Hedonic Property Prices and Valuation of Benefits From Reducing Urban Air Pollution in India[1]

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Abstract:
This paper provides estimates of benefits from controlling urban air pollution in the metropolitan areas of Delhi and Kolkata in India using a hedonic property price method and the primary data collected from the household surveys. Estimates of the hedonic property price function and the implicit marginal price or the household's marginal willingness to pay function for air quality are obtained first separately for each city and then by using the pooled data for both the cities. Also it provides estimates of aggregate consumer surplus benefits to the households of each city from reducing the air pollution concentration of say suspended particulate matter (SPM) from the current levels to the safe WHO or MINAS standards for India.

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I Introduction

Urban air pollution can cause health damages due to morbidity and mortality effects as also losses of environmental amenity benefits due to reduced visibility to the local residents. Measurement of these losses from air pollution is important from he view point of the environmental policy changes necessary which may involve considerable cost to government and to the agents of the economic activities contributing to air pollution. Various methods may be used for the valuation of environmental services, namely: including physical linkage methods involving estimation of dose response functions in epidemiological studies, observed behavioral methods consisting of household health production function models, and hedonic property price or wage models, and hypothetical behavioral or contingent valuation methods could all be used to estimate benefits from the reduction of urban air pollution[3]. There are now a large number of empirical studies available applying observed behavioral methods of valuation, using especially the developed countries data, for estimating the benefits from the environmental quality improvements. Given that there are not many similar studies available in the developed country context, environmental policy changes in the developing country are evaluated using a benefit transfer method, a method of using the models estimated for the developed countries for making such predictions about the benefits from appripriate policy changes. The benefit transfer method may result in the under or over estimation of benefits from the environmental policy changes because the behavioral responses of households in the developed countries could be different from those in developing countries for a given environmental policy change. This difference in the behavioral responses could be attributed to differences in the socio-economic characteristics and other attributes of households. It is therefore important to undertake a number of studies to estimate household production models using the developing countries data to obtain accurate estimates of the benefits from environmental quality changes in these countries. This paper attempts to make a contribution in this direction.

[3] See Freeman (1993), Mitchell and Carson (1989), and Murty and Kumar (2002) for a detailed discussion of these methods. See Murty, Gulati and Banerjee (2003) for a recent study using the observed behavioral method of household health production function model for estimating benefits of air quality improvement in Delhi and Kolkata

The hedonic property value model is used to estimate benefits to local households of reducing air pollution to a safe level in the cities of Delhi and Kolkata in India. The total user benefits comprising health benefits, and environmental amenity benefits from the reduced urban air pollution could be estimated using the hedonic property value model. Data for estimating the hedonic property value model are obtained through the household surveys. Monthly averages of air pollution given in the form of SPM, SO_2, and NO_x concentrations are available for six monitoring stations in Delhi and 22 monitoring stations in Kolkata. For each city, a sample of 1250 households is drawn with a fair representation of households from the neighborhoods of different monitoring stations. The survey provided data regarding the structural, neighborhood, environmental and socioeconomic characteristics of households. The estimation of the hedonic price function is carried out in two stages. First, the hedonic property value function expressing the monthly rent of a house as a function of the structural, neighborhood and environmental characteristics of households is estimated and the household specific marginal implicit house prices for the environmental quality are calculated. Second, the household marginal willingness to pay function for the environmental quality is estimated by expressing the marginal implicit rent as a function of environmental quality and the socioeconomic characteristics of the households.

II Hedonic Property Prices Model

Commodities could be distinguished by the characteristics they possess and their prices are functions of these characteristics. From the point of view of the owner, land property could be distinguished in terms of its location, size, and local environmental quality, and from the worker's perspective, a job is a differentiated product in terms of the risk of an on job accident, working conditions, prestige, training and enhancement of skills, and the local environmental quality at the work place. By studying the changes in the price of a product with respect to changes in the characteristics it possesses, one will be in a position to find out the premium or the price the consumer pays for possessing a particular characteristic. Given the price of a product as a function of its characteristics, by differentiating this function with respect to a characteristic, one could derive the consumer marginal willingness to pay for that characteristic. The environmental characteristics like air or water quality affect the price of land either as a producer good or as a consumer good. Ridker (1967) and Ridker and Henning (1976) provided the first empirical evidence that air pollution affects the property values. Freeman (1974), and Rosen 1974 used the hedonic price theory to interpret the derivative of hedonic property price function with respect to air pollution as a marginal implicit price and therefore the marginal value of air pollution improvement. Thaler and Rosen (1976) are the first to suggest that the labor market could be viewed as the hedonic market. The derivative of the hedonic wage function with respect to any job characteristic could be interpreted as the marginal implicit price of that characteristic.

Hedonic Property Value Model

Let the price of ith residential location (P_{hi}) is a function of structural (S_i), neighbourhood (N_i) and environmental characteristics (Q_i).

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

Consider the utility function of the individual who occupies house i as

$$u(X, S_i, N_i, Q_i) \qquad (2)$$

where X represents a composite private good that is taken as a numeraire. Assume that preferences are weakly separable in housing and its characteristics. The individual maximizes (2) subject to the budget constraint,

$$M = X + P_{hi} \qquad (3)$$

The first order condition for the choice of environmental amenity q_j is given as

$$\frac{\delta u/\delta q_j}{\delta u/\delta x} = \frac{\delta P_{hi}}{\delta q_j} \qquad (4)$$

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. The implicit marginal price is the additional amount paid by any household to choose a house with the additional amount of that characteristic other things being equal. The individual chooses the level of a characteristic at which her marginal willingness to pay for that characteristic is equal to its implicit marginal price.

Figure 1 depicts the hedonic price function. Figure 2 shows the curve depicted by the marginal implicit price function ($\delta P_{hi} /\delta q_j$) and the marginal willingness pay curves of two individuals k and s ($b_k(q_j)$ and $b_s(q_j)$) who have chosen the utility maximizing bundles of housing characteristics. These curves show each individual's marginal willingness to pay for changes in the characteristic, by holding utility constant at the optimum level say u*. Both the individuals have chosen locations for their houses where the marginal willingness to pay for q_j are equated with the marginal implicit price.

The above analysis provides a measure of the price or the marginal willingness to pay for a house at a particular location and will not provide a marginal willingness to pay function for a housing characteristic. In the second stage, the marginal willingness to pay for environmental quality is expressed as a function of q_j given S_i, N_i, and a vector of other environmental characteristics Q_i^* and socioeconomic characteristics (G_i)

$$b_{ij} = b_{ij} (q_j, Q_i^*,S_i, N_i, , G_i) \qquad (5)$$

Equation (5) gives the individual's marginal willingness to pay for an improvement in the environmental quality q_j. Assuming that the individual's utility function is weakly separable with respect to the housing characteristics, the welfare changes for large changes in q_j could be estimated. 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 (5) with respect to q_j .

$$B_{ij} = \int_{q_j^0}^{q_j^1} b_{ij} (q_j, Q_i^*,S_i, N_i, , G_i) \delta q_j \qquad (6)$$

The estimation of marginal willingness to pay for a housing characteristic using the above described model requires an estimation in two stages (Rosen, 1974). In the first stage, the hedonic property price equation (1) is estimated and the implicit marginal prices for a given characteristic are computed for all the observations in the sample given the mean values of the rest of the characteristics. Figure 1 depicts the hedonic price function. In the second stage, taking the calculated implicit marginal price as an endogenous variable, the marginal willingness to pay function (5) is estimated. There are problems of identification of the marginal willingness to pay function in this method of estimation.

The first problem arises from the fact that the data sources for the dependent variable, marginal willingness to pay are not direct observations rather it is the calculation of marginal implicit price from the estimated hedonic price function. Some studies Rosen (1982) and Mendelsohn (1987) show that this method of estimation may lead to parameter estimates for the marginal willingness to pay function that are identical to estimated coefficients in the hedonic price function.

The second problem arises from the fact that both the quantity of the characteristic and its implicit price are endogenous in the hedonic price model. The choice of a point by the individual like point A in Fig. 2 on the curve depicted by the implicit marginal price simultaneously determines the marginal willingness to pay and the quantity of the characteristic. The other marginal prices on the individual marginal willingness to pay function are only observed for other individuals with other socioeconomic characteristics as at point B in Fig. 2 and provide no information on the original consumer's bid for different quantities of that characteristic. Consider two identical individuals with uncompensated bid functions,

$b_i = (q_{ji}, M_i), \; i = 1,2 .$

where M is income, a demand shifter. If two individuals choose different levels of q_j it must be because of the differences in income. That means that the unobserved income of individuals in the data of Fig. 2 is correlated with the observed choices of q so that the estimate of marginal willingness to pay function is biased. Various approaches are used in the literature to deal with this identification problem of which the most reliable approach is to find cases where the marginal implicit prices of characteristics vary independently of the demand shift variables. That means one has to look for cases in which individuals with identical preferences and income face different marginal implicit prices. This in turn means that the data from the segmented markets in a city or from the different housing markets/ cities have to be used in estimating the marginal willingness to pay function of an individual. The first step in implementing this approach is to estimate a separate hedonic price function for each market and to compute the implicit marginal prices faced by the individuals in that market. In the second step, the computed implicit marginal prices are regressed on the observed quantities of characteristics and the exogenous demand shifters to estimate the uncompensated bid function.

Fig. 1: Hedonic Price Curve

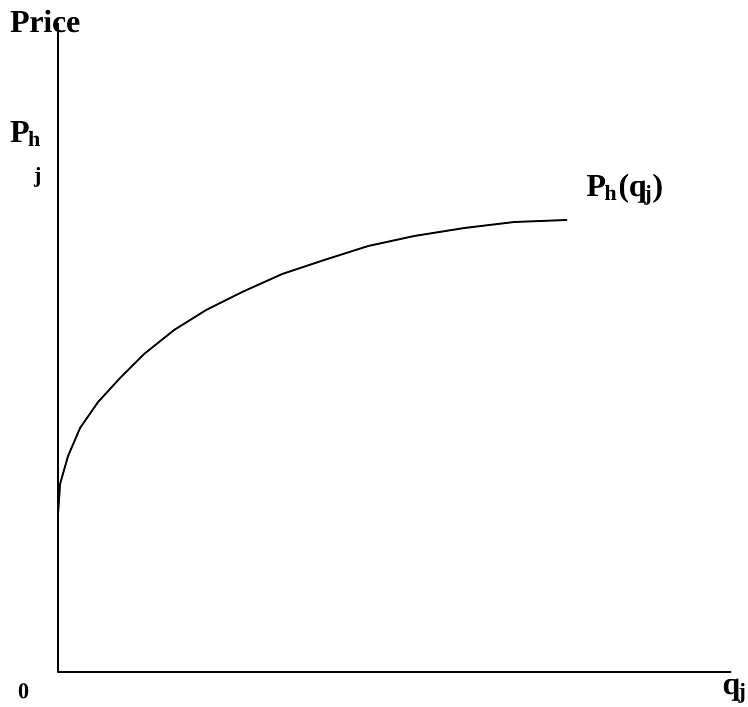
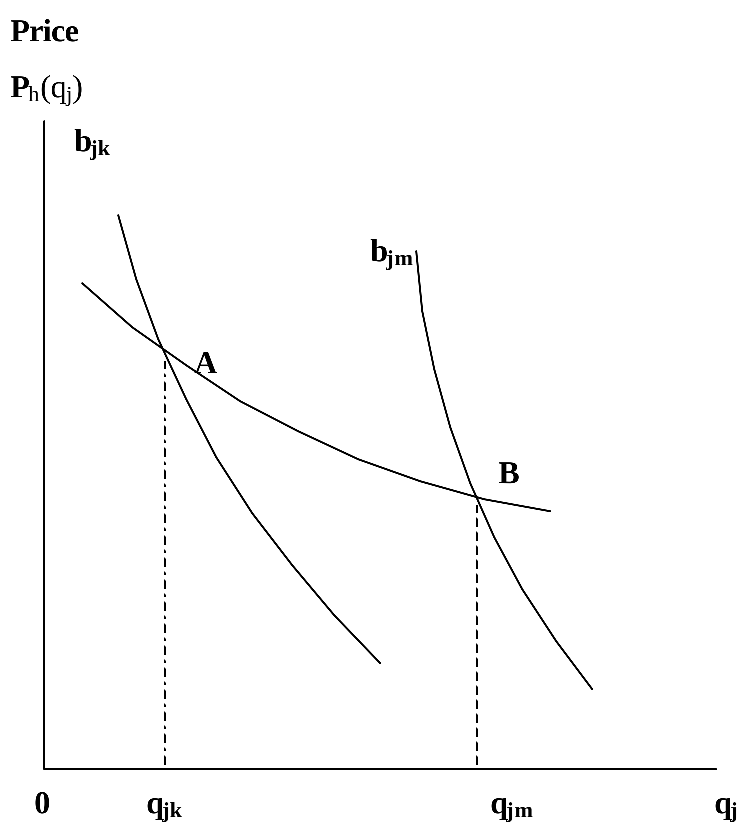


Fig. 2: Marginal Implicit Price Curve



The hedonic property values method is now widely used for finding the value people place on urban environmental quality. Ridker (1967) and Ridker and Henning (1976) provide the first empirical evidence that air pollution affects the property values. The early studies include Freeman (1974a; 1974b), Anderson and Crocker (1971; 1972), Lind (1973), Pines and Weiss (1976), Polinsky and Shavell (1976), Nelson (1978), Portney (1981), Horowitz (1986), Murdoch and Thayer (1988), and Kanemoto (1988). The most recent studies are Michaels and Smith (1990), Parsons (1992), Lansford and Jones (1995), Kiel (1995), Kiel and McClain (1995), Cheryl and Taff (1996), and Mahan, Polasky.

Most of these studies have so far used data from the developed countries with more developed housing markets. There are some empirical studies in India on the estimation of hedonic property value equation using the data from the urban housing markets. Parikh et al. (1994) have used the hedonic property value equation for the economic valuation of air quality degradation in Chembur, Mumbai. Another study by Sen (1994) has introduced the environmental variables in the hedonic price equation for finding the determinants of residential house prices in Delhi.

III Data and the Model for Estimation

Data about the structural and neighborhood characteristics of houses and socioeconomic characteristics of households are obtained through household surveys of Delhi and Kolkata. A sample of 1250 households in each city is chosen. The Delhi survey was conducted during May-June while the Kolkata survey was done during the month of July in the year 2002. There are 7 monitoring stations in Delhi and 22 monitoring stations in Kolkata providing regular monthly data on the air pollution concentrations of SPM, NO_x, and SO_2. The sample of 1250 households in each city was distributed among the areas representing 7 monitoring stations in Delhi and 22 monitoring stations in Kolkata. A sub-sample of households allotted to a monitoring station is drawn from the house locations within the one kilometer radius of the monitoring station.

Data about the structural characteristics of the house (covered area, number of rooms, indoor sanitation, independent house, and a flat in a multistoried building); neighborhood characteristics (distance from business center, highway, slum, industry, and the shopping center); and the environmental characteristics (household perception of local air quality, water quality, and green cover) are obtained through the household survey. Also, the data on house prices; monthly rent for rented houses, and house prices for owner occupied prices are obtained from the households during the survey.

Information about the demographic characteristics of households such as family size, age and sex composition of the family, the education level of family members, and the occupation of the respondent was collected. Data about the gross annual income of family, family monthly average household expenditure and the household inventory were obtained through the household survey.

The hedonic property value model described in Section II consists of a set of two equations one representing the hedonic price function (Eqn. 1) and another representing marginal willingness to pay function (Eqn. 5) for estimation. The equations for estimation are given as follows:

$$Ln(Y_1) = \alpha_1 + \beta_1 Ln(X_1) + \beta_2 Ln(X_2) + \beta_3 Ln(X_3) + \beta_4 Ln(X_4) + \beta_5 Ln(X_5) + \beta_6 Ln(X_6) + \beta_7 Ln(X_7) + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} Ln(X_{10}) + \beta_{11} X_{11} + \beta_{12} Ln(X_{12}) + \beta_{13} Ln(X_{13}) + \beta_{14} Ln(X_{14}) + \beta_{15} Ln(X_{15}) + \beta_{16} Ln(X_{16}) + \beta_{17} Ln(X_{17}) + u_1 \qquad (7)$$

$$Ln(Y_2) = \alpha_2 + \gamma_{19} Ln(X_{19}) + \gamma_{20} Ln(X_{20}) + \gamma_{13} Ln(X_{13}) + \gamma_{21} Ln(X_{21}) + \gamma_{11} Ln(X_{11}) + u_2 \qquad (8)$$

The variables used in an estimation of the above two equations are described as follows:

Monthly Rent (Y_1): Information on the monthly rents for the house is collected from each household. Imputed monthly rental values were used for the owner occupied houses in Delhi and Kolkata. Data for monthly rents collected through the survey is compared with the information about the market rents and property prices collected from the interviews of property dealers from different localities in Delhi and Kolkata.

Structural Characteristics of the House

Covered area (X_1): Data for total covered area of the houses were collected directly from the households and the figures were reported in square yards. In the case of independent owner occupied or rented houses care was taken to exclude any uncovered area. For the flats of course no such problems were encountered. In the case of multistoried buildings, the covered area was scaled for the number of floors.

Number of Rooms Including Drawing Rooms (X_2): The total number of rooms including drawing room were considered as a control variable for the monthly rental value of the house.

Indoor Sanitation (X_3): The index for indoor sanitation was constructed out of the following information: separate Kitchen, separate bathrooms and toilets, and condition of indoor ventilation. The Index ranges from 0 to 6. Whenever a facility was found separately in a house it scored a value of 1 otherwise 0, in this way it can take up a maximum value of 3 where separate kitchen, toilet and bathroom facilities are available. For ventilation a scale of 1 to 3 was used with higher number denoting better ventilation. These values were then added up to arrive at the composite scale of 0 to 6.

Distance Characteristics:

Distance from Business Centre (X_4): The distance from any common business centre in the city was collected from each household.

Distance from National Highways (X_5): The distance of the house from then national highways were collected and then an average distance was computed which proxied for the overall distance of the house from these national highways.

Distance from Slum (X_6): Distance from the nearby slums was collected for area around each monitoring station in the cities separately.

Distance from Industry (X_7): Distance from nearby industries for each monitoring station in each city was used to control for the extreme conditions of pollution in certain parts of the cities.

Distance from Shopping Centre (X_8): The distance from the nearest local shopping complex was collected for each monitoring stations in the cities.

Environmental Variables:

Perception about Air Quality (X_{10}): This is an ordered variable in the range of 1 to 3, which is used to rank the locality in terms of the air quality as perceived by the households, the higher being the rank, the higher the air quality.

Perception about Water Quality (X_{12}): This is also an ordered variable in the range of 1 to 3, which is used to rank the locality in term of the water quality as perceived by the residents of that area, the higher being the rank, the higher the water quality.

Dummy for Adequacy of Green Cover (X_{11}): This is a 1, 0 binary dummy variable, which is used to find out the perception of a household in any locality about the adequacy of the green cover (tree cover) in its location.

SPM (X_{13}): The average concentration of SPM in ì gms/m^3 in the last 6 months from the month of survey for a particular locality is used as the pollution variable.

$\mathbf{SO_2}$ (X_{14}): The average concentration of SO_2 in ì gms/m^3 in the last 6 months for a particular locality is used as the pollution variable.

$\mathbf{NO_x}$ (X_{15}): The average concentration of NO_x in ì gms/m^3 in the last 6 months for a particular locality is used as the pollution variable

Other variables:

Business or Salaried Class (X_9): Certain colonies inhabited by the business community have very high rental values than localities where the salaried class is in a majority. X_{10} is a dummy variable assigning 1 to business communities and 0 to Salaries class communities.

Variables for the Second Equation:

Marginal Willingness to pay (Y_2): The marginal willingness to pay for unit changes in the concentration of SPM or implicit marginal price for environmental quality is estimated using the following expression:

$$\frac{\partial(Monthly\,\mathrm{Re}\,nt)}{\partial(SPM)} = \left|Coefficient\,of SPM\_inEq7\right| \times \frac{\overline{Monthly\,\mathrm{Re}\,nt}}{SPM}$$

Education in Years (X_{18}): The education variable is constructed by adding up the years of education undertaken by the first five adult members of the family and dividing by 5.

Annual Gross Family Income (X_{19}): This is based on the gross annual family income of the household. In the absence of any concrete figures for actual incomes for certain households it was necessary to offer certain income brackets to the respondents to choose from.

Square of SPM (X_{20}): The log value of SPM and the square of the Log value of SPM are used in the second equation keeping in mind the necessary curvature property of the willingness to pay function. It is expected that the pollution, SPM, positively related to the marginal willingness to pay for reduction in pollution. Alternatively the environmental quality, inverse of SPM, is expected to be inversely related to the marginal willingness to pay. The descriptive statistics of all the selected variables under the purview of the present study are presented in the Appendix Tables A1, A2 and A3.

IV Estimates of Hedonic Property Model

Estimates of the hedonic property price function for Delhi, Kolkata, and the pooled data for Delhi are provided in Table 1. These estimates are corrected for heteroscedasticity using White's heteroscedasticity consistent standard errors. The coefficient for covered area (X_1) has expected positive signs with a 1% and 10% level of significance in Delhi and Pooled estimates; however for Kolkata the variable is insignificant and bears an opposite sign. The rental value of the house is also found to increase with the number of rooms (X_2) and the coefficient of this variable is significant at 1% for all the three estimates. The coefficient of the index for indoor sanitation (X_3) has a positive sign as expected and is significant at 1% level in all the three hedonic price functions. In Delhi and the pooled data based estimates of hedonic price function the rental value is found to be positively related to the distance of house from the business centre (X_4), national highways (X_5), slums (X_6) and industries (X_7). The coefficients of all distance variables are found to be significant at a 1% level in these two equations. In the case of Kolkata while all these coefficients have the required positive sign, however only the coefficient of the variable, distance from the business center (X_4) is significant at the 1% level, the others are not significant even at the 10% level. The dummy variable denoting the presence of a slum (X_8) also furnishes a negative coefficient as expected and it is uniformly significant at 1% for all the cities and the pooled data. The coefficients of the environmental variables like air quality (X_{10}), adequacy of green cover (X_{11}) and water quality (X_{12}) also have the required positive sign in each of the three estimates but their significance is found to be low for Delhi. For Kolkata and the pooled data the coefficient of green cover (X_{11}) is significant at the 10% level while the coefficient of water quality (X_{12}) is significant at 5% level. The coefficient of water supply variable (X_{17}) is insignificant in all the three cases. The dummy variable for business and salaried class (X_9) also has an expected positive sign and its significance varies from 1 to 10 % level in all the three equations. The coefficient of pollution variable SPM (X_{13}) has the negative expected sign and is significant at the 1% level in all the three equations. The coefficient for NO_x (X_{15}) has also a negative expected sign and is significant at the 1% level for Delhi and the pooled data and at the 10% level for Kolkata. However SO2 (X14) picks up

Table 1: Estimates of Hedonic Property Price Function Using OLS

Location: →	**Delhi**	**Kolkata**	**Pooled**
Equation 1: Dependent variable Ln (Monthly House Rent)			
Log values of Variables (Expected Signs)	Coefficients (t-statistics)	Coefficients (t-statistics)	Coefficients (t-statistics)
Constant	10.23759*** (11.37)	10.58682*** (14.39)	10.06323*** (19.76)
Covered Area: X_1 (+)	0.183950*** (3.95)	-0.026117 (-1.06)	0.034560* (1.62)
No. of Rooms: X_2 (+)	0.646681*** (9.30)	0.955376*** (14.82)	0.853732*** (18.67)
Indoor Sanitation: X_3 (+)	0.464654*** (4.39)	0.291560*** (3.12)	0.375379*** (5.47)
Distance from Business Centre: X_4 (+)	0.143340*** (4.59)	0.137361*** (5.57)	0.137134*** (7.88)
Distance from National highways: X_5 (+)	0.051224*** (3.36)	0.061320 (0.94)	0.058846*** (4.05)
Distance from Slums: X_6 (+)	0.202827*** (3.22)	0.150310 (1.34)	0.141984*** (3.30)
Distance from Industries: X_7 (+)	0.144710*** (3.03)	0.051119 (0.70)	0.102353*** (2.81)
Dummy for Slums: $^{\$}X_8$ (-)	-0.257561*** (-4.17)	-0.379371*** (-5.59)	-0.373213*** (-10.53)
Dummy for Business or salaried class: $^{\$}X_9$ (+)	0.173580*** (3.43)	0.056327* (1.62)	0.083610*** (2.93)
Perception about Air Qlty: X_{10} (+)	0.089259 (1.22)	0.050404 (0.78)	0.056361 (1.21)
Adequacy of Green Cover: $^{\$}X_{11}$ (+)	0.044258 (0.89)	0.087828* (1.74)	0.060027* (1.67)
Perception about water Qlty: X_{12} (+)	0.060599 (0.86)	0.173977** (2.33)	0.145228*** (2.89)
SPM: X_{13} (-)	-0.658795*** (-5.59)	-0.719903*** (-7.13)	-0.629495*** (-9.16)
SO_2: X_{14} (-)	0.142859* (1.62)	0.174656 (1.13)	0.134722* (1.82)
NO_x: X_{15} (-)	-0.268090*** (-2.63)	-0.177321* (-1.88)	-0.247025*** (-3.87)
Water Supply in Hrs: X_{16} (+)	-0.033733 (-1.23)	0.034463 (0.95)	-0.012218 (-0.56)
Distance from Shopping Centre: X_{17} (-)	0.019048 (1.30)	-0.044881 (-0.71)	0.013567 (0.92)
City Dummy X_{22} (+)			0.654507*** (5.37)
R^2	0.4504	0.3873	0.4809
Adjusted R^2	0.4424	0.3786	0.4770
F-statistic	56.35538	44.10878	122.0922
Prob(F-statistic)	0.000000	0.000000	0.000000

Note: *(**) & (***) denotes significance at 10 (5) & (1) % levels. $ denotes variables without log values.

a positive coefficient in all the estimates and is significant at 10% for Delhi and the pooled data. Given that the SO2 concentrations are below the MINAS standards in both Delhi and Kolkata, further reductions of this pollutant could not be affecting the property prices.

Implicit marginal price functions for SPM concentration that are obtained for each city and the pooled data for both the cities by taking the derivative of hedonic property price function with respect to SPM (X_{13}) are given as follows:

$$\frac{\delta Y_1}{\delta X_{13}} = -0.658 \frac{Y_1}{X_{13}} \quad \text{for Delhi} \qquad (9a)$$

$$\frac{\delta Y_1}{\delta X_{13}} = -0.720 \frac{Y_1}{X_{13}} \quad \text{for Kolkata} \qquad (9b)$$

$$\frac{\delta Y_1}{\delta X_{13}} = -0.629 \frac{Y_1}{X_{13}} \quad \text{for Pooled Data} \qquad (9c)$$

The household specific implicit marginal price for SPM is obtained as the absolute value of derivative of hedonic property value function in equation (9) given the observed values of the variables $\mathbf{Y_1}$ and $\mathbf{X_{13}}$ for the household. The household marginal willingness to pay function for the reduction in SPM is estimated by regressing the implicit marginal prices on income, education and other socioeconomic variables and the SPM concentration (the inverse of the environmental or atmospheric quality). Two separate estimates of the marginal willingness to pay function are made using the pooled data for Delhi and Kolkata. One estimate is based on hedonic property price functions estimated for the segmented house markets Delhi and Kolkata. The implicit marginal prices for SPM reductions are computed for each market and then pooled. The pooled implicit marginal prices are regressed on the SPM levels and the socioeconomic characteristics of households. This is one approach to the econometric problem of identification in the estimation of the household marginal willingness to pay function discussed in Section II. Another estimate is based on the hedonic property price function estimated using the pooled data for Delhi and Kolkata. Table 2 reports the estimated marginal willingness to pay functions for Delhi, Kolkata and the pooled data. Income and education are supposed to affect the household marginal willingness to pay for the reduction of pollution (Y_2) positively. Estimates show that these variables, education, (X_{18}), and income (X_{19}), have positive coefficients, which are significant at the 1% level. The pollution variable SPM (X_{13}) has a positive sign as expected (showing diminishing marginal utility with respect to environmental quality, the inverse of SPM) and is significant at the 5% level in equations for Delhi and Kolkata. However the variable, the square of SPM (X_{21}) has a negative sign reflecting the curvature property of the marginal willingness to pay function and is significant at the 5% level in all the three equations. The variable, environmental perception (X_9) also has a positive coefficient and is significant at the 1% level in all the three equations. The city dummy variable (X_{21}) is positive and significant at the 1% level in the equation of pooled data for Delhi and Kolkata.

Table 2: Estimates of Marginal Willingness to Pay Function Using OLS

Location: →	**Delhi**	**Kolkata**	**Pooled**	
Equation 2: Dependent Variable Ln (Marginal Rent)				
	Individual estimates	**Individual estimates**	**Unsegmented Market Approach**	**Segmented Market Approach**
Log Values of Variables (Expected Sign)	Coefficient (t-statistics)	Coefficient (t-statistics)	Coefficient (t-statistics)	Coefficients (t-statistics)
Constant	-43.17935*** (-3.61)	-22.96979** (-2.48)	-9.528113* (-1.87)	-30.62877*** (-5.25)
Education X_{18} (+)	0.430238*** (5.87)	0.796318*** (6.94)	0.568856*** (9.47)	0.558753*** (9.23)
Income X_{19} (+)	0.538860*** (13.76)	0.571237*** (11.52)	0.581866*** (19.61)	0.554709*** (18.01)
SPM X_{13} (+)	14.32783*** (3.51)	6.737927** (2.07)	2.455464 (1.38)	9.689258*** (4.77)
Sq SPM X_{20} (-)	-1.336191*** (-3.89)	-0.693091** (-2.42)	-0.343254** (-2.22)	-0.950415*** (-5.42)
Perception about Air Quality X_{10} (+)	0.270875*** (3.46)	0.173072*** (3.30)	0.224356*** (5.19)	0.221595*** (5.05)
City Dummy X_{23} (+)			0.805351*** (21.39)	0.790453*** (21.48)
R^2	0.357199	0.333585	0.444870	0.422956
Adjusted R^2	0.354477	0.330727	0.443521	0.421484
F-Statistics	131.2541	116.7321	329.7674	287.3245
Probabilities (F)	0.000000	0.000000	0.000000	0.000000

Note: *(**) & (***) denotes significance at 10 (5) & (1) % levels. Sq SPM is Log(SPM) x Log(SPM)

Ideally one could expect that the similar sets of structural and neighborhood variables (as used in the estimation of the Hedonic price function) along with the environmental and socioeconomic characteristics determine the marginal willingness to pay for environmental quality. However in the current study, it has been observed that the elasticity of marginal willingness to pay jointly determined by the two pollution variables (X_{13} and X_{20}) remain unaffected with the inclusion of the structural and environmental characteristics. The robustness of the parametric estimates can be attributed to the weak separability between the Environmental variables with the Structural and Neighbourhood characteristics while determining the marginal willingness to pay for clean air.

Following a segmented market approach and using only environmental and socioeconomic characteristics in the estimation of marginal willingness to pay function, the welfare gains to a typical household in Delhi and Kolkata is obtained as Rs.10.57 and Rs.5.24, respectively. However, while using a larger model (including structural and neighbourhood characteristics), the welfare gains for Delhi and Kolkata are Rs.10.57 and Rs.5.49, respectively. Thus using either of the methods we arrive at a similar set of welfare gains.

V Estimates of Welfare Gains from Reduced Air Pollution

Estimates of the marginal willingness to pay function reported in Table 2 could be used to estimate the marginal willingness to pay for reducing the SPM concentration by a microgram and the welfare gain to representative household for each city by reducing the SPM concentration from the current level to the WHO safe level or to the MINAS standard. Given that the house price is measured as monthly rent, the household monthly marginal willingness to pay for SPM reduction could be estimated by substituting the sample average values for all the exogenous variables in the estimate of the marginal willingness to pay function given in Table 2. By multiplying the estimate of monthly marginal willingness to pay by the amount of SPM concentration required to be reduced to reach its safe level, an estimate of monthly welfare gain to a representative household in each city could be obtained. Table 3 provides estimates of the annual marginal willingness to pay and the annual welfare gains to a representative household in each city and for the pooled data. The annual welfare gains to a typical household from reducing SPM concentration from the current level to the MINAS standard of 200 ì gms/m^3 in Delhi, and Kolkata are respectively, Rs.19870.70 and Rs.8435.71. According to 2000 census, Delhi and Kolkata have urban populations of 12819761, and 14397983 with sample average household sizes 5.46 and 4.56 respectively. Thus there are 2347942, and 3157452 estimated urban households in Delhi and Kolkata. The annual benefits from reducing the SPM concentration to safe level in Delhi and Kolkata are respectively estimated as Rs. 46655.2 million and Rs. 2663.5.3 million.

Two approaches are used to arrive at the estimates of marginal willingness to pay function using the pooled data of Kolkata and Delhi. In one approach, the marginal implicit prices for reducing SPM are computed separately for households in each market using the estimate of hedonic property price function for each city. Then the pooled marginal implicit prices from the two markets are regressed on SPM and socio economic characteristics of households to arrive at an estimate of marginal willingness to pay function. As explained in Section II, this is one way of dealing with the identification problem in the estimation of marginal willingness to pay function. Another approach is to estimate the hedonic property value model using the pooled data of two cities and then estimate the marginal willingness to pay function for the reduction in SPM. The parameter estimates of marginal willingness to pay function estimated either way are used to estimate the annual marginal willingness to pay and annual welfare gains to a representative household from Delhi and Kolkata by reducing the SPM concentrations from the current levels to safe level. Table 3 provides these estimates. The cities of Kolkata and Delhi taken together could represent a typical urban area in India since they differ significantly with respect to climatic conditions and socio economic characteristics. Out of six major metropolitan areas, Mumbai, Kolkata, Chennai, Delhi, Bangalore and Hyderabad, in India, first three of them belong to coastal areas while other three are located inland. It is possible to make predictions about the annual welfare gains, by reducing SPM levels from its current level to safe level, to the representative household from each city using the parameter estimates of hedonic property value function estimated using the pooled data of Kolkata and Delhi.

Table 3: Estimates of Welfare Gains to Urban Households in Delhi, Kolkata and for the pooled model.

Nature of Gains to households	**Gains to Household based on Individual estimates from cities**		**Gains to Household Using Pooled data model after controlling for city specific Dummy and SPM concentration Unsegmented Market Approach**			**Gains to Household Using Market Segmentation Approach**	
	Delhi	**Kolkata**	**Delhi**	**Kolkata**	**Pooled**	**Delhi**	**Kolkata**
Monthly gains in Rental value due to reduction of SPM concentration by 1 ì gms/m^3	Rs.10.57	Rs.5.79	Rs.9.94	Rs.5.65	Rs.7.07	Rs.10.57	Rs.5.24
Monthly gains in Rental value due to reduction of SPM concentration from the current average to the safe level corresponding to 200 ì gms/m^3	Rs.1655.89	Rs.702.98	Rs.1023.89	Rs.730.80	Rs.974.93	Rs.1655.85	Rs.636.83
Annual gains in Rental value due to reduction of SPM concentration by 1 ì gms/m^3	Rs.126.85	Rs.69.49	Rs.78.43	Rs.67.78	Rs.84.88	Rs.126.84	Rs.62.95
Annual gains in Rental value due to reduction of SPM concentration from the current average to the safe level corresponding to 200 ì gms/m^3	Rs.19870.70	Rs.8435.71	Rs.18686.11	Rs.8769.65	Rs.11699.16	Rs.19870.24	Rs.7641.98
Annual gains in Rental value due to reduction of SPM concentration from the current average to the safe level corresponding to 200 ì gms/m^3 to the total Urban Households.	**Rs.46655.2 millions**	**Rs.26635.3 millions**	**Rs.43873.89 millions**	**Rs.27689.74 millions**	**Rs.63557.8* millions**	**Rs.46654.17 millions**	**Rs.24129.21 millions**

Note: * Based on Total Urban Population of Delhi and Kolkata

VI Conclusion

Recent empirical studies including the one attempted in this paper show that the observed behavioral methods of valuation could be used successfully to estimate the benefits from environmental quality improvements. These methods have the advantage of using data from the real markets for the commodities that are either substitutes or complements to environmental services. As shown in this paper the required data could be obtained from the secondary sources or through household surveys. On the other hand the criticism of hypothetical behavioral methods or contingent valuation methods is well known and the empirical studies using these methods show that there could be a lot of uncertainties about the quality of the data obtained in the hypothetical markets for environmental services created through the survey methods.

The data about air pollution in different locations in the city, the house characteristics, and the socioeconomic characteristics of households collected through household surveys in the cities of Delhi and Kolkata explain well the hedonic property price function. The estimated marginal willingness to pay function shows a positive relationship between the marginal willingness to pay and socioeconomic variables income and education as expected. However, it shows the required curvature properties with respect to pollution variables in a certain range especially for lower values of pollution concentrations.

The welfare gains from reducing air pollution from the current levels to the safe levels in the cities of Delhi and Kolkata as revealed through the location choices of houses by the households are very high. A representative household gets an annual benefit of Rs.19, 870.70 in Delhi and Rs.84, 355.71 in Kolkata. When the benefits are extrapolated to all the urban households in each city, the households in Delhi gets benefits worth Rs.46, 655.2 million while those in Kolkata gets benefits worth Rs.26, 635.3 million. Though these benefits appear to be high, they are not so in comparison to the cost to the Government and polluters to reduce the air pollution levels from the current level to the safe level. In fact these benefit estimates justify the cost of environmental policy changes like introducing CNG operated vehicles, and substituting the metro rail to road transport and the relocation of polluting industries in the cities.

Two separate estimates of the hedonic property price model for the combined markets for houses in Delhi and Kolkata are made depending upon the method of pooling the data. One approach uses the segmented markets for houses, one market for Delhi and another for Kolkata and estimates a hedonic price function for each market. Household specific marginal implicit prices for environmental quality are computed separately for each market and then pooled to estimate the marginal willingness to pay function for air quality by households in the cities of Delhi and Kolkata. This is one method of dealing with the econometric problem of identification in the estimation of the hedonic property value model. Another approach uses pooled data of both the cities to estimate the hedonic property price function for the composite housing market of Delhi and Kolkata.

Appendices:

Table A1: Descriptive Statistics of the Variables Used for Estimation of the Hedonic Property Value Model. Location: Delhi

	Rent (Rs/month) (Y_1)	Covered area (Sq yards) (X_1)	Number of rooms (X_2)	Indoor sanitation Index (X_3)	Distance from Business Centre (Km) (X_4)	Distance from National Highway (Km) (X_5)
Mean	9536.612	136.9534	4.096040	4.462511	4.992334	1.279174
Std. Dev.	13725.58	342.6036	2.527597	1.148752	4.975135	1.397169
Observations	1187	1187	1187	1187	1187	1187

	Distance from Slum (Km) (X_6)	Distance from Industry (Km) (X_7)	Dummy for Nearby Slums (X_8)	Dummy for Business Community (X_9)	Perception of Air Quality Index (X_{10})	Index for Adequacy of Green Cover (X_{11})
Mean	1.594302	1.330526	0.571188	0.541702	2.144903	0.622578
Std. Dev.	1.217707	1.317624	0.495115	0.498468	0.623511	0.547041
Observations	1187	1187	1187	1187	1187	1187

	Perception about drinking water (X_{11})	SPM (X_{13})	SO_2 (X_{14})	NO_2 (X_{15})	Water Supply (Hours / day) (X_{16})	Distance from Nearest Shopping Centre (Km) (X_{17})
Mean	2.127211	366.3136	12.96807	36.45013	5.998678	2.788031
Std. Dev.	1.113989	86.42897	4.088191	13.13383	5.958350	3.247169
Observations	1187	1187	1187	1187	1187	1187

	Education Index (Years) (X_{18})	Gross annual Family Income (Rs) (X_{19})	SPM*SPM (X_{20})	Marginal Rent (Rs) (X_{21})
Mean	12.29264	179565.3	141649.4	61.39653
Std. Dev.	4.238082	127156.2	69776.29	51.12671
Observations	1187	1187	1187	1187

Table A 2: Descriptive Statistics of the Variables Used for Estimation of the Hedonic Property Value model: Location Kolkata

	Rent (Rs/month) (Y_1)	Covered area (Sq yards) (X_1)	Number of rooms (X_2)	Indoor sanitation Index (X_3)	Distance from Business Centre (Km) (X_4)	Distance from National Highway (Km) (X_5)
Mean	3902.831	1169.304	4.324751	4.889535	5.157973	1.137949
Std. Dev.	4288.262	1284.462	3.041145	1.356095	6.775391	1.062752
Observations	1204	1204	1204	1204	1204	1204

	Distance from Slum (Km) (X_6)	Distance from Industry (Km) (X_7)	Dummy for Nearby Slums (X_8)	Dummy for Business Community (X_9)	Perception of Air Quality Index (X_{10})	Index for Adequacy of Green Cover (X_{11})
Mean	0.330133	0.627816	0.553156	2.095515	1.830565	0.347176
Std. Dev.	1.167176	0.789318	0.497373	0.761728	0.785062	0.483201
Observation	1204	1204	1204	1204	1204	1204

	Perception about drinking water (X_{12})	SPM (X_{13})	SO_2 (X_{14})	NO_2 (X_{15})	Water Supply (Hours / day) (X_{16})	Distance from Nearest Shopping Centre (Km) (X_{17})
Mean	2.182724	331.3123	8.892027	123.3310	8.711379	1.243937
Std. Dev.	0.807179	83.98949	2.018197	37.08074	6.359156	1.309642
Observation	1204	1204	1204	1204	1204	1204

	Education Index (Years) (X_{18})	Gross annual Family Income (Rs) (X_{19})	SPM*SPM (X_{20})	Marginal Rent (Rs) (X_{21})
Mean	14.28763	158930.1	116816.2	8.610870
Std. Dev.	3.165503	102890.3	53862.82	10.56282
Observation	1204	1204	1204	1204

Table A 3: Descriptive Statistics of the Variables Used for Estimation of the Hedonic Property Value Model: Location Pooled data of Delhi and Kolkata

	Rent (Rs/month) (Y_1)	Covered area (Sq yards) (X_1)	Number of rooms (X_2)	Indoor sanitation Index (X_3)	Distance from Business Centre (Km) (X_4)	Distance from National Highway (Km) (X_5)
Mean	6546.224	679.1058	4.194072	4.677541	4.973521	1.782558
Std. Dev.	10354.50	1146. 499	2.783644	1.275187	5.904172	2.033789
Observations	2391	2391	2391	2391	2391	2391

	Distance from Slum (Km) (X_6)	Distance from Industry (Km) (X_7)	Dummy for Nearby Slums (X_8)	Dummy for Business Community (X_9)	Perception of Air Quality Index (X_{10})	Index for Adequacy of Green Cover (X_{11})
Mean	0.957724	0.976673	0.560484	1.328437	1.976979	0.486410
Std. Dev.	1.349522	1.139571	0.496428	1.009871	0.727994	0.548683
Observations	2391	2391	2391	2391	2391	2391

	Perception about drinking water (X_{12})	SPM (X_{13})	SO_2 (X_{14})	NO_2 (X_{15})	Water Supply (Hours / day) (X_{16})	Distance from Nearest Shopping Centre (Km) (X_{17})
Mean	2.147190	349.0961	10.81923	82.08902	7.376280	2.533180
Std. Dev.	0.968021	86.66497	3.770856	52.22872	6.330675	2.637017
Observations	2391	2391	2391	2391	2391	2391

	Education Index (Years) (X_{18})	Gross annual Family Income (Rs) (X_{19})	SPM*SPM (X_{20})	Marginal Rent (Rs) (X_{21})	Dummy Delhi=1, Kolkata=0 (X_{22})
Mean	13.76080	167671.7	129375.9	13.01224	0.477474
Std. Dev.	3.790868	115361.6	63181.19	24.05491	0.499593
Observations	2391	2391	2391	2391	2391

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