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House Price Dynamics and Granger Causality: An Analysis of Taipei New Dwelling Market

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The primary purpose of this paper is to examine dynamic causal relationships between house price and its five determinants, including total household income, short-run interest rates, stock price index, construction costs, and housing completions, in Taipei new dwelling market. Granger causality tests, variance decomposition, impulse response functions based on the vector error-correction model are utilised. All five determinants Granger cause house prices, but only house prices and stock price index have a bilateral feedback effect. The variance decomposition results suggest that disturbances originating from current house prices inflict greatest variability (66 percent of variance) to future prices. The remaining 34 percent of the variance is explained by the five determinants. On the supply side, the construction costs and housing completions together explain about 10 percent of the house price variance. On the demand side, short-run interest rates, total household income and stock price index explain about 24 percent of the variance.

Keywords

Vector Error-correction Model; Granger Causality Test; Generalised Impulse Response Function.

1. Introduction

Housing market remains one of the most volatile sectors of the Taiwanese economy. During the last twenty-five years, Taipei pre-sale house prices have increased 12 fold in nominal terms, with an average 15 percent annual rate of increase and approximately 23 percent standard deviation. There have been three major booms in recent years: around 1973, 1979 and 1988. The first two peak periods, 1973-74 and 1979-80, can be explained as having been induced by both cost-push in construction industry and demand pull inflation due to the oil embargo. Since almost all oil is imported from overseas, the oil shock to Taiwan economy as well as to the house building sector was severe. The major factor behind the third boom period between 1987-89 is believed to be the rapid increase of money supply which was triggered by looser monetary policy and financial liberalisation.

The fluctuations in house prices have stimulated a great deal of academic research. These research concentrated attention on modelling and explaining the house price behaviour in the context of a partial macroeconomic framework, however, the causal relationships and detail sources of volatility between house price and its determinants have not been sufficiently captured. In addition, previous studies seem to have overlooked the great changes in the housing market induced by changes of macroeconomic activity, which could lead to mis-specify the house price model. Therefore, this paper examines house price fluctuation with three aims. The first is to examine the causal relationships between house price and its determinants, including income, demographics, monetary variable, housing supply, house costs and relative return of other assets. The second is to further examine their relationships in term of the detail the sources of house price fluctuations and the degree of the impact on house prices from its determinants. Special care is taken to consider the structural changes in the late 1980s.

The paper is structured as follows. The next section, begins by reviewing some of the existing studies on house prices. In Section III, the theoretical framework of house price determination is established. Section IV describes the methodologies employed in this paper. Section V reviews the data and their time-series properties. Section VI presents empirical results from the estimation of the Vector Error Correction Model. Conclusions are presented finally in Section VII.

2. Background Discussion

In the neo-classical economics framework, variation in house prices are a result of demand and supply imbalance, in which demand for housing is a function of demographic factors, income, mortgage interest rate and housing stock, and supply of housing is a function of land cost, construction cost and availability of credit. While the determinations of house prices have been theoretically modelled in terms of macroeconomic equilibrium relationships, previous Taiwan studies either have not explained sufficiently well the dynamic behaviour of house prices (Wu 1994, for example) or have not managed to explain the short run price volatility around the long-run trend (Hwang, 1994, for example). These house price studies have some common features and shortcomings.

First, the studies which span 1980s had to find a method for dealing with the dramatic jump in house price series. The usual explanation for the dramatic jump in house prices between 1986 and 1990 in Taiwan is the rapid increase in money supply which resulted in high investment and/or speculative activity in the housing market. However, after this boom, house prices remained relatively stable, and this suggests that house prices established by 1990 do not seem to be a temporary bubble but represent a new long-run equilibrium price level. The existing econometric studies on Taiwan house prices have not paid sufficient attention to house price changes during this major structural change period from 1986 to 1990.

Second, although housing as a consumption good has been long acclaimed, its characteristic as a store of wealth, which is more like an investment asset, is also very important. The perception of housing as an investment asset has only just begun to be recognised by researchers. Some of the recent studies (Meen, 1990, for example) have focused on the concept of user cost of capital which involves both consumption and investment decision. But, the excess demand for housing has still not been sufficiently well explained. Given the especially strong investment demand over the past years, monetary variables, which have significant impact on credit availability, should be considered in order to capture the large short-run volatility induced by the investment demand.

Third, a possible reason for the failure of existing house price models may also result from a mis-understanding of the actual relationship between house price and its determinants. The relationships between house price and its determinants are complex because of their nature, or when the housing market environment is in a state of flux. According to Maclennans (1994),

> ... the housing market is a large sector of the economy and it is highly possible that the housing market and the economy interact. Although the feedback mechanism is possible, it is not very clear. It is not only important to determine a timing relationship, but also a direction relationship between house price and its aggregate determinant series.

Early studies on short-run analysis of house prices (Chen, 1990 and Meen, 1990, for example) focused on disequilibrium rather than equilibrium analysis. The recently developed cointegration technique provides a useful tool for analysing the long-term equilibrium and short-run dynamics of economic relationships. Although this approach has been used lately by some researchers in the housing market such as Giussani and Hadjimatheou (1990), their focus is on modelling house prices rather than testing the short-run house price volatility.

3. Analytical Framework

3.1 The Theoretical Model

The model of house prices that we adopt in this paper arises out of micro-to-macro framework of the housing market (further details can be found by Chen (1998)). On demand side, the model is based on the asset market approach, as set out by Dougherty and Van Order (1982), and Meen (1990) amongst others. The model begins with a highly simplified world, in which a representative household attempts to solve a utility maximisation problem where there are two goods - housing services and a composite consumption good (*CG*). We assume for simplicity that the flow of housing services is directly proportional to the housing stock (*H*). Both *CG* and *H* enter the household's utility function. The household maximises utility over time, subjects to a budget constraint and technical constraints. Assuming that there is a perfect capital market, the first order condition of this optimisation problem provides the following expression for the marginal rate of substitution between housing and the composite consumption good (u_h/u_{cg}):

$$\frac{U_h}{U_{cg}} = Ph[(i - PhGr^e] \qquad (1)^1$$

where *Ph* is the real house price, *i* is the real interest rate, and $PhGr^e$ is expected real capital gains on housing. In an equilibrium capital market, the real rental price of housing (*R*), which is the real rental price paid by consumers for the flow of services from a unit of the housing stock in each time period, is unobservable and must equal the real user cost in (1) so that:

[1]This is the standard and simple definition of the real housing user cost of capital. A more complex variant of the use cost of housing capital also considers the elements such as property taxes, depreciation and transaction costs. Here the model adopts the simple version of the term as indicated by Peterson et al (1997) that a simpler user cost might be more realistic for empirical analysis.

$$R = Ph(i - PhGr^e) \qquad (2)$$

Since *R* is unobservable, the conventional approach is to replace it by its determinants. Then, substituting *R* into (2), the real house price can be expressed in terms of the determinants of real permanent income (*PY*) and demographic factors (such as household formation) (*D*). In addition, net addition to the stock of dwelling, which is dominated by house completions (*HC*), is an important factor influencing prices in the Taiwan new dwelling market. Thus:

$$Ph = f(PY, (i - PhGr^e), D, HC) \qquad (3)$$

Taiwan housing market is characterised by an investment demand, which is induced by the rapid expansion of money supply (*MS*). This is because when there is a rapid expansion in money supply, households invest the money in hand, or borrow, to invest in the housing market. Also real assets are normally perceived to be a good investment and a better inflation hedge than financial assets. However, household may still consider investing in other financial assets depending on the relative rates of return on the assets, therefore, stock price index (SPI) is also included as one of the determinants of house prices.

In addition, in the new dwelling market, supply of houses is also determined by construction costs (*CC*) and land cost (*LC*). Therefore, as equilibrium in the new housing market is considered, house prices are determined by both demand and supply side factors as follows:

$$Ph = f(Y, D, HC, (i - PhGr^e), MS, SPI, CC, LC) \qquad (4)$$

As stated earlier, the dramatic increases in house prices between 1986 and 1990 is suspected as a structural changes in house price series. This because that there were several changes emanating from financial markets in Taiwan which affected macroeconomic variables in the late 1980s[2]. However, previous Taiwan house price models all assume a constant environment and ignore the possible structural change in the market. This paper follows standard approach of dealing with a structural change along the lines of Henrdy (1984)

[2] For example, the exchange control on current account of the balance payment was completely abolished in 1987. Also, on March 1985, ten leading banks in Taiwan announced that their interest rate would be determined by banks individually according to their own position and market condition. This so-called "basic lending-rate system" was followed by other banks in September 1987.

and Drake (1993) who use a dummy variable.

Due to the large number of determinants and relatively few observations for house price series in this study, the VAR model adopted as the methodology could be overparameterised. Consequently, equation (4) has to be modified in order to arrive at a parsimonious system for the purpose of empirical analysis. First, equation (4) considers both household formation (*D*) and household permanent income (*PY*). These two determinants can be combined as the total household permanent income variable (*TPY*), which was adopted by Hendry (1984). This total household income actually can capture both scale changes in demographics and income. Second, the user cost of housing capital ($i-PhGr^e$) in the equation considers the effects of both interest rates (i) and expected house price growth ($PhGr^e$), but the influence of expected house price growth can be captured by the dynamic VAR system. Hence, it seems that only interest rate should be retained. In addition, theoretically, money supply and interest rates are closely related, one of these two variables can be dropped. This paper uses interest rate instead of money supply in order to test the relationship between the loose monetary policy and the feedback effect on interest rate from house prices. Also, short-term interest rate rather the long-term interest rate is used because it may more likely capture the investment demand in Taiwan pre-sale market. In this market, only a small initial deposit in a pre-sale agreement is required on the part of investors to invest in the market. Third, land prices and house prices appear to move closely together, particularly in the long run (Chen (1998)). So, land price variable is dropped, which is also in line with Hendry (1984), assuming that house price can be assumed to be a good proxy for land price. Thus, the final empirical model to be tested is:

$$Ph = f\,(\underset{+}{TPY},\ \underset{+/-}{HC},\ \underset{+}{CC},\ \underset{+/-}{i},\ \underset{+/-}{SPI},\ \underset{+}{dummy}) \qquad (5)$$

3.2 Causality Relationships

The relationships between house price and its determinants sometime are ambiguous and there is an ongoing debate in this area. Theoretically, house price determinants are expected to be exogenous variables and therefore are expected cause house price changes, i.e. house price determinants $\Rightarrow$ house prices. However, in most cases, there could exist two-way relationships, meaning that house prices may also affect these determinants.

Construction costs (*CC*), which consist of material and labour costs, is one of the major component of new house building costs. Increases in construction costs will certainly result in house price increase. On the other hand, house price increases could cause construction costs to increase, too. This is because increases in house prices may induce workers and building material suppliers to demand higher wages and raw material prices. This feedback may be more complex and not necessarily reflected in house prices in the short-run, but in the long-run this feedback effect is likely to exist.

An increase in disposable income makes household more affluent. This leads to increase in both demand for housing and prices. On the other hand, income also has a feedback effect from house prices. This is due to the fact that a house represents an accumulation wealth of a household that rises with the appreciation of the house prices. Conversely, falling house prices depress homeowner's wealth and in turn can lead to reduction in consumption spending over and above that associated with current income. Dipasquale and Wheaton (1996) indicate that US real estate, valued at $8.77 trillion in 1990, account for 56 percent of the nation's wealth in that and residential real estate, representing 70 percent of total real estate value, comprised 39 percent of national wealth. As a result, even a small percentage decline in the value of housing assets will generate wealth losses that are large in relation to national income.

Demographic factors are normally expected to cause house prices (*D* Þ *Ph*). However, it is important to point out that the process of household formation can be said to be endogenous to the housing market. Hendershott and Smith (1985) find that a decline in cost of renting or owning a house by 10 percent seems to result in an increase in headship rates by about 0.25 percent in the US. Hence, it is possible that house prices have a bilateral relationship with household formation (*Ph* Û *D*).

Although it is presumed that in the long-run demand equals supply, in the short-run, an imbalance may exist. If a shortfall exists in one period, the insufficient housing supply will cause house prices to increase (*HC* Þ *Ph*) and induce builders to build more houses (*Ph* Þ *HC*). Conversely, if an excess supply is expected, this will dampen the number of new building project starts, and further cause house prices to fall.

Prices of financial assets, namely stock prices, may also have a two-way causality to house prices (*Ph* Û *SPI*) given that households portfolios comprise both financial and real assets. This bilateral causality suggests that stocks and shares act as an alternative investment market. However, it is also feasible that the stock market is an initial holding place for capital investment whilst investors build up their equity capital before investing in housing. Housing in Taiwan requires a large initial deposit compared to the bundles of shares. Also, owner-occupiers cannot afford to buy and sell houses just on the relatively small price changes caused by economic circumstances because of relatively high cost of acquisition. It can be, therefore, argued that the stock market and the housing market are two independent markets with no short-term causality in either direction (*Ph* <≠> *SPI*).

House prices could have two-way causality with monetary variables. As we know that expansion of money supply is responsible for house price booms in Taiwan. Taiwan government have used interest rates and loan control in order to dampen house prices rises. This intervention is has been observed to occur with a lag of two years of rapid house price rises.

4. Methodologies

4.1 Vector Autoregression Model and Cointegration Theory

The aim of this paper is to analyse house price dynamics and causality, which is achieved by the application of Vector Autogression (VAR) model suggested by Sims (1980). However, one area of controversy for the VAR models is whether the variables included in a VAR should be stationary or not. Some argue that if the time series is non stationary, regression of one time series variable on one or more time variables can often give spurious results due to the effect of a common trend. Sims (1980) and others, though, recommend against differencing even if the variables have a unit root. The main argument against differencing is that "it throws away" information concerning the comovement in the data which will, in general, lead to poor forecast. Recently, the concept of the cointegrated series has been suggested by Engle and Granger (1987) as a solution to this problem. According to the Granger Representation Theorem, if a set of variables are cointegrated, that is, X_t, $Y_t \sim CI(1)$, then there must exist an "error correction" representation which describes the short-run dynamics of Y_t and X_t, in the following general form:

$$DY_t = b_1 DX_t + b_2 m_{t-1} + e_t \qquad (6)$$

where D denotes first difference, m_{t-1} is the one period lagged value of the residuals from estimation of equilibrium error term, and e_t is the error term with the usual properties.

For cointegrated series, the error correction term (m_{t-1}), which represents the speed of adjustment toward the long-run values, provides an added explanatory variable to explain changes in Y_t. Without m_{t-1}, cointegrated system estimated in differences are overdifferenced. The equation above is a single equation of ECM which can be also used in multivariate systems. For a bivariate system:

$$\Delta Y_t = g_y m_{t-1} + \sum_{i=1}^{n} a_i \Delta Y_{t-i} + \sum_{j=1}^{n} b_i \Delta X_{t-j} + e_{1t} \tag{7}$$

$$\Delta X_t = g_x m_{t-1} + \sum_{i=1}^{n} d_i \Delta Y_{t-i} + \sum_{j=1}^{n} f_j \Delta X_{t-j} + e_{2t} \tag{8}$$

The above two equations constitute a vector autoregression model (VAR) in first difference, which is a VAR type of ECM. In equation (7) and (8), if g_x and g_y equal zero, it is a traditional VAR in first difference. If g_y differ from zero, DY_t responds to the previous period's deviation from long-run equilibrium. Hence, estimating Y_t as a VAR in first differences is inappropriate if Y_t has an error-correction representation. Therefore, if the variables are non stationary and are cointegrated in the same order, the correct method is to estimate the Vector Error Correction Model (VECM), which is a VAR in first-differences with the addition of a vector of cointegrating residuals. Thus, this VAR system does not lose long run information.

4.2 Granger Causality Test

A time series Y_t Granger causes another time series X_t if present value of X can be better predicted by using past values of Y than by not doing so, considering also that other relevant information (including the past values of X) are used in either case. The standard Granger-causality test can be expressed equation (7) without m_{t-1}. But if the variables are cointegrated, m_{t-1} is necessary. Therefore, more specifically, X_t is said to cause Y_t, provided some b_i in equation (7) is non-zero. Similarly, Y_t is causing X_t if some d_i is not zero in equation (8). If both of these events occur, there is a feedback effect present.

The test for causality can be based on an F-statistic. The causality test can be easily extended to a multivariate framework involving more than two variables. For example, there may be another variable, Z, which jointly cause X or Y. This study utilises the classical procedure of Granger (1969, 1986) and Engle and Granger (1987). The appropriate methodology to be used depends on whether the time series are cointegrated or not. If they are not, then it is appropriate to use the standard methodology developed by Granger (1969).

4.3 Test of Volatility

There are two approaches, impulse response function and variance (forecast error) decomposition, for characterising the dynamic behaviour of the VAR model. Equations (7) and (8) are rather difficult to describe in terms of a_i and f_i coefficients; the impulse response functions and variance decomposition technique suggested by Sims (1980) are useful devices in the VAR framework for testing the sources of variability. The impulse response function can trace the response of the endogenous variables to a shock in another variable. The variance decomposition breaks down the variance of the forecast error for each variable into components that can be attributed to each of the endogenous variables.

Following Sims' (1980) seminal paper, dynamic analysis of VAR model is routinely carried out using the "orthogonalized" impulse responses, where the underlying shocks to the VAR model are orthogonalized using the Cholesky decomposition method. This method assumes the system is recursive and the estimations of impulse response function and variance decomposition are orthogonalized so that the covariance matrix of the resulting innovations is lower triangular. Therefore, the Choleski decomposition method is criticised as an arbitrary method in attributing a common effect and changing the order of the equation may dramatically change the impulses. Recently, Pesaran and Shin (1998) proposed an alternative approach, the generalised impulse response analysis, which is invariant to the ordering of the variables in the VAR. In contrast to the Choleski decomposition method, the generalised impulse response functions are unique.

5. Data Discussion

5.1. Data Description

The only form of housing market data available for long-term analysis in Taiwan are pre-sale house prices and the government survey of house price index. There were no official aggregate price series or indices until recent years. The government survey house price data, released since 1994 from the Directorate General of Budget, Accounting and Statistics, covers the period 1971 to 1993 and is based on detailed attributes of houses on an annual basis. In a comparative study of the government survey data and transaction data from estate agents to estimate annual quality-fixed house prices, Chang (1995), found that the government survey data appears to offer a better quality, but the sample of 23 observations is insufficient for sensible empirical analysis. Therefore, pre-sale listing house price data, collected from monthly reports published for the Taipei district by *Realty Market Monthly*, *Market & Commodity Quotations*, *Land Management Today* and *Construction and Valuation*, is used in this study. The pre-sale prices are listing prices published by house building companies prior to construction of houses, they are not based on actual transactions. The data are a fairly good representation of the new housing market since almost all the pre-sale prices of new houses on the market are collected over the sample period. The information available is an average price per pin of apartments from second floor to top floor. The sample period comprises 1973Q2 to 1994Q4. There are on average 160 observations in the sample per quarter.

This paper adopts a changing-weighted average method to compose a quarterly price index (further details can be found by Chen (1998)) using an assumption that the sample sizes of Taipei downtown are linearly decreasing and those of Taipei county are increasing. This measure reflects the real activity in these areas, and removes seasonal volatility of housing supply. There are in total 87 quarterly observations in our compiled simple average price series.

The data for house price determinants are from various sources (precise definition and sources are provided in the Appendix) and cover the same period as our quarterly house price index. Some economic series are available only on an annual basis and others on monthly basis. Therefore, the annual series are interpolated[3] to generate quarterly observations and monthly data are averaged to produce quarterly observations. These series are not seasonally adjusted. Some variables, measured in nominal terms such as house prices, interest rates, income, stock price index and construction cost index, are deflated by the consumer price index. All the variables are converted to natural logarithms, with the exception of interest rates.

5.2 The Time Series Properties of the Variables

The first step in the cointegration analysis is to determine the order of differencing for the series to achieve stationarity. In other words, we have to find the orders of integration for the variables. Although Dickey-Fuller (1979) test is the most popular tests for stationarity, these tests suffer from some weakness. Therefore, the non-parammetric tests proposed by Phillips-Perron (1988) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) (1992) are performed. The results of these testes are presented in Table 1.

Our model comprises six variables: house prices (lnPh), interest rate (i), construction cost index (lnCC), housing completions (lnHC), total household permanent income (lnTPY), stock price index (lnSPI). The results of both PP and KPSS test indicates that these variables are not stationary in level, but

[3]This paper uses cubic spline interpolation which involves joining segments of third-degree (cubic) polynomial curves.

are stationary after first-differencing. Therefore, these variables are all I(1).

Table 1 : Tests for Stationarity

	Levels				First Difference				Inference
Variables	Z_t	$h_u(0)$	$h_u(4)$	$h_u(8)$	Z_t	$h_u(0)$	$h_u(4)$	$h_u(8)$	
LnPh	-0.54	7.10	1.48	0.87	-7.70	0.24	0.12	0.09	I(1)
LnCC	-1.73	3.27	0.74	0.47	-6.38	0.09	0.05	0.06	I(1)
LnHC	-1.64	2.45	0.52	0.32	-3.54	0.43	0.14	0.15	I(1)
LnTPY	-0.82	8.59	1.81	1.06	-6.10	0.19	0.10	0.10	I(1)
I	-4.81	1.23	0.48	0.39	-12.25	0.01	0.02	0.04	I(1)
LnSPI	-0.70	6.29	1.33	0.78	-6.45	0.20	0.13	0.12	I(1)

Note: 1. Z_t is Phillips-Perron test statistic; η_u is KPSS test statistic for stationary. PP tests: null hypothesis: contain a unit root (not stationary), KPSS test: null hypothesis: stationary

2. The lag length is set equal to four for PP test in order to ensure white noise residuals. Numbers inside the brackets of the η_u are the number of lags. Eight lags of KPSS test, suggested by Kwiatkowski *et al*. (1992) as the maximal value, are tested, but only values of 0, 4 and 8 lags are reported in the table.

3. Critical value for Phillips Z_t:, 5%=-2.89, 1%=-3.51, based on sample size 100, Constant included. Critical value for η_u: 5%=0.463. Number underlined indicates significant at 5% level.

6. Empirical Results and Discussion

The empirical analysis reported here is based on a two stage estimation. In the first stage, cointegration analysis is used to identify cointegrating relationship among these variables. This is important because if two nonstationary variables are cointegrated, a VAR model in the first difference is misspecified. If cointegration relationship is identified, the model should include residuals from the vectors (lagged one period) in the dynamic VECM system.

6.1 Identification of Cointegration Relationship

The estimation procedure consists of estimating cointegration relationship with all the variables from equation (5). The dummy for structural change[4] is treated as an exogenous variable. This is estimated by Johansen (1988) multivariate cointegration test[5]. The test statistics and asymptotic 5% critical values are shown in Table 2 and 3. Both tests reject the hypothesis of no cointegration ($r = 0$) at the 5% level, whereas they do not reject the hypothesis that $r <= 1$. Therefore, the conclusion is that $r = 1$, that is, there is one stationary relationship between the level of the variables. Given that the cointegration relationship exists among these variables, empirical tests are performed based on the VECM.

Table 2 : Johansen's Cointegration Test - Maximal Eigenvalue Test

Null Hypothesis	Alternative Hypothesis	Statistic	95% Critical Value
r = 0	r = 1	46.88*	30.74
r<= 1	r = 2	18.77	24.22
r<= 2	r = 3	5.20	16.90

*Significant at the 5% level

Table 3 : Johansen's Cointegration Test - Trace Test

Null Hypothesis	Alternative Hypothesis	Statistic	95% Critical Value
r = 0	r>= 1	70.85*	53.41
r<= 1	r>= 2	23.96	33.35
r<= 2	r>= 3	5.20	16.90

*Significant at the 5% level

6.2 The Vector Error Correction Model

The model, as specified in section 3, has six endogenous variables in first difference (ΔlnPh, ΔlnTPY, Δi, ΔlnSPI, ΔlnCC, ΔlnHC). The exogenous variables include constant, dummy for structural break and an error correction term as the first period lagged term. The VECM involves selection of lag length in order to check model adequacy. An inappropriate lag selection may give rise to problems of overparameterization and oversimplification. Our objective here is to maximise the forecast precision and ensure that there is no serial correlation present in the residuals. Hence, Schwarz Bayesian criterion (SBC) and Hannan-Quinn criterion (HQC) are used to select the appropriate lag length. Up to seven lags are tested. In a model of six endogenous

[4]Dummy is takes the value 1 from 1987Q1 to 1988Q4 and zero elsewhere.
[5]The details of cointegration tests are not presented, though will be made available upon request.

variables and three exogenous variables, there are six equations, with 45 coefficients of lagged variables, to be estimated with 87 observations. The resulting lag structures are reported in Table 4. The smallest values occur in the first period lags for SBC and in the second period lag for HQC. Too short lag in VAR model may not capture the dynamic behaviour of the variables, consequently, second period lag is considered to be appropriate here[6].

Table 4 : The Selection of Lag Length

Lag Length	SBC	HQC
1	-41.32	-42.30
2	-41.21	-42.84
3	-40.04	-42.32
4	-38.98	-41.91
5	-37.79	-41.38
6	-37.17	-41.41
7	-35.90	-40.79

6.3 Causality Tests

This section is concerned with tests of Granger causality between house price and its determinants. The estimated *F*-statistics of the causality test are reported in Table 5. Row 1 gives the direction of causality, that is, ΔlnTPY ⇒ ΔlnPh denotes that the relevant test is that total household income Granger cause house prices. Column 1 (ΔlnPh ⇒ ΔlnTPY) reports the presence of feedback effect from house prices to the relevant determinant. Row 2 and Column 2 shows the *F*-Statistics for the null hypothesis of no causality (H_0: $Sb_i = 0$ and $Sd_i = 0$ in equation (7) and (8)) between the relevant determinants and house prices.

The results of *F*-tests suggest that, all five house price determinants ⇒ house prices. The hypothesis of non-Granger causality is rejected at the 5% level of significance. The results of the feedback effect, fail to reject the null hypothesis of non-Granger causality at the 10 percent level of significance for most variables, with the exception of house prices and stock price index.

A number of points emerge from this test. First, as Case and Shiller (1989) indicate, there is always some evidence of inertia in house prices, increases in prices over any year tends to follow increase in the subsequent period. Second, permanent income is not found to have a feedback effect on house prices, although theory suggests there exists some wealth effect between

[6]The details of the estimation of the VECM are not presented, though will be made available upon request

asset values and permanent income. The problem may be that the permanent income variable, which is a measure of long-run income stream, does not fully capture the effect of wealth. Chen (1998) that Taipei house prices to household disposable income ratios are increased from 6:1 in 1974 to 9:1 in 1994, reflecting that income did not keep up with the increase in house prices over this period. This implies that increase in wealth created by rapid economic growth is not fully captured by the proxy for permanent income. It is highly likely that wealth accumulated in stock market may show some causality effect on the permanent income variable. The use of total household income is also expected to capture the influence of demographics. However, the rejection of causality weakly implies that house prices do not Granger cause household formation as found by Hendershott and Smith (1985).

Table 5 : *F*-statistics for Tests of Granger-Causality Based on VECM

Dep Variable	ΔlnPh	ΔlnTPY	Δi	ΔlnSPI	ΔlnCC	ΔlnHC
ΔlnPh	8.49**	9.65**	8.11**	3.34**	6.76**	6.17**
ΔlnTPY	2.05	-	-	-	-	-
ΔI	1.05	-	-	-	-	-
ΔlnSPI	2.82*	-	-	-	-	-
ΔlnCC	0.44	-	-	-	-	-
ΔlnHC	0.78	-	-	-	-	-

*Significant at the 10% level, **Significant at the 5% level.

Third, given that in Taiwan pre-sale housing market relatively small amount of initial capital downpayment is required to purchase house, the main effect of interest rate on house prices is likely to come through its effect on builders funding cost. We also expect to observe some feedback effect from house prices to interest rate due to the fact that the Taiwan government have used interest rate to dampen rapid increases in house prices. This feedback effect is, however, not observed in our result.

Fourth, the results indicate that construction costs Granger cause house prices as expected, but the feedback effect is not observed. Although the theory suggests that increase in house prices could push up construction costs, this may not be the case in the short run.
Space Fifth, the Granger test provides an indication of a bilateral relationship between stock price index and house prices, which supports the view that people tend to hold both real and financial assets in their portfolios.

6.4 Test of Source of Volatility

In order to provide further insight into on the relationships of house price and its determinants, the variance decomposition and impulse response function are calculated. These two approaches give an indication of the dynamic properties of the system and allow us to gauge the relative importance of the variables beyond of the sample period.

6.4.1 Variance Decomposition

The variance decomposition measures the percentage of variation in house prices induced by shocks emanating from its relevant determinants. The estimates of variance decomposition are shown in Table 6 for a 24 quarter time horizon. The results indicate that disturbance originating from house price itself inflicted the greatest variability to future prices: it contributes upto 79 percent variability one quarter ahead, approximately 67 percent four quarters ahead. The proportion of variance remains high (66 percent) even until six years (24 quarters). This result indicates that current change in house prices heavily influence people's expectation of future prices changes. Despite an average of 66 percent variability contributed by current price changes, there remains 34 percent of the variability which is explained by other factors. Total household number prevail over all other four house price determinants in influencing house prices. It accounts for approximately 34 percent of the total variance contributed by the five determinants (that is 11 percent of the total house price variance).

Table 6 : Variance Decomposition of House Prices

Quarter	ΔlnPh	ΔlnTRY	Δi	ΔlnSPI	ΔlnCC	ΔlnHC
1	79.44%	2.44%	3.63%	3.00%	7.21%	0.08%
2	68.34%	11.74%	10.25%	4.14%	8.16%	0.29%
3	68.44%	11.51%	10.02%	4.27%	8.05%	0.42%
4	66.94%	11.64%	10.05%	4.49%	8.50%	1.29%
5	66.25%	11.52%	9.94%	4.45%	9.02%	1.92%
8	65.76%	11.42%	9.86%	4.42%	8.96%	2.64%
12	65.68%	11.42%	9.86%	4.42%	8.95%	2.74%
16	65.65%	11.42%	9.86%	4.41%	8.95%	2.78%
20	65.65%	11.42%	9.86%	4.41%	8.95%	2.79%
24	65.64%	11.42%	9.86%	4.41%	8.95%	2.79%
Average	66.01%	11.08%	9.64%	4.34%	8.79%	2.32%

The third largest source of house price variance appears to be from short-run interest rates, which accounts for approximately 29 percent of the total variance contributed by the five determinants (that is 10 percent of the total house price variance). This variable captures the cost of borrowing to household for house purchase as well as builder's development funding cost. A relatively high proportion of the house price variance induced by interest rate confirms its importance to dynamic behaviour of house prices.

The fourth largest source of house price variance appears to be construction cost, which accounts for approximately 26 percent of the variance contributed by the four determinants (that is 9 percent of the total house price variance). Construction cost is a fairly important component of new housing cost that is quite variable in the short time due to changes in material and labour cost. It has been cited by other studies (Chen, (1990), for example) as being one of the important factors behind the first and second house price boom. It is, therefore, not surprising that it contributes a significant proportion of house price volatility.

Apart from these three determinants, the two remaining variables account for less than 7 percent of house price variance. Stock price index accounts for approximately 4 percent to the house price variance (that is, only 13 percent of the total variance from the five determinants). Housing research in Taiwan has found (Hwang, (1994), for example) that the stock market and the housing market markets are interdependent. Our results do not indicate a very significant relationship between the two markets. Clearly, during the past twenty years of rapid economic growth in Taiwan the values of both real assets and financial assets have appreciated enormously. But, the stock market and the housing markets are not perfectly integrated. Stock market, which is highly liquid with relatively low transactions costs, is characterised by high degree of speculative activity. It is possible that the stock market may have some influence on the speculative house building and investment but this is likely to be a temporary phenomenon. Indeed, we observe that although appreciation of stock prices and house prices have coincided over most part of the last twenty years, the dramatic fall in stock prices after 1989[7] was not paralleled by house prices. The strongest co-movement of house prices and stock prices appears to be during the third boom period when stock prices and house prices reached new peaks. This jump across the two markets seems to be caused by structural change, namely, the financial liberalisation in the late 1980s. In our VECM estimation, this jump could have been captured by a dummy.

The final variable in the model, housing completion, contributes very little to house price variance (2 percent of the total variance). The result suggests that the supply factors of the housing market have more long term effect rather than a short-run influence which is being modelled in the VECM.

Compared with existing studies, our VECM results differ in several ways. First, in Hwang's study (1994), the stock price index is the most influential

[7] After mid 1989, the stock price index fell from 12,000 to 4,000 within a year.

variable for house prices and it is the largest source of house price variability (19 percent). This variable is not very significant in our empirical study. The explanation cited above might be a possible reason. Second, construction cost plays a vital role in our specification of the VECM, but this variable is not incorporated in Hwang's model. Third, in Hwang's VAR system with six macro-economic variables, a considerably larger proportion (approximately 67 percent) of the house price variance was accounted for by the house price determinants. Chang *et al* (1994) also find a large proportion (approximately 50 percent) of house price variance was accounted for by its determinants. The likely explanation of this difference might be that this paper has used a structural break dummy and an error correction term in the VECM system which account for a large proportion of house price variance in the system.

6.4.2 Impulse Response Functions

Although variance decomposition by the estimate of the proportion of house price variance accounted its determinants, it cannot indicate whether the impact is positive or negative, or whether it is a temporary jump or long-run persistence. Thus, impulse response functions are computed to give an indication of the system's dynamic behaviour. Also, the impulse response functions can be used to predict the responses from house price determinants to house prices. An impulse response function shows how a variable in the VECM system responds to a single 1 percent exogenous change in another variable of interest.

Figure 1 to Figure 6 illustrates the estimated impulse response functions for twenty-four quarters. In response to a one standard deviation disturbance in current house price itself (Figure 1), future house price increase by 4.1 percent in the first quarter. This appears to die out very quickly, implying that the current price change has a greater influence on people’s expectation of the next quarter’s price rather than over longer term horizon.

A one standard deviation disturbance originating from household permanent income (Figure 2) produces upto 0.38 percent of increase in house prices; the speed of adjustment is fairly is rapid and it declines after the third quarter.

Figure 1 Response from Housing prices

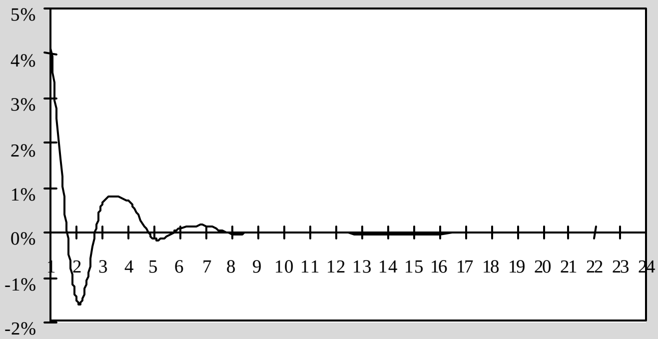


Figure 2 Response from total Household Income

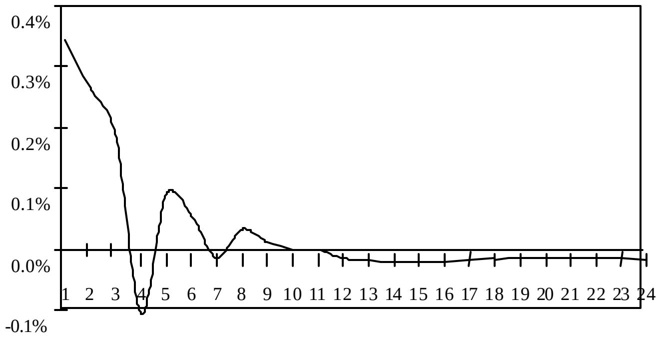
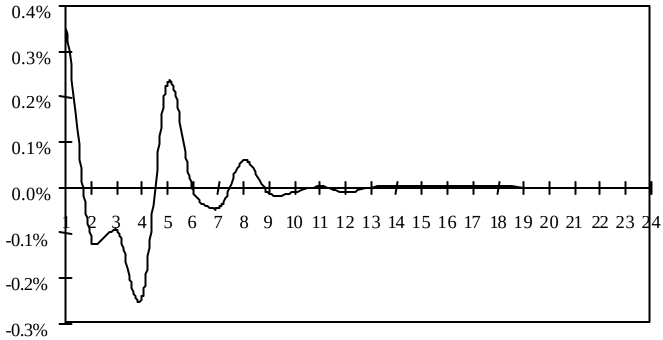


Figure 3:Response from short term interest rates



A one standard deviation disturbance originating from interest rate (Figure 3) results in an approximately 0.4 percent increase in house prices in first quarter; the price adjustment, however, undergoes a reversal (-0.1 to -0.25 percent) between second to fourth quarter. Given that interest rate is often used by the Taiwan government to dampen house price inflation, higher interest cost could both raise house prices and also reduce demand and, consequently, decrease the price. As can be seen in the Figure 3, interest rate has a negative a relationship mostly in first year, implying that the chief determinant change in house prices is on the demand side in the short-run. But the positive sign after fifth quarter suggests that the rise in interest rate increases builders' cost of capital which is subsequently passed on in higher house prices in the long-run.

A one standard deviation disturbance originating from stock price index (Figure 4) results in an approximately 3.2 percent in change in house prices. It initially produces a negative impact on house prices in first two quarter and has a large positive impact in third quarter. The possible explanation for the positive and negative impacts could be the influence of speculative activity in the stock market spilling over to invest in the housing market. It is also feasible that wealth created in the stock market has a positive effect on the housing market in the long run.

Construction cost (Figure 5) has positive effect on house prices as expected. Its greatest positive effect (0.25 percent) occurs in first quarter, implying that builders adjust house prices rapidly in line with change in construction cost.

Housing completion is expected to have a negative effect on house prices. In Figure 6, however, we find that housing completion results in upto 0.5% increase in house prices during the first eight quarters and there is a negative response after eight quarters. The results appear suggest that house price increases induce developers to expect higher profits, thereby undertaking more residential development, so positive responses is found.

Generally the results of the impulse response functions for the variables in this study are consistent with those reported by Hwang (1994). However, given our specific cointegration constraints in the VECM, impulse response function in our study gradually decline to the steady state in all cases. For traditional first-difference VAR model, the impulse response function would not converge to zero.

Figure 4: Response from Stock Prices

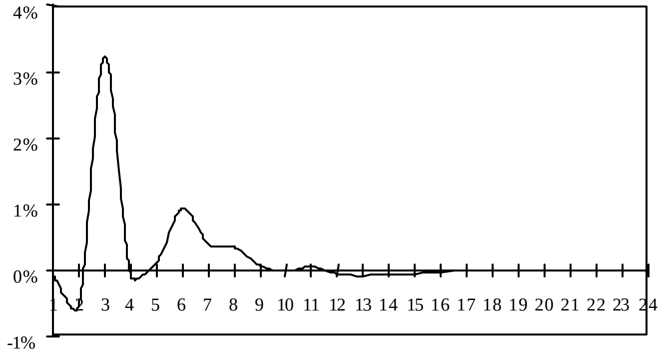


Figure 5: Response from Construction Costs

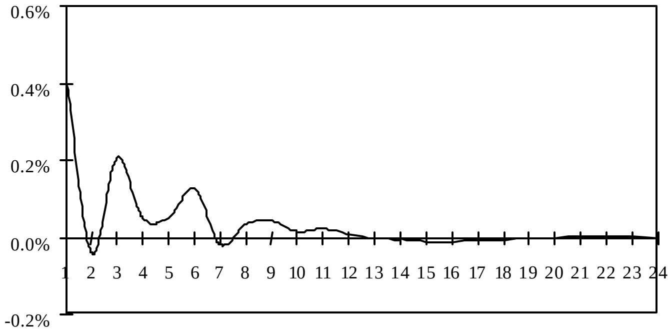
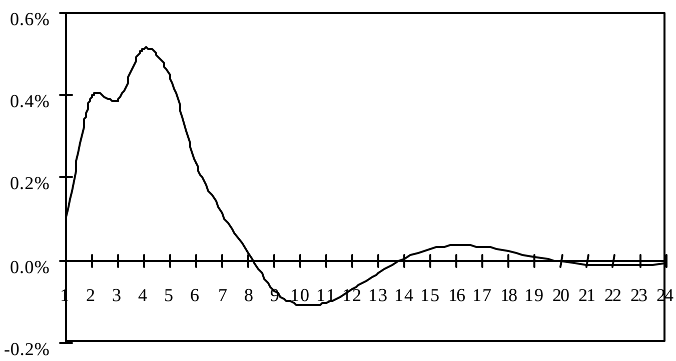


Figure 6: Response from Housing Completion



7. Conclusion

The overall objective of this paper is to investigate the sources and the extent of house price volatility and examine the causality relationship between house price and its determinants within the context of a partial macroeconomic system. The methodology employed include unit root tests, Johansen's cointegration test, Granger causality tests and estimation of the VECM.

A number of limitation of the study should be noted before we highlight our key findings. First, data collection in a newly-industrialised country such as Taiwan presents a number of difficulties. Transaction data on house prices are not available in Taiwan for sufficiently long enough time period. In this study we collected pre-sale house price data for the Taipei region which are listing prices rather than transaction prices. Second, the theoretical model specified in this study is a partial macroeconomic system which did not permit a full investigation of other indirect influences on the house prices. Simplification of specification and assumptions are necessary for empirical purposes and there will always be room for future research to address these shortcomings.

Our findings indicate that there is a long-run equilibrium relationship between house price and its determinants including construction cost, interest rate, total household permanent income, housing completion and stock price index. The results of causality tests confirm that the five house price determinants Granger cause house prices, and feedback effects are observed for house prices and the stock price index. In order to test the source of volatility and identify the responses from house price determinants, we decompose the house price variance. The results indicate that a disturbance originating from current house prices induces the greatest variability to future prices: it accounts for 79 percent of the variability one period ahead, approximately 67 percent four quarters ahead and 66 percent six years ahead. The remaining variance is accounted for by the five determinants. The supply side factors (construction costs and housing completions) account for 10 percent of the variance and demand side factors another 24 percent. Although previous housing market studies place a great deal of emphasis on demand side factors in the short-run, the finding in this study suggests that the supply side factors should not be underestimated in the new dwellings market.

Finally, there are a number of policy implications arising from our results. A detailed decomposition of the variance of house price change provide useful insights into the sources of variability for housing policy consideration. On the supply side, construction costs and housing completions have different magnitudes of impact on house price changes and therefore these supply side factors call for different policy measures. On the demand side, we need to carefully assess the impact of interest rate change in the short run verses the long term effect. For long-run forecasting and hosing policy targets, it is essential to take into account the long-run factors such as permanent income and household formation.

The authors are grateful for the comments of anonymous referees. We alone remain responsible for the contents

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Appendix : Data Definition and Sources

CPI Consumer price index (1991=100). Averaged from monthly data.
Source: Commodity Price Statistics Monthly in Taiwan Area of the Republic of China.

HC Floor area of permit for occupancy (Housing completions) for new residence, m^2. Interpolated from annual series. Taipei city figure instead of Taipei area figure is used as a proxy because the figures for Taipei county are not obtainable before 1976.
Source: Urban and Regional Development Statistics, Republic of China

HHN Household numbers Taipei city and county. Interpolated from annual series.
Source: The Statistical abstract of Taipei Municipality and Taipei County Statistics

CC Taipei construction cost index (1991=100). Averaged from monthly data.
Source: Commodity Price Statistics Monthly in Taiwan Area of the Republic of China.

Ph Average pre-sale listing house prices, NT$1,000/Ping.
Source: Various real estate journals.

PY Household permanent income in Taipei city and county. Estimated from household current receipts (disposable incomes, denoted Y) by Almon polynomial (A_2(Y)) after interpolated from annual data.
Source: The Statistical abstract of Taipei Municipality and Taipei County Statistics

i Short-term secured loans (Temporary accommodations), 1 year and less. Averaged from monthly data.
Source: Financial Statistics Monthly, Taiwan District, the Republic of China

SPI Stock price index (1991=100). Averaged from end of month figures.

Source: Taiwan Stock Exchange
TPY $HHN_t \times PY_t$