READING HOUSE PRICES IN AUSTRALIAN CAPITAL CITIES

Le Ma, Chunlu Liu

Deakin University, Geelong, Victoria, Australia

INTRODUCTION

House prices in the Australian capital cities have been increasing over the last two decades. An over 10% average annual increase arises in the capital cities. In Melbourne, Brisbane and Perth, the house prices increased by more than 15% annually, while the house prices in Darwin increased by even higher at about 21%. It is surprising that, after a decrease in 2008, the house prices in the Australian capital cities show a strong recovery in their last financial year's increase. How to read the house prices in cities across a country has been an issue of public interest since the late 1980s. Various models were developed to investigate the behaviours of house prices over time or space. A spatio-temporal model, introduced in recent literature, appears advantages in accounting for the spatial effects on house prices. However, the decay of temporal effects and temporal dynamics of the spatial effects cannot be addressed by the spatio-temporal model.

This research will suggest a three-part decomposition framework in reading urban house price behaviours. Based on the spatio-temporal model, a time weighted spatio-temporal model is developed. This new model assumes that an urban house price movement should be decomposed by urban characterised factors, time correlated factors and space correlated factors. A time weighted is constructed to capture the temporal decay of the time correlated effects, while a spatio-temporal weight is constructed to account for the time-varied space correlated effects. The house prices of the Australian capital cities are investigated by using the time weighted spatio-temporal model. The empirical findings suggest that the housing markets should be clustered by their geographic locations. The rest parts of this paper are organised as follows. The following section will present a principle for reading urban house prices. The next section will outline the methodologies modelling the time weighted spatio-temporal model. The subsequent section will report the relative data and empirical results, while the final section will generate the conclusions.

THE PRINCIPLE FOR READING URBAN HOUSE PRICES

A house has dual properties. In one aspect, houses can be regarded as assets, whose prices tie tightly to temporal information. Much previous research utilised a series of temporal factors to explore the house price movements in a city or nation (Poterba *et al.* 1991; Liu *et al.* 1997; Tsatsaronis and Zhu 2004; Abelson *et al.* 2005; Song and Liu 2005). In another aspect, houses can also be treated as commodities, the prices of which may determined by their own characteristics. Many studies evaluated house prices according to their individual structures (Rosen 1974; Case and Shiller 1987; Meese and Wallace 1997). Moreover, other literature highlighted the effects on house prices, which were generated from the spatial factors (Can 1990; Maher 1994; Jones and Leishman 2006; Karaganis 2011). Those previous studies indicate that house prices may not be influenced by the houses' own features, but also be correlated with the temporal and spatial factors.

Meen (1999) demonstrated that the housing market within a nation could not be regarded as an aggregate. Instead, it should be composed by a series of interregional markets, across the country. The segmentations, ripple-down behaviours and convergences of urban or regional house prices have drawn attention from a number of researchers. In order to address to the temporal and spatial relationships between house prices across cities or regions, a record of research and investigations was conducted based on the technique of time-series regressions (MacDonald and Taylor 1993; Bourassa and Hendershott 1995; Meen 1996; Tu 2000; Liu *et al.* 2008; Liu *et al.* 2009; Shi *et al.* 2009). However, those studies only focused on how the dynamics of house prices spread over and across time and space respectively. Holmes (2007) carried out a panel regression method to investigate the convergence of urban house prices. It was suggested that the panel regression method could capture the impacts of urban heterogeneity on house prices, which were ignored by time-series regression methods. Ma and Liu (2010) also proposed a panel regression approach to decompose the urban house prices in to three categories, including regional factors, own-market factors and neighbouring market factors. Based on the framework of panel regression, recent research implemented spatial analysis method to capture the spatial effects on urban or regional house prices. Beenstock and Felsenstein (2007) proposed a spatial vector autoregression model to explore the relationships between house prices over time and across space. Holly *et al.* (2011) outlined a spatio-temporal methodology to investigate the temporal and spatial diffusion of house prices in the U.K. The advantages of the spatio-temporal methodology make the underlining research can perform well in taking account of the effects of previous house price movements, heterogeneity and spatial correlations. However, this newly developed method still has drawback in ignoring the effects generated from the corresponding time point.

Based on previous research on house prices, it can be demonstrated that the movements of house prices are influenced by factors of three dimensions, which are internal characteristics, temporal information and the spatial information. Therefore, this research argues a three-part-decomposition method, when reading the house price movements. Built on the spatio-temporal method, this research introduces a temporal weight, with purpose of simulating the effects correlated with a specific time point. By reading the effects allocated in each dimension, the similarities and the disparities of urban house prices can be explored. The house price indices in the Australian capital cities and the correlated regional information are used as a case study to interpret the modelling process and results.

THE MODEL FOR READING URBAN HOUSE PRICES

This research decomposes the house price movements in a city into three parts, which are urban characterised factors, time correlated factors and space correlated factors. The conception model for the urban house price movements can be expressed as follows:

$$\Delta P = f(R,T,S) \tag{1}$$

ΔP stands for the urban house price movements. *R, T* and *S* indicate the factors belong to urban characteristics, time correlated factors and space correlated factors respectively.

Time Weighted Spatio-temporal Models

Based on the framework of spatio-temporal models, this research raises a time weighted spatio-temporal model, which is expressed as follows:

$$\Delta P_t = R + BT\Delta P_{t-1} + \Gamma W\Delta P_{t-1} + E_t \tag{2}$$

The variables, ΔP_t and ΔP_{t-1}, are $N \times 1$ vectors, where N is the number of cities. The symbols, T and W, are $N \times N$ matrices, standing for the temporal and spatio-temporal weights respectively. T is a diagonal matrix, while W is a symmetric matrix with 0 diagonal. Parameters, R,B and Γ, are estimated correlation coefficients, while E_t is the residual term. The single equation of Eq.(2) can be expressed as follows:

$$\Delta P_{it} = r_i + \beta_i \tau_{t-1} \Delta P_{it-1} + \gamma_{ij} \sum_{j=1}^{N} w_{ij} \Delta P_{jt-1} + \varepsilon_{it} \tag{3}$$

As mentioned above that house prices are determined by their own structural characteristics, urban house price movements, ΔP_{it}, should be correlated with the factors that carried by their corresponding cities. It is assumed that the parameter, r_i, standing for this decomposed part should be invariable over time but distinguished across cities.

It is well proved by previous research that house prices are highly correlated with spatial factors. Thus, urban house prices should be influenced by the space correlated factors. Since the prices should fully reflected the available information under the efficient market hypothesis (Fama 1970), this research uses the spatial weighted house price movements, $w_{ij}\Delta P_{jt-1}$, in other cities to indicate the space correlated factors. The term w_{ij} is constructed by the geographic information between city *i* and city *j*. Two types of constructing methods of the spatial weights are widely applied in empirical studies, which are simple contiguity and distance contiguity (Anselin 1988). In this research, there is no real contiguity between each pair of cities, so that the spatial weights are constructed based on the distance decay policy.

Urban house price movements are also impacted by temporal factors. This research uses the previous movements, ΔP_{it-1}, of urban house prices are used as the indicators. Although the implemented temporal lags can subtract the effects generated from the historical behaviours of urban house prices, the impacts carried by the time are not taken into account. Therefore, this research introduces a temporal weight, τ_t, to cover this effects, which are assumed to be invariable across cities but changeable over time.

Constructions of the Temporal and the Spatio-temporal Weights

Seen from Eq.(3), the time correlated and space correlated factors are controlled by the temporal and spatio-temporal weights respectively. This research combined the distance and the new dwelling numbers to construct the spatio-temporal weight, which is calculated as follows:

$$w_{ijt} = \frac{1}{d_{ij}} \frac{n_{jt}}{n_{it}+n_{jt}} \tag{4}$$

The term, d_{ij}, indicates the distance between city *i* and city *j*, while n_{it} denotes the new dwelling numbers in city *i* at time t. The weights signify the importance of geographical impacts of city *j* on city *i*. The developing scale of city *j* also makes an influence on city *i*. It can be found that the weights, under this calculation, are asymmetric unless there is a same developing scale in the both cities. Moreover, the spatio-temporal weights are able to vary over time. This may make the estimation closer to the practice.

Nappi-Choulet Pr and Maury (2009) set a temporal weight by the inverse of the time lags, assuming that the time correlated factors should impact on house price movement evenly over the time. Another disadvantage of their temporal weight setting is that the correlations between different time points are ignored. Therefore, this research utilises the population shares between two time points to stands for the effects generated by time correlated factors. The corresponding temporal weights are calculated as follows:

$$\tau_t = \frac{1}{\Delta pop_t} \tag{5}$$

The term, pop_t, indicates the national population at time t, while $\Delta pop_t = (pop_t - pop_{t-1})$ indicates the population increase. One reason for choosing population to construct the temporal weight is that it can well reflect one important temporal aspect of a nation. In addition, the population is selected because of the tight relationships with house prices.

READING THE HOUSE PRICES IN THE AUSTRALIAN CAPITAL CITIES

Three kinds of data, collected from the Australian Bureau of Statistics (ABS), are applied in this research. The observing period of the data is from the March quarter 1993 to the June quarter 2010. The house price indices in the Australian capital cities are based on 1989-90=100 (ABS 2011c). Although the reference base of the published HPI has changed to the 2003-04 financial year since the September quarter 2005, to keep the consistency, the old reference base (1989-90) is used in this research. Figure 1 shows the house price indices over the observing period.

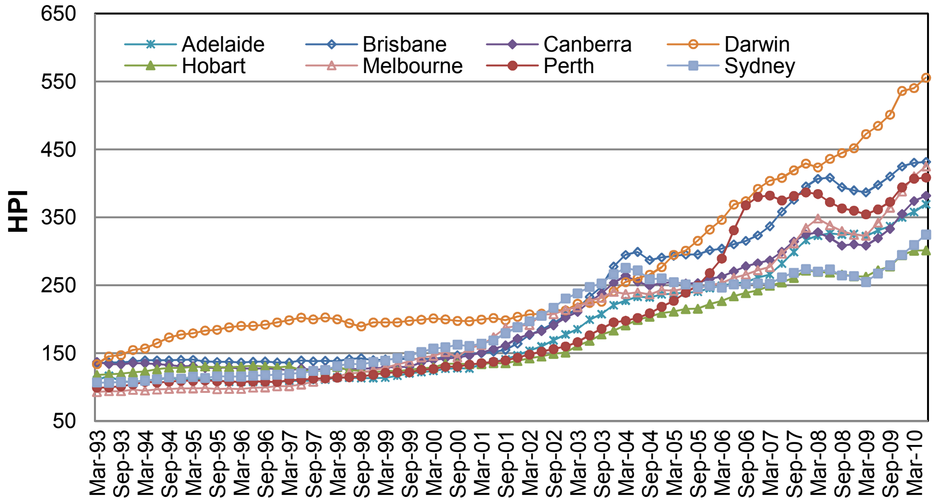

Figure 1: House price indices of the Australian capital cities

The new dwelling numbers are published by the Building Approvals (ABS 2011b). This set of data focuses on the scales of change for each capital city's real estate. Since this study analyses the interactions between the dynamics of each residential property market, it is better to construct the spatial weight matrix rather than the total stock of property. The original monthly data is converted into quarterly data by summing the numbers every three months, in order to match the frequency of the HPI. Table 1 reports the quarterly new dwelling numbers in the Australian capital cities. Significant differences can be observed between the cities. According to the large differences in house market developing scales, the spatial heterogeneity across the regional house markets may not only depend on the geographic location, but also on the characteristics of the markets. Therefore, the spatial weights of regional house prices should be adjusted by using the developing scales of markets.

Table 1: Descriptive statistics for the number of dwelling units in the Australian capital cities

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Minimum	698.00	1646.00	179.00	22.00	87.00	2524.00	1719.00	1415.00
Maximum	2007.00	4024.00	773.00	289.00	365.00	7105.00	4127.00	4650.00
Mean	1355.52	2773.07	349.91	110.48	222.91	4778.34	2910.16	2848.73
Std. Dev.	310.33	543.66	116.06	48.22	65.13	1043.97	619.30	856.85

Combine with the distances between pairs of cities, the spatial weights of the cities at each time point can be calculated by Eq.(4). The averages of the spatial weights are reported in Table 2. The spatial weights range from 0.0389 to 0.0941. Each pair of cities does not exhibit huge differences. It can be seen that Melbourne always accounts for relatively higher spatial effects to the other regional house markets. This may be caused by the central location and large housing market scale of Melbourne. In contrast, the small market and remote location could be the reason that the housing market of Darwin is relatively low compared to the other housing markets.

Moreover, the Australian national populations are collected from Australian Demographic Statistics (ABS 2011a). The statistical results are based on 2 main censuses of population and housing. The censuses were carried out in 2001 and 2006. As mentioned in Eq.(5), the inverse of the national population change at each time point over the observing period is calculated, indicating the time correlated factors of Australia at the corresponding time point. Smoothly increasing temporal weights are generated, due the flat population growth of Australia.

Table 2: Average spatial weights

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
Adelaide	0.0000	0.0605	0.0553	0.0438	0.0540	0.0712	0.0593	0.0633
Brisbane	0.0549	0.0000	0.0517	0.0409	0.0471	0.0616	0.0536	0.0629
Canberra	0.0682	0.0703	0.0000	0.0481	0.0614	0.0795	0.0625	0.0856
Darwin	0.0663	0.0680	0.0589	0.0000	0.0567	0.0700	0.0671	0.0669
Hobart	0.0724	0.0696	0.0667	0.0503	0.0000	0.0941	0.0650	0.0740
Melbourne	0.0599	0.0571	0.0542	0.0389	0.0591	0.0000	0.0530	0.0616
Perth	0.0530	0.0528	0.0453	0.0397	0.0434	0.0563	0.0000	0.0531
Sydney	0.0577	0.0632	0.0633	0.0404	0.0503	0.0667	0.0541	0.0000

This research utilised the information described in the previous section to explore the urban house price movements in the Australian capital cities by Eq.(2). The coefficients of the urban characteristic effects, temporal effects and spatial effects were estimated and reported in Table 3.

Table 3: The estimations of house prices in the Australian capital cities

Cities	τ_i	β_i	γ_i
Adelaide	0.0034	0.7479 (0.5188)	1.7900 (0.0000)
Brisbane	0.0008	5.1680 (0.0000)	1.2424 (0.0059)
Canberra	-0.0004	1.9910 (0.0985)	1.4725 (0.0003)
Darwin	0.0155	2.5476 (0.0295)	0.0488 (0.8789)
Hobart	0.0030	0.7696 (0.5040)	1.0759 (0.0001)
Melbourne	0.0151	-0.3727 (0.7630)	1.1860 (0.0188)
Perth	0.0064	7.8328 (0.0000)	-0.1020 (0.8039)
Sydney	0.0052	3.1523 (0.0055)	0.8937 (0.0257)

Note: The numbers in the brackets indicate the p-values of the t statistic test for the corresponding correlation coefficient is significantly different from 0.

As shown in the second column, the scales of the coefficients of the urban characteristic effects are small. The smallest one is found in Canberra at -0.0004, while the largest one is allocated in Darwin at 0.0155. The positive coefficients suggest the urban effects should push up the house prices in the corresponding cities, while the negative coefficients argue that the urban effects should depreciate the house price. The results indicate that the urban belonging factors, like the urban locations and cultures, should not contribute much influence on their house price movements in the Australian capital cities. In other words, if the eight capital cities shared the similar housing markets of their own, the house price movements would still show some distinctions across the cities. However, differences would be very limited from city to city.

The third column displays the coefficients of the urban temporal effects on the house price movements in the Australian capital cities. The results, at this occasion, vary across the cities. When 10% was used as a significantly critical level, significant and large scaled coefficients were estimated in Perth, Brisbane, Sydney, Darwin and Canberra. The temporal coefficients for Melbourne, Adelaide and Hobart are not significant. It is shown that the largest temporal coefficient is in Perth at 7.8328, followed by Brisbane at 5.1680, Sydney at 3.1523, Darwin at 2.5476 and Canberra at 1.9910. The larger the temporal coefficients are, the higher the urban house price movements are influenced by their previous behaviours. The house price movements of Perth are demonstrated highly influenced by its previous dynamics. According to the results, a one unit increase will cause nearly eight unit increase in the next quarter. In the contrast, the house price movements in Adelaide, Hobart and Melbourne are hardly influenced by their previous dynamics, shown by the insignificant coefficients.

In addition, the spatial effects on urban house price movements are suggested by the results in the fifth column. Huge disparities are found in the spatial coefficients across the capital cities of Australia. The house price movements in Adelaide, Brisbane, Canberra, Hobart, Melbourne and Sydney are significantly impacted by the house price dynamics in the neighbouring cities. On the other hand the spatial effects on Darwin and Perth are not significant.

Based on the estimated coefficients, the Australian urban house price movements can be classified into three groups, as shown in Table 4.

Table 4: The classified urban house price movement in Australian capital cities

Cities	Urban effects	Temporal effects	Spatial effects
Adelaide	5	No	Yes
Hobart	6	No	Yes
Melbourne	2	No	Yes
Brisbane	7	Yes	Yes
Canberra	8	Yes	Yes
Sydney	4	Yes	Yes
Darwin	1	Yes	No
Perth	3	Yes	No

According to Table 4, a geographic distribution can be found in the classification of the urban house price movements in Australia. House price movements in Adelaide, Hobart and Melbourne, which are located in the southern part of Australia, are hardly influenced by the temporal effects. However, the movements are significantly impacted by the spatial factors. House price movements in Brisbane, Canberra and Sydney are influenced by both the temporal and spatial factors. These capital cities are located in the east part of Australia. The capital cities in the west of Australia appear isolated from the others. The house price movements are influenced only by their previous behaviours.

CONCLUSIONS

As a conclusion, this research originally developed a time weighted spatio-temporal model to explore the house price movements in the Australian capital cities. The national population was used to capture the temporal decay of the effects generated from the time correlated factors. The geographic distances between and developing scales of the capital cities were utilised to account for the time-varied spatial effects on the urban house prices. The house prices of the Australian capital cities can be then accessed in three dimensions, namely, urban characteristics, temporal and spatial factors, by estimating the time weighted spatio-temporal model. This provides a fresh perspective of inspecting house price movements.

The results of the estimated model suggested house prices in Adelaide, Hobart and Melbourne should be sensitive to the space-correlated factors. House prices in Brisbane, Canberra and Sydney can be influenced by both the time-correlated and space-correlated factors. House prices in Darwin and Perth are determined on the factors correlated to their own markets. Therefore, three classifications of the capital cities can be integrated, which distributed in the south, the east and the west of Australia. These findings contribute to policy and investment in providing a map of the Australian urban housing markets.

However, this time weighted spatio-temporal model discussed in this paper can be further improved. First, a further analysis based on the estimated model can be carried out to explore the temporal and spatial interconnections between house price movements in details. A comparison of the constructions of temporal and spatio-temporal weights will be carried out to identify the optional factors that are used to capture the temporal decay and dynamic spatial effects. Moreover, the data can be expanded by adding more cities or time periods. In addition, other regression methods can be adopted.

REFERENCES

Abelson, P., Joyeux, R., Milunnovich, G. and Chung, D. (2005), "Explaining house price in Australia: 1970-2003". *The Economic Record*. Vol. 81, No. 255, PP. s96-s103.

ABS (2011a). Australian demographic statistics. 3101.0. Australian Bureau of Statistics, Canberra.

ABS (2011b). Building approvals. 8731.0. Australian Bureau of Statistics, Canberra.

ABS (2011c). House price indexes: eight capital cities. 6416.0. Australian Bureau of Statistics, Canberra.

Anselin, L. (1988). *Spatial econometrics: methods and models*. Kluwer Academic Publishers incorporates, Dordrecht.

Beenstock, M. and Felsenstein, D. (2007), "Spatial vector autoregressions". *Spatial Economic Analysis*. Vol. 2, No. 2, PP. 167 - 96.

Bourassa, S. C. and Hendershott, P. H. (1995), "Australian capital city real house prices, 1979-1993". *The Australian Economic Review*. Vol. 28, No. 3, PP. 16-26.

Can, A. (1990), "The Measurement of Neighborhood Dynamics in Urban House Prices". *Economic Geography*. Vol. 66, No. 3, PP. 254-72.

Case, K. E. and Shiller, R. J. (1987), "Prices of single-family homes since 1970: new indexes for four cities". *New England Economic Review*. Vol. Sep/Oct, No. 45-56.

Fama, E. F. (1970), "Efficient Capital Markets: A Review of Theory and Empirical Work". *The Journal of Finance*. Vol. 25, No. 2, PP. 383-417.

Holly, S., Hashem Pesaran, M. and Yamagata, T. (2011), "The spatial and temporal diffusion of house prices in the UK". *Journal of Urban Economics*. Vol. 69, No. 1, PP. 2-23.

Holmes, M. J. (2007), "How convergent are regional house prices in the United Kingdom? Some new evidence from panel data unit root testing". *Journal of Economic and Social Research*. Vol. 9, No. 1, PP. 1 - 17.

Jones, C. and Leishman, C. (2006), "Spatial dynamics of the housing market: an interurban perspective". *Urban Studies*. Vol. 43, No. 7, PP. 1041 - 59.

Karaganis, A. N. (2011), "Seasonal and spatial hedonic price indices". *Journal of Property Investment & Finance*. Vol. 29, No. 3, PP. 297-311.

Liu, C., Luo, Z., Ma, L. and Picken, D. (2008), "Identifying house price diffusion patterns among Australian state capital cities". *International Journal of Strategic Property Management*. Vol. 12, No. 4, PP. 237-50.

Liu, C., Ma, L., Luo, Z. Q. and Picken, D. (2009), "An interdependence analysis of Australian house prices using variance decomposition". *International journal of Housing Markets and Analysis*. Vol. 2, No. 3, PP. 218 - 32.

Liu, C. H., Hartzell, D. J. and Hoesli, M. E. (1997), "International evidence on real estate securities as an inflation hedge". *Real Estate Economics*. Vol. 25, No. 2, PP. 193-221.

Ma, L. and Liu, C. (2010), "The decomposition of housing market variations: a panel data approach". *International journal of Housing Markets and Analysis*. Vol. 3, No. 1, PP. 6 - 16.

MacDonald, R. and Taylor, M. P. (1993), "Regional house prices in Britain: long-run relationships and short-run dynamics". *Scottish Journal of Political Economy*. Vol. 40, No. 1, PP. 43-55.

Maher, C. (1994), "Housing prices and geographical scale: Australian cities in the 1980s". *Urban Studies*. Vol. 31, No. 1, PP. 5-23.

Meen, G. (1996), "Spatial aggregation, spatial dependence and predictability in the UK housing market". *Housing Studies*. Vol. 11, No. 3, PP. 345-72.

Meen, G. (1999), "Regional house prices and ripple effects: a new interpretation". *Housing Studies*. Vol. 14, No. 6, PP. 335-46.

Meese, R. A. and Wallace, N. E. (1997), "The construction of residential housing price indices: A comparison of repeat-sales, hedonic-regression, and hybrid approaches". *The Journal of Real Estate Finance and Economics*. Vol. 14, No. 1-2, PP. 51-73.

Nappi-Choulet Pr, I. and Maury, T.-P. (2009), "A Spatiotemporal Autoregressive Price Index for the Paris Office Property Market". *Real Estate Economics*. Vol. 37, No. 305-40.

Poterba, J. M., Weil, D. N. and Shiller, R. (1991), "House price dynamics: the role of tax policy and demography". *Brookings Papers on Economic Activity*. Vol. 1991, No. 2, PP. 143-203.

Rosen, S. (1974), "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition". *Journal of Political Economy*. Vol. 82, No. 1, PP. 34-55.

Shi, S., Young, M. and Hargreaves, B. (2009), "The ripple effect of local house price movements in New Zealand". *Journal of Property Research*. Vol. 26, No. 1, PP. 1 - 24.

Song, Y. and Liu, C. (2005), "Economic performance analysis of the Australian property sector using input-output tables". *Pacific Rim Property Research Journal*. Vol. 11, No. 4, PP. 412-25.

Tsatsaronis, K. and Zhu, H. (2004), "What drives housing price dynamics: cross-country evidence". *BIS Quarterly Review*. Vol. March 2004, No. 65-78.

Tu, Y. (2000), "Segmentation of Australia housing market: 1989-98". *Journal of Property Research*. Vol. 17, No. 4, PP. 311-27.