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Hedonic house prices in the presence of spatial and temporal dynamics

Keywords house price, hedonic method, monocentric model, spatial dependence, Hodrick and Prescott filter

Abstract The purpose of this article is to combine structural, spatial and temporal attributes of house prices within a single set-up. We use the hedonic price method (HPM) which is founded on the idea that a commodity is characterized by its constituent properties, and the value of a commodity can be calculated by adding up the estimated values of its separate properties.

Based on this proposition, the HPM provides a basis to estimate house prices taking into account the structural characteristics of a housing unit. On the other hand, the urban monocentric model states that the principal variable causing variations in constant-quality house prices within a metro area is land price, and hence suggests that distance to the Central Business District (CBD) should be included in the house price model. In addition, literature related to temporal dynamics of house prices justifies adding-in a time variable as a determinant of house price. The inclusion of the temporal dimension allows capturing the time related dynamics of the market such as volatile prices or price cycles. Most of the previous analyses of house prices do not typically take into account structural, spatial and temporal dimensions jointly; thus, the estimates produced are likely to be biased. The composite model suggested here will reflect temporal and spatial dimensions in addition to the quality of a house represented by its intrinsic characteristics.

INTRODUCTION

An increasing number of theoretical and empirical studies have dealt with the determinants of house prices over the last several decades. The hedonic price method (hereafter, HPM) is undoubtedly one of the most popular and most used methods employed in these studies. The idea of hedonic prices has its origin in microeconomics. Determination of demand of certain goods – particularly of those that come as composite goods with several intrinsic features or characteristics – becomes increasingly difficult, and this difficulty led to the introduction of the HPM. There were several different applications that considered this “multi-dimensional” nature of commodities, although Rosen (1974) was the first to clearly refine the concept by mapping out how the hedonic prices represented the joint envelope of bids (from demand side) and offers (from supply side).

Most early hedonic models of house prices typically included several structural characteristics of housing units as exogenous variables. Subsequently, spatial hedonic models emerged with the widespread use of location and neighbourhood concepts in urban economics.

Hedonic models were further expanded recently to include temporal dimension as a result of the increasing number of panel data-sets available for real estate and urban economics research. The extended model takes into account both spatial and temporal dynamics of house prices

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simultaneously. The applications of this extended model which is known as the spatial panel model include, among others, Mendelsohn et al. (1992), Kim (1993), and Baltagi and Chang (1994). Herath and Maier (2010) provide a detailed account of HPM applications in real estate research.

The purpose of the present article is to put forward a new mechanism that is capable of capturing temporal dynamics and to combine structural characteristics of houses along with spatial and temporal aspects within the house price model. Initially, the article deals with the research question "what factors influence house prices?" This section provides a discussion of theoretical and methodological developments related to the hedonic regression, spatial hedonic models, and temporal models of house price dynamics. The article then deals with a conceptual composite model that incorporates these three pillars of house price determinants, i.e. structural characteristics of houses, spatial attributes and temporal dynamics. The research question addressed in this section is whether the proposed composite model produces unbiased and consistent estimates of implicit prices of characteristics. If the error term of the composite model is stochastic and independently and identically distributed (*iid*), then it provides statistical evidence that house prices are influenced by a combination of structural characteristics, spatial attributes and temporal dynamics.

The motivation for this study comes from the appraisal practice and appraisal literature. The traditional appraiser considers intrinsic attributes of real estate property, and attempts to homogenize the quality of the sample properties when assessing the value of a subject property. The appraisal process today, additionally, makes efforts to standardize the impact of change in temporal dynamics and the possible effect of location of properties by considering only similar properties sold recently in the same neighbourhood. The valuer reduces heterogeneity through selection of comparables and this approach to real estate valuation allows for a strong role of the appraiser's personal opinion. For instance, the sales comparison approach to real estate appraisal derives the estimated value of a subject property from transaction prices of recently sold similar properties in the local market. In this way, only a very limited number of available transaction information is utilized in the appraisal. What transactions are to be used in the appraisal and what to be excluded is decided by the valuer alone, although the appraiser is someway able to make available a set of comparable properties for appraisal.

Similarly, the early appraisal literature considers structural attributes as the principal determinant of the value of a house. The appraisal literature advances one step further when it takes into account spatial and temporal interdependencies when assessing value of real estate (Björklund & Söderberg 1999). Two such examples are found in Born & Pyhrr (1994) and Clayton (1996) where property cycles are integrated into the income approach to real estate valuation. Additionally, real estate price indices in general and house price indices in particular are used to standardize effects of macroeconomic variables on house prices.

On the one hand, the appraisal literature and literature related to indices can provide some vital information about factors that may have an influence on house prices. For instance, if it is possible to assess the price of a constant-quality house, it provides the possibility to estimate how the prices are expected to change when the distance from the city centre increases. On the other hand, these index prices can provide the possibility of undertaking comparisons since they are adjusted for changes in the overall economy. Today, the value of real estate is typically assessed in the literature taking into account all the above facets, i.e. the intrinsic attributes of the property, the movements of the overall economy and particularly the movements in and around the real estate economy.

The remainder of the article is structured as follows: Section 2 presents a brief overview of the hedonic regression methodology as presented in previous literature. It also provides an overview of the urban economics literature on spatial dynamics of house prices based on monocentric and polycentric models. This section also looks at factors that influence temporal change of house prices. Section 3 proposes a model that can combine these determinants in a single set-up. It also reviews issues related to functional form and model specification of the composite model. Section 4 concludes the article by providing a summary of the discussion.

LITERATURE REVIEW

Housing characteristics and house prices

The HPM, derived mostly from Lancaster's (1966) consumer theory and Rosen's (1974) model implies that commodities are characterized by their constituent properties; therefore, the value of a commodity can be calculated by adding up the estimated values of its separate properties. Since the HPM offers a basis to estimate demand and prices of composite commodities, the method can be applied to estimate house prices taking into account the specific characteristics of housing units. The heterogeneous nature of real estate properties in fact justifies the use of HPM for estimating their value and demand, and, as a result, the HPM has been extensively used in real estate and housing market research in the recent past. The application of the HPM is further warranted by the fact that the amount and number of distinctive features a housing unit possesses influences the quality of services that a particular housing unit provides.

Spatial attributes including location and accessibility

The first hedonic models of house prices primarily included physical attributes of housing units although urban economists demonstrate that not only physical characteristics, but also location characteristics influence the overall level of services offered by a housing unit. Subsequent hedonic papers, therefore, incorporate location variables explicitly in addition to structural characteristics. A justification for these location determinants of house prices is very well articulated in the urban economics literature. For instance, most of the scholarly work on urban monocentric models include either distance to the city centre, travel time or travel cost in the model specification to capture the price dynamics generated by location in space. This standard urban economic monocentric model developed initially by Alonso (1964) suggests that the principal variable causing variations in constant-quality house prices within a metro area is land price. A typical land rent equation includes distance from the Central Business District (CBD), agricultural land rent, a conversion parameter that depends on transport cost per kilometre and community income, suggesting that distance to the CBD should be included in any house price model. Alonso's model has been empirically tested by many scholars. Ball (1973), Richardson (1988) and, more recently, Huriot and Thisse (2000) provide literature surveys on this topic.

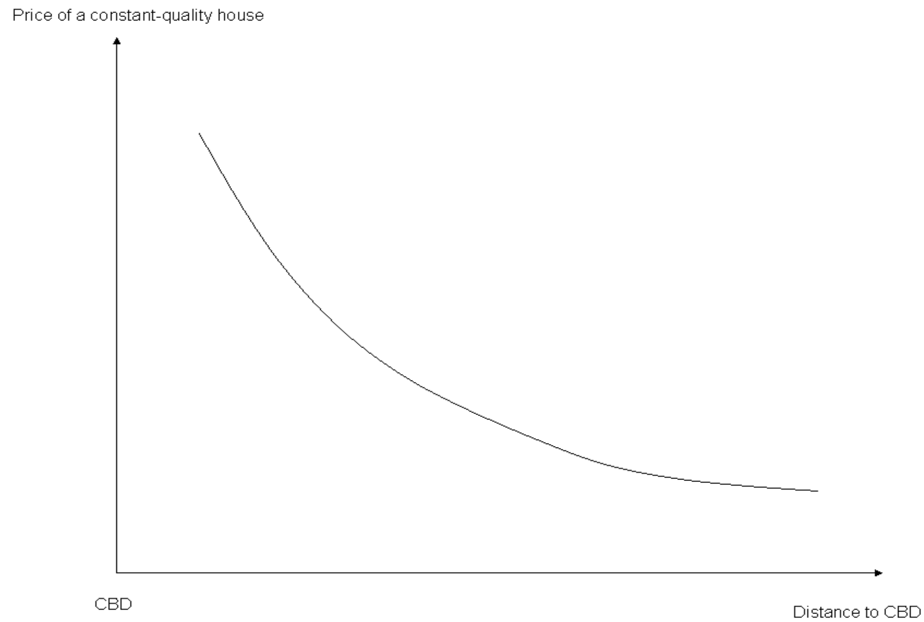

Figure 1 The idea of the Monocentric Model, Alonso (1964)

Fig. 1 depicts the basic idea behind the monocentric model. The concept of monocentricity assumes that all the interaction and economic exchange take place in the CBD, and that the households need to travel to the CBD for work, shopping and schooling etc. The travel to the CBD involves time and cost. This implies that potential home buyers are willing to pay more to acquire constant-quality houses in the CBD than for houses located away from the CBD. The central part of this model is, therefore, accessibility as a determinant of value of land (or value of houses in the context of this article). Numerous papers have studied accessibility as a determinant of real estate value. Jackson (1979), for instance, uses trend surface analysis to examine accessibility effects in a study of house prices in Milwaukee. He found that a quadratic accessibility polynomial is preferred in explaining house prices and that accessibility effects are significant. Rents peak at an area west of the CBD which is well served by expressways.

Despite early dominance of Alonso's model, the existence of contradictory results in the expected signs of the regression model's coefficients and, above all, with regard to the accessibility variable is evident. The reason for these contradictory results is probably the presence of multicentric urban spatial structures. In a study by Bender and Hwang (1985), the estimated coefficient was positive on distance from the CBD when a regression was estimated for the entire study area of Chicago. When they subdivided the study area into catchment areas for the employment centre of Chicago, the coefficient on distance to the relevant employment centre turned negative. Similarly, Dubin (1992) published that there is lack of empirical support for the capitalization of neighbourhood and accessibility effects probably because of the multicentric nature of cities. The point to note here is that house price models that assume a monocentric urban structure when polycentric rent gradients are present can lead to contradictory results.

In monocentric theory, as stated earlier, accessibility is measured as the distance, cost or time to the CBD. It becomes more complicated in the presence of other sub-centres in addition to the CBD, because the existence of those multi-centres also needs to be taken into account. The polycentric theory that deals with the multicentric nature of cities evolved in this context. For example, Dubin & Sung (1987) allow for the existence of non-CBD peaks in the rent gradient by using a spline function to estimate the rent gradient along four rays emanating from the CBD. They demonstrate that centres such as the CBD, universities, and industrial parks do influence rents but this influence is limited to properties in close proximity to the centre. Their estimates show the effect of the CBD was limited to a circle with a radius of 1.7 miles. The universities affected rents within a circle of one mile radius. Dubin (1992) states that non-CBD peaks in the rent gradient cause traditional means of capturing accessibility effects to give inconclusive results. He suggests a more flexible means of capturing neighbourhood and accessibility effects: one that allows for multiple peaks in the rent surface. According to Dubin (1992), in addition to polycentric rent gradients, measurement problems with regard to neighbourhood quality are also possible reasons for inconclusive results. Neighbourhood quality is unobservable and must be addressed through the use of proxy variables. The proxies themselves are measured with error due to the boundary problem, because the concept of neighbourhood boundaries is often vague. Dubin and Sung (1987) also report that multicentric nature of cities poses several challenges with regard to the selection and spatial delimitation of these sub-centres. Dubin (1992) subscribes to a geostatistical model when he omits all neighbourhood and accessibility measures from the set of explanatory variables and instead models the resulting autocorrelation in the error term to avoid above mentioned complexities associated with the analysis. In addition to the issue of measurement and neighbourhood boundaries, Olmo (1995) put forward other difficulties that emerge with the multicentric theory. One of them is the specification of neighbourhood characteristics. Another is that the parameters referring to the neighbourhood characteristics of the model are constant for the whole of the urban space, but a structural change test will show otherwise in the majority of cases.

The presence of spatial dependence of the neighbourhood characteristics and the accessibility on the location is the other important issue in this context. The implication of this spatial dependence is spatial heterogeneity and autocorrelation. If the location is omitted from the hedonic model, the estimated coefficients will be biased and inconsistent, because the models without spatial variables tend to produce wrong standard errors of the estimates of the implicit price of characteristics. For instance, Olmo (1995) suggests that the OLS estimator of the parameters of the hedonic model in the presence of spatial autocorrelation is inefficient. To control for these spatial effects, the spatial dimension was incorporated into the hedonic models by Anselin (1998), Pace et al. (1998), Orford (2000), Bradford et al. (2004), Brasington (2004) and others.

Temporal dynamics of house prices

It is a widely accepted fact that house prices are sensitive to temporal dynamics. Most macroeconomic studies available on temporal dynamics of house prices emphasise changes of macroeconomic variables and their co-movement with house prices. Most of these studies are based on national level data. For instance, Poterba (1991) examines intertemporal fluctuations of house prices in particular cities and regions with shifts in income and construction costs, and provides evidence that there is no impact deriving from aggregate demographic effects and user cost variations. The highly cited scholarly work of Mankiw and Weil (1989), and Case and Shiller (1990) demonstrate significant effects of population demographics on house prices. There are also a considerable number of articles on house price bubbles. Abraham and Hendershott (1993, 1996), for instance, publish support for speculative bubbles in the housing market.

This literature related to temporal dynamics of house prices justifies adding-in a time variable as a determinant of house prices. The inclusion of the temporal dimension allows capturing the time related dynamics of the market such as volatile prices generated by a persistent trend in the economy or cyclical behaviour. The scholarly work on temporal changes of house prices belongs to two main classes of studies. One class assumes that a temporal trend, i.e., the trend of market fundamentals, is what drives house prices. Most of the studies in this category are national level studies that take into account the trend of the national economy, i.e. real income, or trend of main fundamental variables such as construction costs. The second class presumes that cyclical components of the economy explain house prices to a certain extent. These studies consider business cycle movements over time, and investigate whether there is a relation between the business cycles and the house prices.

There are recent studies evaluating spatial and temporal changes of house prices using panel data. The models employed in these studies typically assess movements in temporal as well as spatial variables simultaneously, and look at their effect on house prices. The panel data model of Kim (1993) reported that construction costs, interest rates, metro population, income, income growth and climate have an impact on house prices. Baltagi and Chang (1994), using a panel data set of the Boston area predicted that crime rate, air pollution, tax rate, pupil-teacher ratio, proportion of the population in lower status, age of the house and the distance from the employment centres influence median house prices. In a separate study, Mendelsohn et al. (1992) used panel data on repeated single family home sales in Massachusetts and found a significant reduction in housing values as a result of these houses' proximity to hazardous waste sites.

A new class of hedonic models, i.e. spatiotemporal housing models considers spatial and temporal determinants of house prices simultaneously. In spatiotemporal models, the hedonic model is augmented to include previous values of the dependent and explanatory variables from nearby observations or regions. These spatiotemporal models deal with changes of explanatory variables X over time and resulting changes in house prices Y, and contain both time as well as space-time lags of the model variables. A detailed account of these spatial panel and spatiotemporal models is provided by LeSage and Pace (2004) and Anselin et al. (2004).

METHODOLOGY

Prior to proposing a conceptual model, it is appropriate to note that there are several reasons to be cautious about using rent values as an indicator of value of real estate. The conventional hedonic price regression equation with regard to the housing market is either rent or value against the characteristics of a housing unit. The majority of scholars would argue that rent values do not represent the actual value of real estate. On the one hand, the rent values may need adjustments for tax payments, depreciation and other transactions costs. On the other hand, rents are based on current demand and supply conditions rather than the actual value of the underlying real estate. Since it is almost impossible practically to obtain the actual value of real estate, most studies, in empirical analyses, consider rent value to be a proxy for the value of real estate.

The first hypothesis of this study is that house price is influenced by its structural characteristics. Section 2 of the article draws from literature to support the argument that house price is influenced by structural characteristics of the housing units. Literature related to the HPM provided the foundation and background knowledge to model this econometric relationship. The model can be extended to incorporate the accessibility variables, for instance distance to the CBD, as a measure to capture location effects. This possibility was justified in urban economics literature in general and in literature related to the monocentric model and the polycentric model in particular. The resulting hypothesis at this stage is that the house price is influenced by structural as well as location characteristics. Part 2 of section 2 documents the foundations of this idea. The model can be extended once more with a temporal variable to test the hypothesis whether house price is influenced by structural, location as well as temporal characteristics. Part 3 of section 2 provides details about literature related to this third extension.

The conceptual model

Most of the previous analyses of house prices do not typically take into account all three dimensions, i.e. housing characteristics, accessibility and temporal dynamics jointly so that the estimates produced are likely to be biased. The composite model suggested here will reflect temporal and spatial dimensions in addition to the quality of the houses represented by their intrinsic characteristics (see conceptual model in Fig. 2).

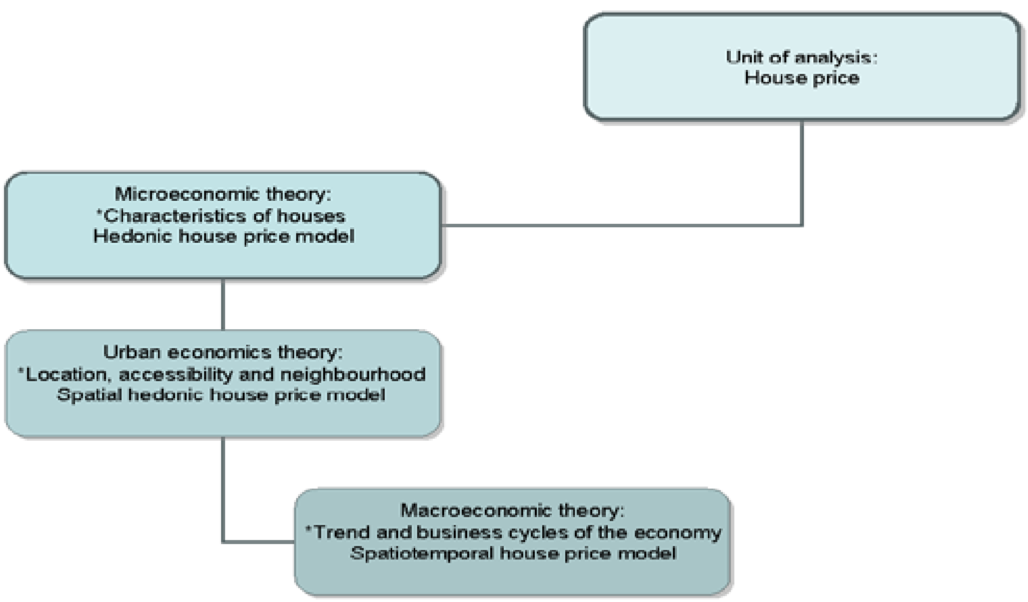

Figure 2 The conceptual model

Regression analysis is the most popular estimation approach among scholars using the HPM. As mentioned earlier, the conventional hedonic price regression equation with regard to the housing market is either rent or house value against the characteristics of the housing unit that influence the respective rent or value. The fundamental assumption of regression analysis that the relevant determinants of the dependent variable, i.e., rent, price or value in this case, are known precisely is valid in this study as well. In practice, various structural variables are employed based on previous literature, scholars' preference, or availability of data. Most common structural variables that appear in hedonic price analyses include, among others, number of rooms-bedrooms-bathrooms, floor area, the category of the house (single-family/multifamily, attached/detached), number of the floor, structural features including presence of a basement-fireplace-garage, age, availability and type of heating and cooling systems, structural material used, and quality of finish.

The hedonic regression equation can either be in linear, semi-log, or log-log functional form. The most common is the semi-logarithmic form which offers the advantage that the coefficient estimates are proportions of the price that are directly attributable to the respective characteristics. The advantage of the log-log form is that the hedonic regression equation estimates elasticities with respect to each and every characteristic under consideration (Herath and Maier, 2010). The linear hedonic equation is as follows:

a sample of *n* independent observations of house price y_i, i = 1, ..., *n* [preferably log of house price ln (y_i)] are linearly related to structural characteristics in a matrix X

$$y_i = X_i \beta + \varepsilon_i \text{ with the assumption } \varepsilon_i \sim N(0,\sigma^2) \quad i = 1,\dots,n$$

If the error term of the hedonic regression model specified above is stochastic and independently and identically distributed (*iid*), then it is possible to conclude that house prices are influenced by structural characteristics alone. This is an indication that the estimated model with structural characteristics has captured most of the variation of house prices although it is highly unlikely that spatial characteristics and temporal dynamics do not play some role.

In the extended composite model a second step additionally takes into account the effects of the location. There are alternative variables that are employed in various studies to capture effects of the location and those of the neighbourhood on house prices, but a simple and obvious way is to include distance to the city centre as an explanatory variable. Based on the monocentric model, the expected coefficient of this variable should be negative. The longer distance to the city centre would mean the price of a constant-quality house is lower. The extended model with the accessibility variable is as follows:

a sample of *n* independent observations of house price y_i, i = 1, ..., *n* [preferably log of house price *ln* (y_i)] are linearly related to structural characteristics in a matrix *X* and to location characteristics in a matrix *Z*

$$y_i = X_i\beta + Z_i \delta + \varepsilon_i \text{ with the assumption } \varepsilon_i \sim N(0,\sigma^2) \qquad i = 1,\dots,n$$

The introduction of location in space into the analysis means that necessary measures should be taken to correct for spatial dependence as well as endogeneity of the house price variable. The alternative methods of taking into account the implications of spatial dependence, i.e., spatial heterogeneity and autocorrelation, include applying lattice, geostatistical and semiparametric models. The lattice models are among the popular spatial models, and the variants of lattice models in the literature include spatial lag model and spatial error model. A kriging method has been proposed by Dubin (1992) as an instrument to model and estimate house prices in the presence of spatial autocorrelation. Olmo (1995) suggests using the GLS estimator, because the OLS estimator of the parameters is inefficient in the presence of spatial autocorrelation.

This article subscribes to the lattice models and includes a spatial weight matrix as a measure to capture spatial dependence. There are two alternative spatial models, within the lattice models, to choose from once the source of spatial autocorrelation is determined. The Lagrange Multiplier (LM)

tests are the predominant tests in spatial econometrics that provide the possibility to test jointly the hypothesis of no spatial dependence due to an omitted spatial lag or due to spatially autoregressive errors. The results of the LM tests, therefore, point to the most appropriate spatial model from the spatial error model and the spatial lag model. See Anselin (1988) for detailed LM test equations.
Spatial correlation among the dependent variables is defined as a spatial lag situation which is specified by the spatial lag model (SAR). The spatial lag specification takes the form

$$y_i = \rho \, W y + X_i \beta + Z_i \delta + \varepsilon_i \text{ with the assumption } \varepsilon_i \sim N(0,\sigma^2) \quad i = 1,\dots,n$$

where ρ is the spatial autoregressive coefficient, W is a spatial weights matrix, and all the other symbols are as previously defined.
When spatial dependence exists in the error term, a spatial error model (SEM) is employed. The spatial error specification takes the form

$$y_i = X_i \beta + Z_i \delta + u_i, \quad u_i = \lambda \, Wu + \varepsilon_i \text{ with the assumption } \varepsilon_i \sim N(0,\sigma^2) \quad i = 1,\dots,n$$

where λ is the error correlation coefficient, W is a spatial weight matrix, and all the other symbols are as previously defined.
If the error term of the extended hedonic regression model is stochastic and independently and identically distributed (iid), it is possible to conclude that house prices are influenced by structural characteristics and accessibility variables. If this is the case, the notion that 'structural characteristics and accessibility variables together explain most of the variation of house prices' will be supported. It is also important to ensure that the difference of coefficients from the previous non-spatial model and the current spatial model are significant. The fact that difference of coefficients from different models is significant suggests that the inclusion of new variables considerably improves the predictability of the model.
The third step incorporates temporal dynamics of house prices into the extended model. The trend of the economy and the cyclical movements of the economy are considered possible candidates as explanatory variables. The important point to note here is whether the investigation is at a national level or a regional level. The main distinction between the studies cited in the literature and the present article is that most previous studies are country-wide macroeconomic analyses of house prices while the present study provides a model to deal with house prices both in a specific country as well as in a specific region. If the model is estimated in the context of a regional housing market, the trend and the cyclical movements of the regional economy should be considered. If the underlying study is a national level enquiry, the trend of the national economy and national level business cycles should be considered.
There are several ways to take into account the temporal dynamics of house prices. One way is to include a dummy variable that starts from zero and goes up by one every year. For instance, if there is a list of housing sales transactions from the year 1990 until 2010, the dummy for a house that was sold in the year 1990 takes the value 0, the dummy for a house that was sold in the year 2000 takes the value 10, and the dummy for a house that was sold in the year 2010 takes the value 20.
There is an alternative yet superior way of capturing the trend and the cyclical movements of the economy explicitly into the analysis using the Hodrick and Prescott (HP) filter (1997). The HP filter has not been used before in this context, therefore, it is an original contribution of this study. The procedure is explained below.
The HP filter is widely used among macroeconomists to obtain a smooth estimate of the long-term trend component of a data series. The series y_t is made up of a smoothed series (trend component) and a cyclical component $y_t = T_t + C_t$. The HP filter is a two-sided linear filter that calculates the smoothed series *s* of *y* by minimizing the variance of *y* around *s*, subject to a penalty that constrains the second difference of *s*.

In other words, the HP filter chooses *s* to minimize

$$\sum_{t=1}^{T} (y_t - s_t)^2 + \lambda \sum_{t=2}^{T-1} ((s_{t+1} - s_t) - (s_t - s_{t-1}))^2$$

where λ is the penalty parameter that controls the smoothness of the variance series. The larger the λ, the smoother the variance. As $\lambda=\infty$, *s* approaches a linear trend. Since annual data is used in this analysis, a penalty parameter of 100 is recommended to smooth the series (Ravn and Uhlig, 2002). This procedure considers a fundamental variable such as real GDP, and use the HP filter to decompose it into the trend component and the cyclical component. The interest in this study is not only in the temporal trend but also in the cyclical movement of the overall economy. Therefore, both the trend and the cyclical component are included as explanatory variables in the final composite model. For instance, a transaction that was completed in 1990 will have the relevant decomposed trend value and also the value of the business cycle for that year produced by the decomposition mechanism using the HP filter. The advantage of taking into account two components of real GDP separately over including the entire temporal variable as one variable into the model is that it provides the possibility, based on estimation results, to examine which of these components have a significant impact on house prices. If trend or the cyclical variable has an impact, the value and the sign of the coefficient can provide additional information as to the direction and the dimension of the impact. The final composite model takes the following form:
a sample of *n* independent observations of house price y_{it}, $i = 1, \ldots, n$ recorded at time *t* [preferably log of house price ln (y_{it})] are linearly related to structural characteristics in a matrix *X*, to location characteristics in a matrix *Z*, to a trend variable *T* at time *t*, and to a cyclical variable *C* at time *t*

$$y_{it} = X_i\beta + Z_i\delta + T_t\lambda + C_t\gamma + \varepsilon_{it} \text{ with the assumption } \varepsilon_{it} \sim N(0,\sigma^2) \quad i = 1,\ldots,n$$

This model also poses the same challenge, i.e. spatial dependence, when observations represent regions or points in space. Therefore, the spatial weights matrix can be included in the spatial lag model as follows:

$$y_{it} = \rho WY_t + X_i\beta + Z_i\delta + T_t\lambda + C_t\gamma + \varepsilon_{it} \text{ with the assumption } \varepsilon_{it} \sim N(0,\sigma^2) \quad i = 1,\ldots,n$$

where ρ is the spatial autoregressive coefficient, W is a spatial weights matrix, Y_t is a vector of house prices at time t, and all the other symbols are as previously defined.
If the spatial error specification is employed, it takes the form

$$y_{it} = X_i\beta + Z_i\delta + T_t\lambda + C_t\gamma + u_{it}, \quad u_{it} = \lambda WU_t + \varepsilon_{it} \text{ with the assumption } \varepsilon_{it} \sim N(0,\sigma^2) \quad i = 1,\ldots,n$$

where λ is the error correlation coefficient, W is a spatial weight matrix, U_t is a vector of error terms and all the other symbols are as previously defined.
If the error term of the composite hedonic regression model is stochastic and independently and identically distributed (*iid*), then it is possible to conclude that house prices are influenced by structural characteristics, accessibility variables, and temporal dynamics. If the trend variable or cyclical variable is not significant, the insignificant variable has to be excluded. If the trend variable is significant, it indicates that the trend of the economy, among other things, influences house prices and vice versa. It may also be interesting to observe whether the differences of coefficients from non-spatial and spatial models are significant and how the coefficients change with addition of temporal variables.

The spatial panel house price models, as stated earlier, are typically estimated using repeat sales price data. However, houses are durable goods that are sold only infrequently, making it difficult to obtain a continuous panel data set of repeat sales. In addition, the spatial panel models also require that the transactions referring to specific houses are identified and traced back, which makes the process even more complicated. The use of decomposed values of a temporal variable based on the HP filter rather accommodates observations regardless of the point in time they are recorded as far as applicable temporal data is available.

SUMMARY

The HPM, derived mostly from Lancaster's (1966) consumer theory and Rosen's (1974) model implies that commodities are characterized by their constituent properties, and the value of a commodity can be calculated by adding up the estimated values of its separate properties. In view of that, the hedonic price model provides a basis to estimate house prices taking into account the quality or the characteristics of a housing unit. Additionally, the urban monocentric model developed initially by Alonso (1964) suggests that the principal variable causing variations in constant-quality house prices within a metro area is land price. A typical land rent equation includes distance from the CBD, agricultural land rent, and a conversion parameter that depends on transport cost per kilometre and community income and hence suggests that distance to the CBD should be included in the house price model. On the other hand, literature related to temporal dynamics of house prices justify adding-in a temporal variable as a determinant of house prices. The temporal dynamics are rarely incorporated into the hedonic models although it is widely accepted that house prices are sensitive to them. The inclusion of temporal dimension allows capturing the time related dynamics of the economy such as volatile prices generated by cyclical movements of the market fundamentals.
Most of the previous analyses of house prices do not typically take into account structural, location, and temporal dimensions jointly so that the estimates produced are likely to be biased. This article introduces three versions of the hedonic price model to examine if the house prices are influenced by any of the factors specified above: the first incorporates structural characteristics of housing units; the second structural and location attributes; and the third structural, location and temporal attributes. The originality of this study lies in the fact that it uses Hodrick and Prescott (HP) filter (1997) to decompose the temporal variable into trend and cyclical components before incorporating these into the house price model. The final composite model suggested in this article is likely to produce unbiased estimates because it will reflect location and temporal dimensions in addition to the quality of a house represented by its intrinsic characteristics.

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