IDENTIFYING HOUSE PRICE DIFFUSION PATTERNS AMONG AUSTRALIAN STATE CAPITAL CITIES

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ABSTRACT. Prior research supports the proposition that house price diffusion shows a ripple effect along the spatial dimension. That is, house price changes in one region would reflect in subsequent house price changes in other regions, showing certain linkages among regions. Using the vector autoregression model and the impulse response function, this study investigates house price diffusion among Australia's state capital cities, examining the response of one market to the innovation of other markets and determining the lagged terms for the maximum absolute value of the other markets' responses. The results show that the most important sub-national markets in Australia do not point to Sydney, rather towards Canberra and Hobart, while the Darwin market plays a role of buffer. The safest markets are Sydney and Melbourne. This study helps to predict house price movement trends in eight capital cities.

KEYWORDS: Regional house prices; House price diffusion; Vector autoregression model; Impulse response; Market efficiency

1. INTRODUCTION

House prices in Australian main metropolitan areas displayed sharp increase trends from 1996 to late 2003 and early 2004 when the trends eased. Although the current Australian house prices movement trend does not exhibit any obvious recessionary signs, the housing market at the sub-national level, such as in Sydney, is taking the lead in experiencing a downturn after 2004. Housing prices in Sydney in the June quarter 2006 were still lower than in the December quarter 2003. On the other hand, Perth held its high rates of increase in the same period (ABS, 2008).

House prices in cities were influenced by their past house prices, house prices in other cities, mortgage rates, net migration, policy factors and others. The relationships between house prices and economic variables, and between house prices at the national level and a subnational level in Australia were tested by using the real estate data in the period 1989-1998 (Tu, 2000). Using the Granger cau-

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sality test, two diffusion paths which formed a geographic diffusion pattern in the Australian housing market were determined: starting from Brisbane via Sydney ending at Melbourne, and starting from Brisbane via a national path and ending at Melbourne. A ripple effect which showed a diffusion pattern from north to south was detected in some capital cities. It was also found that house price indices were correlated statistically in several Australian capital cities (Abelson and Chung, 2004). It was suggested that a long-run relationship exit between house prices, house income and consumer index, while adjustment to equilibrium was found to be in significant lags, in the short run (Abelson et al., 2005). Moreover, Luo et al. (2007) studied the housing price diffusion pattern of Australian capital cities. The results supported that a 1-1-2-4 diffusion pattern exists.

This study investigated the dynamics of the house price diffusion in Australia's state capital cities, examining the response of one market to the innovation of other markets and determining the lagged terms for the maximum absolute value of the response. Using the eight capital cities' house price indices, the vector autoregression (VAR) model is constructed to investigate the impulse response function (IRF), which is utilized to analyse the sensitivity of one market to the shocks of others. The next section provides a review of related literature. Section 3 describes the data source and the investigation period with respect to the house price indices of eight capital cities in Australia. Section 4 presents the unit root tests and the results of the stationarity test on the data series. The VAR model and the impulse response function are described and used to measure the interregional housing markets' responses, respectively in the section 5 and the section 6. Finally section 7 provides conclusions.

2. LITERATURE REVIEW

Dynamic analysis of VAR model is carried out using the impulse response function (Sims, 1980). This approach is widely used in the real estate research. Using the Engle-Granger cointegration test and the vector autoregression Granger causality test, the relationships of regional housing markets were investigated in the South of England and, in the North and Midlands of England (Alexander and Barrow, 1994). Podlodowski and Ray (1997) examined regional repeat sales house prices from 1975 to 1994 in the USA. Using the VAR model, this study estimated the significance of a one lag order. The findings supported the notion that the market was inefficient and that contiguous regions release more influence than non-contiguous regions.

Evidence from prior research supports the proposition that house price shocks in one area are likely to spread to other areas (MacDonald and Taylor, 1993; Alexander and Barrow, 1994; Ashworth and Parker, 1997; Pollakowski and Ray, 1997; Meen, 1999; Tu, 2000; Stevenson, 2004; Cook, 2005). This is the so-called house price diffusion or ripple effect. The ripple effect or house price diffusion has been mentioned recently in literature describing the examination of UK regional house prices. It describes how house prices rose first in the South East and how this gradually spread out over the rest of the UK. In this case, two key elements should be focused on: diffusion paths and epicentre. Diffusion paths are certain kinds of relationships between regional housing markets.

It was demonstrated the concept of spatial dependence to explain the ripple effect (Meen, 1996). Spatial dependence refers to the linkages between regional markets. It was suggested that a single national housing market should be treated as a series of interregional linkages between housing markets (Meen, 1999). Both bidirectional and unilateral causalities between the regional housing markets illustrated a series of linkages between them. It was examined that the causal relationships between Irish regional housing markets (Stevenson, 2004). The results supported the view that Dublin had a lead effect with other markets. It was displayed that a causal relationship pattern and revealed the so-call "ripple down" effect in the UK regional housing markets (MacDonald and Taylor, 1993).

Market efficiency was also identified in this issue in some previous research. Tirtiroglu (1992) constructed two models, containing contemporaneous neighbouring and non-neighbouring markets; and lagged neighbouring and non-neighbouring markets, to test the speed of spatial diffusion. The results indicated that the market was inefficient. Clapp and Tirtiroglu (1994) tested the significance of a positive feedback hypothesis in Hartford, Connecticut. The study found that regional markets were affected not only by their own past values but also by neighbouring regions' past values.

3. DATA DESCRIPTION

The study focuses on house prices diffusion at the subnational level. House price indices for the eight state capital cities were collected from the publications of the Australian Bureau of Statistics (ABS). The period is from the December quarter 1989 to the June quarter 2007. The indices are based on the quarterly house prices for established and newly erected dwellings and each capital city's house price index based on 1989-90=100.

Figure 1 shows the house price movements in eight capital cities. The biggest change in house prices was in Darwin (+350.3%) during the investigated period, followed by Brisbane (+318.7%) and Adelaide (+286.9%). The Darwin housing market shows very different behaviour from the other seven markets. Except for Darwin, the other seven show a similar propensity during the investigated period. They all have a slow increase trend at first which is followed by

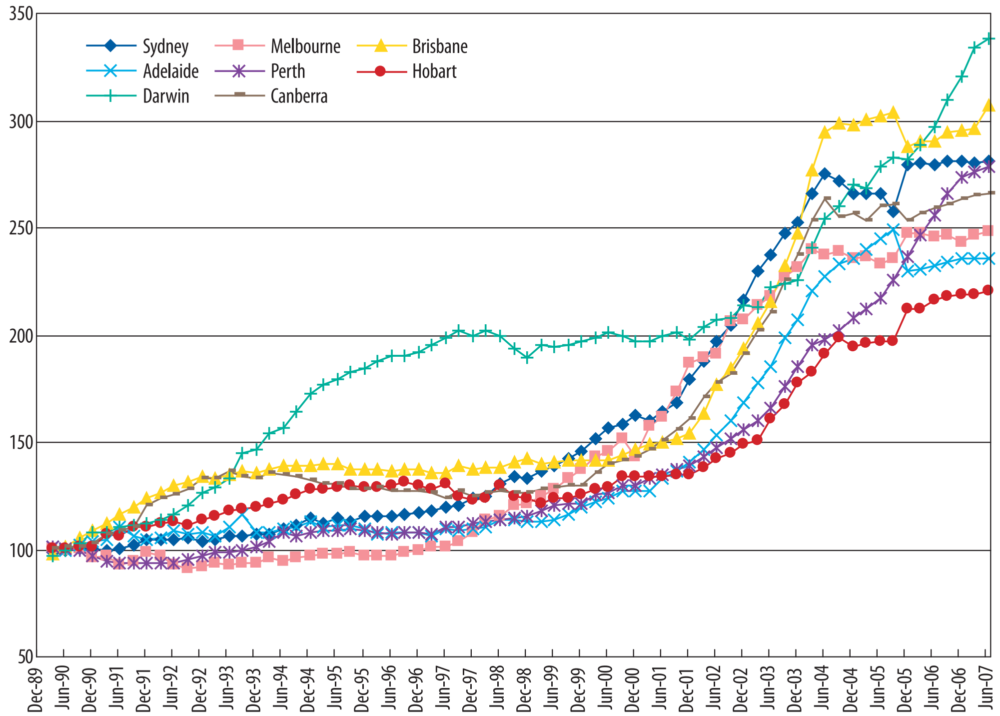

Figure 1. House price indices in Australia's eight capital cities

a sharp increase. The start of the latest boom in Melbourne, Adelaide, Perth and Sydney led the other markets. Melbourne's boom started in the December quarter 1996 while the booms in Adelaide, Perth and Sydney started in the March quarter 1997, followed by Brisbane (June quarter, 2002), Canberra (June quarter 2000) and Hobart (June quarter, 2000). Darwin started its first sharp increase from the December quarter 1989 until the June quarter 1997, with an average change rate of 3.62% per quarter followed by a steady increase until the September quarter 2000. The latest sharp increase in Darwin started from the December quarter 2001. Melbourne, Sydney, Brisbane, Canberra, and Hobart both had an obvious hesitation in the December quarter 2003 and the March quarter 2004. However, Perth, Darwin ignored this strike and were experiencing their rapid increases.

4. STATIONARITY TEST FOR HOUSE PRICE INDICES

A stationary time series is significant to a regression analysis based on the time series, because useful information or characteristics are difficult to identify in a nonstationary time series. Therefore, a nonstationary time series would lead to a spurious regression. However, most economic time series are nonstationary in practice. Fortunately, time series can be made to be stationary after differencing. Useful information or characteristics can still be identified in the time series after differencing. Moreover, if two or more variables are nonstationary and have the same order of integration, they can be constructed in a cointegration model. Therefore, the stationarity test should be launched before the cointegration test. A time series is said to be stationary if its mean and variance are constant and, the covariances depend on upon the distance of two time periods. In order to indicate the difference from strict stationarity, the word "stationary" in the term "stationary time series" means weak stationarity or covariance stationarity in this study.

In this step, the unit root test is used to test the variables' stationarity and the order of integration. The Dicky-Fuller unit root test (DF), Augmented Dicky-Fuller unit root test (ADF) (Dicky and Fuller, 1979) and the Phillips-Perron unit root test (PP) (Phillips and Perron, 1988) are often used to test stationarity. The ADF and PP tests were used in this study. There are 3 forms of the ADF and PP unit root test model.

$$\Delta X_t = \delta X_{t-1} + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t, \tag{1}$$

$$\Delta X_t = \alpha + \delta X_{t-1} + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t, \tag{2}$$

$$\Delta X_t = \alpha + \beta t + \delta X_{t-1} + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \varepsilon_t. \tag{3}$$

The symbol of α is an intercept and the product of β and t is a deterministic trend. Equation 1 contains no intercept and trend; this means that X is a stationary time series with a zero mean if the null hypothesis is rejected. In the same way, equation 2 comprises an intercept but no trend; this means that X is a stationary time series with a non zero mean. Equation 3 includes an intercept and a trend; this means that X is a stationary time series around a deterministic trend.

Table 1 shows the unit root test results of eight capital cities, using the ADF unit root test and the PP unit root test. The null hypothesis of non-stationarity was performed at the 1% and 5% significance levels. There are three different null hypotheses of the time series processes in this test: process as a random walk, process as a random walk with drift, and process as a random walk with drift around a deterministic trend. They are shown in Table 1 respectively: no trend and intercept, intercept without trend and, intercept and trend. The results shows that eight capital cities' house price index data series are not stationary at the level form but stationary after the first dif-

Table 1. Eight capital cities' house price index series unit root tests from 1989 Q4 to 2007 Q2

		ADF test at level			ADF test in first difference			PP test in first difference		
		t-statistic	Sig. level	Lag	t-statistic	Sig. level	Lag	t-statistic	Sig. level	Lag
No intercept and trend	Adelaide	2.5340	na	1	-3.1972	**	1	-5.1792	***	4
	Brisbane	0.2531	na	1	-3.8612	***	0	-3.1331	***	1
	Canberra	2.1796	na	1	-2.6895	***	1	-3.9897	***	4
	Darwin	3.9016	na	1	-2.5189	**	1	-4.3282	***	5
	Hobart	5.0396	na	0	-2.9181	***	1	-6.0911	***	5
	Melbourne	4.3615	na	0	-3.1167	***	1	-6.8206	***	5
	Perth	2.3819	na	1	-1.9367	na	0	-1.7038	na	5
	Sydney	5.0847	na	0	-3.0011	***	1	-5.3459	***	5
Intercept without trend	Adelaide	0.7849	na	1	-5.6886	***	0	-5.9340	***	4
	Brisbane	0.2531	na	1	-3.8612	***	0	-3.8612	***	0
	Canberra	0.2341	na	1	-4.7179	***	0	-4.8049	***	4
	Darwin	2.2110	na	0	-5.7789	***	0	-6.0175	***	4
	Hobart	2.2717	na	0	-3.8282	***	1	-7.1177	***	4
	Melbourne	1.4149	na	0	-3.8925	***	1	-7.7271	***	4
	Perth	1.7846	na	1	-2.6790	na	0	-2.5035	na	4
	Sydney	1.5799	na	0	-6.1056	***	0	-6.3662	***	4
Intercept with trend	Adelaide	-1.1858	na	1	-5.9733	***	0	-6.2076	***	4
	Brisbane	-1.2929	na	1	-4.0209	**	0	-4.0209	**	0
	Canberra	-1.1711	na	1	-4.8041	***	0	-4.9137	***	4
	Darwin	-0.1223	na	1	-6.0043	***	0	-6.2360	***	4
	Hobart	0.0132	na	0	-7.3735	***	0	-7.5396	***	4
	Melbourne	-2.2582	na	0	-4.1799	***	1	-8.1439	***	4
	Perth	-0.3022	na	1	-4.0153	**	0	-4.0824	**	2
	Sydney	-1.6303	na	0	-6.4341	***	0	-6.6681	***	4

Note: ** and *** denote the rejection of null hypothesis at the 5% and 1% significance level respectively.

ference at the 1% and 5% significance levels. That is, all the eight data series are I(1) which denotes that the time series is integrated at the first difference level.

5. CONSTRUCTING THE VECTOR AUTOREGRESSION MODEL

Unfortunately, the VAR model using the price indices as variables directly, does not satisfy the stability condition; due to the house price indices probably not being stationary in level form. If the VAR model does not satisfy the stability condition, certain results such as impulse response standard errors are not valid (Lutkepohl, 1993; Greene, 2000). This will lead to an invalid conclusion. In this case, the house price indices series after first difference are used to construct the VAR model.

There are at least two advantages when using the first difference data series to explain the impulse response function. Firstly, it focuses more on the increase or decrease trend rather than the actual house prices change. Because the first difference data series is the increase or decrease between every two consecutive quarters, a strengthening or weakening of the trend will be detected by the impulse response function. Secondly, it captures more information on the shocks of house prices, because the first difference data shows the changes in the past two quarters while the level data shows the changes in one quarter in impulse response function. In this section, a regional housing market affecting the others means that the movement trend change in a market could affect the trend change in the others. The symbols such as 'D(Adelaide)' in tables or figures stand for the first difference series.

5.1. Selection of optimal lag

One of the biggest and common practical problems in the VAR model is to select the optimal lagged term. One of the common and simple approaches in selecting optimal lag length is to reestimate a VAR model, reducing lag length from a large lag term until 0. In each of these models, the smallest value of the Akaike information criterion and the Schwarz criterion are used to select the optimal lag length (Grasa, 1989; DeJong et al., 1992; Maddala and Kim, 1998; Gujarati, 2003). Using VAR estimates, the optimal lag length can be determined by comparing the Akaike information criterion (AIC) and the Schwarz criterion (SC) (Grasa, 1989). Moreover, the judgement of the optimal lag length should still take other factors into account: for example, autocorrelation, heteroskedasticity, possible ARCH effects and normality and normality of the residuals (Asteriou, 2005). In this study, 5 criteria: Sequential modified LR test statistics (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn information criterion (HQ), which have been introduced by Lutkepohl (1993) were inspected. Similarly, the smallest value of these 5 criteria points to the optimal lag length.

Table 2 shows the results of VAR lag order selection criterion. The first left hand column shows the lag orders from 0 to 4. The LR, FPE, AIC, SC and HQ are the 5 criteria mentioned above. The numbers with an asterisk are the smallest value in each of criteria. Before selecting the lag length, two situations should be identified. Firstly, too short a lag length in the VAR may not capture the dynamic behaviour of the variables (Chen and Patel, 1998), so the optimal lag length would be selected by the smallest lag shown under the criteria. Secondly, DeJong et al. (1992) point out that too long a lag length will distort the data and lead to a decrease in power. Based on the results, one lag which is considered as one quarter is selected in the VAR model; that is VAR (1).

Table 2. Eight capital cities' house price indexes VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1407.209	NA	5.82e +08	42.8851	43.1505*	42.9900
1	-1286.854	207.8855	1.07e +08*	41.1771	43.5661	42.1213*
2	-1229.074	85.7948	1.40e +08	41.3659	45.8779	43.1488
3	-1165.218	79.3359	1.76e +08	41.3702	48.0056	43.9922
4	-1071.483	93.7957*	1.14e +08	40.4692*	49.2278	43.9301

The asterisk indicates lag order selected by the criterion.
LR: sequential modified LR test statistic (each test at 5% level).
FPE: Final prediction error.
AIC: Akaike information criterion.
SC: Schwarz information criterion.
HQ: Hannan-Quinn information criterion.

5.2. Test for the stability of the VAR model

Once the VAR model is constructed, the stability of the model should be verified. If the VAR model does not satisfy the stability condition, certain results such as impulse response standard errors are not valid. Stability is achieved if the characteristic roots of the matrix of coefficients have a modulus of less than one. Table 3 shows the results of the roots of the characteristic polynomial. The results show that all roots are less than 1 and no root lies outside the unit circle. It indicates that the VAR(1) model satisfies the stability condition. So the results of the impulse response function deriving from the VAR(1) are valid in our study.

Table 3. Eight capital cities' house price indexes VAR roots of the characteristic polynomial

Root	Modulus
0.762973	0.762973
0.664085 - 0.070243i	0.667790
0.664085 + 0.070243i	0.667790
-0.175650	0.175650
-0.353334	0.353334
-0.335239	0.335239
0.086945	0.086945
-0.075582	0.075582

6. IMPULSE RESPONSES AMONG REGIONAL HOUSING MARKETS

One of the key elements of the VAR model is the impulse response analysis. It presents the dynamic effect of each exogenous variable response to the individual unitary impulse from other variables. The IRF can explain the current and lagged effect over time of shocks in the error term. It estimates the sensitivity of one variable to the change in another. The impulse response function (IRF) derived from the VAR model is used to trace out the response of one variable to the shocks in the error term of another variable. The IRF can explain the current and lagged effect over time of shocks in the error term.

6.1. Impulse response of regional house prices

Figure 2 shows the impulse response results of the eight capital cities' housing markets individually. It traces out the response of each regional housing market to the shocks in the error terms of other markets. There are eight curved lines in each figure. Seven lines in the eight starting from zero in time 1 explain the impulse response of one housing market to the other seven markets. The impulse response of the seven markets is assumed as zero in the first quarter and these seven markets are assumed to receive a one positive unit standard deviation shock from external markets in the first quarter. The eighth line explains the response of one market to its past shock. The X axis shows the quarters and the Y shows the shock in the movement trend. The positive symbol does not mean an increase in house price. It means an increase in movement trend is strengthened or a decrease in movement trend is weakened. In the same way, the negative symbol means an increase in trend is weakened or a decrease in trend is strengthened. In short, a positive symbol means a favourable effect on house prices growth and a negative symbol means an adverse effect. In addition, the value shown in the figure indicates a change on the house prices movement trend.

Figure 2 shows that, all of the capital cities are impacted more from themselves than the exogenous factors. Canberra and Hobart received a stronger impact (positive) from the past performance of themselves, while Darwin has a negative impact on itself after the fourth period. Each of the five housing markets in

Sydney, Melbourne, Adelaide, Brisbane, and Perth received more influence from the Canberra or Hobart markets than others. The influences on the five markets from Darwin are negative. Two conditions are applied to judge the epicentre, which aggregates Australian housing market in this study. The first one is that the most important influence is from the past performance of the market itself. The second one is that this market should transfer more impact than other markets. In this case, it can be concluded that the main epicentres in the Australian housing market are Canberra and Hobart. Canberra is the key engine of the area of Adelaide, Brisbane, Canberra, Melbourne and Sydney while Hobart is another key engine of the area of Hobart and Perth. However, the Darwin housing market is more independent which can also be detected in the diffusion pattern.

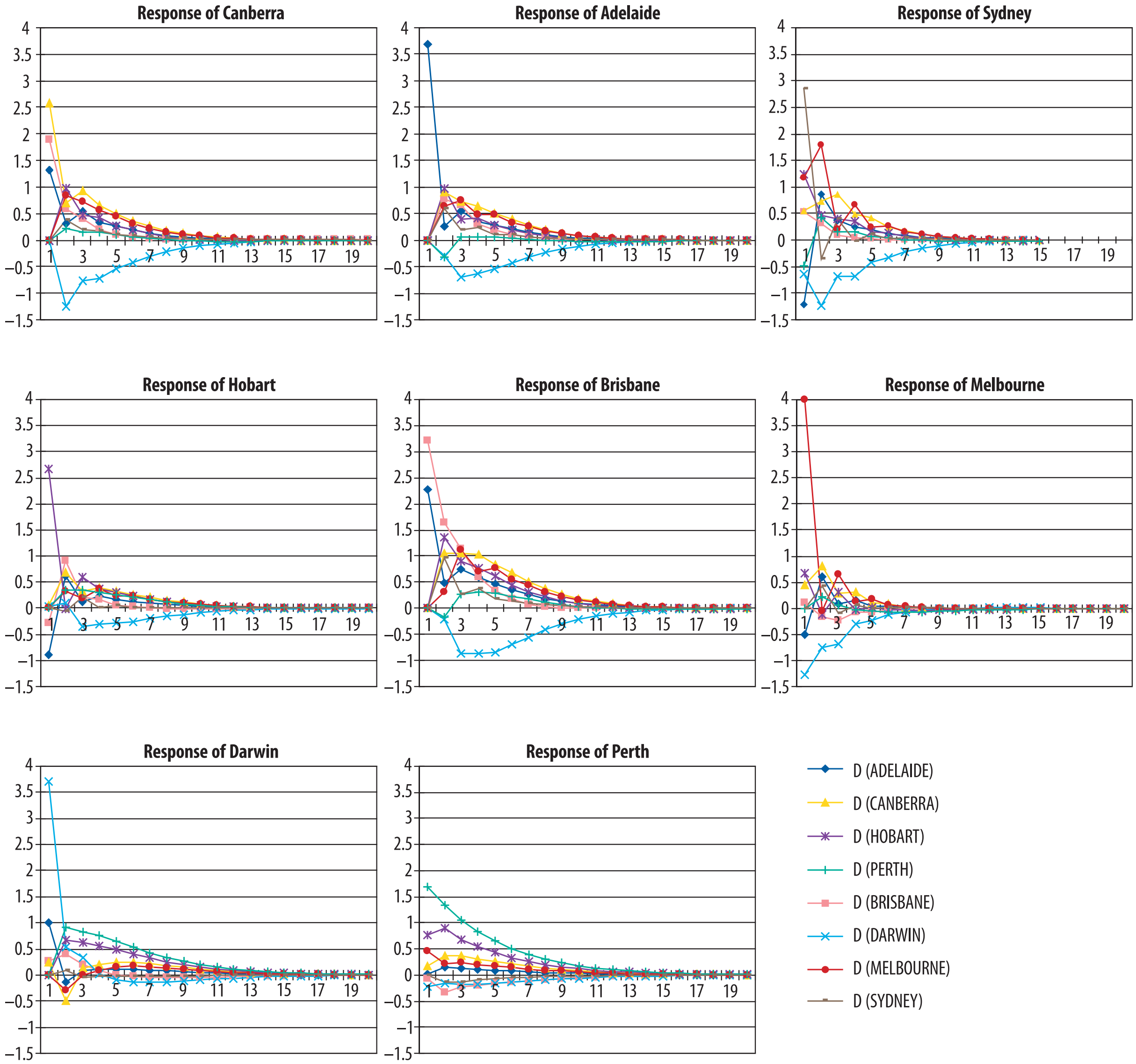

Figure 2. Impulse response of one housing market to shocks from other markets

As the one of most import housing markets in Australia, Sydney does not exert its power as expected. The influence from Sydney is weaker than from Canberra and Hobart. This obviously supports the results in Figure 2 that Sydney does not affect other markets directly. It is surprising that Sydney is not the main epicentre in the aggregate Australian market. Similar findings can be seen in the study by Stevenson (2004) which showed how Dublin is not the most influential market in the Irish housing market. The Rural areas' market was identified as the 'surrogate' of the Dublin market and Dublin affected the provincial markets through its surrogate. If so, Canberra would be seen as the surrogate of Sydney, because the impulse response results show that Canberra market influenced the Sydney market more than Sydney market itself does. Moreover, Canberra and Hobart deliver more influence (positive) than the others.

Some markets have a negative effect on other markets when positive changes exist in the movement trend in the market. Table 4 is generated from the results of the eight cities' impulse responses. It shows the eight cities' total impulse responses within 20 lagged quarters. The bold numbers show a negative value of impulse response. The Darwin housing market exhibits a reversed impact on other markets, especially in the long run. However, all the markets (including Darwin itself) impose a positive influence on Darwin, except Sydney. Therefore Darwin is not one of the main engines but would play the role of a buffer in the aggregate Australian market during a price boom.

Except Darwin, the other seven markets have at least one negative influential factor. The Melbourne housing market has three negative external influential factors. Adelaide, Brisbane, Perth, Melbourne and Sydney, present an acceleration effect on the aggregate Australian market in the long run. These five markets can be regarded as the secondary level epicentres. The numbers on diagonal line in Table 4 describe the impulse response of each market to the innovation of itself. These numbers are the largest one in each row. The results suggest that the most important factor to each regional housing market is from its own individual performance. The values of response to innovation perform kinds of behaviour which first converges to zero (not exactly

Table 4. Total impulse responses of Australian eight cities' market

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
response of Adelaide to	5.745407	2.184805	4.007245	-3.67010	2.476005	3.428463	-0.350280	1.440344
response of Brisbane to	5.763525	7.240090	6.341687	-5.40920	4.936614	4.933022	1.250096	2.221733
response of Canberra to	3.340195	3.336276	6.458619	-4.64844	2.513304	3.536988	0.495353	1.074506
response of Darwin to	1.728453	0.558954	1.629123	3.600891	4.098933	0.863798	5.533672	-0.200650
response of Hobart to	0.726683	1.027749	2.784213	-1.81654	4.704179	1.931526	2.024538	0.308567
response of Melbourne to	0.374445	-0.441780	1.969910	-3.41209	0.548912	4.942501	-0.265630	0.452737
response of Perth to	0.859586	-1.590220	2.424948	-1.55622	4.773987	1.949798	7.762992	-0.695990
response of Sydney to	0.845051	1.042683	3.759696	-4.61664	2.813494	4.794976	0.190057	3.130619

at zero) and then swinging around zero in the long run. The speed of convergence to zero can scale the sensitivity of one market to the influence from other markets. In this study, 0.05 and 0.01 of absolute value are set up as two standards to measure this speed.

6.2. Lagged effect of regional house price diffusion

Table 5 shows the numbers of lagged terms when first reaching a value of impulse response of less than 0.05. Most of the numbers in Canberra columns are greater than the numbers located in the same row. This indicates that the influence from Canberra on other markets will persist over a longer period. This proves again that the Canberra housing markets are two important factors in the aggregate Australian housing market. The smaller number of the lagged terms indicates that the speed is larger. This convergence speeds in the Sydney market and Melbourne market are from 11 to 4 and 10 to 4 respectively, while Adelaide is from 13 to 6, Brisbane is from 14 to 8 and Perth is from 15 to 7. This suggests that the Sydney and the Melbourne markets are safer than others. The impacts, either from themselves or from exogenous markets, can not persist for a long time. However, the markets of Adelaide, Brisbane and Perth are more sensitive to the change in external markets. Furthermore, the numbers of lagged terms shown on the diagonal line in Table 5 explains the duration of the time interval by each market is affected itself. Except for Brisbane and Perth, these numbers are not always the smallest or largest in each row. The number for Brisbane in the row "response of Brisbane to" is the smallest one. It indicates that the impacts of exogenous markets exist longer in Brisbane than the impact from the home market. The number for Perth in the row "response of Perth to" is the largest one. It indicates that the Perth market is more sensitive to itself than changes in external markets.

Figure 3 shows the numbers of lagged term when first reaching a value of impulse response of less than 0.05. There are eight octagons with the same centre (0 of lagged term) in Figure 3. Each octagon shows the sensitivity of one market to the others. The greater the area of the octagon is, the more sensitive the market is. There are eight semidiameter

Table 5. Lagged terms when first reaching a value of impulse response of less than 0.05

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
response of Adelaide to	10	8	12	13	9	12	6	8
response of Brisbane to	12	8	14	14	12	13	10	9
response of Canberra to	10	7	11	12	9	11	7	7
response of Darwin to	10	5	14	13	14	13	16	4
response of Hobart to	10	6	12	12	11	11	11	6
response of Melbourne to	5	6	7	8	4	7	10	5
response of Perth to	8	11	12	11	14	11	15	7
response of Sydney to	9	4	10	11	8	10	6	4

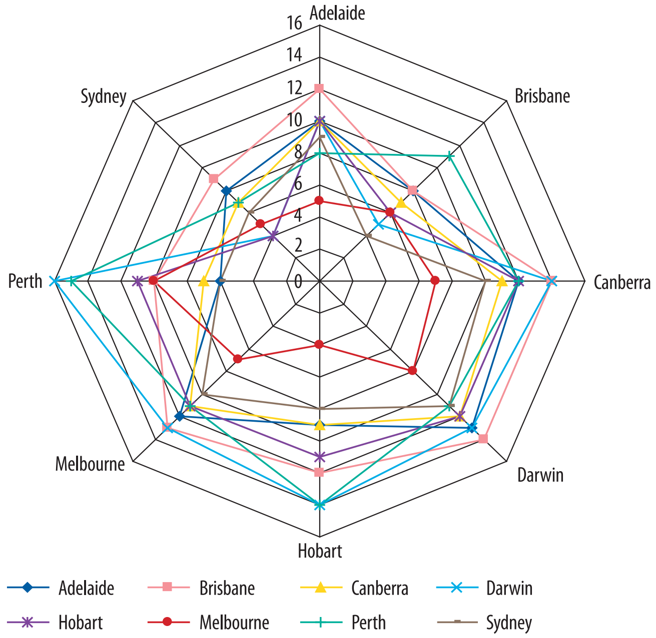

Figure 3. Lagged terms when first reaching a value of impulse response of less than 0.05

lines with eight intersection dots (on each line) where the eight octagons cross through each line. Each line stands for the duration of the time interval that one market affects the others (including influence from itself). The eight intersection dots on each line indicate eight time intervals at which each market affects the others. Figure 3 shows the octagons of Melbourne and Sydney are the smallest and the eight intersection dots on the lines of Melbourne and Sydney are closer to the centre (zero) than the others. The results show that the convergence speeds of Melbourne and Sydney are larger than the others. It demonstrates that the Melbourne and Sydney housing markets can absorb the shock from other markets more efficiently. The octagon for Darwin is the largest, which indicates that the Darwin market is the most inefficient.

The eight lagged terms of convergence speed indicates eight quarters. It does not support the notion in previous research that housing markets are inefficient. However, it can measure the sensitivity of response to the innovation of external markets. Podlodowski and Ray (1997) estimated the significance of the vector autoregression (VAR) model constructed with contiguous regions or noncontiguous regions, to test housing market efficiency. If the VAR model with a small number of lag order such as VAR(1) or VAR(2) is significant, then the market is efficient. Podlodowski and Ray suggested the market is inefficient. In our study, the VAR(1), VAR(2), VAR(3) and VAR(4) all constructed with time series of level form fail to satisfy the stable condition of VAR. In the context of Podlodowski and Ray, the market should be inefficient. However, the VAR(1) constructed with first difference of the data satisfied the stable condition and the impulse response function results show that most of the largest response values from external market shock occurred at the first or the second lagged term. It means the biggest reaction of one market to other markets' shocks performed very quickly. Therefore, the results suggest the housing market is efficient in the spatial dimension.

Table 6 shows the number of the lagged term when first reaching a value of impulse response of less than 0.01. Similar findings were detected as above.

Figure 4 is generated from Table 6. It displays the number of the lagged term when first reaching a value of impulse response of less than 0.01. Eight expanding octagons are found in the figure. It demonstrates similar finding as in Figure 3. The differences between Tables 5 and 6 show that the speed of convergence to zero slows down when the value of impulse response is getting close to zero.

Table 6. Lagged terms when first reaching a value of impulse response of less than 0.01

	Adelaide	Brisbane	Canberra	Darwin	Hobart	Melbourne	Perth	Sydney
response of Adelaide to	14	10	15	16	11	15	7	13
response of Brisbane to	16	10	17	18	14	17	12	13
response of Canberra to	13	9	14	16	11	14	9	12
response of Darwin to	16	17	19	5	20	18	20	12
response of Hobart to	14	12	16	16	15	16	15	8
response of Melbourne to	7	8	8	10	16	9	17	7
response of Perth to	15	17	18	17	20	17	20	13
response of Sydney to	12	6	13	14	10	13	7	11

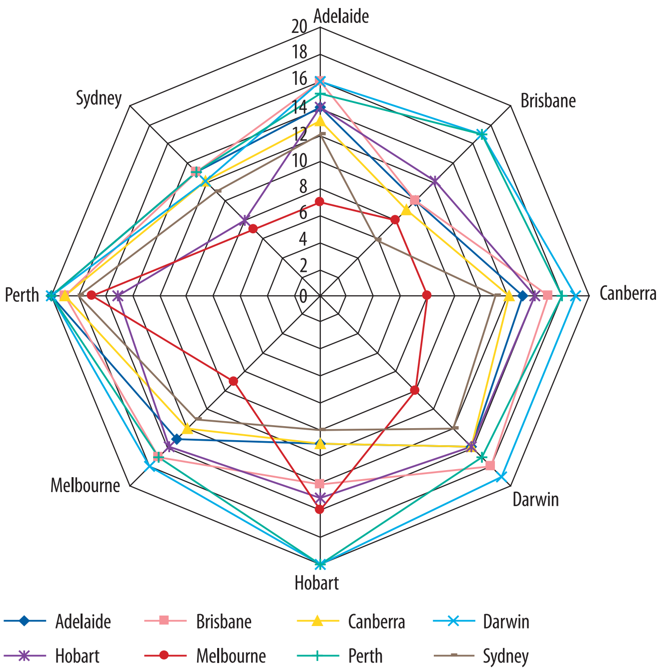

Figure 4. Lagged terms when first reaching a value of impulse response of less than 0.01

7. CONCLUSIONS

This study first estimated the dynamics of house price diffusion within Australia's state capital cities. Using the impulse response function deriving from a VAR(1) model, this study examined the response of one market to the innovation of other markets and determined the lagged terms for the maximum absolute value of the response, from the December quarter 1989 to the June quarter 2007. The findings highlight a number of issues which are summarised below.

Numerical results of this research indicated that house price diffusion exists in all capital cities of Australia. The impulse response results suggest that Canberra and Hobart are the two main epicentres in the Australian housing market. Canberra is the key engine of the area of Adelaide, Brisbane, Canberra, Melbourne and Sydney, while Hobart is another key engine of the area of Hobart and Perth. Darwin played the role of a buffer in the latest housing boom. The other five housing markets in Adelaide, Brisbane, Melbourne, Perth and Sydney would be regarded as having secondary level impetus in Australian housing market.

The impulse responses of eight state capital cities in Australia were found to converge to zero with various speeds. The speed of convergence to zero suggests that Melbourne and Sydney are safer markets than other markets while Adelaide, Brisbane and Perth are more sensitive to the changes from external markets. The results also suggest that the Australian housing market is efficient; and this influence from other markets would last in a long term.

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SANTRAUKA

NEKILNOJAMOJO TURTO KAINŲ KITIMO MODELIŲ TARP AUSTRALIJOS PAGRINDINIŲ MIESTŲ NUSTATYMAS

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Ankstesnių tyrimų duomenimis, nekilnojamojo turto kainų kitimas sukelia bangų efektą atsižvelgiant į erdvinį matmenį. Tai yra nekilnojamojo turto kainų kitimus viename regione rodytų paskesnis nekilnojamojo turto kainų kitimas kituose regionuose. Taip ryškėja tam tikri glaudūs ryšiai tarp regionų. Taikant vektorinį autoregresinį modelį ir impulso perdavimo funkciją, šioje studijoje tiriama nekilnojamojo turto kainų kitimas tarp pagrindinių Australijos miestų, nagrinėjant vienos rinkos reakciją į kitų rinkų naujoves bei nustatant uždelstus terminus kitų rinkų reakcijų maksimaliai absoliutinei vertei. Rezultatai rodo, kad svarbiausios Australijos vidaus rinkos nėra orientuotos į Sidnėjų, bet labiau į Kanberą ir Hobartą. Darvino rinka atlieka buferio vaidmenį. Saugiausios rinkos yra Sidnėjus ir Melburnas. Ši studija padeda numatyti nekilnojamojo turto kainų judėjimo tendencijas aštuoniuose pagrindiniuose Australijos miestuose.