

Development of Mathematical Modeling using Hedonic Price Method to Establish Relation between Housing Price and Air Pollution

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Abstract: *Most environment goods and services are not traded in the markets. Mathematicians and Economists have used methods for environment valuation. Hedonic price method is one of those. It considers an object as a bundle of characteristics and then puts value on each and every characteristic. This paper presents methodology of hedonic price method and presents an abstract model of valuation of air quality vis a vis house prices using this method.*

Key Words: *Housing price, Air Pollution, House rent ,Hedonic price method etc.*

1. Introduction:

Most environment goods and services do not have substitutes and there is not attached any market price for the same. This absence of market price works negatively for these goods and services. This has led to erosion of and degradation of environment resources which has created several problems for the mankind e.g Air Pollution. Recently in NCR region of Delhi, after the festival of Diwali, and in the season of marriage there is huge degradation of air quality. The level of suspended particulate matter has been increased many fold and has crossed the danger level. This if persists then may cause irreversible damage to the health of the people. Such incidents have happened all over world time and again. This has created a need to look upon such problems in monetary value. The mathematicians and economists have thus tried to estimate prices for natural resources using methods for economic valuation of environmental good and services. The environment valuation is therefore important for two reasons:

- (i) To design taxes for pollution.
- (ii) To justify investment or expenditure made for the benefits from preservation.

Attempts of measuring environment goods and services in monetary terms are recent. Mathematical modeling for valuation of environment is carried out by a group of methods and techniques that aims to estimate the value of the environment attributes associated with environment goods.

2. Related Literature for Hedonic Price Method:

Hedonic price model is based on Lancaster (1966)'s consumer theory. Ridker and Hening (1967) used regressing analysis on a measure of sulfate air pollution. As per their study the coefficient on the air pollution variable in the regression equation could be used to predict the change in the price of any residence vis a vis a change in its air pollution level. The total sum of all such changes could be taken as a measure of the benefit of improving air quality in that area. This concept is implemented for commercial area by Rosan (1974), This concept is widely used as an assessment tool for commercial and analysis of urban area. The regression of house prices on a variety of property specific and neighborhood descriptors evaluates their marginal contribution, also called implicit or hedonic prices. Two-step procedure given by Rosen (1974) is (1) estimate a hedonic regression of product price on product attributes and (2) find implicit prices of product attributes by differentiating the hedonic and estimate household demand for each attribute as a function of its implicit price and other things. A.M. Freeman III(1979) reviewed theoretical basis and the assumptions required in order to use hedonic price equations derived from property value

data to obtain measures of the prices for environmental amenities such as air quality. MacDonald, Murdoch, and White (1987) developed a theoretical model of willingness to pay for a marginal reduction in the probability of flooding in the residential location decision. Jeff E. Brown and Don E. Ethridge (1995) worked on various functional forms for hedonic methods. As per a study by Hughes (1997) in Asia Pacific region, among different environmental pollution problems, air pollution is reported to cause the greatest damage to health and loss of welfare. Jorge Rogat (1998) used hedonic price method for the valuation of air quality in Santiago De Chile. Chong Won Kim, Tim T. Phipps and Luc Anselin (2001) developed and estimated spatial-econometric hedonic housing price model for the Seoul metropolitan area to measure the marginal value of improvements in sulfur dioxide (SO₂) and nitrogen dioxide (NO_x) concentrations. Viewu Afua Dei-Tutu (2002) estimated a hedonic property price function using floodplain data coupled with extensive property sales records from Pitt County, North Carolina to estimate the effects of flood hazards on residential property values. Hyung Seok Lee, Kwangtae Park and Sang Young Kim (2003) estimated the value of Internet information by using the hedonic price model (HPM). They specified a hedonic price function, and measure the consumer's willingness to pay for attributes to the Internet connection charge by identifying a functional form for the HPM by using the Box-Cox transformation of the variables. They found that the power functional form provides the best fit in describing the relationship between the Internet connection charge and the service characteristics. Ivar Ekeland (2003) worked on optimal matching problem which one encounters in hedonic pricing. He formulated the problem

of transporting one element from a set X to set Y with positive and equal measures and found the cost of this transportation. Murty, M N (2003) and Dasgupta Purnamita (2004) estimated health benefits from improved air and water quality in India using the variants of Hedonic method viz household health production model and cost of illness methods.. Murty, M. N. and S. C. Gulati (2005) used the hedonic property value method to estimate household marginal Willingness to Pay function for urban air quality improvement in the cities of Delhi, Kolkata and Hyderabad. Alexandre Tangerini and Nils Soguel (2006) used Hedonic Price Method to analyse tourists preference regarding the landscapes of six alpine resorts in the Swiss Canton of Valais. Thrane (2007) used this methodology to value hotel attributes that affect room rates which include location, facilities and amenities, service quality, star rating, atmosphere, etc. Fernando Carriazo-Osorio (2007) used Hedonic Method to value air pollution from the urban housing market in Bogota, Columbia. He examined the impact of air pollution on housing values by determining the marginal willingness to pay for a cleaner air among housing owners. S. Selim (2008) analyzed the factors which determine the house prices in Turkey and found that most important variable that affect house rents are type of house, type of building, number of rooms, size and other structural characteristics such as water system, pool, natural gas. Hasan Selim (2009) compared hedonic Regression with artificial neural network method to determine house prices in Turkey. V. Komarova (2009) used Hedonic price method to evaluate Environmental Impact of Air Pollution in Moscow Ching –Fu Chain and R Rothschild (2010) investigated the impact of a variety of attributes on the rates charged for hotel rooms in Taipei. They employed hedonic pricing method and found that there is negative relationship between proximity to the city centre and room rates, both on weekdays and at weekends. R. Minguez, G. Fernández-Avilés, and J.M. Montero (2010) worked on general spatial hedonic model and proposed an air pollution indicator based on geostatistical principles for European city Madrid. Felipe Vasquez Lavin, Jorge Dresdner and Renato Aguilar (2011) estimated the implicit prices of the crime rate and airborne pollution in Chile using Hedonic Model. John Yinger (2012) built on the theory of household bidding and sorting across communities to derive a bid-function envelope, which provides a form for hedonic regressions. This approach allows for household heterogeneity, yields estimates of the price elasticities of amenity demand directly from the hedonic without a Rosen two-step procedure, and provides tests of hypotheses about sorting. Arief Anshory Yusuf and Budy P. Resosudarmo applied a spatial hedonic property value analysis, using the combination of data on house values and their characteristics from the Indonesian Family Life Survey, and spatial data of the ambient level of six different pollutants to investigate the value of clean air for the people in Jakarta. Natina Yaduma, Mika Kortelainen, Ada Wossink (2012) estimated mortality and economic costs of particulate air pollution in Nigeria using the meta regression method.

3. Methods for Environment Valuation:

There are various methods of estimating benefits from environment valuation. A general classification given by Smith and Krutilla (1982) is as follows:

3.1 Physical Linkage Methods:

The physical linkage methods measure benefits based on a technical relationship between an environment good and the user e.g Damage Function Method

3.2 Behavior Linkage Methods:

These methods are based on the observations of behavior in actual markets or hypothetical markets for environment goods. These methods can be further divided into two: Direct Methods: These are the techniques which assess responses directly related to environment changes e.g Contingent Valuation Method Indirect Methods: These are the methods which examine responses not about the environment goods but also about some set of market conditions related to it e.g. Hedonic Price Method, Travel Cost Method

4. Hedonic Price Method (HPM):

Hedonic Price Method is one of the oldest techniques for economic valuation. The basic idea is that an object is a bundle of characteristics which define the value of the object e.g when someone goes to buy a house then he/she makes his/her decision based on environment and location characteristics. These characteristics can be divided into three viz Socio-economic, Environmental and Structural. Thus an individual values places value on each of the above before making a decision. This individual behavior has allowed Mathematicians and Economists to develop models using data of residential property to estimate positive and negative aspects due to changes on parameters of environmental quality. This was the beginning of Hedonic Price Method. Initially it was used to understand the relationship between air pollution and property value. Later on this method got its spread on theoretical and empirical studies of monetary valuation of no-market goods related to environmental and location characteristics. The fundamental hypothesis of this method is that the environmental changes affect the future benefits and in turn property values. The property price differential reflects differences in the intensity of its characteristics. The HPM is derived from the theory of value adopted by Lancaster (1966), Griches(1971) and Rosen (1974). The theory of hedonic prices assumes that the utility if each object is a function of the individual consumption of a composite good - X , a vector of specific environmental amenities - Q , a vector of structural characteristics of the house such as size, number of rooms, year of make, type of construction – S and a vector of characteristics of the neighborhoods where the house is located – N . Hufschmidt et alli (1983) and Freeman (1993) argued that for using HPM, two hypothesis need to be formulated. The first hypothesis is that the whole urban area should be considered a single housing market. Individuals should have all information before making any decision. This housing market offers a great variety of the same. kind of product. The second hypothesis is that the housing market should be at or near the equilibrium i.e all the individuals should maximize their choices of houses given the alternative prices of the same. These prices should be compatible with the houses and their characteristics. Thus the house prices can be written as a function of its structure, neighborhood and characteristics of the environment quality of its location. This two stage method is described as follows:

In the first stage, the price of i^{th} residential location (P_{hi}) is a function of structural (S_i), neighborhood (P_i) and environmental characteristics (Q_i).

$$P_{hi} = P_h (Q_i S_i N_i) \dots\dots\dots (1)$$

$$b_{ij} = \frac{\delta P_{hi}}{\delta q_j} \dots\dots\dots (2)$$

The partial derivative of (1) with respect to one of the environmental quality characteristics q_j like tree cover or air quality gives the implicit marginal price of that characteristic or marginal valuation of environmental quality by the individual in the market for houses (b_{ij}).

In the second stage, marginal willingness to pay for environmental quality is expressed as a function of ($S_i Q_i N_i$) and socio-economic characteristics (G_i)

$$b_{ij} = b_{ij}(Q_i S_i N_i G_i) \text{-----} (3)$$

Equation (3) gives the individual's marginal willingness to pay for the improvement in the environmental quality. If there is an improvement in the environmental characteristic from q_j^0 to q_j^1 the value individual places on such an improvement (B_{ij}) could be estimated by integrating (3) with respect to q_j –

$$B_{ij} = \int_{q_j^0}^{q_j^1} b_{ij}(q_j, Q_i S_i N_i G_i) \delta q_j \text{-----} (4)$$

5. Hedonic Model for relation between Housing Price and Air Pollution:

Let us consider that there exists a housing market with equilibrium. There are number of characteristics of a house which are available to each and every buyer with same probability. Let us assume that we want to find the change in house rent viz a change in air pollution index. Then the house rent becomes dependent variable and each characteristic is treated as independent variable. There should not be any relationship between different characteristics so as these remain independent. These independent variables can be grouped as follows:

- (i) Socio-economic characteristics viz Family Size, Education Level.
- (ii) Structural characteristics viz Age of the house, type, number of bedrooms, number of bathrooms, water supply, electricity supply, drainage system.
- (iii) Neighborhoods characteristics viz distance from bus stop, distance from railway station, distance from airport, distance from metro station, distance from shopping mall, number of schools in the locality, number of hospitals and distance from the park.
- (iv) Environmental characteristics e.g Air Quality Index, Water Quality Index, Green Cover.

Thus the house rent can be written as a function of its various characteristics as:

$P_h = f(\text{family size, education level, age, type, bedrooms, bathrooms, water supply, electricity supply, drainage system, distance from bus stop, railway station, airport, metro station, business centre, number of schools, number of hospitals, distance from park, air quality index, water quality index, green cover})$

This function can be estimated using different functional forms. Some of the functional forms that can be used are Linear Regression, Multiple Linear Regression, Nonlinear Regression. Studies have been conducted wherein Artificial Neural Network is also being used as a functional form of hedonic function. This can be achieved by collating data around dependent and independent variables using suitable survey methodology. The sample size and sampling distribution can be chose as per the requirement.

6. Conclusion:

The Hedonic Price Method is one of the oldest valuation method to analyze changes in the value of the residential and commercial properties due to change in environmental characteristics. An individual when goes to the real estate market to buy/rent a house, he/she not only buys/rents a piece of land but also its characteristics. Thus in making a decision, perception of these characteristics is more important for an individual. In this paper, basic methodology of HPM is discussed. Also an abstract model for valuation of air quality index has been presented.

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