# METHODOLOGICAL ISSUES IN THE APPLICABILITY OF HEDONIC MODELS IN HOUSE PRICE MEASUREMENT: A REVIEW

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## Abstract
*Accurate measurement of changes in housing prices is key to understanding the efficiency of the housing market. This paper therefore examines methodological issues in applying hedonic regression approach in housing market analyses and its usefulness in understanding housing prices. Findings from literature reveal that despite its drawbacks (model misspecification, inappropriate choice of functional form, multi-collinearity and omitted variable problem) hedonic models provide reliable measure of house prices and are likely to increase the decision making ability of policy makers and professional practice of surveyors when large datasets of similar properties and their attributes are available. This paper therefore concludes that hedonic models should be used in conjunction with other valuation methods as they provide valuers with additional information in the valuation process.*

**Keywords:** *Housing; Housing Market; Hedonic; Implicit Price; Regression.*

## Introduction
Since the classical work of Rosen on *'hedonic prices and implicit markets'* was published in 1974, there has been a preponderance within real estate literature of the application of hedonic models in determining the implicit prices of dwellings in urban housing markets. Several empirical contributions from the literature such as (Meen, 1996; Jones, Leishman, & Watkins, 2003; Huang, Wu, & Barry, 2010) have provided useful insights not only into the structure of urban housing markets (which was the highpoint of Grigsby (1963) exceptional seminal contributions to housing economic research) but also some underlying theories of urban housing market dynamics as well as explanations on the aggregation of housing demand.

Housing as a consumption good fulfils human physical need and his continued sustenance. However, housing price movements would have far-reaching implications on consumers' spending and saving patterns. These changes in housing price across different housing market segments create self-reinforcing effects on demand and supply and then back to housing price itself (Stein, 1995; Ortalo- Magne & Rady, 2004; Sing *et. al.,* 2006). The accurate measurement of changes in housing prices is equally key to understanding the investment behaviour of market participants and the efficiency of the housing market itself, especially, in periods of weak economic climate. As such, real estate market actors are bound to generate considerable interest in housing price trends and dynamics and link them back to some explicative factors.

Reliable housing price measurement is however a difficult task and has often been exacerbated by the peculiar nature of the housing market. The housing market is a dynamic entity, as its heterogeneous nature, the substitution effect of its attributes, plus the consumption-investment behaviour exhibited by its end users (Kim & Park, 2005) make long run equilibrium almost elusive. Since an accurate housing price is essential for various reasons, a pragmatic approach of determining house prices is hedonic pricing. This involves the use of datasets, by regressing both physical and location attributes of an area's housing stock using regression coefficients, (the characteristic prices) and the price can be estimated by summing up its characteristics prices. Hedonic models have shown to be cost effective and have produced efficient results using large datasets (Dodgson & Tophan, 1990; Crone & Voith, 1992). Hedonic models are equally likely to increase the decision making ability of policy makers, improve the professional practice of surveyors and cushion the effect of housing market recession (Nicol, 1996). However, this method has its drawbacks in terms of methodology, which stem from its choice of functional form and selection of independent variables, the inherent problems of heteroskedasticity, multicollinearity and choice of correct functional form (Gaetano, 2013; Fletcher et al., 2000; Martins-Filho & Bin, 2005). Undoubtedly an understanding and circumventing of these methodological issues would provide researchers in housing economics with a better knowledge of building parsimonious and robust hedonic models, which would in the end provide a far more useful insight into the structure and operation of the malleable urban housing markets.

In view of the foregoing, the objective of this paper is to provide a review of methodological issues surrounding the application of hedonic models for accurate house price measurement. This paper review issues by undertaking a discussion on the theoretical basis for hedonic pricing models. This is aptly followed by a review of empirical results on residential hedonic models to show most used housing attributes and those which consistently predict housing prices. The next section provides an overview of previous literature on methodological issues (hedonic models specification, appropriate choice of the functional form of the models and Specification of the correct dependent and independent variables) in housing price measurement. The final section presents the conclusions drawn on the basis of the review.

**Theoretical Basis of Hedonic Pricing Models**

Most urban real estate analysts have employed hedonic models as an appraisal tool consequent upon the work of Rosen (1974) which centre on the analysis of a market of a single good having many traits. Rosen (1974, p.34) define hedonic prices as "the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amount of characteristics associated with them".

Given the assumption of a perfect competitive market that both buyers and sellers are well informed, housing prices would reflect both parties' preferences. As housing is heterogeneous, the selection of a dwelling means that a buyer select many different housing characteristics, and under market condition the equilibrium price locus will determine the marginal price for changes in each characteristics that make a house a heterogeneous product.

In the market, if $Z^i$ is an amenity (in this case a house) having a range of housing characteristics ($S_1$, $N_1$, $L_1$), then households willingness to buy will be determined by their utility functions, as utility is derived from the individual characteristics. Such that on the demand side, the envelope of buyers' bid price for the house is given by $B^i$ (s) and this will be influenced by income and preferences. The bid function depict the price buyers are willing to pay for a given dwelling unit by deriving a specific amount of utility there from (Ham, 2011). As such:

$B^i = f(Z^i, I, α)$ ……………………………………………………………………………(i)
Where (I) is the income and (α) is the household tastes and preferences. $Z^i$ is the house with its array of housing attributes. Re-writing this, we have,

$B^i = f(S_1, N_1, L_1, I, α)$ ………………………………………………………………………… (ii)
$S_1$ is the physical and structural characteristics of the house; $N_1$ is its neighborhood characteristics such as landscape and amenities while $L_1$ is the specific location within the market.

Thus, buyers' derive maximum utility when their bid function ($B^i$) = house price. It must be noted that the concavity of the buyers' utility function as seen in figure1 means that, their bid function increases at a decreasing rate as their corresponding characteristic increase. For example, if more additional units of apartment are acquired by a household, utility and hence value derived from acquiring an additional unit would decrease as more units of apartment are consumed. This is based on the law of diminishing marginal utility.

On the supply side, the sellers' offer function ($O^1$s) determines the minimum price sellers can give out their housing units in other to make profit, at a given level of output (Q) and a variable (μ) denoting the difference in firms' production costs:

$O^i = f(S_1, N_1, L_1, Q, μ)$ ………………………………………………………………………… (iii)
The convexity of the production function in figure1 means a constant or increasing return to scale. Sellers' maximum production occur when their offer function ($O^i$) = price.

Fig.1 gives a graphical depiction this relation. The hedonic price ($P(z^i|z^{*k≠i})$ locus for a house $Z^i$ is determined where the envelope of buyers' bid ($B^i$) is in tangency to the envelope of sellers' offers (represented by the $O^i$). This also means that the implicit bid and offer price for any particular attribute will be at equilibrium when:
$B^i = O^i$ ; $B^i_{Si} = O^i_{Si}$ ; $B^i_{Li} = O^i_{Li}$ ; $B^i_{Ni} = O^i_{Ni}$ . Here, $B^i_{Si}$ and $O^i_{Si}$ ; $B^i_{Li}$ and $O^i_{Li}$ as well as $B^i_{Ni}$ and $O^i_{Ni}$ are partial derivatives of $B^i$ and $O^i$ with respect to Si, Li and Ni.

Detailed theoretical underpinnings on hedonic models are discussed in Follain and Jimenez (1985) and Buchel and Hoesli (1995).

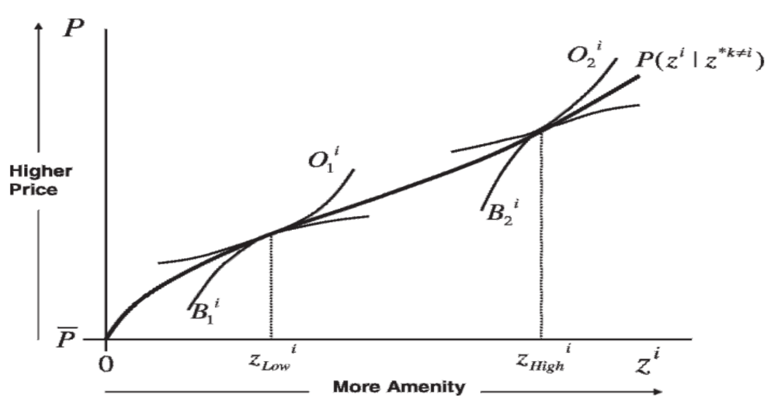


**Fig1: Standard Hedonic Diagram of Amenity, *j***
**Source:** Jaren (2008)

Therefore, hedonic models probe the question of estimating the implicit price of housing characteristics, given the constraint that these housing characteristics are sold as a single unit which cannot be unbundled in the market (Di pasquare and Wheaton, 1996 and Brunauer *et al,* 2009).

**Variables Employed in Hedonic Regression and How They Best Predict Housing Price**

Although economic theory provides no guide as to the variables that goes into model specification (Mason and Quigley, 1996), but existing literature by Basu and Thibodeau, (1998), Fan and Koh (2006) and Paez, *et al.* (2008) identify three broad factors: structural traits of the dwelling, location and neighbourhood factors. Typical examples of structural characteristics include floor area, lot size and bathrooms. With respect to location and neighbourhood factors, Galster (2003) mention that, "it does not mean that they are intrinsically coupled with the geography - some are physical environment (presence of scenery and neighbourhood image) others are related with individuals who lend their collective attributes to the space through aggregation (for example income and race)"

**Table1: Most Frequent Housing Characteristics Used in Hedonic Pricing Models**

| Variables | Appearances | No. of times Positive | No. of times Negative | No Significant Difference |
|---|---|---|---|---|
| Lot size | 52 | 45 | 0 | 7 |
| Square feet | 69 | 62 | 4 | 3 |
| Brick | 13 | 9 | 0 | 4 |
| Age | 78 | 7 | 63 | 8 |
| No. of Stories | 13 | 4 | 7 | 2 |
| No. of Bathrooms | 40 | 34 | 1 | 5 |
| No. Of Rooms | 14 | 10 | 1 | 3 |
| Fireplace | 57 | 43 | 3 | 11 |
| Full Baths | 37 | 31 | 1 | 5 |
| Air-conditioning | 37 | 34 | 1 | 2 |
| Basement | 21 | 15 | 1 | 5 |
| Garage spaces | 61 | 48 | 0 | 13 |
| Pool | 31 | 27 | 0 | 4 |
| Distance | 15 | 5 | 5 | 5 |
| Time on Trend | 13 | 2 | 3 | 8 |
| Time on Market | 18 | 1 | 8 | 9 |

**Source:** Adapted from Sirmans *et al, (*2005) in the composition of hedonic pricing models, p.10.

In this regards, Sirmans *et al.* (2005) examine about 125 empirical studies on hedonic models. Some of their results which are presented in table 1 and 2 show most used housing attributes and those which consistently predict housing prices based on number of times their estimated coefficients have been positive, negative or show no significant difference with housing price. Table 1 indicates that twenty (20) housing characteristics are the most frequently used. The frequency of each of the characteristics is give by its appearance, which means for example that out of 125 empirical researches, 78 of them considered AGE in which 63 of these concluded that age is negatively correlated with housing price, 7 reveals a positive relationship and 6 shows that there is no significant relationship between age and housing price. Attributes that feature dominantly are age and square feet. These are followed by garage, fire place and lot size. Others characteristics that are used include bathroom, air conditioning among others as shown in the table. It must be mentioned that some of the housing characteristics like lot size and Ln lot size (log of lot size) are the same though with different parameter specification so as to allow for the non-linearity relationship between lot size and housing price.

**Table2: Housing Characteristics that Best Predict House Price**

| Housing Characteristics | Appearances | No. of times Positive | No. of times Negative | No Significant Difference | Interpretation of Coefficients of Determination |
|---|---|---|---|---|---|
| Lot size | 52 | 45 | 0 | 7 | 1.50%*** |
| Square feet | 69 | 62 | 4 | 3 | 0.04-0.07%** |
| No. of Bathrooms | 40 | 34 | 1 | 5 | 10-12%** |
| Age | 78 | 7 | 63 | 8 | -1.00%** |
| Fireplace | 57 | 43 | 3 | 11 | 6-12%** |
| Air-conditioning | 37 | 34 | 1 | 2 | 4-13%** |
| Basement | 21 | 15 | 1 | 5 | 12-16%** |
| Garage spaces | 61 | 48 | 0 | 13 | 6-12%** |
| Pool | 31 | 27 | 0 | 4 | 4-13%** |

**contribution to price across geographical locations based on coefficient estimates. ***Estimates from Sirmans and Macpherson (2003).
**Source:** Modified from Sirmans et al. (2005) in the composition of hedonic pricing models.

Again, in table 2 the characteristics which best predict housing prices are selected from table 1 based on those having higher frequency relative to the 125 empirical studies and the extent to which those selected are positively or negatively correlated with housing price. Added to these, are their coefficient of determination across different hedonic studies so as to estimate those that indicate consistency across various hedonic locations. The table depicts that nine housing characteristics such as square feet, lot size, age, fireplace, number of bathrooms and pool best predict prices. These attributes were used at least 21 and at most 78 of the 125 empirical studies with all having positive coefficients of determination except age. This implies all are consistent in predicting house prices across different locations though age has negative contribution. Given the knowledge of these variables in housing market analyses, valuers and surveyors can work with them as additional information to aid the valuation process and improve their accuracy of value-price determination in the property market.

Again, Vanderford *et al*. (2005) examine 13 studies that employed local and nationwide data to predict housing price. They show that though, neighbourhood attributes were fairly inconsistent across studies, physical characteristics of dwellings such as lot size, square feet, size of garage and number of fire place produce significant results across the studies, buttressing the consistency in Sirmans *et al*. (2005) results. However, the results should be interpreted with caution. For example, garage in all cases never have any negative significant effect but have shown no significant difference on housing prices in 13 similar studies. The reason might not be unconnected with difference in geographical boundaries but also parameter uncertainty (Zietz *et al.,* 2008).

**Methodological Issues in Application of Hedonic Pricing Models**

**Specification of Hedonic Price Functions**

Though, not in all cases, hedonic models are usually used in a two-step procedure. The first stage involves determining the price for the housing characteristics and the second, to recover the structural parameters of demand and supply by treating the partial derivatives of those characteristics as observations of their inverse demand and supply functions (Horowitz, 1987 and Malpezzi, 2003). For example, the price of individual housing characteristics calculated in the first stage can be placed on the left side of the equation so as to estimate the demand for each characteristic by including household data like income, which affects demand and supply.

The specification of parsimonious hedonic functions is however a difficult task, especially at the first stage since the second stage is presumed to be linear. There exists for instance, a non-linear relationship in the first stage, between price and housing characteristics: because the heterogeneity of property means its characteristic prices are not constant but vary with quantity (Malpezzi, 2003; Kestens, Thériault & Rosiers, 2006; Bruaner *et al.,* 2009).

Like other regression models, proper specification of the correct independent variables and functional form is required to prevent inconsistent house price estimates (Mason & Quigley 1996; Wang & Zorn 1997; Meese & Wallace 1997 & Bourassa *et al.* 2005). Inconsistency in house price estimates have been mentioned by Gatzlaff and Haurin (1997), Pace and Gilley (1998) and Bourassa *et al.* (2007) to be discernible when any of the assumptions of regression model is violated (for example the assumption that the disturbance error should be independent among the variables). Fletcher et al. (2000), point out that not using a semi log functional form may violate the assumptions and therefore result in heteroscedasticity. Heteroscedasticity occurs when the variances of the disturbance term of the model are unequal as a result of missing variables (for example when the variance of the disturbance term differs by property type).

Hedonic models often require large datasets (location and neighbourhood attributes). These datasets are onerous to assemble and even when available, the specification of these many spatial-based attributes could lead to complex models (Hoesli *et al.,* 1997 & Dubin *et al,.* 1999; Mueller & Loomis. 2008). A detailed specification of the correct dependent and explanatory variables as well as the relevant choice of functional form for the model must suffice.

**The Dependent Variable and Selection of the Explanatory Variables**

Economic theory on its own does not give a clear-cut guide of the variables that enter into a hedonic model. Because real estate has some peculiar characteristics which vary across locations and property type, the selection of the right dependent and explanatory variables is partly an empirical one in addition to what economic theory provides (Pace, 1995 & Hannonen, 2005).

With respect to the dependent variable, the choice of is always between rent, housing price and appraisal value. Problems however arise from different units of measurement (for example, should the net or gross sale price be specified as the predictor?). According to Hoesli and Macgregor (2000) and Sirmans *et al.* (2005), a preferred option of dependent variable is the recent selling price. Using the observed selling price is thought to minimise bias as compared to self assessed or appraisal value. This is because, large transaction volume of traded housing units provide higher rate of price information flow and reduces price dispersion that causes heteroscedasticity (Yiu *et al.* 2006). Unlike appraisal values which are based on valuers' judgement, housing transaction data give accurate reflection of price change in the market. However, appraisal values are typically employed as a dependent variable in a thin market when transactions are infrequent.

Conversely, choosing the correct set of explanatory variables is by no means an easy task (Mason & Quigley, 1996). Butler (1982) and Gat (1996) mention that the list of these variables is not exhaustive, but that most variation in housing prices can best be captured using few variates. While (Butler, 1982; Gat, 1996) opine that inclusion of numerous variables would result in multi-collinearity (for example neighbourhood socioeconomic variables are correlated with unobserved neighbourhood quality among the explanatory variables), Pindyck and Rubinfeld (1998) rightly caution that the omission of variables in the model may produce biased and inconsistent regression estimate. However, Malpezzi (2003) further argues that "the same correlation between omitted and included variables that biases individual coefficient estimates can help improved prediction from a 'sparse' model". Therefore, while the availability of variables which influence housing price is important, the removal of variables from the model should be done with caution.

**The Choice of an Appropriate Functional Form**

Since the non- linear relationship between housing price and housing attributes would affect the model results, parameter specification in terms of the appropriate functional form would mitigate this problem. Economic theory does not suggest however the correct model functional forms (Pace, 1993; Pace, 1995; Anglin & Gencay, 1996). This makes Freeman (1993) assert that "any functional form is plausible in hedonic price function because the form could reflect the hedonic price structure of different housing markets". That is, the functional form could be concave, convex or linear.

In view of the nature of these functional forms (for instance, linear, semi-log and log-log) across different housing markets, Halvorsen and Pollakowski (1981) reveals that, by including these functional forms in the general quadratic Box-`Cox model of 1964, a flexible or appropriate functional form can be determined through statistical tests such as likelihood ratio tests. Most empirical analyses have applied semi logarithmic form over the linear, double log and translog specification (Forrest, 1991; Wooldridge 2003). Compared to the translog form which has the problem of multi-collinearity due to large information requirements of the model (Hannonen, 2005), Wooldridge (2003) reveals that, semilog functional form can reduce heteroscedasticity, as the variance of the error term for the house price is expected to be constant (Goodman & Thibodeau, 1995; Fletcher *et al.,* 2000; Melpezzi, 2003). Also, while the multiplicative form of the log-log is intrinsically linear (Hannonen, 2005), such transformation which gives a model which is linear in parameters, makes inference difficult. Melpezzi (2003) and Schultz and Schmitz (2009) explain that a semi-log model gives a simple interpretation of the extent to which the independent variables predict price, expressed as percentage change in the dependent variable.

The role of functional form in hedonic models is that, if the first stage of the model were to be linear (the first stage is always non-linear as the price of one housing characteristics is affected by the quantity of another), then the marginal prices of the housing attributes would be constant and needless to estimate the second stage demand and supply function (Malpezzi, 2003).

**Conclusion**

This paper has provided a review of literature on resolving methodological issues and understanding housing prices using hedonic models. This is against the background that, it is unlikely that our understanding of the economic context within which housing is placed will improve without refinement in the measurement of housing price changes. In addition, this paper provided a formal theoretical exposition of hedonic pricing models and proceeded with discussions on variables employed in most hedonic empirical studies and how they best predict house prices. Hedonic model is a pricing model which has been found to be cost effective and devoid of inconsistencies in house price estimate, given a robust dataset. However, by overcoming some of its inherent shortcomings, such as misspecification of the hedonic models and the functional form, multi-collinearity and omitted variable problem, hedonic models are likely improve the professional practice of valuers by providing additional information to the valuation process.

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