The decomposition of housing market variations

A panel data approach

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Abstract

Purpose – This paper develops a new decomposition method of the housing market variations to analyse the housing dynamics of the Australian eight capital cities.

Design/methodology/approach – This study reviews the prior research on analysing the housing market variations and classifies the previous methods into four main models. Based on this, the study develops a new decomposition of the variations, which is made up of regional information, home-market information and time information. The panel data regression method, unit root test and F test are adopted to construct the model and interpret the housing market variations of the Australian capital cities.

Findings – This paper suggests that the Australian home-market information has the same elasticity to the housing market variations across cities and time. In contrast, the elasticities of the regional information are distinguished. However, similarities exit in the west and north of Australia or the south and east of Australia. The time information contributes differently along the observing period, although the similarities are found in certain periods.

Originality/value – This paper introduces the housing market variation decomposition into the research of housing market variations and develops a model based on the new method of the housing market variation decomposition.

1. Introduction

House price indexes (HPI) are normally used to describe the changes in house prices. The values of indexes indicate the house price movements of certain countries or cities rather than house price levels. There are many institutions which construct and publish the national or sub-national HPI. In Australia, Australian Bureau of Statistics (ABS), Australian Property Monitors, Commonwealth Bank of Australia, Reserve Bank of Australia, Real Estate Institute of Australia and Valuer General’s Office are considered as the major sources for HPI. However, the HPI constructed by each institution are different from each other, due to the distinguished methods and original data.

The issue of housing market variations is widely argued in the real estate research area. There are four popular models to analyse the factors which cause dynamics of house prices, namely the fundamental model, the hedonic model, the repeat-sales model and the ripple-effect model. All these models are based on the efficient market hypothesis, which states that the market prices should fully reflect available information (Fama, 1970). Each model classifies the information and intends to find how the certain category of information
attributes to the housing market variations. The fundamental model is based on the idea that the housing market variations are driven by the economic factors, such as incomes, gross domestic products, rents, mortgage rates, inflation rates, supplies and demands and so on. The hedonic model focuses on how the structure characteristics and the neighbourhood information would drive the movements of house prices in a certain period. The repeat-sales model uses the differences between the initial sale price and the final sale price to construct the dynamics of house price. The ripple-effect model considers that the housing dynamic in one region is caused by the shocks of house prices in the same and other regions. However, the most controversial issue for those models is whether the models have included sufficient information or excludes the unrelated information.

The valuation of houses is complicated, due to the unique properties of houses. However, all the sets of information, which can influence housing prices, vary along either or both of the two dimensions, namely time and region. In that case, the characteristics of houses, which will change temporally and regionally, are one of the main determinations of house valuation. Moreover, as the immobility and un-transportation of houses, regional information of houses, which will not move along with the time, is also regarded as a main factor when valuating house prices. Furthermore, the aggregate time trends are another factor influencing house prices. This study investigates the housing market variations under the assumption that the information should be decomposed of home-market information, regional information and time information. The panel data regressions are adopted to estimate the model under the decomposition method. Furthermore, the HPI of the Australian capital cities are used to interpret the application of the model. The results show that the home-market information has the same impacting power on the housing market variations across the Australian capital cities. The regional information of western and northern cities enhances the increases of house prices, while the one of eastern and southern cities slow down the increases of house prices. Moreover, the trends of the impacts of the time information changed during the last two decades. The next section provides the reviews of prior research that studies the background of efficient market and the housing market variations through fundamental models, ripple-effect models, hedonic models and repeat-sales models. The following section shows an introduction of the new decomposition of the housing market variations and the construction of the model with panel data regression. The application and the interpretation of the new model based on the HPI of the Australian capital cities are given in the subsequent section. And the conclusions are suggested finally.

2. **Decomposition methods of conventional housing market variations**

2.1 **Classification of previous housing market variation decomposition practices**

In the fundamental models the housing-dynamic information is composed of economic factors, which can be expressed as follows: (Equation 1) where \( \Delta p_t = p_t - p_{t-1} \), which denotes the house price dynamics at time \( t \). \( \Phi_{econo,m} \) and \( B \) are the sets of economic factor information at time \( t \) and the corresponding estimates, respectively. \( r \) stands for the housing market returns in certain economic conditions. That means fundamental models regard the economic factors, such as GDP, mortgage rates, incomes, inflation rates, rents and so on, as the major engine of house price dynamics. One research decomposed the
dynamics of house prices into five factors, namely growth rate of GDP, inflation rate in consumer prices, the real short-term interest rate, the term spread and the growth rate in inflation-adjusted bank credit, in 17 countries (Tsatsaronis and Zhu, 2004). The results showed that the inflation of consumer prices accounted for most proportion of the variation of house prices. The factors related to the mortgage finance were less important in explaining the dynamics of house prices, while the household income had the lowest explanatory power over house price movements. Other studies suggest that the housing market variations should be determined by the spread of costs of housing, which are caused by depreciation rates, property tax rates, income tax rates, interest rates and the rents generated from houses. This is so-called rent-price ratio, which is widely regarded as an indicator of housing market bubbles. Gallin (2008) examined the predicting power of the rent-price ratio through error-correction model and long-horizon regression models. The findings supported the statement that the rent-price ratio was an indicator of housing markets. In another study, two models were proposed to estimate house prices, which were rent model and supply-demand model (Hott and Monnin, 2008). In the rent model, the actual rents were used to stand for the imputed rent, while in the supply-demand model the imputed rents were regarded as the outcome of a market for housing, which was determined by the supply of and the demand for housing. The results indicated that the latter model had better forecasting power. Although the fundamental models can explain the relationships between house prices and other economic factors, the research is limited in a certain country or region. In other words, the potential interconnections between regions are ignored.

The hedonic model is based on the hypothesis that goods were valued for their utility-bearing attributes or characteristics (Rosen, 1974). The model can be simply expressed as (Equation 2) Equation (2) indicates that the house price variations (Δ p_i) of the houses in region i are determined by the set of information (Φ_characteristics_i) carried by the characteristics of the houses. It was mentioned that the variations of houses can be decomposed into different factors, which are the national, market, submarket (neighbourhood) and structural characteristic returns (Zabel, 1999). Another study formulated a rich class of spatial-temporal hedonic models for house prices to examine spatial and temporal effects on house prices (Gelfand et al., 2004). It was suggested that the characteristics of location include neighbourhood features and accessibility to certain externalities and spatial effects should be very important in explaining the house prices. Sirmans et al. (2005) supplied a review of 125 studies, which estimated house prices through the hedonic model. Their findings implied that the results of coefficients of the house characteristics varied across studies and no clear conclusion about the selection of key characteristics had been made. Another research also stated that the valuations of characteristics were different across a given distribution of house prices (Zietz et al., 2008). However, how to address the effects that are brought by the time variation cannot be resolved completely with hedonic models.

Another method to analysing the housing market variations is the repeat-sales model, which was first proposed by Bailey et al. (1963). This method constructs the housing market variations based on sales prices of the same property at different times. In this way, it can avoid the estimating difficulty of quality differences, assuming the house characteristics constant. The models is expressed as (Equation 3) Case and Shiller (1987) improved the
repeat-sales model through the generalized least square regression, which was the weighted repeat-sales model, and analysed the appreciation rate of single-family homes. This method was widely adopted by researchers to construct the HPI. It was applied to develop an HPI for the Netherlands and the accuracy was proved to be adequate through the revision of the model and exploring the heteroskedasticity (Jansen et al., 2008). However, whether it is reasonable that the physical characteristics keep constant between two time-points of sales is argued. Cannaday et al. (2005) suggested that at least the asset’s age should change between sales. Furthermore, a multivariate repeat-sales model was proposed in their study, which could control for the effects of age and time individually.

The ripple-effect models were early mentioned in the research of the UK regional house prices literature (Alexander and Barrow, 1994; Ashworth and Parker, 1997; Pollakowski and Ray, 1997). This model is based on the consideration that the aggregated housing market should be made up of a series of interconnected regional and local markets (Meen, 1996). The models can be expressed as: (Equation 4) Therefore, the housing market variations at time \( t \) in region \( i \) are caused by the housing market information \( (\Phi_{market_{t,1}}) \), which is decomposed of the information from the home market and neighbouring markets. The ripple effects of housing prices in the Republic of Ireland were detected through the cointegration test and the Granger causality test (Stevenson, 2004). Furthermore, Liu et al. (2008) identified the interconnections between housing dynamics of the Australian capital cities using the impose response. Although the house price correlations between different regions can be interpreted by ripple-effect models, the estimating method of the model determine that the regional effects are still unconsidered.

### 2.2 Housing market variation decomposition principles

Four traditional models, which are used to analyse variations of house prices, are classified according to the information. It is indicated that the basic idea of modelling the housing market variations is that, under the efficient market hypothesis, the market prices fully reflect available information, which was raised by Fama (1970). That is to say house prices are regarded as the representative of the aggregate of the information. Thus the house prices can be expressed as follows: (Equation 5) where \( P_R \) denotes the house prices in region \( i \) at period \( t \), \( \Phi_{i,t} \) stands for the information available for the housing market in region \( i \) at period \( t \) and \( r_R \) indicates returns. The log form of above estimation is: (Equation 6) where lowercase \( p \) denotes the log values of house prices and \( f(\Phi_{i,t-1}) = \ln(1+E(r_{jt} | \Phi_{i,t-1})) \). According to Equation (6), the housing dynamics at period \( t \) is determined by the past information, which can be expressed as (Equation 7) where \( inf_{j,t-1} \) and \( \beta_{j,t} \) stand for the past information \( j \) and the estimated coefficients in region \( i \) at period \( t \), respectively. Therefore housing market variations can be considered as the impacts of series of available related information. There are several ways to analyse housing market variations. Therefore, the decomposition methods of the housing market variations vary in different research methods. Table I generalizes the information, which is used in the four models to analyse the housing market variations.

To sum up, the housing research based on fundamental models can explain the housing market dynamics in a certain country or region by time lagged economic factors, while the ripple-effect models consider that the housing market dynamics would be influenced by the
historical performances of the home market and other markets. However, both these two set of models assume that the investigated markets should be isolated from each other. This means that the potential interconnections between markets in different regions are ignored when estimating the models. Moreover, the hedonic and the repeat-sales models are not able to interpret the effects from time variations to house price dynamics, although the models can explain valuations of houses across regions for a certain period.

3. A new decomposition method

3.1 The housing market information

As mentioned above, the controversial issue about previous models is whether the decomposition models contain all variables that cause the housing market variations. Moreover, the previous models cannot address the housing price dynamics in both temporal and regional respects. The new decomposition method developed in this paper group all information affecting the variations of a housing market into time, region and its identity dimensions. First, the characteristics such as house sizes, lots, ages, building materials and so on form one determination of house values, and these kinds of home-market information distinguish a housing market from the others. Under the efficient market hypothesis, all the information of the housing market in region $i$ at time $t$ is reflected by the latest house prices $(p_{i,t-1})$ and the price movements $(\Delta p_{i,t-1})$. Second, the housing market of a region can be regarded as a unique note of the national housing market, and the regional information reflects its connections with other regions but is independent from time. The regional information is another determination of the market variations. Third, the time differences of house prices indicate that the time information also affects the housing market variations and the influence of time onto the housing market is unrelated to its location and self characters. The regional and time information categories are denoted as $\alpha_i$ and $\gamma_t$, respectively. The housing market variations being decomposed into home-market, regional and time information can therefore be modelled as Equation (8) and the remaining of this section will briefly demonstrate the process using panel data analysis to estimate the coefficients of three sorts of information. (Equation 8) Seen from Equation (8), the house price dynamics move along the time and across regions. In addition, the regional information varies across regions and time information varies along time, while the home-market information move temporally and spatially.

3.2 Identifying the decomposition model using a panel data approach

The stationarity, which indicates that the data series have the constant mean and variance, is an important property for house price levels. If the house price levels are stationary process, the information generated from past house prices will contribute to the housing market variations. However, if the price levels are not stationary, the house price movements will hardly be impacted by the price levels, which means the price information do not drive the housing dynamic significantly. Therefore the first stage is to test the stationarity of house price levels. There are two main methods for panel data to test the unit root. One is the common unit root test, while the other is the individual unit root test. Both of the sets of tests are based on the expression of Augmented Dicky-Fuller test (Dicky and Fuller, 1979). In this study, the method used to test the common unit root is the Levin-
Lin-Chu (LLC) test (Levin et al., 2002). Im-Pesaran-Skin (IPS) test (Im et al., 2003) is introduced in this study to test the individual unit root for the house price levels. Once the house price levels are confirmed as non-stationary processes, the housing market variations are hardly correlated with the house price levels. Therefore the housing market variations decomposition will be modified as: (Equation 9) where the $\alpha_t$, $\beta_{it}$, $\psi$, and $\varphi_i$ are estimated parameters, while $e_{it}$ is the error term which is assumed to be the independent and identically distributed process.

The other issue of the current model is that whether the effecting powers of the regional information, the home-market information and the time information change over regions or time. This is the so-called test of homogeneities of parameters for panel data regressions, which is achieved through $F$ tests (Hsiao, 2003). The $F$ tests are carried out to test whether the elasticity of the regional information and the home-market information should vary along time or across regions. The non-hypothesis of $F$ tests is that the elasticity of regional information and home-market information should be the same at different periods and regions. The calculations of $F$ tests are interpreted in the book of Hsiao (2003). $F_0$ and $F_1$ denote the values of $F$ tests for the elasticities of regional information and home-market information across the regions, respectively. If $F_0$ is not significant, it means the regional information and the home-market information have the same contribution to the housing dynamics across regions. However, if $F_0$ is significant but $F_1$ is not, it is indicated that the regional information may impact the house price movements differently across regions, although the powers of home-market information are the same. If $F_1$ is also significant, it means that the home-market information have different elasticity in each region. The process can also be adopted to test the parameters of time effects, in which the values of the $F$ tests are denoted by $F_0'$ and $F_1'$.

4. An empirical study

4.1 The Australian housing markets

The HPI published quarterly by ABS are a series of price indices measuring changes in the prices for each of the eight capital cities of Australia (ABS, 2009). The stratification approach is used by ABS to calculate the HPI for the capital cities. This approach weights the medium prices of groups of houses, which are stratified to minimize the physical heterogeneity of houses, to construct the HPI. The HPI are constructed by reference to the current and historical market prices of the entire stock of residential dwellings and calculated on the reference base 1989-1990 = 100 (ABS, 2005). Although the ABS has changed the reference base since 2005, to keep the constant, all the data used in this research have been converted to the values which take 1989-1990 as the reference base. The observation period is from the December quarter 1989 to the December quarter 2008.

During 1989-2008, the biggest change in house prices was in Darwin increasing by 350.3 per cent, followed by Brisbane (318.7 per cent) and Adelaide (286.9 per cent). The Darwin housing market showed a very different behaviour from the other seven markets. Except for Darwin, the other seven all had a slow increase trend at first which was followed by a sharp increase. Melbourne’s boom started in the December quarter 1996 while the booms in Adelaide, Perth and Sydney started in the March quarter 1997, followed by Canberra and
Hobart at June quarter 2000, and Brisbane at June quarter 2002. Darwin started its first sharp increase from the December quarter 1989 until the June quarter 1997, with an average change rate of 3.62 per cent per quarter followed by a steady increase until the September quarter 2000. The latest sharp increase in Darwin started from the December quarter 2001.

Table II shows the results of LLC common unit root test and IPS individual unit root test for HPI of the eight cities. The results of these two tests indicate that the HPI of the eight capital cities are not stationary, although the first differences of the HPI are proved to be stationary. As non-stationary series, the parameters of historical price levels \( \varphi_i \) in Equation (8) cannot be different from 0 significantly. That means the information carried by the house prices of the capital cities do not contribute to the housing market variations. Furthermore, including the non-stationary data will make the estimations of the regressions biased and inconsistent, which leads to the statistical results unreliable. Therefore, it is better to estimate the regressions with Equation (9).

4.2 Influences of the home-market, regional and time information

At this stage, it is to test the regional and time homogeneity of the contributions of each set of the information to the Australian housing market variations. The results of the \( F \) statistics for the parameters of the regressions show that the values of \( F_0 \) and \( F' \) are significant at 5 per cent, while the values of \( F_1 \) and \( F'1 \) are not. This suggests that the regression should share the same slope across regions and time but the individual regional effects and the time effects be required. This indicates that the information from the eight housing markets of the Australian capital cities supplies the same impacts for the house price dynamics. However, the impacts of the regional information vary across different cities. Meanwhile the contributions of time information are distinguished over the observing period (Table III).

Table IV shows the estimated parameters of regional information based on Equation (9). The regional information has positive elasticities of house price dynamics in the models for Adelaide, Brisbane, Darwin and Perth, but negative elasticities in the models for Canberra, Hobart, Melbourne and Sydney. The regional information of Darwin, Brisbane and Perth, which have the positive elasticities at 0.0029, 0.0013 and 0.0007, will strongly enhance the increase speed of house prices, while the one of Hobart, Sydney and Canberra, which have the negative elasticities at –0.0021, –0.0020 and –0.0006, will slow down the house price increases. The regional information of Adelaide and Melbourne have the less significant elasticities compared with others, which indicates that the impacting powers of the regional information are low in these two cities. Furthermore, the slope of the model, which stands for the elasticity of the home-market information to the housing market variations, is about 0.3162. This indicates that the information of Australian individual housing markets share the same power of influencing the housing market variations. It is suggested that around 32 per cent of the last housing market variations should contribute the current ones. However, the impacts cannot last for long but decrease to 0 after a few quarters.

Moreover, Figure 1 describes the time information affecting on the dynamic HPI from the June 1990 to December 2008. During the first 11 years, most the time effects are negative,
which would slow down the HPI increase of the eight capital cities. However, from the last quarter of 2000, the effects began to accelerate the speed of the HPI increase, and until the third quarter of 2003 the acceleration reached the peak at about 0.0361. The time effects cooled down the HPI increases during the next three quarter, and the second boom of housing market occurred at the end of 2004, which lasted unit 2007. The increase speed of HPI was slowed down by the time effects during the whole year of 2008.

5. Conclusions

This study reviews the prior research on analysing housing market variations. Four main models are classified based on the decomposition of housing market variations, namely fundamental models, hedonic models, repeat-sales models and ripple-effect models. Although these models explained the house price dynamics well in certain respect, they can hardly cover all the information influencing housing dynamics and analyse in only one dimension. Moreover, this study develops a new decomposition of the housing dynamics, which can based on the whole property of housing dynamics, assuming the housing market variations should be made up of regional information, home-market information and time information. The panel data regression is adopted to analyse the housing market variations under the decomposition. Unit root test and F test are also included to determine the specification of the model.

The HPI of the Australian capital cities from the December 1989 to the December 2008 were taken as an example to interpret the model. The results suggest that the home-market information of the Australian capital cities had the equal impacting power to the housing dynamics across the eight capital cities over the observing period. However, the regional information contributed differently from city to city. Specifically, the regional information of the cities in the west and north of Australia enhanced the increase speed of house prices, while the eastern and southern cities slowed down the increases. The time information played a filter role on the house price changes in the first decade over the observing period and then pushed the house price up by the end of 2008.
Figure 1. The quarterly time effects on the Australian housing market variations

Table I. Conventional methods of the housing market variation decomposition

<table>
<thead>
<tr>
<th>Decomposition models</th>
<th>Cited publications</th>
<th>Decomposition variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedonic model</td>
<td>Rosen (1974), Zabel (1999), Gelfand et al. (2004), Sirmans et al. (2005), Zietz et al. (2008)</td>
<td>House structures and neighbourhoods, like sizes, lots, ages, neighbourhood facilities, etc.</td>
</tr>
<tr>
<td>Repeat-sales model</td>
<td>Bailey et al. (1963), Case and Shiller (1987), Cannaday et al. (2005), Jansen et al. (2008)</td>
<td>Prices of the sales for the same houses</td>
</tr>
<tr>
<td></td>
<td>LLC common unit root test</td>
<td>IPS individual unit root test</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td></td>
<td>( t )-Statistic</td>
<td>( p )-Value</td>
</tr>
<tr>
<td>The level</td>
<td>3.6951</td>
<td>0.9999(^{a})</td>
</tr>
<tr>
<td>The first difference</td>
<td>-6.9592</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

**Note:** \(^{a}\)Denotes the stationary property is rejected at 5 per cent

**Table II.** The results of LLC and IPS unit root tests

<table>
<thead>
<tr>
<th></th>
<th>( F_0 )</th>
<th>( F_1 )</th>
<th>( F_0' )</th>
<th>( F_1' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values of ( F ) statistics</td>
<td>2.851.4761</td>
<td>4.7860(^{a})</td>
<td>28.7752</td>
<td>1.6489(^{a})</td>
</tr>
</tbody>
</table>

**Notes:** \(^{a}\)Denotes the \( F \) test is not significant, therefore accept the non-hypothesis: \( F_0 \) and \( F_1 \) are the values of \( F \) tests for the elasticities of regional information and home-market information across the regions, respectively, while \( F_0' \) and \( F_1' \) are the values of \( F \) tests for the elasticities of time information and home-market information along the time

**Table III.** The results of \( F \) tests for model identification

<table>
<thead>
<tr>
<th>Cities (i)</th>
<th>Adelaide</th>
<th>Brisbane</th>
<th>Canberra</th>
<th>Darwin</th>
<th>Hobart</th>
<th>Melbourne</th>
<th>Perth</th>
<th>Sydney</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_4 )</td>
<td>0.0000</td>
<td>0.0013</td>
<td>-0.0006</td>
<td>0.0029</td>
<td>-0.0021</td>
<td>-0.0001</td>
<td>0.0007</td>
<td>-0.0020</td>
</tr>
</tbody>
</table>

**Table IV.** The effects of the regional information in eight capital cities

\[
\Delta p_i = f(r_i | B, \Phi_{economic,i})
\]

**Equation 1**

\[
\Delta p_i = f(r_i | B, \Phi_{characteristics,i})
\]

**Equation 2**

\[
\Delta p_i = f(r_i | B, \Phi_{spread,i})
\]

**Equation 3**

\[
\Delta p_i = f(r_i | B, \Phi_{markets,i})
\]

**Equation 4**
\[ P_{i,t} = [1 + E(r_{i,t}|\Phi_{i,t-1})]P_{i,t-1} \]  \hspace{1cm} (5)

Equation 5

\[ \Delta p_{i,t} = f(r_{i,t}|\Phi_{i,t-1}) + p_{i,t-1} \]  \hspace{1cm} (6)

Equation 6

\[ \Delta p_{i,t} = f(r_{i,t}|\Phi_{i,t-1}) = \sum_{j} (\beta_{j,i,t} \times \inf_{j,i,t-1}) \]  \hspace{1cm} (7)

Equation 7

\[ \Delta p_{i,t} = f(\alpha_{i}, \Delta p_{i,t-1}, \gamma_{i}, p_{i,t-1}) \]  \hspace{1cm} (8)

Equation 8

\[ \Delta p_{i,t} = f(\alpha_{i}, \Delta p_{i,t-1}, \gamma_{i}) = \alpha_{i} + \beta_{i} \Delta p_{i,t-1} + \gamma_{i} + \varepsilon_{i} \]  \hspace{1cm} (9)

Equation 9

References


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