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The hedonic price method in real estate and housing market research: a review of the literature

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Abstract

The Hedonic Price Method (HPM), also known as hedonic regression, is used for estimating the value of a commodity or the demand for a commodity. The HPM has been extensively used in real estate and housing market research in the recent past. In this paper, we discuss theoretical and methodological developments related to hedonic regression and undertake an examination of use of this methodology in the recent real estate and housing literature. We first define the HPM, and explain the fundamentals behind the methodology. The idea behind the HPM is that the commodities are characterized by their constitute properties, hence the value of a commodity can be calculated by adding up the estimated values of its separate properties. In the second part of the paper, we emphasise that the heterogeneous nature of real estate property justifies the use of HPM for estimating their value or demand. We also take a stock of most cited empirical studies on real estate and housing using the HPM, and classify those into several categories. The classification indicates that neighbourhood characteristics of real estate are relatively over-researched as a determinant of price or rent. It also shows that implicit value of structural characteristics is under-researched. In general, implicit value of environmental amenities in the neighbourhood and air pollution are relatively over-researched. The effect of social factors, i.e. racial segregation and crimes on real estate value is under-researched.

1. Introduction

The hedonic price method (hereafter, HPM) is also known as the hedonic demand theory or hedonic regression. This methodology estimates the value of the characteristics of a commodity that indirectly affects its market price. Alternatively it is used for estimating the demand for a commodity. The HPM is used in consumer and market research (e.g. Hirschman and Holbrook, 1982), calculation of consumer price indices (e.g. Moulton, 1996), tax assessment (e.g. Berry and Bednarz, 1975), valuation of cars (e.g. Cowling and Cubbin, 1972), computers (e.g. White et al, 2004) etc. in addition to real estate economics and real estate appraisal, the topic we discuss in this paper. The methodology has recently been used extensively in real estate and

housing market research: some of the most applied areas include correction for quality changes in constructing a housing price index, assessment of the value of a property in the absence of specific market transaction data, analysis of demand for various housing characteristics or housing demand in general, and testing assumptions in spatial economics.

The fundamental idea of the HPM is as follows: commodities are characterized by their constitute properties, hence the value of a commodity can be calculated by adding up the estimated values of its separate properties. According to this informal definition, a couple of requirements need to be fulfilled in order to be able to calculate hedonic prices. Those are that the composite good under consideration could be reduced to its constituent parts and there is an implicit value for those constituent parts in the market.

In the first part of the paper, we discuss fundamentals behind the HPM. We continue with a discussion of theoretical and methodological developments related to hedonic regression. The latter part of our paper undertakes an examination of areas of empirical studies in the recent real estate and housing literature using the HPM. The research question here is whether some topics are over-researched and some are under-researched in recent real estate and housing research.

This paper begins discussing definitions of hedonic price method as presented in previous literature. Section 2 provides a brief overview of historical developments related to the methodology. Section 3 looks at different estimation techniques and issues related to functional form and model specification of popular HPM models. Section 4 evaluates various contributions encountered in our classification of empirical studies and section 5 concludes the paper by providing a summary of our survey findings.

2. A brief historical account of the hedonic price method

There is no consensus among scholars as to who first introduced the method of hedonic regression even though most of the scholars agree that it was Court (1939) who first used the HPM. Accordingly, Bartik (1987), Goodman (1998), Robert and Shapiro (2003) among many others argue that the first actual estimation of a hedonic

price model was a hedonic price index for automobiles by A.T. Court (1939). These scholars document that the methodology was popularised by Zvi Griliches in the early 1960s.

Court (1939) states that passenger cars serve many diverse purposes and suggests to combine several specifications to form a single composite measure in price index procedures. He went on to use the term 'hedonic' for the first time, to explain the weighting of the relative importance of the various components including horsepower, braking capacity, window area, seat width, and tire size. One reason to consider Court's study as a significant contribution is that it deals with problems of non-linearity and with changes in underlying goods bundles (Goodman, 1998).

Robert and Shapiro (2003), commenting on Court's methodology, contend that "…implicit price components for each of a bundle of product characteristics are determined by a regression procedure that expresses the price of a product as a function of the coefficients associated with each characteristic. The price of a new product (or different product) can then be compared with that of the previously existing product when one utilizes these coefficients…" They further highlight that Court (1939) and Griliches (1961) allow for time dependence that does not require any new methodology making it possible to simply use the previous time-independent methodology restricting the regression to two consecutive periods. This will calculate a measure of overall price change for the hedonic commodity.

A second group of scholars pioneered by Colwell and Dilmore (1999) demonstrate that Haas (1922a, 1922b) conducted a hedonic study more than fifteen years prior to A. T. Court even though he never used the term 'hedonic'. Haas analysed price per acre adjusted for year of sale, road type, and city size, using data on 160 sales transactions gathered from farm sales in Minnesota. The independent variables in the hedonic analysis included depreciated cost of buildings per acre, land classification index, soil productivity index, and distance to the city centre. Colwell and Dilmore (1999) argue that Haas was influential but deny making a comprehensively strong case for Haas as the pioneer to estimate a hedonic model. Surprisingly, their alternative hypothesis is not Court (1939), but Wallace (1926), who used data aggregated by county to calculate comparative farm land values in Iowa.

Many other scholars contributed to the HPM over the years. Houthakker (1952) takes into account the problem of quality variation within the theory of consumer behaviour. He leaves out a multitude of corner solutions necessitated by conventional demand theory and assumes that consumers purchase only a negligible fraction of all goods available to them. This treatment is preserved by many subsequent authors to maintain simplicity in the analysis. This early contribution of Houthakker was later developed and extended by Becker (1965), Muth (1966), and Lancaster (1966) to explicitly take into account the utility bearing characteristics in the context of consumer behaviour.

Griliches (1958) revived the HPM by further developing Court's work. Griliches's paper embedded technological change and innovation into hedonic prices through quality of goods. This hedonic model on demand for fertilizer contributed to popularise the HPM at the early stage. Here demand for fertilizer relates prices and mixes of different components of fertilizer (nitrogen, phosphoric acid and potash) to derive better weights, which in turn are used to develop a series of constant quality fertilizer quantities and prices. Griliches (1961) worked on automobile price indices using automobile models as unit of analysis, and this work attracted considerable attention although it was published in an 'inaccessible' publication (Goodman, 1998).

Most important theoretical foundations of the HPM are *Lancaster's consumer theory* and *Rosen's model*. These scholarly works are considered early but significant contributions to the development of HPM. Lancaster (1966) establishes microeconomic foundations for analyzing utility-bearing characteristics and applies that to a range of topics including housing market, financial assets, the labour-leisure trade off, and the demand for money. In his model quantities of goods and quantities of characteristics are linked by a fixed relationship called "household production function". While households face a budget constraint defined over quantities of goods, they derive utility from the quantities of characteristics these goods do "produce". With this model, Lancaster (1966) focuses on the demand side of the market.

Rosen (1974) integrates the HPM into standard economic theory. Inspired by work of Houthakker (1952), Becker (1965), Muth (1966), and Lancaster (1966), he derives "bid functions" of utility maximizing consumers and "offer functions" of profit

maximizing producers and shows that in equilibrium the hedonic price function represents the joint envelope of these functions. In this form Rosen put forward a meticulous explanation of the implicit market and hedonic prices in the context of differentiated products. Using a vector of objectively measured characteristics representing a class of differentiated products, he observes product prices and the amounts of characteristics associated with each good to estimate a set of implicit or hedonic prices. Because of the joint derivation of the hedonic price function from the supply and the demand side, Rosen argued further that the entire set of implied prices guides both consumer and producer locational decisions in characteristics space. His study extends to analyse buyer and seller choices, market equilibrium and the empirical implications of the HPM.

Rosen's theoretical foundation leads to a two step approach, which works as follows: first, a hedonic equation is estimated. Subsequently, the implicit price of a characteristic is derived as the partial derivative of the hedonic equation with respect to that characteristic. Depending on the functional form involved, this derivative has to be evaluated at a particular bundle of characteristics. In this context, the empirically derived prices are embedded in a system of demand and supply equations.

In Rosen's model, income is directly incorporated in the budget constraints of the consumer. This implies that the consumer's marginal willingness to pay for a certain implicit attribute may also change with his income. Buyers bid price (or willingness to pay) for an attribute is a function of the utility level, the buyer's income, and other variables which influence tastes and preferences including education, age etc. An inverse demand function can be estimated by using the marginal price as an endogenous variable in the second-stage simultaneous equation. If it is possible to trace back the inverse demand function based on the implicit marginal price function, then measuring the utility change with respect to certain quality changes can also be estimated by integrating the inverse demand.

Lancaster's and Rosen's ideas differ from each other basically in two ways: the functional form of hedonic regression and the answer to the question whether the consumers buy a bundle of goods or separate goods. The fact that a bundle of goods or separate goods are purchased have an impact on the implicit market as follows. The Lancastrian index (1966) is based on the idea that usefulness of goods depends on

their characteristics, and goods can be arranged into groups based on their characteristics. Consumers buy goods within groups based on the number of characteristics they possess per dollar. According to Lancaster, the consumer's utility originates from the different characteristics (not just the quantities of the different goods) which the goods themselves provide. Goods are members of a group and some or all of the goods in this characteristic group are consumed in combinations, subject to the consumer's budget. Accordingly, the Lancastrian index is more appropriate for consumer goods.

Rosen's model (1974), on the other hand, has two distinct steps: an initial step involving an estimation of the marginal price for the attribute of interest (by regressing the price of a commodity or good on its attributes), and a second step to identify the inverse demand curve (or the marginal willingness to pay function) from the implicit price function estimated in the first stage. Rosen maintains that there is a range of goods, but that consumers typically do not acquire preferred attributes by purchasing a combination of goods, rather each good is chosen from the spectrum of brands and is consumed discretely. Accordingly, Rosen's model looks appealing to estimate demand for durable goods.

Model specifications in these two theories differ as well. Lancaster's consumer theory assumes a linear relationship between the price of goods and the characteristics contained in those goods. Implicit prices are therefore constant over their range of characteristic amounts, and only a change in the combination of goods consumed is possible. On the other hand, Rosen's model assumes a nonlinear relationship between the price of goods and their inherent attributes. The implicit price is not a constant, but a function of the quantity of the attribute being bought and of the quantities of other attributes associated with the good (depending on the actual functional form of the equation).

3. Estimation approaches, functional form and the model specification

Regression analysis related estimation is the most popular estimation approach among the scholars. Multiple regression analysis may either be an OLS regression or a maximum likelihood estimation of the log-likelihood function derived from the hedonic function. Both these estimation techniques try to find a vector of parameters

that best matches the values of explanatory variables of observations with the respective observed price. They differ by the criterion they use for identifying the best match. The explanatory variables may be the characteristics values, or mathematical transformations thereof, dummy variables or panel variables making it possible to allow for non-linearity, variable interaction, or other complex valuation situations. This information can be used to construct a price index that can be used to compare the price of constant quality housing in different cities (spatial aspects) or in one city over time (temporal aspects).

Regression analysis related estimation approaches are common in HPM models in real estate as well. The conventional hedonic price regression equation with regard to the housing market is either rent or house value against the characteristics of the unit that determine the respective rent or the value of the house. The fundamental assumption of regression applies that the relevant determinants of the dependent variable (rent, price, or value in this case) are known precisely and in advance. A classical hedonic equation is as follows:

$$R = f\left(P, N, L, C, t\right)$$

where R is rent or price of the house; P is property related attributes; N is neighbourhood characteristics; L is locational variables; C is contract conditions and; t is an indicator of time.

In practice, various variables are applied based on the scholars' preference or the availability of data. Malpezzi (2003) notes that experience from many studies suggests the following variables often appear in hedonic price analyses:

- Number of rooms and type of rooms (bedrooms, bathrooms, etc.)
- Floor area
- Category (Single family, multifamily, attached, detached, number of floors)
- Availability and type of heating and cooling systems
- Age
- Structural features (presence of basement, fireplaces, garages, etc.)
- Structural material used, and quality of finish

The functional form of the hedonic regression equation can either be linear, semi-log, or log-log form. Most common is the semi-logarithmic form which has the advantage that the coefficient estimates are proportions of the price that are directly attributable to the respective characteristic. The advantage of the log-log form is that the hedonic regression equation estimates elasticities with respect to each and every characteristic under consideration. Taking logs of the dependent variable also takes into account that prices are non-negative. This property is at odds with normality assumptions in the case of a linear specification.

Hedonic regression analysis is commonly used in real estate valuation as well. Sales comparison approaches that are used in valuation of real estate are also variations of hedonic-type measurements. One special case of the sales comparison approach, the Sales Adjustment Grids takes into account a small number of recently sold properties in the immediate vicinity of the subject property to value the attributes of that property. An adjustment to the comparables is typically done using trend analysis, matched-pairs analysis, or simple surveys of the market. Sales adjustment grids and multiple regression models are theoretically the same. In comparison, multiple regression analysis considers a large number of more geographically dispersed property transactions to determine the significance and magnitude of the impact of different attributes on property value. The multiple regression model builds on statistical techniques, while the sales adjustment grid method constitutes a heuristic approach.

The HPM was later extended to take into account spatial dimension in the presence of spatial dependence and spatial autocorrelation. One of the most popular and probably the simplest ways of considering spatial aspects in the hedonic model is to include distance from the central business district as an explanatory variable, although this becomes nonsensical when there are multiple centres in a city. Anselin (1988) specify two main spatial models in the literature namely the spatial lag model (LAG) and the spatial error model (ERR). Recent spatial hedonic models of house prices reflect these spatial econometric developments. The variations of more comprehensive hedonic models with spatial variables include the lattice model, the geostatistical model and the semiparametrics model. These hedonic models use spatial weights based on alternative criteria that are defined based on the relationship between spatial units.

4. A classification of real estate and housing studies that use the HPM

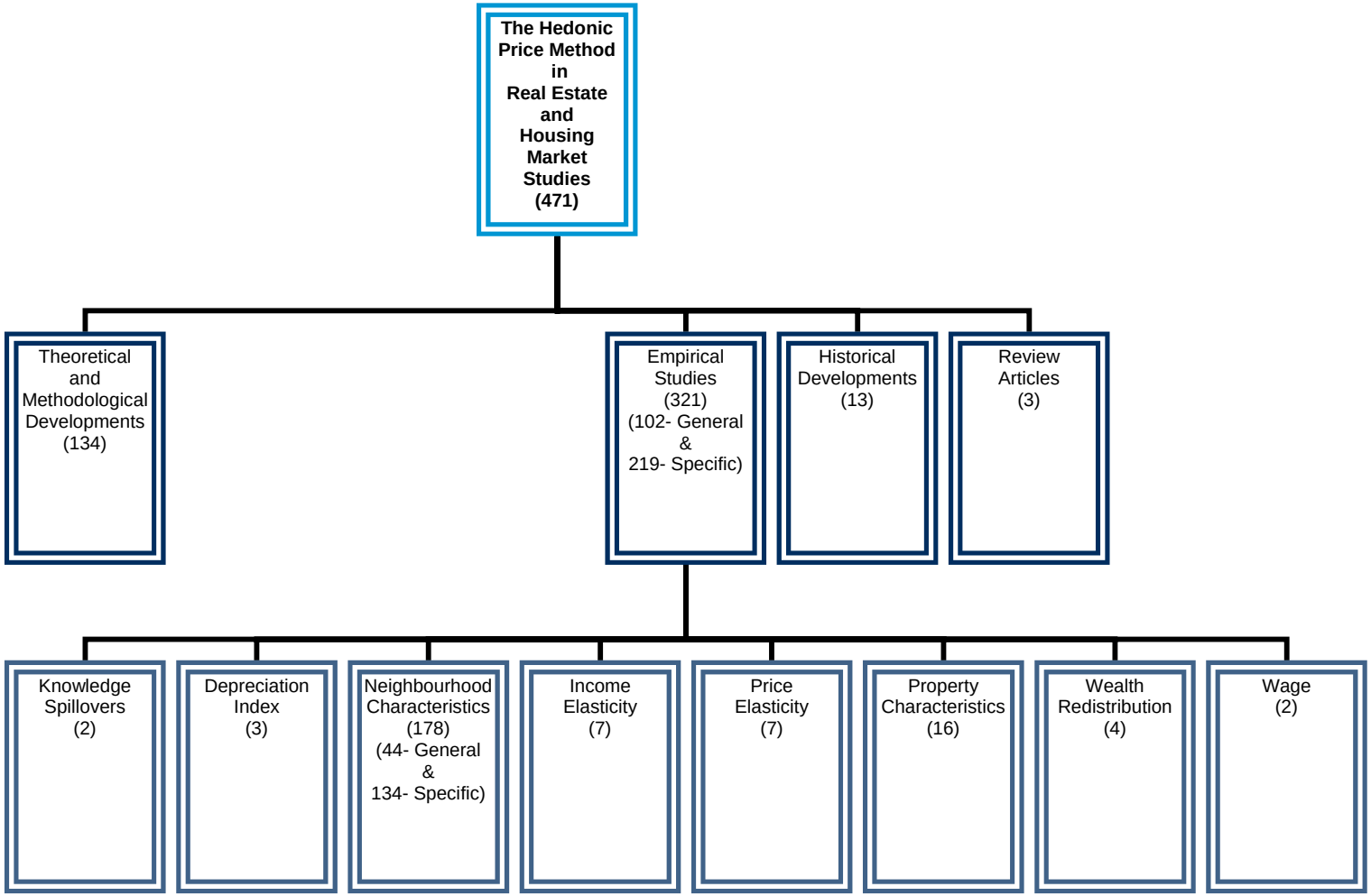
The heterogeneous nature of houses, buildings and other real estate property justifies the use of the HPM for estimating their demand or value. Houses, buildings and land slots are different at least by their location, making it difficult to estimate the demand for them generically. Therefore, the HPM takes into account the properties of real estate separately and estimates prices based on the assumption that these properties could be separated into characteristics such as attributes of the spatial unit (size of plot, number of bed rooms, bathrooms, toilets, etc.), infrastructure and locational attributes (including distance to the city centre), natural environment, social environment, ecology, and quality of design and architecture.

A caution is in order before proceeding to the empirical section. In the section on estimation we stated that 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 determine the respective rent or the value of the house. There is also a prolonged argument that rent values do not represent the actual value of real estate. On the one hand, rent values may need adjustments for tax payments, depreciation and other transactions costs etc. On the other hand, rents are based on current demand and supply conditions rather than the actual value of underlying real estate. However, since it is almost impossible practically to obtain the actual values of real estate, most studies consider rent values to be proxies for value of the real estate in empirical analyses.

The initial classification based on the ISI Web of Knowledge citations shows that there is a myriad of studies using the HPM to analyse various aspects of the housing market and the impact of various factors on real estate prices in general and housing prices in particular. We take into account the most cited 471 papers on housing and real estate that use the HPM, and classify them into several sub-categories (see Graph 1). It turns out that majority of studies, i.e. 321 papers altogether, are empirical studies looking at the real estate price dynamics. Out of those empirical scholarly works, 102 papers deal with real estate price dynamics in general while 219 papers examine price dynamics related to a specific variable. A considerable amount of scholarly works, i.e. 134 papers in our total sample, are devoted to discuss theoretical and methodological developments related to the HPM.

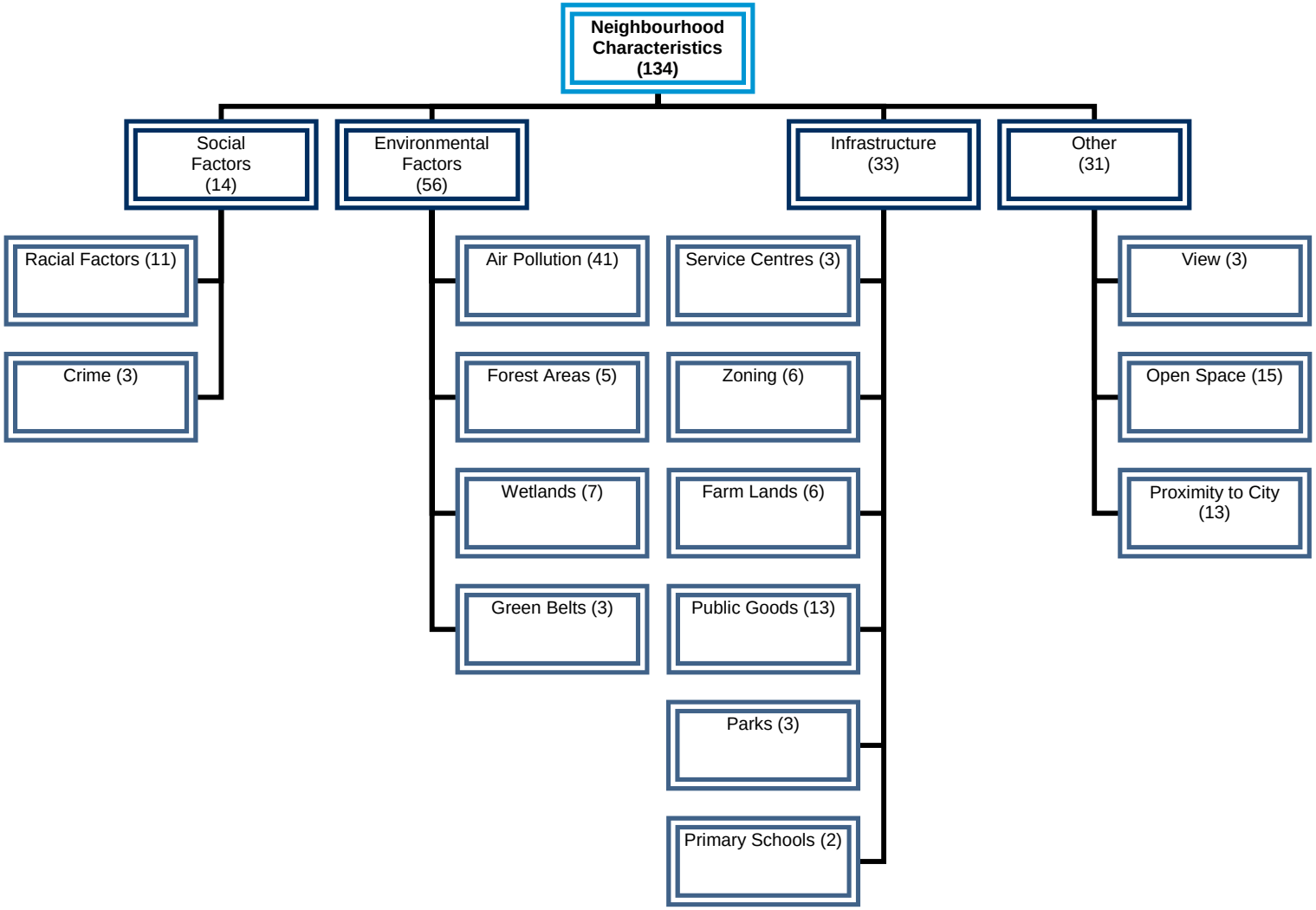
The sub-classification of empirical scholarly works show that most popular topic for empirical studies is regarding the implicit price of neighbourhood characteristics and their value addition to price or value of real estate. There were 178 papers on this topic. Out of those papers, 134 of them studied value of a specific neighbourhood characteristic and 44 papers examined value of neighbourhood characteristics in combination. Even though there is an extensive discussion on implicit value of structural characteristics of housing including energy efficient structures, surprisingly we encountered only 16 studies that deal with this issue.

In Graph 2, we further classify empirical work dealing with value of neighbourhood amenities. Most common topic within this sub-category is estimation of the value of environmental factors. Among these papers, 56 papers estimate the value of environmental factors in general and 41 papers attempt to examine significance of air pollution in particular. The sample of papers includes 33 papers on infrastructure while other neighbourhood characteristics are researched frequently as well. Social factors including racial segregation and crimes are under-researched among neighbourhood characteristics.



Graph 1. The types of real estate and housing market studies that use the hedonic price method

Notes: Number of papers is shown in parentheses.



Graph 2. The types of neighbourhood characteristics and hedonic studies of housing market
Notes: Number of papers is shown in parentheses.

5. Summary and future steps

There are mainstream methodologies of hedonic regression, extensions to the existing methodology, and innovations of new techniques. The HPM has evolved from a new technology to the standard way that economists deal with heterogeneity of real estate and housing.

Most cited research articles evaluate environmental factors and air pollution as determinants of real estate price dynamics, but only few studies cite to property characteristics as a determinant of change of price. Our classification indicates that neighbourhood characteristics are relatively over-researched as an explanatory variable of real estate price or rent. Based on the initial classification, we also suggest that implicit value of structural characteristics is under-researched. In general, implicit value of environmental amenities in the neighbourhood and air pollution are relatively over-researched. The effect of social factors, i.e. racial segregation and crimes, on real estate value is under-researched.

This analysis could be expanded in several ways. Literature related to the HPM is enormous that explaining everything related to the methodology in one paper is virtually impossible. One possible solution for this is to look at methodological developments and empirical evidence as two separate review articles. An alternative way of dealing with this vast literature is to consider papers in view of one specific characteristic or group of characteristics at a time. This will provide an opportunity to critically discuss theoretical applications and empirical investigations relevant to one class of papers that deal with valuing one specific characteristic of houses. Other prospective work can emphasise on hedonic literature that involve different asset types or different sub-markets. Those different asset types and sub-markets may include single-family, multi-family, attached, or detached housing markets, office markets or land markets. One last suggestion is to either emphasis on hedonic literature related to temporal changes of house prices or spatial changes at one time.

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