issues, national accounts, labour forces, household income and expenses and agriculture. Producer price indices and house price indices are also generated by the Australian Bureau of Statistics, and they are significant economic indicators to measure the degree of economic health.

This study focuses on the producer price indices of general construction at the sub-national level in Australia. The six states and two territories general construction price indices are used in this study specifically. The quarterly construction producer price indices are extracted from the producer price indices data of the general construction industry from 1998Q3 to 2013Q1. The data structure chart of PPI of the general construction industry in Australia is presented in Figure 1. As Australian Bureau of Statistics (ABS 2013) indicated, the calculations of the output indices are processed on the foundation of the reference base 1998-99=100.00. The constituent groups and classes of the ANZSIC subdivision 41 embrace the building construction group (411), which contains three classes which are house construction (4111), residential building construction and non-residential building construction (4113). Another group is the non-building construction group (412) which covers road and bridge construction (4121) and non-building construction (4122), which includes railways, telecommunications, electricity infrastructure, etc. The index employed in this study is that of output prices for general construction (41).

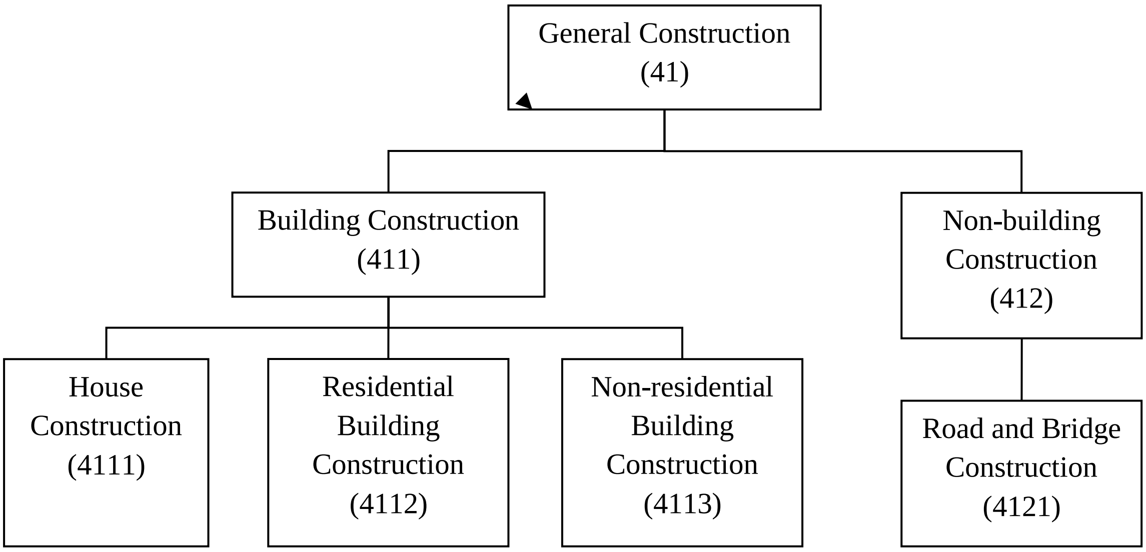

Figure 1 Structure chart of producer price indices of the general construction industry in Australia

Testing for Spatial Autocorrelation among Australian Construction Markets

Prior to testing spatial autocorrelation among regional construction markets, a spatial weight matrix is needed. Based on the geographic location of each state and territory, a geographic weighting matrix can be developed and summarized as in Table 1, which shows South Australia is contiguous with five states. The construction market in South Australia received influence from five neighbouring regions each wi8th a spatial weight of 0.2. In contrast, Tasmania is only contiguous with Victoria and the spatial weight from Victoria to Tasmania is 1. The unbiasedness condition would hold if and only if the spatial weights sum up to one.

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	0	0.25	0.25	0.25	0	0	0	0.25
VIC	0.25	0	0	0.25	0	0.25	0	0.25
QLD	0.33	0	0	0.33	0	0	0.33	0
SA	0.2	0.2	0.2	0	0.2	0	0.2	0
WA	0	0	0	0.5	0	0	0.5	0
TAS	0	1	0	0	0	0	0	0
NT	0	0	0.33	0.33	0.33	0	0	0
ACT	0.5	0.5	0	0	0	0	0	0

Table 1 The spatial weight matrix of Australian regional construction markets

The Moran's *I* statistic test is carried out to investigate the spatial autocorrelation between the construction prices of Australia's six states and two territories at each quarter over the observing period. The results of Moran's *I* tests and the Z-scores are shown in Figure 2. The figure shows the Moran's *I* values of construction prices across Australia's six states and two territories are positive at each quarter throughout the whole observing period. This means that the construction price at one region is positively associated with those at its neighbouring regions. In addition, Figure 2 gives the Z-scores of those Moran's *I* values, whose critical values are -1.96 and 1.96 with the significance of 5%. The results suggest the presence of significant positive spatial correlation between the construction prices of Australia's regional markets at each quarter from 1998Q3 to 2013Q1. That means that when the construction prices in one market increase, it will positively affect construction prices in other contiguous markets in most of the quarters from 1998 to 2013. Furthermore, the autocorrelation results seem to suggest that the degree of dependence decreases quickly as the space between units increase.

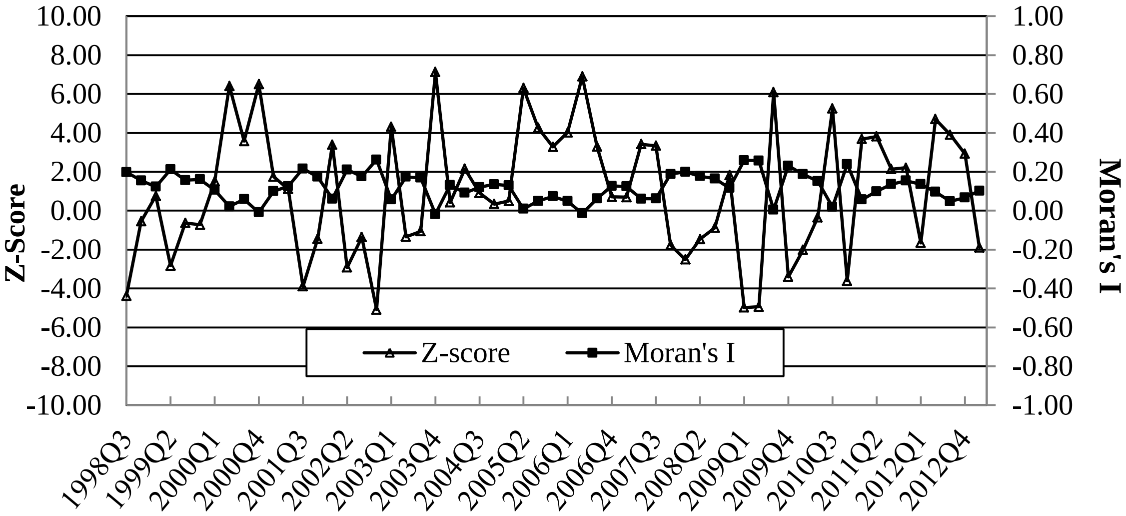

Figure 2 Spatial autocorrelation test for construction prices in eight regional markets

Testing for Spatial Convergence in Australian Construction Markets

The co-integration analysis is employed for testing spatial convergence to detect long term equilibrium relationships. The variables are co-integrated if they share a common trend and tie together in a long term equilibrium relationship. The Engle-Granger test method is employed to test the co-integration relationships of the six states and two territories construction prices indices. The casual relationships between the regional indices will be explored as well.

The construction price indices in eight regional markets are tested for non-stationarity. There are two different co-integration regression analysis included in this research: co-integration regression analysis without deterministic trend is shown in Table2, and co-integration regression analysis with deterministic trend is presented in Table 3. For every pair of two states, there is one least square regression equation. The values of R-square indicate the fits of the spatial convergence estimation models. ADF test on residuals is the Augmented Dickey-Fuller unit root test on the residuals obtained from each least square regression equation. The item 'na' denotes the residuals acquired from individual regression equations are non-stationary according to the ADF unit root test. The percentages are the significance levels when the null hypothesis can be rejected. This indicates that the series of residuals is stationary, so these two variables can be considered co-integrated.

		NSW	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	R^2	-	0.969	0.979	0.983	0.966	0.979	0.923	0.986
	ADF on residuals		-2.218	-1.639	-2.551	-2.947	-2.468	-1.996	-5.209
			5%	10%	5%	5%	na	na	1%
VIC	R^2	0.969	-	0.943	0.981	0.935	0.954	0.881	0.979
	ADF on residuals	-2.103		-1.840	-3.769	-2.055	-2.755	-2.075	-3.708
		5%		na	1%	na	10%	na	1%
QLD	R^2	0.980	0.943	-	0.956	0.984	0.966	0.928	0.971
	ADF on residuals	-1.679	-2.04		-2.53	-1.282	-0.255	-1.159	-2.156
		na	na		10%	na	na	na	5%
SA	R^2	0.983	0.981	0.956	-	0.959	0.978	0.925	0.992
	ADF on residuals	-2.469	-3.875	-1.836		-1.811	-3.174	-2.492	-2.234
		5%	1%	na		na	5%	na	na
WA	R^2	0.966	0.935	0.984	0.959	-	0.973	0.967	0.964
	ADF on residuals	-3.007	-2.206	-1.317	-2.867		-1.959	-1.077	-1.775
		10%	na	na	5%		na	na	na
TAS	R^2	0.979	0.954	0.965	0.977	0.973	-	0.966	0.979
	ADF on residuals	-2.669	-3.518	-0.486	-2.510	-1.961		-1.328	-2.050
		na	5%	na	na	na		na	na
NT	R^2	0.923	0.881	0.928	0.925	0.967	0.966	-	0.915
	ADF on residuals	-1.626	-2.470	-1.438	-2.46	-1.412	-1.575		-1.626
		na	na	na	na	na	na		na
ACT	R^2	0.987	0.979	0.971	0.992	0.964	0.979	0.915	**-**
	ADF on residuals	-2.537	-3.887	-2.110	-2.29	-1.760	-2.001	-1.576	
		5%	1%	na	na	na	na	na	

Table 2 Pairwise co-integration test results (without deterministic trend)

Note: The percentage number in the ADF on residuals row denotes the significance level when the null hypothesis is rejected respectively.

From the results revealed in Table 2, there are 19 pairs of state construction price indices which are co-integrated, each pair having a long term equilibrium relationship. While 9 pairs of state series are tested to be co-integrated, and they are all observed as co-integrated pairs in table 3 as well. The coefficients of determination (R-square) values in Tables 2 and 3 suggest that the pairwise relationships among these regions are quite stable. Most of the coefficients of determination values are above 0.9, however a few R square values lower, e.g. the regression of Victoria on Northern Territory and Northern Territory on Victoria. There are several factors affecting co-integration, such as the amount of market information reflected in the prices of a particular market (Buccola, 1985,1989). Maybe the factor of market volume (Tomek, 1980), and degree of industry concentration (Goodwin and Schroeder, 1991) are also relevant in affecting co-integration. The co-integration regression tests also indicate that the law of one price is valid in the markets, and the co-integration regional linkages are shown through the test results. All the outcomes support the hypothesis that there is regional convergence of construction prices.

		NSW	VIC	QLD	SA	WA	TAS	NT	ACT
NSW	R^2	-	0.981	0.982	0.996	No trend	0.986	0.930	0.993
	Time trend		0.005	-0.004	0.006		0.006	0.007	0.005
	ADF on residuals		-4.68	-2.074	-1.939		-1.972	-2.539	-2.539
			5%	na	na		na	na	na
VIC	R^2	0.973	-	No trend	0.993	0.945	0.977	0.926	0.988
	Time trend	0.004			0.007	0.011	0.013	0.022	0.007
	ADF on residuals	-1.506			-1.506	-1.791	-2.948	-2.001	-2.256
		na			na	na	5%	na	na
QLD	R^2	0.991	0.980	-	0.995	No trend	No trend	0.942	0.996
	Time trend	0.004	0.006		0.008			0.007	0.007
	ADF on residuals	-3.270	-2.236		-2.609			-1.593	-2.149
		5%	na		10%			na	na
SA	R^2	0.985	No trend	0.966	-	0.962	0.979	No trend	No trend
	Time trend	-0.005		-0.015		-0.001	0.006		
	ADF on residuals	-1.866		-2.509		-2.226	-3.429		
		na		na		na	5%		
WA	R^2	0.980	0.976	No trend	0.994	-	0.989	No trend	0.990
	Time trend	0.005	0.008		0.008		0.007		0.008
	ADF on residuals	-3.667	-1.024		-3.267		-1.853		-1.078
		1%	na		5%		na		na
TAS	R^2	No trend	0.976	No trend	0.992	No trend	-	0.972	0.987
	Time trend		0.009		0.008			-0.007	0.007
	ADF on residuals		-2.883		-1.018			-1.355	-0.659
			10%		na			na	na
NT	R^2	0.969	0.976	0.947	0.991	0.976	0.992	-	0.984
	Time trend	0.007	0.009	0.007	0.009	0.006	0.007		0.011
	ADF on residuals	-1.883	-2.838	-1.414	-2.562	-0.773	-2.007		-0.352
		na	na	na	na	na	na		na
ACT	R^2	No trend	0.981	0.982	0.996	No trend	0.982	0.923	-
	Time trend		0.004	-0.012	0.005		0.006	0.011	
	ADF on residuals		-3.791	-2.206	-2.418		-2.926	-1.998	
			1%	na	na		na	na	

Table 3 Pairwise co-integration test results (with deterministic trend)

Note: The percentage number in the ADF on residuals row denotes the significance level when the null hypothesis is rejected respectively.

The co-integration regression tests explore the spatial convergence of the pairs of state producer price index series of construction. However, even during long term equilibria, there are still some short term disequilibria caused by short term changes. The error correction model is applied to estimate this short term disequilibrium. In practice, the error correcting mechanism can be arbitrage and trading activities in the economic system. Table 4 presents the error correction model equations for the six states' and two territories' producer price index series of house construction based on Engle-Granger co-integration test results. D(.) denotes the data series of the item included in the bracket at the first difference level. The coefficient of the D(.) on the right of the equation denotes the short term elasticity of changing, which is the short term changing rate. The coefficient of ecm_{t-1} denotes the speed of adjustment from short term disequilibrium back to a long term equilibrium relationship.

States or Territories	Error correction model equations
NSW	D(NSW) = 0.007015+ 0.209221*D(VIC) - 0.011709* ecm_{t-1}
	D(NSW) = 0.002279+0.701268*D(SA) + 0.082590* ecm_{t-1}
	D(NSW) = 0.004677+ 0.321239*D(WA) + 0.074515* ecm_{t-1}
	D(NSW) = 0.002943+ 0.583805*D(ACT) + 0.108472* ecm_{t-1}
VIC	D(VIC) = 0.006400+ 0.274281*D(NSW) + 0.144992* ecm_{t-1}
	D(VIC) = 0.006182+ 0.280789*D(SA) + 0.244234* ecm_{t-1}
	D(VIC) = 0.005035+ 0.360342*D(TAS) + 0.007604* ecm_{t-1}
	D(VIC) = 0.008051+ 0.069847*D(ACT) + 0.226173* ecm_{t-1}
QLD	D(QLD) = 0.002532+ 0.862309*D(NSW) + 0.076747* ecm_{t-1}
SA	D(SA) = 0.005269+ 0.470845*D(NSW) +0.025234* ecm_{t-1}
	D(SA) = 0.008180+ 0.141004*D(VIC) -0.061004* ecm_{t-1}
	D(SA) = 0.006851+ 0.260981*D(QLD) -0.020564* ecm_{t-1}
	D(SA) = 0.005986+ 0.269687*D(WA) -0.006359* ecm_{t-1}
WA	D(WA) = 0.007362+ 0.621413*D(NSW) -0.037730* ecm_{t-1}
TAS	D(TAS) = 0.008552+ 0.242047*D(VIC) -0.047163* ecm_{t-1}
	D(TAS) = 0.008559+ 0.231615*D(SA) -0.041348* ecm_{t-1}
NT	Nil
ACT	D(ACT) = 0.006623+ 0.399335*D(NSW) +0.080874* ecm_{t-1}
	D(ACT) = 0.009821+ 0.032321*D(VIC) -0.060559* ecm_{t-1}
	D(ACT) = 0.007254+ 0.284091*D(QLD) +0.042953* ecm_{t-1}

Table 4 Error correction models of construction producer price indices

Jiang et al. (2011) indicated that when the co-integration relationship exists, it is considered that a Granger causality must occur in at least one direction. The causal links between six states and two territories have been presented in Figure 3, which indicate the elasticity of changing in the diffusion of regional construction prices based on the co-integration regression test and error correction model estimations. Figure 3 shows that there are no causal relationships with the Northern Territory. In contrast, construction prices in New South Wales receives four significant positive causal effects from Victoria, South Australia, Western Australian and Australian Capital Territory. The figures also indicate that Victoria and South Australia construction prices both receive positive causal effects from four regional prices. Queensland and Western Australia are only influenced by New South Wales. The changes of New South Wales construction prices generate the most significant effects on construction prices in five regional markets.

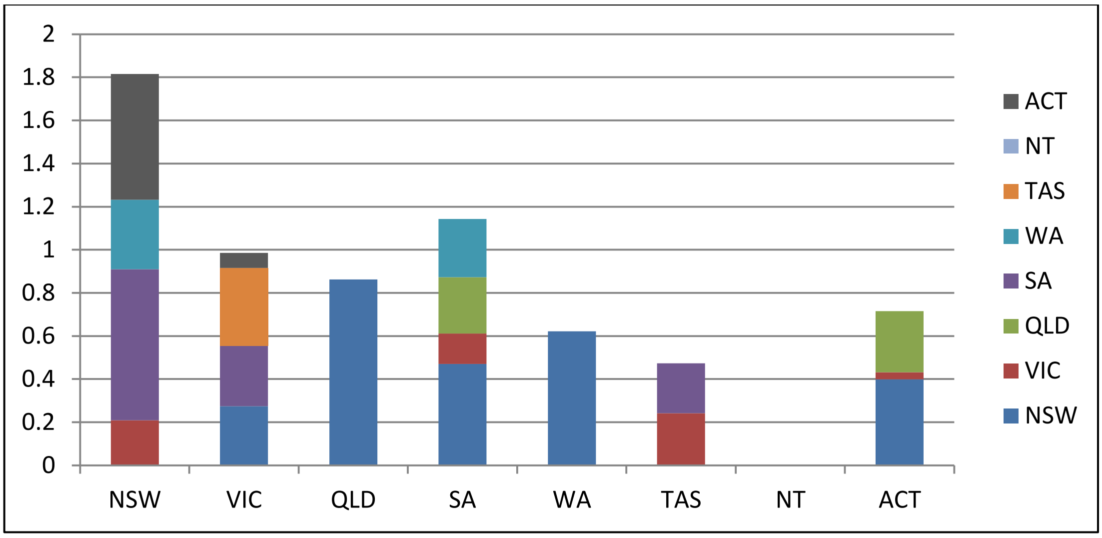

Figure 3 The short term inputs to changes of construction prices in each regional market

The results of our spatial convergence tests suggest that there are 14 pairs of regional market with bidirectional causalities and other 5 pairs of regional markets with one-way causality only with other regional markets. It is also found that each market has at least one one-way causality with other regional markets except Northern Territory, and the causality links between the states are mainly with adjoining states. Furthermore, there are no causal relationships with the Northern Territory meaning that movements of construction prices in the Northern Territory do not affect other regions. This may be because the construction market in Northern Territory is the smallest of the eight regional markets. The construction price in New South Wales has the highest degree of positive influences on five regional markets may be because New Sales Wales in the last two decade has become the largest construction market in Australia. These results further present evidence on “ripple effect” in the construction prices in Australian regional markets and that the changes in regional construction prices will positively influence neighbouring states first, and then spread out into other regions. Finally the regional prices converge and reach a long-run equilibrium in the following quarters.

In the regional construction markets, investors, developers and policy makers need to consider spatial linkages in modelling construction prices and demand to increase the accuracy of calculation. The fluctuation of construction prices in one state, such as New South Wales or South Australia, could be induced by the policies and strategies adopted in their neighbouring states and territories, and their economic development.

Conclusions

The linkages among different construction markets are widely discussed. This study focuses on analysing spatial linkages between construction price indices in Australia’s eight regional construction markets by employing spatial autocorrelation and convergence tests.

The results show the presence of significant positive associations between the construction prices in Australia’s eight construction markets. The autocorrelation results also suggest that the degree of dependence decreases as the space between the markets increases. Each construction market has at least one one-way causality with other regional markets except the Northern Territory’s. The construction prices in New South Wales has the highest degree of positive influences on other regional markets.

The results of convergence tests present further evidence on a ripple effect on construction prices in Australia. The changes in regional construction prices first influence neighbouring states in a positive direction, and then spread out into other regions, and finally the regional prices converge and reach a long-run equilibrium after a few quarters.

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