HOUSE PRICE BUBBLE ESTIMATIONS IN AUSTRALIA'S CAPITAL CITIES WITH MARKET FUNDAMENTALS

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ABSTRACT

This paper investigates the existence of house price bubbles in Australia's eight capital cities in recent years by using quantitative analyses including Johansen cointegration test, Granger causality test, impulse response and Chow forecast test. While interactions between house prices and market fundamentals are discussed in long-run and causal estimations, shocks from the market fundamentals to house prices are investigated in generalized impulse response analyses. Findings from estimating house price bubbles for eight capital cities suggest that there was an obvious house price bubble in Perth, while a slight house price bubble occurred in Sydney. In contrast, house prices in Adelaide and Darwin can be explained very well by market fundamentals, while house prices in Melbourne, Brisbane, Hobart and Canberra were undervalued in the study period.

Keywords: House price bubble, Cointegration test, Granger causality, impulse response

INTRODUCTION

The boom in house prices over the last decade around the globe has made the real estate market one of the hottest economic topics. The real estate market has played an important role in the rapid growth of the economy, but soaring house prices can also lead to a bubble. In the 1990s, the housing market crisis made real estate prices drop more than 25% in many countries, such as Switzerland, the UK and Japan (Hott and Monnin, 2008). On the other hand, housing affordability concerns were very high in some years. For example, more than 1.2 million households in Australia were in housing pressure due to the boom of the house prices (Yates, 2008). Housing price fluctuation may cause several economic effects not only in the real estate and financial markets, but also at the macroeconomic level such as the effect on household wealth and hence consumption. If house prices rise, the house owners will think that their wealth has increased. As real consumption is a function of perceived real lifetime wealth, consumers are therefore tempted to spend more. Once the boom bursts, consumers will feel less wealthy and reduce spending, and thus investors will lose confidence in the market and economy (McKibbin and Stoeckel, 2006). Furthermore, with the increase of house prices, there are more jobs in real estate and its relevant industries and property investment also generates more economic activities.

Oppositely, the turndown of house prices can drastically diminish all housing market activities and then raise the unemployment rate as well. Malpezzi and Wachter (2002) expressed a key feature of financial crises is that most seriously affected economies often first experience a collapse in property prices. Therefore, the maintenance of a stable relationship between real house price and the economy is important. The real estate market cycle contains rise, fall and equilibrium of the house price. The characteristics of a cycle, include frequency, peak, trough, amplitude and phase (Liow, 2007). Renaud (1997) indicated most of Organisation for Economic Co-operation and Development (OECD) industrial countries and new industrial middle-income countries experienced unusually strong real estate booms, followed by sharp busts in the 1980s cycle. Consequently, the boom and bust of house price bubbles can be seen as a part of the housing market cycle.

A bubble may be explained as a sharp rise in the price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers (generally speculators) interested in profits from trading in the asset rather than its use or earning capacity (Siegel, 2003). The definition of a bubble most often used in economic research is that part of asset price movement that is unexplainable based on fundamentals (Garber, 2000). The market fundamentals in the academic field are interpreted as exogenous macroeconomic variables. The existence of price bubbles can be implied by the relationship between real estate prices and macroeconomic variables. If real estate prices are in line with variations of macroeconomic variables, or a price change can be explained by both fundamentals and reasonable shifts, the assumption of a price bubble can be rejected (Hui and Yue, 2006). The normal price fluctuations in the real estate market cycles can be explained by the change of market fundamentals if there is no house price bubble. However if there is a bubble, the abnormal movements in house prices can not be explained.

A number of academic studies have been focused on house price bubble issues worldwide (Hendershort, 2000; Yu, 2005; Hui and Yue, 2006; Kranz and Hon, 2006; Fraser *et al.*, 2008; Wheaton and Nechayev, 2008). There are various methods to determinate house price bubbles in empirical studies; for example, according to the relationship between house price movement and income growth or change of rent. Price to income ratio indicates the affordability of a house. By contrast, house price to rent ratios indicate the return on an investment in a house (Case and Shiller, 2003). A house price bubble cannot be determined by one sole fundamental factor, such as house rent or household income. Meen (2008) pointed out that there is no simple and stable relationship between real house price and rent or income.

Previous studies in the house price bubble utilised the house price index of new dwelling or repeated sales house price index (Henry, 1995; Hansen, 2006; Hui and Yue, 2006). There are some limitations using the repeated sales house price index and hedonic house price. For instance, the repeat-sales house price is inefficiently reacted by information and the hedonic house price depends heavily on the quality of the data available. A mismatch between the house price index and the analytical objective may occur (Hui and Yue, 2006). The price of new houses is determined by the value of the existing houses. The cost of new houses can affect the price of existing houses only if new house supply significantly affects the size of the total housing stock (Abelson *et al.*, 2005). In Australia, the proportion of new dwelling's sales is within 2%-7% in the total housing market from 1995-2008.

Therefore, the house price indexes of all dwellings are used in this research to determine the existence of house price bubbles in the Australian eight capital cities by examining the long-run and causal relationships among real house prices and market fundamentals. The Chow forecast test was employed to select the best forecasting point for each city to regress and predict more efficiently, based on the housing demand and supply model. The next section of this paper provides a brief summary of the Australian housing market. The following investigates the interactions between house prices and market fundamentals in Australia's eight capital cities. The housing demand and supply model is built for each city and used to estimate the existence of its house price bubble. The final section provides concluding comments.

AUSTRALIAN HOUSING MARKET

In this paper, established house price indices (HPI) and six market fundamental factors are employed to measure the interactions among house prices and market fundamentals. However, the time series data of real house prices and fundamentals are often violated. In this study, uniform quarterly data can control the quality of this study. The six market fundamental factors are the consumer price index (CPI), the number of new dwellings (ND), the household income (FI), the vacancy rate (VR), the stock price index (SPI) and the mortgage interest rate (MIR). Established house price indices, consumer price indices and number of new dwellings of eight capital cities were extracted from Australian Bureau of Statistics (ABS). The HPI and CPI base points are 100 in 1989-1990.The household expenditure on housing is dependent on the household income which is an important variable and can affect housing demand. The household income is replaced by family income in this study due to lack of quarterly capital cities level data. The vacancy rate of all dwellings is the market equilibrium indicator (Hui and Yue, 2006). Family income and vacancy rate of all dwellings are available from Real Estate Institute of Australia (REIA). Stock price index and mortgage interest rate are collected from Yahoo Finance and Reserve Bank of Australia (RBA) respectively.

Table 1 shows descriptive statistics of eight Australian capital cities from December 1995 to June 2008. Melbourne has the highest average quarterly number of new dwellings with 5089, which may indicate that Melbourne's house demand is the largest in the eight capitals. In contrast, Darwin has the lowest average number of new dwellings with 122, but its average house price index and the vacancy rate of all dwellings are at the top at 254.31 and 5.42% respectively. The average weekly family income in Canberra is the highest in these eight cities with $1679.14. The highest standard deviation occurred in Perth's statistic, with 95.74 which represents that the house price in Perth is more volatile than those in other seven cities during the study period.

Table 1: Descriptive statistics of Australian eight capital cities from December 1995 to June 2008

Minimum	HPI	CPI	FI($)	MIR(%)	ND	SPI	VR(%)
Sydney	115.2	118.3	810.47	6.05	1487	2142.88	1.0
Melbourne	97.1	118.3	815.34	-	2524	-	0.9
Brisbane	136	118.6	727.71	-	1719	-	0.9
Adelaide	106.7	121.1	685.23	-	698	-	0.5
Perth	107.5	116.3	801.56	-	1826	-	0.8
Hobart	121.7	119.2	642.59	-	87	-	1.5
Darwin	121.7	119.2	642.59	-	87	-	1.5
Canberra	124.3	119.8	1266	-	179	-	0.7
Maximum	**HPI**	**CPI**	**FI($)**	**MIR(%)**	**ND**	**SPI**	**VR(%)**
Sydney	275.3	164.1	1260	10.5	4650	6593.65	4.6
Melbourne	348.12	162.5	1300	-	7105	-	4.9
Brisbane	408.14	168.4	1242	-	3781	-	5.8
Adelaide	326.93	167.6	1062	-	1781	-	5.3
Perth	386.54	165.1	1510	-	4127	-	5.39
Hobart	271.31	162.9	1000	-	315	-	8.3
Darwin	436.3	160.8	1773	-	289	-	14.1
Canberra	327.84	165	2248	-	586	-	5.2
Mean	**HPI**	**CPI**	**FI($)**	**MIR(%)**	**ND**	**SPI**	**VR(%)**
Sydney	196.86	137.29	1013.26	7.46	2763.63	3581.39	2.5
Melbourne	193.79	135.91	1030.34	-	5089.41	-	2.8
Brisbane	230.3	139.08	960.79	-	2718.96	-	2.9
Adelaide	180.17	139.08	863.66	-	1230.52	-	2.3
Perth	192.23	134.75	1026.76	-	3036.67	-	3.0
Hobart	170.04	136.73	788.01	-	202.16	-	3.0
Darwin	254.31	134.81	1387.58	-	122.12	-	5.4
Canberra	197.38	136.85	1679.14	-	312.63	-	2.6
Std. Dev.	**HPI**	**CPI**	**FI($)**	**MIR(%)**	**ND**	**SPI**	**VR(%)**
Sydney	59.12	14.18	142.58	1.1	945.49	1181.95	1.0
Melbourne	72.12	13.84	151.11	-	1056.36	-	1.1
Brisbane	91.13	15.72	157.4	-	419.03	-	1.3
Adelaide	71.57	15.42	118.8	-	273.8	-	1.0
Perth	95.74	14.74	187.63	-	590.25	-	1.1
Hobart	49.91	13.75	101.34	-	65.31	-	1.6
Darwin	80.97	12.33	219.57	-	46.47	-	3.6
Canberra	68.81	14.26	300.45	-	79.61	-	1.1

Correlation matrixes for the eight capital cities are displayed in Table 2. The results reveal that both consumer price indices and family income have very strong positive relationships with house price indices in all capital cities, and the stock price index also has strong positive relationships with house price indices in eight capital cities. Except in Sydney, vacancy rates of all dwellings have negative relationships with house price indices. Weak correlations are found between house prices and the mortgage interest rate in all of these eight capital cities.

Table 2: Correlation between HPI and market fundamentals in eight cities

	CPI	FI	MIR	ND	SPI	VR
HPI_Sydney	0.953	0.956	-0.113	-0.803	0.756	0.162
HPI_Melbourne	0.988	0.984	0.011	0.307	0.890	-0.200
HPI_Brisbane	0.978	0.976	0.149	0.211	0.908	-0.599
HPI_Adelaide	0.984	0.972	0.118	0.677	0.905	-0.590
HPI_Perth	0.951	0.966	0.225	0.415	0.969	-0.584
HPI_Hobart	0.963	0.961	0.221	0.775	0.932	-0.439
HPI_Darwin	0.931	0.909	0.272	-0.012	0.967	-0.591
HPI_Canberra	0.983	0.973	0.100	0.002	0.881	-0.031

EXAMINING HOUSE PRICES AND MARKET FUNDAMENTALS

An econometric analysis approach is utilised to investigate the interactions and relationships among house prices and market fundamentals. This approach contains testing stationary of the data via unit root test, analysing long-run and causal relationships by using Johansen cointegration and Granger causality tests and providing insight investigation about the relationships based on an impulse responses analysis.

Unit root tests

A prior condition for the cointegration test is that all the variables should be integrated at the same order or contain a deterministic trend (Engle and Granger, 1991; Luo *et al.*, 2007). The unit root test is conducted for each variable using the Augmented Dicky Fuller unit root test (ADF) which was developed by Dickey and Fuller (1979). The null hypothesis of non-stationary is performed at the 5% significance levels. The results are summarised in Table 3 which shows that all the variables are stationary after first differencing during the December quarter 1995 and June quarter 2008. When the multiple individual time-series variables are found to be integrated of order one, an additional test is required to determine whether long-term relationships exist among the variables. The cointegration test is used to investigate such a relationship.

Table 3: Augmented Dickey-Fuller unit root test

Variables	Sydney				Melbourne				Brisbane				Adelaide			
	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value
logHP	Intercept	-1.223	1	0.657	Trend & intercept	-1.720	0	0.727	Trend & intercept	-2.204	1	0.477	Trend & intercept	-2.662	2	0.257
logCPI	Trend & intercept	-2.062	0	0.554	Trend & intercept	-2.316	0	0.418	Trend & intercept	-1.635	0	0.765	Trend & intercept	-2.460	0	0.346
logFI	Trend & intercept	-2.867	0	0.182	Trend & intercept	-2.214	0	0.472	Trend & intercept	-2.285	0	0.434	Intercept	-0.449	0	0.892
logMIR	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079
logND	Intercept	-1.161	0	0.684	Intercept	-2.626	0	0.095	Intercept	-2.840	0	0.060	None	0.869	0	0.894
logSPI	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882
logVR	Intercept	-1.149	0	0.689	None	-0.949	0	0.301	Intercept	-2.606	1	0.099	Intercept	-2.124	1	0.237
Varibles in first difference																
logHP	Intercept	-3.917	0	0.004	Intercept	-7.340	0	0.000	Intercept	-3.137	0	0.030	Intercept	-3.548	0	0.011
logCPI	Intercept	-5.486	0	0.000	Intercept	-6.278	0	0.000	Intercept	-6.268	0	0.000	Intercept	-6.214	0	0.000
logFI	Intercept	-5.831	0	0.000	Intercept	-8.420	0	0.000	Intercept	-8.117	0	0.000	Intercept	-6.790	1	0.000
logMIR	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008
logND	Intercept	-7.944	0	0.000	Intercept	-7.235	0	0.000	Intercept	-6.258	0	0.000	Intercept	-6.221	0	0.000
logSPI	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000
logVR	Intercept	-8.134	0	0.000	Intercept	-8.564	0	0.000	Intercept	-9.706	0	0.000	Intercept	-11.075	0	0.000

Variables	Perth				Hobart				Darwin				Canberra			
	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value	Model	T-statistic	Lags	P-value
logHP	Trend & intercept	-2.200	1	0.479	Trend & intercept	-2.637	2	0.267	Trend & intercept	-0.682	0	0.969	Trend & intercept	-2.232	1	0.462
logCPI	Trend & intercept	-1.647	0	0.760	Trend & intercept	-2.126	0	0.519	Intercept	2.266	0	0.296	Trend & intercept	-2.186	0	0.487
logFI	Intercept	3.718	4	1.000	Trend & intercept	-2.370	0	0.390	Trend & intercept	-2.569	0	0.967	Trend & intercept	-2.969	0	0.151
logMIR	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079	Intercept	-2.716	1	0.079
logND	Trend & intercept	-3.124	0	0.112	Intercept	-1.706	0	0.422	Intercept	-2.832	0	0.061	None	0.187	1	0.736
logSPI	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882	Intercept	-0.500	1	0.882
logVR	Intercept	-2.176	6	0.218	None	-1.593	0	0.104	Intercept	-1.119	0	0.701	None	-1.546	1	0.114
Varibles in first difference																
logHP	None	-1.891	0	0.050	Intercept	-4.490	0	0.001	Trend & intercept	-5.893	1	0.000	Intercept	-3.473	0	0.013
logCPI	Intercept	-5.883	0	0.000	Intercept	-6.352	0	0.000	Intercept	-5.261	0	0.000	Intercept	-5.448	0	0.000
logFI	Trend & intercept	-6.416	1	0.000	Intercept	-7.884	0	0.000	Intercept	-9.479	0	0.000	Intercept	-8.516	0	0.000
logMIR	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008	Intercept	-3.659	0	0.008
logND	Intercept	-7.900	0	0.000	Intercept	-7.717	0	0.000	Intercept	-8.754	0	0.000	Intercept	-10.275	0	0.000
logSPI	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000	Intercept	-5.200	0	0.000
logVR	Intercept	-3.322	3	0.020	Intercept	-7.804	0	0.000	Trend & intercept	-4.471	6	0.005	Intercept	-9.002	0	0.000

Reject the null hypothesis of unit root based on their P-value at the 0.05 level

Long-run relationships via Johansen cointegration test

The Johansen cointegration test was employed in this research (Johansen and Juselius, 1990). This method is based on the vector autoregression model (VAR). To carry out the Johansen cointegration test, a vector autoregression model should be formulated first. A VAR model for *k* variables with *i* lagged variable terms can be expressed as,

$$BY_t = \sum_{i=1}^{p} A_i Y_{t-i} + \varepsilon_t, \ t = 1, 2, 3 \dots k, \ i = 1, 2, 3 \dots p \tag{1}$$

where B is a $k \times k$ matrix in which the leading diagonal are all 1; Y_t is the k variables symbolised with a k-dimension vector; A_i is the number i $k \times k$ matrix and Y_{t-i} is the number i lagged variables corresponding to Y_t; ε_t is a k-dimensional vector of error term. The symbols of B, Y_t A_i and Y_{t-i} are made as:

$$B = \begin{bmatrix} 1 & -\alpha_{12} & -\alpha_{13} & \cdots & -\alpha_{1k} \\ -\alpha_{21} & 1 & -\alpha_{23} & \cdots & -\alpha_{2k} \\ -\alpha_{31} & -\alpha_{32} & 1 & \cdots & -\alpha_{3k} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ -\alpha_{k1} & -\alpha_{k2} & -\alpha_{k3} & \cdots & 1 \end{bmatrix}, \qquad Y_t = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \cdots \\ Y_k \end{bmatrix},$$

$$\mathrm{A}_i = \begin{bmatrix} \beta_{11}^i & \beta_{12}^i & \beta_{13}^i & \cdots & \beta_{1k}^i \\ \beta_{21}^i & \beta_{22}^i & \beta_{23}^i & \cdots & \beta_{2k}^i \\ \beta_{31}^i & \beta_{32}^i & \beta_{33}^i & \cdots & \beta_{3k}^i \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \beta_{k1}^i & \beta_{k2}^i & \beta_{k3}^i & \cdots & \beta_{kk}^i \end{bmatrix},$$

$$Y_{t-i} = \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \\ Y_{3,t-1} \\ \cdots \\ Y_{k,t-1} \end{bmatrix}, \ \varepsilon_t = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \cdots \\ \varepsilon_k \end{bmatrix}.$$

Cointegration, an econometric property of time series variables, is generally used to estimate the long-term relationships between non-stationary variables. If the level of time series data is not stationary but a linear combination of variables is stationary after first differences, then the series are said to be cointegrated of order one or *I(1)*. They will tend to come back to the trend in the long run, even though they deviate from each other in the short run. The test results were summarised in Table 4, which represents the number of cointegration equations at 5% level for all capital cities in Australia. The trace test results indicate that house prices and variables were cointegrated and shared common trends from December 1995 to June 2008. It does not mean that the house price bubble did not exist in these eight cities, even though the house prices have the long-run equilibrium relationships with these market fundamentals in all the capital cities in the period of 1995 and 2008. The house price can deviate from the intrinsic value in the short run and the bubble term does not have to be estimated in this procedure (Hui and Yue, 2006).

Table 4: Johansen cointegration test for eight capital cities

Sydney

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.576	148.298	139.275	0.013
At most 1	0.482	106.272	107.347	0.059
At most 2	0.437	74.009	79.341	0.118
At most 3	0.365	45.816	55.246	0.258
At most 4	0.262	23.601	35.011	0.470
At most 5	0.161	8.738	18.398	0.607
At most 6	0.003	0.139	3.841	0.710

Melbourne

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.767	172.589	125.615	0.000
At most 1 *	0.469	101.108	95.754	0.020
At most 2 *	0.437	70.121	69.819	0.047
At most 3	0.350	41.955	47.856	0.160
At most 4	0.216	20.862	29.797	0.366
At most 5	0.157	8.922	15.495	0.373
At most 6	0.011	0.529	3.841	0.467

Brisbane

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.725	167.596	125.615	0.000
At most 1 *	0.526	104.373	95.754	0.011
At most 2	0.384	67.788	69.819	0.072
At most 3	0.328	44.036	47.856	0.109
At most 4	0.221	24.582	29.797	0.177
At most 5	0.168	12.328	15.495	0.142
At most 6	0.066	3.339	3.841	0.068

Adelaide

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.604	136.222	125.615	0.010
At most 1	0.495	95.463	95.754	0.052
At most 2	0.417	65.414	69.819	0.107
At most 3	0.375	41.641	47.856	0.169
At most 4	0.241	20.940	29.797	0.361
At most 5	0.178	8.792	15.495	0.385
At most 6	0.003	0.153	3.841	0.696

Perth

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.692	153.143	125.615	0.000
At most 1	0.471	95.370	95.754	0.053
At most 2	0.393	64.170	69.819	0.130
At most 3	0.328	39.668	47.856	0.235
At most 4	0.241	20.174	29.797	0.411
At most 5	0.092	6.654	15.495	0.618
At most 6	0.039	1.941	3.841	0.164

Hobart

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.563	140.166	125.615	0.005
At most 1 *	0.479	99.550	95.754	0.027
At most 2	0.383	67.579	69.819	0.075
At most 3	0.351	43.909	47.856	0.112
At most 4	0.230	22.733	29.797	0.259
At most 5	0.183	9.912	15.495	0.288
At most 6	0.000	0.018	3.841	0.894

Darwin

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.637	170.312	139.275	0.000
At most 1 *	0.532	120.725	107.347	0.005
At most 2 *	0.487	83.527	79.341	0.023
At most 3	0.354	50.824	55.246	0.116
At most 4	0.268	29.405	35.011	0.176
At most 5	0.234	14.094	18.398	0.180
At most 6	0.021	1.047	3.841	0.306

Canberra

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.585	144.790	125.615	0.002
At most 1 *	0.530	101.723	95.754	0.018
At most 2	0.393	64.756	69.819	0.119
At most 3	0.365	40.266	47.856	0.213
At most 4	0.208	18.044	29.797	0.563
At most 5	0.112	6.598	15.495	0.625
At most 6	0.016	0.774	3.841	0.379

*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Causal relationships using Granger causality test

The definition of causality can be referred to Granger (1969). This test is a technique for determining whether one time series is useful in forecasting another. An unrestricted VAR model is usually assumed to implement the Granger causality test and block exogeneity Wald test, but the VAR model for the Granger causality test would contain some misspecification when the time variables are cointegrated. So, this kind of test should be processed under a Vector Error Correction Model (VECM). Once all variables are proved to be stationary and cointegrated, a vector error correction model could be formulated. Granger causality relationships between house prices and market fundamentals variables are summarized in Table 5.

Family income values can Granger cause the housing prices in Melbourne, Brisbane, Adelaide and Darwin, which indicates that the soaring house prices of these four cities is affected partly by the family income, but in Sydney, Perth and Canberra, the family income cannot Granger cause the house prices. In contrast, the house prices can Granger cause the family income in Sydney, Melbourne, Perth and Canberra. These casual relations may be largely due to obtaining capital gains from investment in the housing market. Two-way Granger causalities between the house price index and the family income are found in Melbourne only. It seems to suggest that householders of Melbourne are earning from the housing market while investing. Furthermore, the relationships between the consumer price indices and the house price indices reveal that changes of the consumer prices can Granger cause the house price movements in Sydney, Brisbane and Perth. However, changes of the house price indices cannot Granger cause shifts of the consumer price indices in the most of capital cities.

Table 5: Granger causality test for eight capital cities

	Sydney		Melbourne		Brisbane		Adelaide	
	Chi-square	Probability	Chi-square	Probability	Chi-square	Probability	Chi-square	Probability
CPI => HP	16.89	0.00*	2.47	0.65	24.87	0.00*	0.66	0.72
HP => CPI	3.58	0.47	3.87	0.42	0.09	0.95	6.77	0.03*
FI => HP	4.03	0.40	14.86	0.01*	18.09	0.00*	13.42	0.00*
HP => FI	9.42	0.05*	10.88	0.03*	0.16	0.92	3.37	0.19
MIR => HP	5.41	0.25	12.92	0.01*	25.79	0.00*	3.66	0.16
HP => MIR	11.04	0.03*	4.09	0.39	1.97	0.37	3.02	0.22
ND => HP	0.31	0.99	0.95	0.92	21.83	0.00*	4.03	0.13
HP => ND	9.97	0.04*	5.40	0.25	14.66	0.00*	7.74	0.02*
SPI => HP	5.15	0.27	7.82	0.10	17.63	0.00*	12.01	0.00*
HP => SPI	2.17	0.70	1.35	0.85	0.96	0.62	4.95	0.08
VR => HP	7.06	0.13	2.97	0.56	26.63	0.00*	5.41	0.07
HP => VR	4.78	0.31	18.07	0.00*	0.23	0.89	0.16	0.92

	Perth		Hobart		Darwin		Canberra	
	Chi-square	Probability	Chi-square	Probability	Chi-square	Probability	Chi-square	Probability
CPI => HP	11.68	0.02*	0.80	0.67	0.06	0.97	1.17	0.76
HP => CPI	7.73	0.10	0.91	0.64	3.51	0.17	0.26	0.97
FI => HP	4.34	0.36	3.52	0.17	9.69	0.01*	2.17	0.54
HP => FI	9.07	0.05*	0.61	0.74	0.15	0.93	12.61	0.01*
MIR => HP	5.70	0.22	1.21	0.55	4.07	0.13	1.76	0.62
HP => MIR	5.62	0.23	2.62	0.27	0.10	0.95	1.63	0.65
ND => HP	11.20	0.02*	1.23	0.54	4.38	0.11	0.72	0.87
HP => ND	37.95	0.00*	10.23	0.01*	0.40	0.82	3.19	0.36
SPI => HP	13.85	0.01*	6.01	0.05	1.05	0.59	2.24	0.52
HP => SPI	6.40	0.17	1.92	0.38	3.52	0.17	11.39	0.01*
VR => HP	13.02	0.01*	1.50	0.47	1.19	0.55	3.17	0.37
HP => VR	4.74	0.31	3.42	0.18	1.43	0.49	0.55	0.91

=> means the null hypothesis that there is no Granger causality
* means the rejection of the null hypothesis.

The interest rate is a key determinant of the user cost of housing (Himmelberg *et al.*, 2005). A lower mortgage interest rate means that the house ownership becomes more attractive. On the other hand, a higher mortgage interest rate will raise the mortgage payment, but may not necessarily reduce the demand because if the inflation rate is high, people may purchase property to hedge against inflation. Based on the test results, no causal relationships exist between the mortgage interest rate and the house price indices except in Sydney, Melbourne and Brisbane. In Sydney, the mortgage interest rate cannot Granger cause house price, but the house price can affect the mortgage interest rate. The causality relationships only exist from the real mortgage rate to the house prices in Melbourne and Brisbane with no feedback. The boom of housing prices sometimes accompanies the boom of the stock market and vice versa. The housing market seems as a substitute for the stock market for the urban household (Hui and Yue, 2006). However, the substituted relations are not found in this study. The test results suggest only one-way causality exist between the stock price index and house price indices in Brisbane, Adelaide, Perth and Hobart, which indicate that the change of stock price can affect the house price movements in these four cities in the short-term.

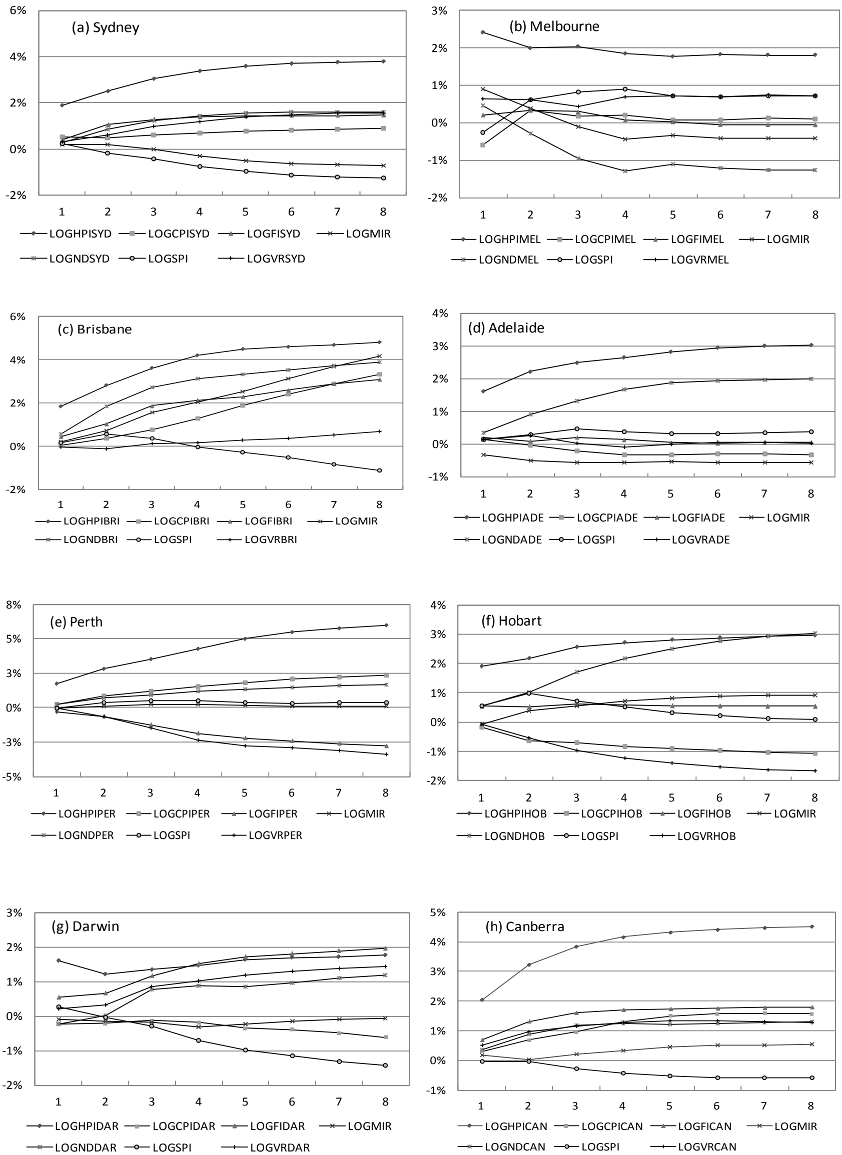
The increasing in the rate of vacancy will lead to a decline of average selling price of new houses. This may have resulted from the housing stock surplus in the market (Hui and Yue, 2006). The findings suggest no causal relationships exist from house prices to vacancy rates in seven capital cities and only in Melbourne, the house price can Granger cause the rate of vacancy. If the housing price is overvalued in a local housing market, the house price will stimulate market speculations and cause a corresponding increase in the number of new dwellings. According to the Granger causality test results, the house price boom in Sydney, Brisbane, Adelaide, Hobart and Perth can lead the increase in the number of new houses. Comparing all eight capital cities, the abnormal interactions between house price indices and consumer price indices, family income and house price indices, house price indices and number of new dwellings occurred in Sydney and Perth, which seems to suggest that house price bubbles may exist in these two cities.

Generalized impulse responses analysis of the house prices and market fundamentals

To obtain further insights on the relationship between house prices and market fundamentals, an impulse response function based on VECM was conducted in this research. The impulse response function procedure can be used to trace responses of a set of variables to shock in another set of variables. A shock to the *i*-th variable directly affects the *i*-th variable itself and then indirectly transmits to all of the endogenous variables through the dynamic structure of the VAR or VEC model. Pesaran and Shin (1998) pointed out a generalized impulse response constructs an orthogonal set of innovations that does not depend on the VAR or VECM ordering. Hence, the generalized impulse response was employed in this study. Impulse response functions are computed to give an indication of the system's dynamic behaviour. It can indicate whether the impacts are positive or negative, or whether these impacts are temporary jumps or long-run persistence.

Figure 1 reports the generalized responses of house prices to market fundamentals in each capital cities in 8 lagged quarters. Standard deviations of the house prices in the eight capital cities will lead significant positive increases in future house prices, indicating that the housing consumer's expectation is largely affected by the current house price. The house prices have the largest impacts on the future house prices in most capital cities, but in Hobart and Darwin, the most influential macroeconomic factors to future house prices are the number of new dwellings and family income respectively. Only in Melbourne does the response from the current house price to the future decrease in the next 5 quarters, and then the impact becomes stable at 1.8%. Generally, the increase in family income and householders consuming will lead an increase in the house price. The findings suggest that house price indices of Sydney, Brisbane and Canberra are positively affected by consumer price indices and family income. In contrast, in Adelaide, Hobart and Darwin, the consumer price indices have negative impacts to the future house price indices. The shock of the family income to the house price in Perth is negative. The impacts from the consumer price indices and the family income to house prices are quite weak in Melbourne and Adelaide.

Figure 1: Impulse response analyses of house prices and market fundamentals in eight capital cities



The future house prices receive a negative impact from the mortgage interest rate and the stock price at around 1% in Sydney, which indicates that the higher mortgage rate will reduce the demand for housing and increase the cost of housing in Sydney, while a raise of stock price will decrease the price of housing. House prices of Brisbane, Darwin and Canberra have similar shocks from the stock price index, but there are positive impacts from the mortgage interest rate to each local house price. In Melbourne, Adelaide, Perth and Hobart, the mortgage rate has insignificant shocks to the future house prices around positive 0.5 % to negative 0.5%. The response of the number of new dwellings in the capital cities to house prices are significantly positive, and only in Melbourne is there a strong negative relationship. There are positive impacts from vacancy rates to house price indices found in Sydney, Melbourne, Brisbane, Darwin and Canberra. No relationship is found between the house price and the vacancy rate in Adelaide. Strong negative relationships between house prices and vacancy rates exist in Perth and Hobart.

BUBBLE ESTIMATION IN AUSTRALIA'S CAPITAL CITIES

House demand and supply model

In a competitive housing market, the housing supply and demand will determine house prices (Quigley, 1999; Hui and Yue, 2006). The interactions can be represented by

$$HP_{it} = f(HD_{it}, HS_{it}) \quad (2)$$

where HP_{it} represents the house price index in Australian capital city *i* at time *t*, then HD_{it} and HS_{it} are the quantities of housing demanded and supplied in Australia's capital city *i* at time *t*. The functions of demand and supply for housing can be expressed as:

$$HD_{it} = d[L(HP_{it}), CPI_{it}, FI_{it}, SPI_{it}, X_{it}] \quad (3)$$

$$HS_{it} = s[L(HP_{it}), ND_{it}, MIR_{it}, VR_{it}, Y_{it}] \quad (4)$$

where *L*( ) is the lag operator.

The house demand at time t in the Australian housing market is a function of house prices (HP), consumer price index (CPI), family income (FI), stock price index (SPI) and a vector of exogenous variables X_{it}. The house supply at time t in the market is a function of house prices, number of new dwellings (ND), mortgage interest rate (MIR), vacancy rate of all dwellings (VR) and a set of exogenous variables Y_{it}.

Substituting *Eqs*. (3) and (4) into *Eq*. (2) and solving for real house price, we can get *Eq*. (5) which is the house price determination. *Z* is a vector of exogenous variables.

$$HP_{it} = f[L(HP_{it}), CPI_{it}, FI_{it}, ND_{it}, SPI_{it}, MIR_{it}, VR_{it}, Z_{it}] \quad (5)$$

Bubble determination

Before forecasting house prices for the eight capital cities, a correct regression and prediction point needs to be selected for each city. The Chow forecast test (CF) is employed in this study. This test is used to determine whether it is reasonable to say that the coefficient values are the same in the estimation and the forecasting period. The hypothesis is rejected at the 10% level. However in this case, if the house price is deeply overvalued or undervalued in the forecast period, the coefficient values will be different in the estimation and forecast period. Forecasting points were tested from March 2000 to December 2004 based on quarterly values to find out when the best forecasting point was for each capital city. The best regression and prediction point can be determined based on the F-statistic and probability. The smaller the F test value, the better the prediction efficiency is achieved. The test results are represented in Table 6, which shows the best forecasting points for the eight capital cities between 2000 and 2004. Probability values of F statistics are smaller than 10%, which suggest that all the prediction models are stable.

Table 6: Chow forecast test for eight capital cities

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra
CF point	Mar 02	Dec 03	Sep 02	Sep 03	Dec 00	Jan 03	Sep 03	Mar 02
F-statistic	2.088	1.923	2.673	2.130	5.016	1.967	2.499	2.561
Probability	0.059	0.063	0.016	0.049	0.003	0.063	0.018	0.024

Table 7 reports the regression models of housing price determination for the eight capital cities based on *Eq*. (5) in the period between 1995 December and each forecasting point. There are no partial correlations between house prices and market fundamentals by testing the residuals of the regression equations, but strong autocorrelations are found in house prices. Therefore, the house price trends of the eight cities can be predicted from forecasting points through the eight regression models. According to the coefficients of the independent variables, the strength and direction of the relationship between each variable and local house price are indicated.

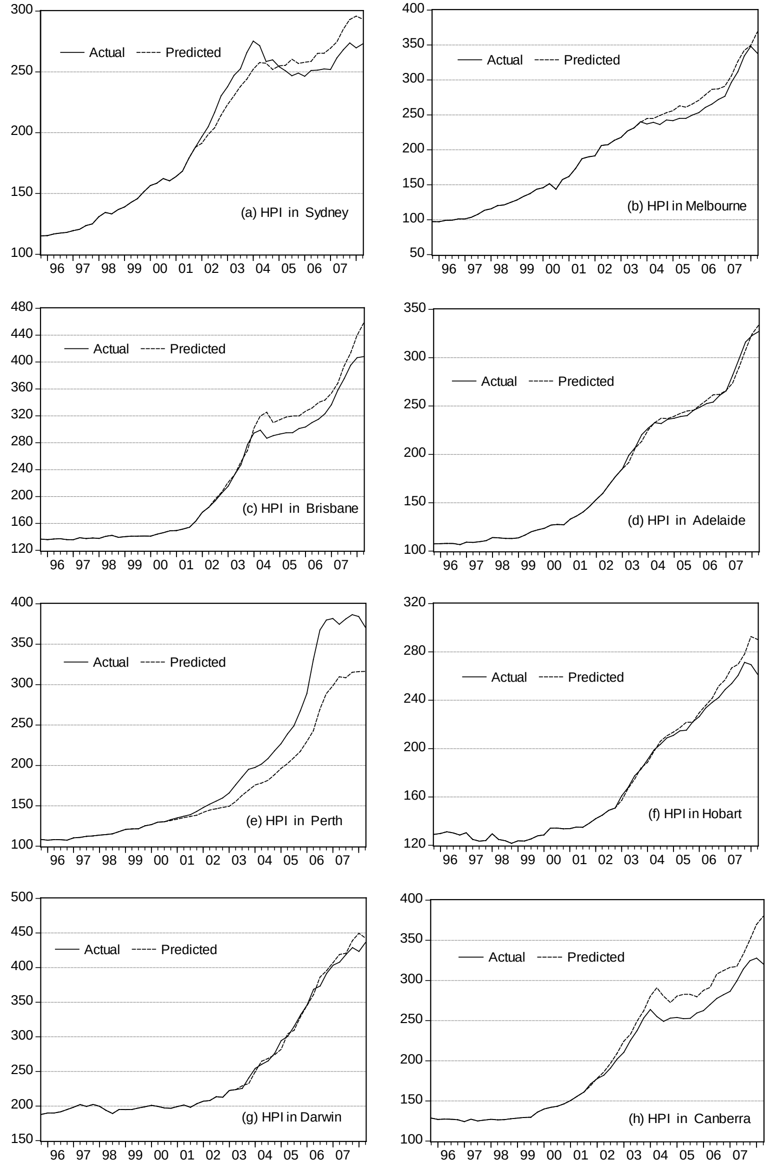
Table 7: Models of house price determination for eight capital cities

Variables	Sydney		Melbourne		Brisbane		Adelaide	
	Coe	Std.Error	Coe	Std.Error	Coe	Std.Error	Coe	Std.Error
logHP(-1)	0.612	0.168	0.525	0.184	1.027	0.167	1.013	0.105
logCPI	0.302	0.350	1.053	0.505	0.313	0.491	0.264	0.311
logFI	0.716	0.462	0.506	0.461	0.069	0.386	-0.027	0.291
logND	0.010	0.041	0.017	0.072	0.017	0.022	-0.004	0.022
logSPI	0.045	0.027	0.081	0.047	-0.006	0.062	-0.034	0.072
logMIR	0.045	0.090	0.076	0.076	-0.062	0.096	-0.076	0.042
logVR	0.004	0.022	0.034	0.037	-0.005	0.011	0.015	0.010
C	-5.133	1.855	-7.547	2.948	-1.717	0.739	-0.712	0.897
R^2	0.994		0.993		0.971		0.995	
Adjusted R^2	0.992		0.992		0.960		0.993	
Variables	Perth		Hobart		Darwin		Canberra	
	Coe	Std.Error	Coe	Std.Error	Coe	Std.Error	Coe	Std.Error
logHP(-1)	0.641	0.278	0.405	0.220	0.701	0.182	1.069	0.180
logCPI	-0.153	0.353	0.401	0.363	0.211	0.199	0.202	0.436
logFI	0.310	0.264	0.374	0.241	0.014	0.186	0.214	0.183
logND	0.003	0.041	0.085	0.037	-0.106	0.044	-0.001	0.033
logSPI	-0.002	0.019	0.038	0.016	-0.025	0.013	0.006	0.020
logMIR	0.141	0.143	-0.070	0.082	-0.148	0.045	-0.124	0.091
logVR	0.013	0.016	-0.004	0.007	0.004	0.007	-0.017	0.011
C	-0.768	1.131	-1.288	0.631	1.968	0.894	-1.890	0.940
R^2	0.983		0.945		0.914		0.982	
Adjusted R^2	0.973		0.927		0.888		0.975	

Coefficients in Table 7 show that there are positive relationships among house price indices at time t, house prices indices at time t-1, consumer price indices and family income in Sydney, Melbourne, Brisbane, Darwin and Canberra. In Perth and Hobart, there are negative relationships between the consumer price indices and the house price indices, but house price indices of the last quarter and family income have significant positive relationships with house price indices. A slightly negative relationship between the family income and the house price index is found in Adelaide. Simultaneously, correlations among house price indices, number of new dwellings, stock price index and vacancy rates of all dwellings are very weak, which seems to suggest that movements of these four market fundamentals could not cause significant changes of house prices.

A comparison of actual house prices and predicted house prices from each forecasting point to June 2008 in the eight capital cities are displayed in Figure 2. Between March 2002 and December 2004, the real house price of Sydney is slightly higher than the predicted house price, and then is lower than the forecasting price after 2004 to 2008. This result may suggest that there was a house price bubble existing between March 2002 and December 2004. This phenomenon of house price movements of Sydney can be explained by the house price bubble having burst from the end of 2004. Comparison results suggest that an obvious house price bubble existed in Perth from December 2000 to June 2008. Furthermore, actual house prices matched quite well with the forecast house prices in Adelaide and Darwin. Additionally, predicted house price indices of Melbourne, Brisbane, Hobart and Canberra shift to above actual house price indices. This may represent that the house prices were undervalued in Melbourne, Brisbane, Hobart and Canberra from 2003 to 2008.

Figure 2: House price bubble estimation for eight capital cities

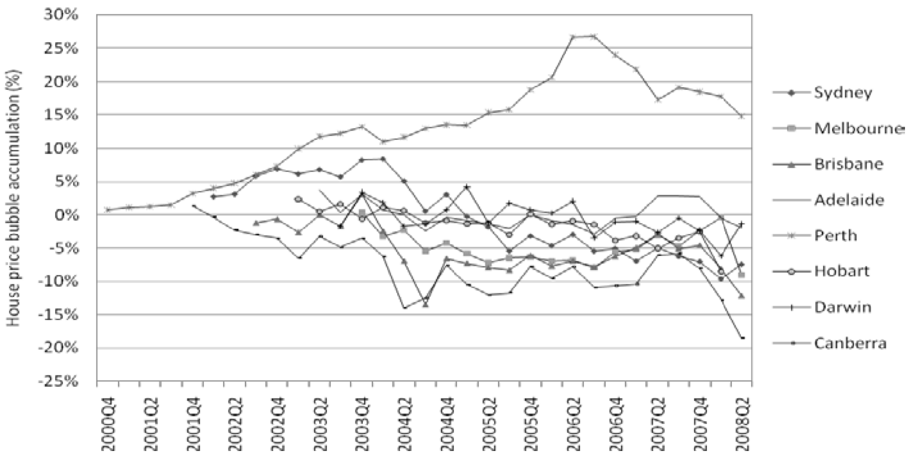


The difference between the real house prices (HP_{it}) and the predicted house prices (HPF_{it}) can be seemed as bubble terms ($HP_{it}\%$) in the eight capital cities. The estimation equation could be written as,

$$HP_{it}\% = \frac{\Delta HP_{it}^{*}}{HP_{it}} = (HP_{it} - HPF_{it})/HP_{it} \tag{6}$$

The accumulated percentages of house price bubbles in the eight capital cities are represented in Figure 3, which suggests that approximately 27% of the house price can be attributed to the bubble term in Perth at the second season of 2006. The accumulated percentage of house price bubbles in Sydney reached a maximum with 9% at the beginning of 2004. There are no bubbles in the other six cities, but the house prices of Melbourne, Brisbane, Hobart and Canberra are around 7% lower than predicted prices during 2003 and 2008.

Figure 3: The accumulated percentage of house price bubbles of eight capital cities



CONCLUSIONS

This paper has explored the possible existence of house price bubbles in Australia's eight capital cities in recent years. A number of econometric methods are employed to investigate the long run and causal relationships among house price indices and six market fundamental factors including consumer price indices, family income, interest rates, amounts of new dwellings, stock price indexes and vacancy rates of all dwellings in the eight Australian capital cities.

The cointegration test results indicate that there are long-term equilibrium relationships among house prices and six fundamentals during the study period in Australia's state capital cities. The Granger causality test results suggest that house price bubbles occurred in Sydney and Perth. The general impulse response analysis reveals that house prices are the key factors to positively impact the future house price in all eight capital cities. Furthermore, consumer price indices and family income also positively affect house price indices in Sydney, Brisbane and Canberra. In contrast, the impact from consumer price indices to future house price indices are negative in Adelaide, Hobart and Darwin, and so is the shock of family income to the house price in Perth. In Melbourne and Adelaide, consumer price indices and family income have very weak shocks to house prices. Responses of mortgage rate to house price indices are positive in Brisbane, Darwin and Hobart, but shocks from the stock price index are negative. Relationships between house prices and vacancy rates are quite strong in Perth and Hobart, but it is much weaker in other cities.

The research presented in this paper categorises eight state capital cities into three groups according to their house price bubble estimates. There was an obvious house price bubble in Perth from December 2000 to June 2008 and a slight house price bubble occurred in Sydney from March 2002 to December 2004. In contrast, the house prices in Melbourne, Brisbane, Hobart and Canberra were undervalued during 2002 to 2008. The house prices in Adelaide and Canberra can be well interpreted by their market fundamentals.

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