GRANGER CAUSALITY AMONG HOUSE PRICE AND MACROECONOMIC VARIABLES IN VICTORIA

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ABSTRACT

This study analyses the dynamic causality of four macroeconomic variables on house prices. The four macroeconomic variables have interrelationships with house prices in certain lagged terms, but these relationships are not always the same as the notions put forward in prior research. The relationships are detected to be unstable in the three observation periods. The instability of these relationships would cause difficulty in predicting house prices in the market, especially for policy makers and market participants.

Keywords: House price index, unit root, Granger causality, cointegration, vector error correction

INTRODUCTION

The issue of housing is critical to basic human needs. The needs for shelter and personal independence have a close connection to housing. Thus, the impact of house prices will have a great influence on these basic needs. House prices are affected by various macroeconomic variables. Sirmans *et al* (2005) organised these characteristics into eight categories: construction and structure variables, internal house features, external house features, natural and environmental characteristics, environmental neighbourhood and location factors, public service amenities, marketing, occupancy and selling factors and financing issues. Berry and Dalton (2004) classified house prices into different categories, including short term factors (e.g. interest rate, investment demand and current economic climate); institutional factors (e.g. financial deregulation and innovation, and government taxes, levies and charges); and long term factors (e.g. demography, economic growth and, wealth levels and distribution). Tu (2000) focused on affordability, housing finance, inflationary, housing supply and demographic variables. Harter-Dreiman (2004) identified that income shocks impacted on house prices at a slow pace.

Meanwhile, housing almost always involves mortgage borrowing because of the high purchase price. This suggests that housing supply could be affected by mortgage rates (Painter and Radfearn, 2002). Abelson *et al.* (2005) also found that the unemployment rate and the mortgage rate had a negative impact on house price, and disposable income is a spur to house purchasing. Case and Shiller (1990) found a lagged effect on house price

was affected not only by changes in house prices itself, but also by changes in adult population and real income. Case *et al.* (2003) found the relationship between house prices and incomes was remarkably instable. House buyers' behaviour is influenced by recent market information. Thus, house prices are raised by individual's expectations rather than income.

On the other hand, changes in house prices also affect some macroeconomic variables. Meen (2003) reported that house prices had a straightforward influence on the sub-section of labour market: wage pressure, unemployment and migration patterns. House prices have a potential effect on migration patterns and unemployment rates. Baffoe-Bonnie (1998) pointed out that the housing market could be "shocked sensitively" by the change of employment and mortgage rates at both national and regional level. Reichert (1990) found that regional house prices reacted to some national economic factors, such as the mortgage rate. Johnes and Hyclak (1999) described how house prices have a great effect on labour force size. Hamalainen and Bockerman (2004) suggested that rising house prices would lessen the increase of inward migration in a region. Portnov *et al.* (2001) found that inward migration still reduced in an area with growing employment but a sharp increase in house prices.

The relationships between house price and variables have been determined in prior research but the research addressing instability of these relationships is limited (Case *et al.*, 2003). The instability of these relationships might be expected to have great influence on the decisions of policy makers and market participants. The aim of this study was to quantify the causal relationships between house prices and population, income, unemployment rate and mortgage rate in the period from the September quarter 1989 to the June quarter 2005 and try to determine whether these relationships are stable or unstable in the three observation periods. The influence of these characteristics on house price is not equal and change over time and location. It is very difficult to take account of all variables into one house price model. The selection of these variables depends on the research objective and data availability. The Granger causality test, the main technique in this study, was utilised to investigate the causal relationships.

The following section introduces several major property market data resources and outlines the data used in this research. Section 3 describes the use of the unit root test and vector autoregression model to test the stationarity and the optimal lag length order of the data series. In Section 4, the use of the cointegration test to test the long run equilibrium is described. Section 5 sets out the analysis, using the conventional pairwise Granger causality test and a VEC Granger causality test, to examine the causal relationships between house prices and the four selected macroeconomic variables. The last section provides a concluding discussion.

DATA DESCRIPTION

The data series of house price index, population, mortgage rate, weekly earning, and unemployment rate are five time series data. Because the mortgage rates are different between the various lenders, we selected data on the mortgage rate from the Reserve Bank of Australia. The house price index was used to measure the house price in this study.

Figure 1 shows graphs which illustrate the house price index, mortgage rate, population, unemployment rate and weekly earnings from the September quarter 1989 to the June quarter 2005 in Victoria. There are two noteworthy stages in the house price index movement: a steady fluctuation from 1989 to 1996 and a sharp increase with about 12.8% annually from 1996 to 2004. In the same period, the mortgage rate showed a decreasing trend from 17% to 7% for the period 1989 and 1996, and has remained steady at about 7% until 2005. The unemployment rate increased sharply from 4.2% in 1989 to its peak at 12% in 1994 and decreased to 5% in 2005. The other two variables: population and weekly earnings, showed an approximately linear increase from 1989 to 2005.

Figure 1: House prices index and selected macroeconomic variables (September quarter 1989 to June quarter 2005)

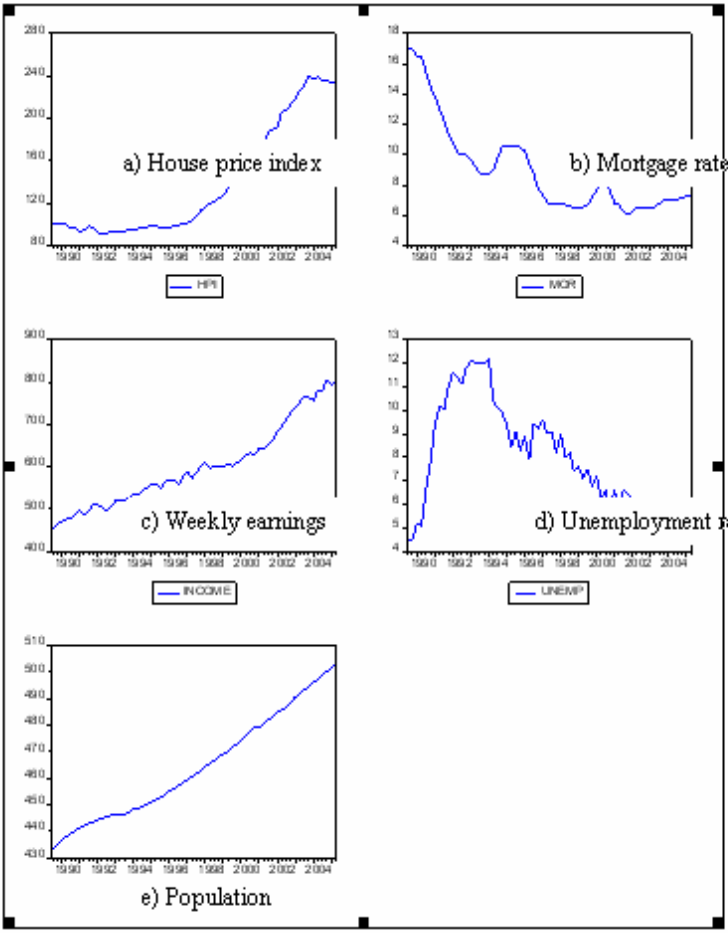


Figure 1 identifies several issues. Firstly, house prices did not increase as expected from 1989 to 1996 when the mortgage rate decreased sharply in the same period. On the other hand, when the mortgage rate kept steady after 1996, house prices increased. Secondly, house prices did not put pressure on personal incomes as noted above. Lastly, the house price boom seems not to have deterred an increase in population. In response to these issues, five related variables were analysed in three observation periods: from the September quarter 1989 to the June quarter 1996, from the September quarter 1996 to the

June quarter 2005 and from the September quarter 1989 to the June quarter 2005. Because of the time lag effect, the observed time interval for the first stage ends at the December quarter 1996, not the June quarter 1996. Similarly, the second stage starts at the March quarter 1996, not the September quarter 1996.

Several abbreviations are used in this the rest of this study, and HPI, MOR, POPU, UNEMP and INCOME stand for house price index, mortgage rate, population, unemployment rate and weekly earnings respectively.

TESTING FOR STATIONARITY AND OPTIMAL LAG ORDER

Unit root test for stationarity

Table 1 shows the result of unit root tests from the September quarter 1989 to the June quarter 2005, using the Dicky Fuller unit root test (DF) at the level form, the Augmented Dicky Fuller unit root test (ADF) and the Phillips Perron unit root test (PP) at the first difference level. The null hypothesis of non-stationarity is performed at the 1% and the 5% significance levels. In Table 1a, the result of the DF test illustrates that all the data series during the September quarter 1989 and the June quarter 2005 are non-stationary at level. However, the result of the ADF test on the first difference and the PP test on the first difference strongly supports that all data series are stationary after the first difference at the 1% or 5% significance levels. Similarly, Table 1b shows the result of unit root tests from the September quarter 1989 and the June quarter 2005. It indicates that the weekly earnings series is I(0) which indicates the series is integrated at the level form and the others are I(1). Table 1c shows the result of unit root tests during the March quarter 1996 and the June quarter 2005. It indicates that all the 5 variable series are I(1).

Table 1: Unit root tests of housing price index and macroeconomic variables series

a) September quarter 1989 to June quarter 2005

		DF test at levels			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 trend	house price index	-2.327	na	6	-3.183	**	1	-7.293	***	4
	mortgage rate	-0.461	na	1	-4.509	***	0	-4.596	***	3
	weekly earnings	3.103	na	0	-9.276	***	2	-9.291	***	1
	unemployment rate	-0.837	na	1	-9.217	***	2	-9.159	***	4
	population	1.218	na	4	-3.044	**	1	-5.729	***	4
With trend	house price index	-1.111	na	2	-3.183	**	1	-8.152	***	4
	mortgage rate	-1.450	na	1	-4.509	***	0	-5.115	***	3
	weekly earning	-1.170	na	0	-9.276	***	2	-9.812	***	6
	unemployment rate	-1.259	na	1	-9.217	***	2	-9.615	***	3
	population	-1.048	na	2	-3.044	**	1	-6.616	***	3

b) June quarter 1989 to December quarter 1996

		DF test at levels			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 trend	house price index	-1.707	na	0	-5.809	***	0	-5.870	***	2
	mortgage rate	-0.684	na	1	-1.961	na	0	-2.985	**	3
	weekly earnings	0.071	na	1	-6.848	***	1	-10.175	***	1
	unemployment rate	-1.728	na	4	-1.220	na	3	-5.003	***	3
	population	1.463	na	2	-2.227	na	0	-3.444	**	1
With trend	house price index	-1.941	na	0	-5.011	***	2	-12.675	***	4
	mortgage rate	-2.345	na	1	-1.960	na	0	-3.022	**	2
	weekly earnings	-4.394	***	1	-6.728	***	1	-9.341	***	6
	unemployment rate	-2.770	na	4	-0.931	na	3	-5.883	***	3
	population	-2.217	na	2	-3.445	**	0	-3.282	**	1

c) March quarter 1996 to June quarter 2005

		DF test at levels			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 trend	house price index	-0.312	na	2	-6.371	***	0	-6.388	***	3
	mortgage rate	-1.367	na	1	-3.025	**	0	-3.025	**	0
	weekly earnings	0.445	na	2	-4.729	***	1	-7.401	***	2
	unemployment rate	-0.413	na	1	-3.728	***	8	-12.994	***	2
	population	-0.193	na	3	-6.865	***	0	-6.887	***	1
With trend	house price index	-1.509	na	0	-6.275	***	0	6.306	***	3
	mortgage rate	-2.312	na	1	-2.960	na	0	-2.939	na	1
	weekly earnings	-1.544	na	0	-7.786	***	0	-7.823	***	1
	unemployment rate	-2.281	na	2	-15.031	***	8	-12.789	***	0
	population	-2.042	na	0	-7.183	***	0	-8.270	***	6

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

Selecting optimal lag length using vector autoregression model

One of the approaches in selecting optimal lag length is to re-estimate a vector autoregression (VAR) model, reducing lag length from a large lag term until zero. In each of these models, the smallest value of the Akaike information criterion and the Schwarz criterion point to the optimal lag length. The Akaike information criterion and the Schwarz criterion are introduced to make the choice (DeJong *et al.*, 1992, Grasa, 1989, Gujarati, 2003, Maddala and Kim, 1998). 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, 2006). In addition, sequential modified likelihood ratio test statistics (LR), final prediction error (FPE), and Hannan-Quinn information criterion (HQ) are inspected in this study (Lutkepohl, 1993). Similarly, the smallest value of these three criteria points to the optimal lag length.

Table 2 shows the results of the VAR lag order selection criterion. The first left hand column shows the lag orders from 0 to 8. The LR, FPE, AIC, SC and HQ are the 5 criteria mentioned above. The numbers with asterisks 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 VAR may not capture the dynamic behaviour of the variables (Chen and Patel, 1998), so the optimal lag length might 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. Therefore, the optimal lag lengths shown in Tables 2a, 2b, 2c and 2d are 2, 4, 5 and 1 respectively.

Table 2: VAR lag order selection criteria between house price index and selected macroeconomic variables (September quarter 1989 to June quarter 2005)

a) HPI and MOR

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-394.3096	NA	4808.627000	14.153910	14.226250	14.181960
1	-175.2897	414.573200	2.223506	6.474634	6.691636	6.558765
2	-156.5726	34.091920	1.315506*	5.949022*	6.310692*	6.089241*
3	-152.8698	6.479915	1.331772	5.959636	6.465974	6.155942
4	-151.3652	2.525575	1.460276	6.048758	6.699763	6.301151
5	-148.8308	4.073081	1.546035	6.101102	6.896776	6.409583
6	-147.6681	1.785581	1.722748	6.202434	7.142776	6.567002
7	-141.0460	9.696777*	1.583784	6.108784	7.193794	6.529440
8	-139.5138	2.134081	1.751858	6.196921	7.426599	6.673665

b) HPI and POPU

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-468.8543	NA	68904.600000	16.81622	16.88856	16.84427
1	-180.1374	546.4998	2.643799	6.647766	6.864767*	6.731897*
2	-179.2599	1.598444	2.957902	6.759281	7.120951	6.899499
3	-172.053	12.61207	2.64223	6.644749	7.151087	6.841055
4	-165.5113	10.98068*	2.420181*	6.553974	7.20498	6.806368
5	-161.4672	6.499482	2.427812	6.552399*	7.348072	6.86088
6	-160.0878	2.11828	2.684463	6.645993	7.586335	7.010562
7	-156.5484	5.182692	2.755162	6.662443	7.747453	7.083099
8	-154.4587	2.910677	2.987460	6.730668	7.960346	7.207411

c) HPI and UNEMP

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-386.7294	NA	3668.165000	13.88319	13.95553	13.91124
1	-213.3293	328.2216	8.650710	7.833190	8.050192*	7.917321*
2	-208.7749	8.295592	8.487447	7.813389	8.175059	7.953607
3	-203.4168	9.376585	8.099171	7.764887	8.271225	7.961193
4	-200.0147	5.710780	8.298761	7.786238	8.437244	8.038632
5	-194.7774	8.416993	7.977642*	7.742051*	8.537725	8.050532
6	-194.2941	0.742229	9.107828	7.867647	8.807989	8.232216
7	-187.2929	10.25184*	8.260559	7.760459	8.845469	8.181115
8	-186.2798	1.41109	9.308151	7.867135	9.096812	8.343878

d) HPI and INCOME

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-553.5816	NA	1420407.00000	19.8422	19.91453	19.87024
1	-362.1738	362.3077	1760.783*	13.14906*	13.36606*	13.23319*
2	-360.6495	2.776349	1925.00000	13.23748	13.59915	13.3777
3	-354.5227	10.72185	1787.19100	13.16153	13.66786	13.35783
4	-352.6622	3.123039	1934.88500	13.23794	13.88894	13.49033
5	-350.9806	2.702594	2111.86400	13.32073	14.11641	13.62922
6	-350.284	1.069701	2392.75900	13.43871	14.37906	13.80328
7	-340.791	13.90050*	1985.38600	13.24254	14.32755	13.66319
8	-340.597	0.270164	2303.58300	13.37847	14.60814	13.85521

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

COINTEGRATION TESTS

Cointegration means economic variables share the same stochastic trend so that they are combined together in the long run. Even if they deviate from each other in the short run; they tend to come back to the trend in the long run. A necessary 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). The unit root test results show that all the time series of house price index, mortgage rate, population, unemployment rate and weekly earning are integrated at first difference, but not integrated at level form during the September quarter 1989 and the June quarter 2005 and during the March quarter 1996 and the June quarter 2005. That is, all five variables are I(1). Therefore, these five time series in the two periods are valid in the cointegration test. In the same way, the weekly earnings series is I(0) and the others are I(1) during the September quarter 1989 and the December quarter 1996. Therefore, it is excluded from the cointegration test. Once the variables are cointegrated, the short run changes can be explained through the vector error correction model (Engle and Granger, 1987). Following the cointegration test, the VECM was used to analyse the causality within the 5 variables and this is described in the following section.

The results in Table 3 are based on the Johansen cointegration test, reporting the hypothesized number of cointegration equations in the first left column, the eigenvalue, the likelihood ratio statistics and 5% critical value. The asterisks indicate the rejection of the hypothesis. The trace test in Table 3a indicates 2 cointegration equations at the 5% level. It demonstrates that the five variables are cointegrated and share the common trends from the September quarter 1989 to the June quarter 2005. Because the weekly earnings series in the period of the September quarter 1989 and the June quarter 1996 is I(0), it is excluded from the Johansen cointegration test in Table 3b respectively. Theoretically, the exclusion of weekly earnings series and unemployment series do not exclude the possibility of that the two variables have other relationships in each of their own sets.

The trace test in Table 3b indicates two cointegration equations at the 5% level. It suggests that house price, mortgage rate, unemployment rate and population have a long run equilibrium relationship during the September quarter 1989 and the December quarter 1996. The trace test in Table 3c indicates two cointegration equations at the 5% level. It suggests that house price, mortgage rate, weekly earnings and population (the unemployment rate series is excluded from this cointegration test) have a long run equilibrium relationship during the March quarter 1996 and the June quarter 2005. To sum up, the Johansen cointegration test results show the five variables are cointegrated in the three periods, except the income series is excluded from the test during the September quarter 1989 and the December quarter 1996.

Table 3: Johansen cointegration test

a) HPI, INCOME, MOR, POPU and UNEMP (September quarter 1989 to June quarter 2005)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.551904	104.639900	69.818890	0.000000
At most 1 *	0.312782	55.672280	47.856130	0.007800
At most 2	0.295408	32.790930	29.797070	0.021900
At most 3	0.156245	11.432570	15.494710	0.186200
At most 4	0.017373	1.069068	3.841466	0.301200

b) HPI, MOR, POPU and UNEMP (September quarter 1989 to December quarter 1996)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.739533	71.481660	47.856130	0.000100
At most 1 *	0.522938	35.159110	29.797070	0.011000
At most 2	0.357038	15.176190	15.494710	0.055800
At most 3	0.113444	3.251108	3.841466	0.071400

c) HPI, MOR. POPU, UNEMP and INCOME (March quarter 1996 to June quarter 2005)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.693274	90.200430	69.818890	0.000500
At most 1 *	0.557887	48.837360	47.856130	0.040300
At most 2	0.302759	20.270750	29.797070	0.404700
At most 3	0.160864	7.648907	15.494710	0.503700
At most 4	0.042240	1.510517	3.841466	0.219100

* denotes rejection of the hypothesis at the 0.05 level

GRANGER CAUSALITY TESTS

The four variables are investigated to show whether they contain useful information for predicting house prices in this study. Once the stationarity is validated by a unit root test and the optimal lag lengths are selected respectively, these selected factors can be used in a pairwise Granger causality test. Two Granger causality tests are used in this research, including the conventional pairwise Granger causality test and VAR Granger causality/block exogeneity Wald test.

Pairwise Granger causality test

The pair-wise Granger causality test is formulated as,

$$Y_t = \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{i=1}^{m} \beta_i Y_{t-i} + \mu_{1t} \quad (1)$$

$$X_t = \sum_{i=1}^{m} \lambda_i Y_{t-i} + \sum_{i=1}^{m} \delta_i X_{t-i} + \mu_{2t} \quad (2)$$

Y_t and X_t are time series of variables which can be any pairs of house price index and a macroeconomic variable. Y_{t-i} and X_{t-i} are the lagged term of Y_t and X_t respectively. μ_{1t} and

μ_{2t} are the error terms. If $\alpha_i \neq 0$ and $\lambda_i = 0$, X Granger causes Y and Y does not Granger cause X. If $\alpha_i = 0$ and $\lambda_i \neq 0$, Y Granger cause X and X does not Granger cause Y. If $\alpha_i \neq 0$ and $\lambda_i \neq 0$, Y Granger causes X each other. If $\alpha_i = 0$ and $\lambda_i = 0$, Y Granger does not cause X each other.

Table 4a shows the probability value of pairwise Granger causality test from the September quarter 1989 to the June quarter 2005. The null hypothesis of the first part is 'each of the macroeconomic variables (MOR, INCOME, UNEMP and POPU) does not Granger cause the house price index', and for the second part is 'House price index does not Granger cause the macroeconomic variables'.

Table 4: Pairwise Granger causality test

a) September quarter 1989 to June quarter 2005

lag	mortgage rate	weekly earnings	unemployment rate	population
	does not Granger Cause house price index			
1	0.00567***	0.22116	0.63792	0.00239***
2	0.01463**	0.39804	0.73908	0.00267***
3	0.12156	0.34929	0.60857	0.00633***
4	0.19654	0.53745	0.42637	0.00308***
5	0.10806	0.75542	0.32639	0.01452**
6	0.13071	0.84952	0.42776	0.02917**
7	0.26356	0.85112	0.71828	0.24312
8	0.37223	0.91867	0.51601	0.34533
9	0.17300	0.79481	0.94222	0.28892
10	0.31915	0.85690	0.90614	0.43913
lag	house price indexdoes not Granger Cause			
	mortgage rate	weekly earnings	unemployment rate	population
1	0.37934	0.00762***	0.01913**	0.26944
2	0.68794	0.01799**	0.02339**	0.73019
3	0.54231	0.02995**	0.03822**	0.52268
4	0.61330	0.04095**	0.01497**	0.08182
5	0.89517	0.11244	0.03136**	0.01423**
6	0.79772	0.29234	0.11810	0.02232**
7	0.62175	0.26542	0.35436	0.03059**
8	0.54172	0.32145	0.41741	0.04424**
9	0.53141	0.40882	0.32641	0.05912
10	0.53721	0.69519	0.46726	0.03675**

b) September quarter 1989 to December quarter 1996

lag	mortgage rate	weekly earnings	unemployment rate	population
	does not Granger Cause house price index			
1	0.54981	0.34986	0.59659	0.22660
2	0.59327	0.04339**	0.92663	0.08249
3	0.29403	0.04423**	0.49821	0.12854
4	0.08689	0.02430**	0.73095	0.10660
5	0.39225	0.15964	0.66530	0.42298
6	0.29882	0.07333	0.33875	0.26351
7	0.76953	0.63137	0.66089	0.62109
8	0.52240	0.78499	0.87544	0.47502
lag	House price index does not granger cause			
	mortgage rate	weekly earnings	unemployment rate	population
1	0.64402	0.17362	0.48085	0.00003***
2	0.65922	0.07140	0.12854	0.00215***
3	0.67885	0.20858	0.22058	0.01690**
4	0.71238	0.10704	0.21913	0.01684**
5	0.89870	0.03167	0.35627	0.00429***
6	0.23383	0.12828	0.13652	0.01717**
7	0.64917	0.26376	0.38444	0.12645

c) March quarter 1996 to June quarter 2005

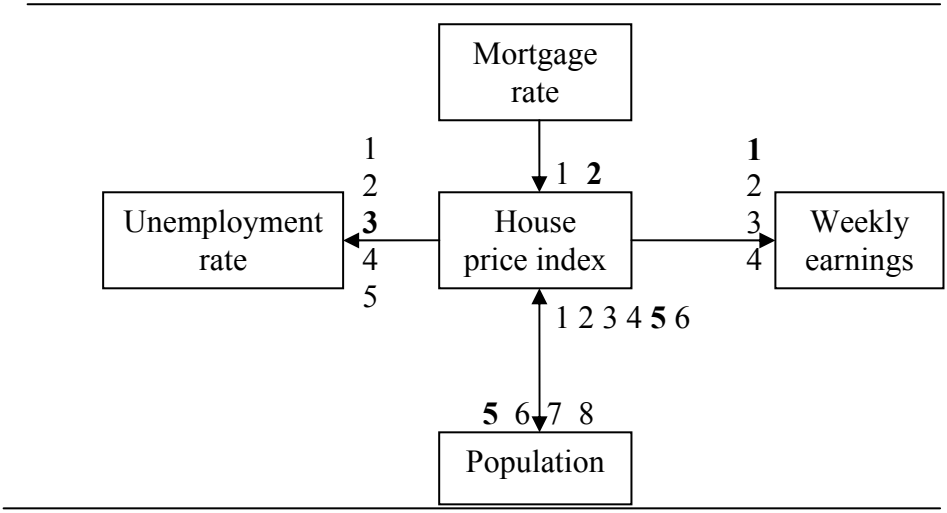
lag	mortgage rate	weekly earnings	unemployment rate	population
	does not Granger Cause house price index			
1	0.10696	0.20985	0.15612	0.20972
2	0.17246	0.16937	0.02003*	0.30467
3	0.37297	0.43408	0.13548	0.03385**
4	0.48219	0.60594	0.16266	0.02155**
5	0.01036**	0.61553	0.34963	0.05999
6	0.01569**	0.20069	0.51318	0.15526
7	0.01814**	0.55763	0.76726	0.34830
8	0.06542	0.45828	0.44626	0.47021
lag	House price index does not granger cause			
	mortgage rate	weekly earnings	unemployment rate	population
1	0.14408	0.00408***	0.03121*	0.38303
2	0.45899	0.01857**	0.43679	0.35523
3	0.33927	0.05200	0.12617	0.46506
4	0.32570	0.07020	0.16217	0.07508
5	0.46342	0.06825	0.29665	0.05836
6	0.66424	0.17543	0.22081	0.13370
7	0.81953	0.29118	0.24769	0.12099
8	0.44683	0.11531	0.26885	0.12100

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

The first left hand column indicates lag length. The p-values with asterisks mean rejection of the null hypothesis at 1% or 5% significance levels. Table 4a indicates that mortgage rate and population Granger cause house price, and house price Granger cause weekly earnings, unemployment rate and population during the September quarter 1989 and the June quarter 2005. To detect the changes in these relationships over time, the observation period is divided into two stages. The results are shown in the two following test in Table 4b and Table 4c. Table 4b indicates that only weekly earnings Granger cause house price and house price only Granger cause population during the September quarter 1989 and the December quarter 1996. Similar to Table 4a, Table 4c shows that mortgage rate and population Granger cause house price, and weekly earnings and unemployment rate during the March quarter 1996 and the June quarter 2005. The results in Table 4 support the findings that the house price influences the macroeconomic variables in some extents in the existing literature, such as Abelson *et al* (2005). However, the relationships between house price and macroeconomic variables change in association with the observed period.

Figure 2 is generated from Table 4. It shows the individual direction of the Granger causality and optimal lag from the September quarter 1989 to the June quarter 2005. In Figure 2, the arrows indicate the direction and the numbers indicate the lag length, and the bold numbers are the optimal lag length which has been selected from the results of Table 1.

Figure 2: The direction of Granger causality using pairwise Granger causality test (September quarter 1989 to June quarter 2005)



In reviewing the test results, we can say that weekly earnings and unemployment rate do not Granger cause house price during the September quarter 1989 and the June quarter 2005. However, weekly earnings Granger cause house price in the first stage and unemployment rate Granger causes house price in the second stage. Mortgage rate and population Granger cause house price during the September quarter 1989 and the June quarter 2005, but the two causations are not captured in the first stage and occur in the second stage.

VEC Granger causality/block exogeneity Wald test

A multivariate Block Exogeneity Wald test derived from the VEC model was used to examine the further causal relationships between house price and four variables in this research. Table 5 shows the lag order selection criteria using the VAR model. The criteria are estimated in the three observation periods. Because the weekly earnings series in the period of September quarter 1989 and June quarter 1996 is I(0), weekly earnings is excluded from Table 5b. Table 5a suggests that lag length eight is selected in this test, because the values of FPE, AIC and HQ are smallest at lag eight. This lag interval is acceptable, for 2 years (8 quarters) is suitable in this study. In the same way, Table 5b indicates that lag length two is the optimal lag length in the group of HPI, MOR, POPU and UNEMP during September quarter 1989 and December quarter 1996. Table 5c

indicates that lag length four is the optimal lag length in the group of HPI, MOR, POPU and INCOME during March quarter 1996 and June quarter 2005.

Table 5: VAR lag order selection criteria between variables

a) HPI, MOR, INCOME, UNEMP and POPU (September quarter 1989 to June quarter 2005)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-837.516	NA	8044439	30.08986	30.27069	30.15997
1	-424.4844	737.5564	7.739445	16.23159	17.31660*	16.65224
2	-375.7684	78.29369	3.390793	15.38458	17.37377	16.15579
3	-349.4969	37.53073	3.426634	15.33917	18.23253	16.46092
4	-325.4019	30.11864	3.952702	15.3715	19.16903	16.84379
5	-283.9725	44.38866	2.664723	14.78473	19.48644	16.60758
6	-257.7918	23.37561	3.499526	14.74257	20.34845	16.91596
7	-219.4788	27.36649	3.594566	14.2671	20.77716	16.79103
8	-141.3269	41.86706*	1.210832*	12.36882*	19.78305	15.24330*

b) HPI, MOR, UNEMP and POPU (September quarter 1989 to December quarter 1996)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-208.8592	NA	82.76264	15.76735	15.95933	15.82443
1	-87.39889	197.9353*	0.03409	7.955473	8.915353*	8.240896
2	-67.92574	25.9642	0.028800*	7.698203	9.425986	8.211963*
3	-48.91224	19.7177	0.029332	7.474981*	9.970667	8.217079

c) HPI, MOR, INCOME, UNEMP and POPU (March quarter 1996 to June quarter 2005)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-431.3239	NA	96452.96	25.66611	25.89058	25.74266
1	-238.0495	318.33430	4.937701	15.76762	17.11440	16.22691
2	-190.8982	63.79290*	1.485516	14.46460	16.93371*	15.30664
3	-161.4206	31.21153	1.513164	14.20121	17.79265	15.42600
4	-112.6162	37.32107	0.702587*	12.80095*	17.51471	14.40848*

* 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

Table 6 shows the VEC Granger causality/block exogeneity Wald test results. It estimates the χ square value of coefficient on the lagged endogenous variables. The causality is investigated in the three periods. The hypothesis in this test is that the lagged endogenous variables do not Granger cause the dependent variable.

Table 6a indicates that mortgage rates, population, unemployment rates, and weekly earnings Granger cause house prices in the long run. The house prices do not Granger cause the unemployment rate, but Granger cause population, mortgage rate and weekly earnings. Table 6b indicates that mortgage rate, population and unemployment rate do not Granger cause house price, but the house price Granger cause unemployment rate. Table 6c indicates that weekly earnings, mortgage rate, unemployment rate and population Granger cause house price, but house price does not Granger cause them. Because the

weekly earnings series in the period of September quarter 1989 and June quarter 1996 is I(0), the weekly earnings series is excluded from Table 6b. However, it does not imply

Table 6: VEC Granger causality/Block exogeneity Wald tests

a) HPI, MOR, INCOME, UNEMP and POPU (September quarter 1989 to June quarter 2005)

Dependent variable: D(HPI)			
Excluded	Chi-sq	df	Prob.
D(MOR)	17.69134	8	0.0237
D(INCOME)	34.46488	8	0.0000
D(UNEMPL)	21.12653	8	0.0068
D(POPU)	13.02832	8	0.1109
All	70.5947	32	0.0001
Dependent variable: D(MOR)			
Excluded	Chi-sq	df	Prob.
D(HPI)	31.76175	8	0.0001
D(INCOME)	14.26578	8	0.0751
D(UNEMPL)	17.76857	8	0.0230
D(POPU)	26.02320	8	0.0010
All	103.56530	32	0.0000
Dependent variable: D(INCOME)			
Excluded	Chi-sq	df	Prob.
D(HPI)	9.90044	8	0.2721
D(MOR)	16.26973	8	0.0387
D(UNEMP)	21.63881	8	0.0056
D(POPU)	13.88432	8	0.0848
All	47.21428	32	0.0406
Dependent variable: D(UNEMP)			
Excluded	Chi-sq	df	Prob.
D(HPI)	21.07275	8	0.0070
D(MOR)	15.35109	8	0.0527
D(INCOME)	20.49576	8	0.0086
D(POPU)	25.39586	8	0.0013
All	78.66553	32	0.0000
Dependent variable: D(POPU)			
Excluded	Chi-sq	df	Prob.
D(HPI)	2.98762	8	0.9351
D(MOR)	11.69692	8	0.1652
D(INCOME)	12.59948	8	0.1264
D(UNEMP)	11.99304	8	0.1515
All	48.22249	32	0.0328

b) HPI, MOR, UNEMP and POPU (September quarter 1989 to December quarter 1996)

Dependent variable: D(HPI)			
Excluded	Chi-sq	df	Prob.
D(MOR)	3.048785	2	0.2178
D(UNEMP)	2.092809	2	0.3512
D(POPU)	2.096584	2	0.3505
All	6.99568	6	0.3212
Dependent variable: D(MOR)			
Excluded	Chi-sq	df	Prob.
D(HPI)	1.380011	2	0.5016
D(UNEMP)	7.315636	2	0.0258
D(POPU)	2.081212	2	0.3532
All	9.054221	6	0.1706
Dependent variable: D(UNEMP)			
Excluded	Chi-sq	df	Prob.
D(HPI)	7.394847	2	0.0248
D(POPU)	21.14907	2	0.0000
D(MOR)	6.808541	2	0.0332
All	41.02763	6	0.0000
Dependent variable: D(POPU)			
Excluded	Chi-sq	df	Prob.
D(HPI)	4.402662	2	0.1107
D(UNEMP)	0.971695	2	0.6152
D(MOR)	0.709882	2	0.7012
All	6.549788	6	0.3645

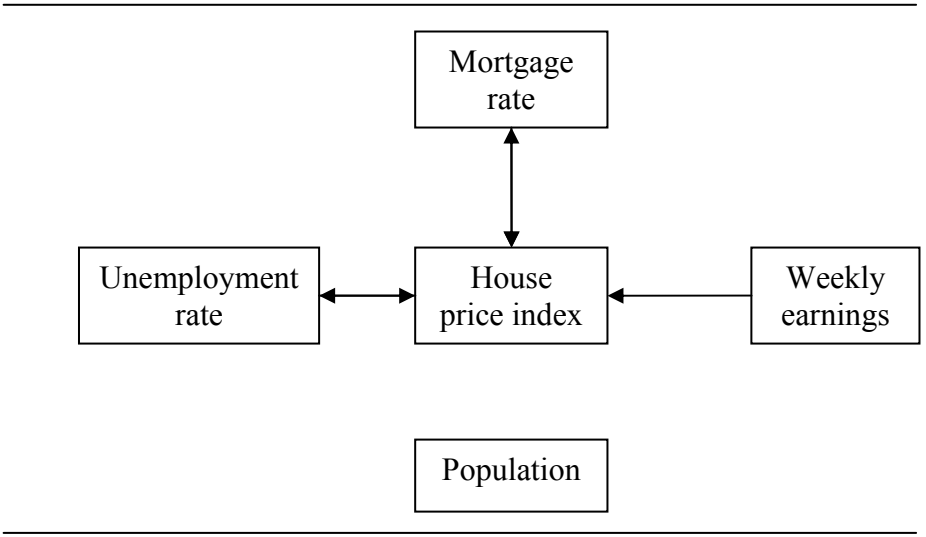
c) HPI, MOR, INCOME, UNEMP and POPU (March quarter 1996 to June quarter 2005)

Dependent variable: D(HPI)			
Excluded	Chi-sq	df	Prob.
D(MOR)	40.13668	4	0.0000
D(INCOME)	33.50139	4	0.0000
D(UNEMP)	18.80395	4	0.0009
D(POPU)	9.52670	4	0.0492
All	145.31640	16	0.0000
Dependent variable: D(MOR)			
Excluded	Chi-sq	df	Prob.
D(HPI)	2.99260	4	0.5591
D(INCOME)	4.45202	4	0.3483
D(UNEMP)	3.28191	4	0.5118
D(POPU)	4.29167	4	0.3680
All	16.95734	16	0.3884
Dependent variable: D(INCOME)			
Excluded	Chi-sq	df	Prob.
D(HPI)	4.95802	4	0.2916
D(MOR)	5.01800	4	0.2855
D(UNEMP)	9.55774	4	0.0486
D(POPU)	2.61681	4	0.6238
All	25.06455	16	0.0687
Dependent variable: D(UNEMP)			
Excluded	Chi-sq	df	Prob.
D(HPI)	3.37628	4	0.4969
D(MOR)	10.75190	4	0.0295
D(INCOME)	12.40977	4	0.0146
D(POPU)	8.51365	4	0.0745
All	52.35688	16	0.0000
Dependent variable: D(POPU)			
Excluded	Chi-sq	df	Prob.
D(HPI)	4.96703	4	0.2907
D(MOR)	4.91623	4	0.2960
D(INCOME)	1.81240	4	0.7702
D(UNEMP)	1.71401	4	0.7882
All	15.93927	16	0.4572

that there is no relationship between house prices and income. The stability of relationships between house prices and economic variables over time and space has not received much attention in prior literature (Case *et al.* 2003). This research indicates that the relationships between house prices and economic variables are unstable over time.

Figure 3 is generated from Table 6a, the VEC Granger causality/Block exogeneity Wald test results. The arrows stand for the direction of Granger causality from the September quarter 1989 to the June quarter 2005.

Figure 3: The direction of Granger causality using VEC Granger causality/block exogeneity Wald test (September quarter 1989 to June quarter 2005)



To avoid a spurious conclusion, the result of Figure 3 which derives from the vector error correction model was suggested for adoption in this research. The reason has been discussed. Figure 3 indicates that weekly earnings, mortgage rate and unemployment rate Granger cause house price, while population does not Granger cause house price from the September quarter 1989 to the June quarter 2005. House price Granger causes mortgage rate and unemployment rate, while house price does not Granger cause weekly earnings and population in this period.

Based on the conventional pairwise Granger causality result in Table 4b, it shows that weekly earnings Granger causes house price during the September quarter 1989 to the June quarter 1996. However, the weekly earnings series is found to be I(0) in this period and the other 4 variables are I(1). In this case, weekly earnings should be excluded from the cointegration test. The VEC Granger causality tests are shown in Table 3b and Table 6b. Thus, the conclusion that personal income Granger cause house price from the September quarter 1989 to the December quarter 1996 could be invalid in this research. Meanwhile, the other four variables, including house price index, population, mortgage rate and unemployment rate, have long run equilibrium from the September quarter 1989 to the December quarter 1996, but the VEC Granger causality results, even the results of the conventional Granger causality test do not indicate that mortgage rate, unemployment rate and population Granger cause house price. That is, no Granger causality occurs between house price and mortgage rate, unemployment rate and population in this term.

On the other hand, the VEC Granger Causality test results show that the entire four macroeconomic variables Granger cause house price from the March quarter 1996 to the June quarter 2005. However, the result is different from results in the period of the September quarter 1989 to the June quarter 2005. Population does not Granger cause house price, but the other three macroeconomic variables Granger cause house price.

Based on the VEC Granger causality test results and the cointegration test results in the three periods, it is noticeable that Granger causality does not always happen even though the long run equilibrium occurs in the five variables. There is no effect in the first stage, but emerges in the period of 1996 and 2005. There are two remarkable events in the period of 1989 and 1996: a high mortgage rate at 17% in 1989 to 10.5% in 1996 and high unemployment rates, for example, from 10.2% in the June quarter 1992 to 12.2% in the March quarter 1994. They deter house prices increasing in this period. It is probably one of the reasons that there is no Granger causation in this period. However, when the mortgage rate dropped to a reasonable level in the period of 1996 and 2005, and the unemployment rate started to decrease from 1995, the power which has accumulated by the increasing weekly earnings and population in the first stage, would be one of the dynamic pushes for house prices to move up in the period of 1996 and 2005.

The causal relationships between macroeconomic variables and house prices are detected to be unstable in the three observation periods by the conventional Granger causality test and the VEC Granger causality/ block exogeneity Wald test. The instability of these relationships would cause difficulty in predicting house prices in the market, especially for policy makers and market participants.

CONCLUSIONS

Using the cointegration test, the vector error correction model and the Granger causality test, this research investigates the causal relationships between house prices, mortgage rates, population, weekly earnings, and unemployment rates in the three observation periods. The cointegration test results suggest that there is a long run equilibrium among house prices, mortgage rates, population, unemployment rates and weekly earnings during the three periods Although a long run equilibrium occurs in house price and four macroeconomic variables during the three periods, the causality is not always captured as expected in these periods. These causal relationships are determined to be unstable, both in the conventional pairwise Granger causality test and the VEC Granger causality test, such as mortgage rate and population. Therefore, monetary policy and demographic policy sometimes fails to affect house prices. This should be significant for policy makers and house owners. The VEC Granger causality test results show the four macroeconomic variables do not Granger cause house price during the September quarter 1989 and the December quarter 1996, but Granger cause house price during the March quarter 1996 and the June quarter 2005. Making an overview, population does not Granger cause house price, but mortgage rate, weekly earnings and unemployment rate Granger cause house

price during the September quarter 1989 and the June quarter 2005. Only the relationship that house prices Granger cause unemployment rate is detected in the three observation periods.

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