A Generalized Method of Hedonic Prices: Measuring Benefits from Reduced Urban Air Pollution*

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Abstract: A generalized hedonic prices model considering household decisions about house location, job and travel as interdependent is used in this paper to estimate the environmental benefits from the reduced exposure of the household to pollution. The data used are obtained from a primary survey of households in the twin cities of Hyderabad and Secunderabad in India. Data are collected about house characteristics, job and travel characteristics of household members, and socio economic characteristics of households. Estimates of inverse demand functions of urban air quality revealed through household choices of house locations and travel are obtained. A typical household in the twin cities has revealed an annual willingness to pay for reducing urban air pollution from the current level to a safe level at Rs 4,499.72 through house location choices and Rs 3,243 through travel choices. Therefore the total annual willingness to pay of a typical household for reducing air pollution to a safe level is Rs 7,743. The gains for all the households in the twin cities are estimated as per 2001 Census (provisional) as Rs 6,437 million. The damages from air pollution in the twin cities constitute 0.0423 per cent of State Domestic Product (SDP) of Andhra Pradesh in 2003 and the SDP corrected for air pollution is given as Rs 15,12,523 million.

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I. Introduction

The valuation of environmental services is required for diverse purposes such as for: (a) estimating Green GDP, (b) making investment decisions, and (c) designing environmental policy instruments.

Environmental values conceptually could be defined as producer values and household values[1]. The UN methodology of Integrated Environmental and Economic Accounting defines producer value or maintenance cost as the cost of sustainable use of environmental resources. A number of valuation methods are suggested in the literature for measuring household values: contingent valuation (CV), household production functions, and hedonic prices. In pollution related studies, all these methods aim at estimating the benefits to the households from reducing exposure to air or water pollution. Therefore, the accurate measurement of household exposure to pollution is an important component of the valuation method. Household members are exposed to different levels of ambient air pollution at home, at office, at school, and on travel. The health benefits of reduced pollution are estimated using CV and health production function methods by measuring household values on reduced total exposure to pollution.

In the case of hedonic prices methods, the hedonic property prices method is used to estimate the benefit to households from reduced pollution at the house location and the hedonic wage model is used to estimate the benefits to a member of the household from the reduced pollution at the work place. The household choices about house location, job location and travel of its members determine the household exposure to pollution. These are interdependent decisions if the household tries to minimize the exposure to pollution through these choices. Therefore, a generalized hedonic prices model considering household decisions about house location, job and travel are interdependent is needed to estimate the environmental benefits from the reduced exposure of households to pollution.

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[1] For detailed treatment of producer values see Murty and Kumar (2004), and Murty and Gulati (2004). See for a comprehensive discussion about household values Freeman (1993), Mitchell and Carson (1989), and Murty and Kumar among many others.

This paper provides a generalized hedonic prices model. An attempt is made to estimate this model using the data collected through a specially designed household survey in the twin cities of Hyderabad and Secunderabad in state of Andhra Pradesh (AP) in India. Household demand function for the air quality and the potential welfare losses from the current air pollution exceeding the safe level in these cities are estimated. It is shown that these welfare losses have to be accounted in the estimation of Green Gross State Domestic Product (GGSDP).

II. A General Model of Hedonic prices: Interdependent Individual Choices of Location of House, Travel and Job

Commodities can be distinguished by the characteristics they possess and their prices are functions of these characteristics. From the owner's point of view, land property could be distinguished in terms of location, size, and local environmental characteristics. From the worker's point of view, a job is a differentiated product in terms of risk of on job accident, working conditions, prestige, training, enhancement of skills, and the local environmental quality. From the commuters point of view, travel is a differentiated product in terms of mode of transport, route, distance, time, and on travel exposure to environmental pollution. Rent, wage, and travel cost are respectively functions of the local air quality at home, air quality at work place, and the air quality in the areas through which one travels. Individuals try to minimize exposure to pollution in a day by an appropriate mix of choices of house location, regular travel, and work place depending upon house rent or price, travel cost, and the wage premium for the environmentally risky jobs thus making these choices interdependent.

A Model of Hedonic prices

Hedonic prices equations of house, travel and wage are given as follows

House price equation

$$P = P(H) \qquad (1)$$

where P: House price;

H: A vector of house characteristics.

Wage equation

W = W(J), (2)

where W: Wage rate

J: A vector of job characteristics.

Travel cost equation

C = C(T), (3)

where C: Travel cost

T: A vector of travel characteristics.

House characteristics could be described as structural (size of the house), neighbourhood (distance characteristics such as nearness to market, work place, hospital, and school, crime rate, majority local community etc.); and environmental characteristics (local atmospheric and ground water quality, tree cover etc.). Travel characteristics are described as route taken, pollution en route, mode of transport, and time spent on travel. Job characteristics are type of job (blue or white collar), work experience, accidental risk, and exposure to environmental pollution at work.

The household utility function and the budget constraint are defined as

U = U (X, H, J, T), (4)

where X is a private good which is taken as a numeraire.

$I^* + W - X - P - C = 0$, (5)

where I^* is non-wage income.

The household chooses H, J, and T by maximizing the Lagranzean

$L = U (X, H, J, T) - l[I^* + W - X - P - C]$. (6)

Let E_1, E_2 and E_3 represent the exposure of an individual to pollution while staying at home, traveling and working; on the environmental characteristics of House, Job and Travel.

Conditions for household choices of E_1, E_2 and E_3 along with other choices are:

$$\frac{U_{E_1}}{U_X} = \frac{\partial P}{\partial E_1} \qquad (7a)$$

$$\frac{U_{E_2}}{U_X} = -\frac{\partial W}{\partial E_2} \qquad (7b)$$

$$\frac{U_{E_3}}{U_X} = \frac{\partial C}{\partial E_3} \quad (7c)$$

The implicit marginal price of environmental pollution is given as:

$$IMP = \frac{\partial P}{\partial E_1} - \frac{\partial W}{\partial E_2} + \frac{\partial C}{\partial E_3} \quad (8)$$

If House Job and Travel choices are interdependent; the hedonic prices equations are given as follows:

P = P (H, J, T, W, C) (9)

W = W (H, J, T, P, C) (10)

C = C (H, J, T, P, W) (11)

The conditions for household choices of E_1, E_2 and E_3 along with other choices are given as

$$\frac{U_{E_1}}{U_X} = \frac{\partial P}{\partial E_1} - \frac{\partial W}{\partial E_1} + \frac{\partial C}{\partial E_1} = IMP_1 \quad (12a)$$

$$\frac{U_{E_2}}{U_X} = \frac{\partial P}{\partial E_2} - \frac{\partial W}{\partial E_2} + \frac{\partial C}{\partial E_2} = IMP_2 \quad (12b)$$

$$\frac{U_{E_3}}{U_X} = \frac{\partial P}{\partial E_3} - \frac{\partial W}{\partial E_3} + \frac{\partial C}{\partial E_3} = IMP_3 \quad (12c)$$

The implicit price of environmental pollution is again given as

$IMP = IMP_1 + IMP_2 + IMP_3$. (13)

The inverse demand function for environmental quality is derived as

MWP = MWP (E_1, E_2, E_3, H, J, T, G), (14)

where G: Socio economic characteristics of the household.

The consumer surplus benefits(compensating or equivalent surplus) of improved environmental quality at home, on travel, and at work are obtained as,

$CS_1 = \int MWP\ \delta E_1$ (15a)

$CS_2 = \int MWP\ \delta E_2$ (15b)

$CS_3 = \int MWP\ \delta E_3$. (15c)

The over all consumer surplus benefits are obtained as

$CS = CS_1 + CS_2 + CS_3$. (16)

III. Estimation of Model

3.1 Model for Estimation

Estimation of hedonic prices model is done by first estimating the hedonic prices function and calculating the implicit marginal prices of characteristics of the commodity and then estimating the marginal willingness to pay function for each characteristic. The marginal willingness to pay function is defined by expressing the household specific implicit marginal price of a characteristic as a function of the characteristics of the commodity and the socioeconomic characteristics of households. Many empirical studies on hedonic prices models show that the Box-Cox transformation of variables yields better model estimates.

The Quadratic Box-Cox Model

$$P^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i X_i^{(\lambda)} + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \gamma_{ij} X_{i=1}^{(\lambda)} X_{j=1}^{(\lambda)} \qquad (17)$$

where P is the price, and X_i's are the characteristics of the commodity and $P^{(\theta)}$, and $X^{(\lambda)}$ are Box-Cox transformations:

$$P^{(\theta)} = \left(P^{\theta} - 1\right)/\theta, \qquad \forall\ \theta \neq 0$$

$$= \text{Ln P} \qquad \theta = 0.$$

$$X_i^{(\lambda)} = \left(X_i^{\lambda} - 1\right)/\lambda \qquad \forall\ \lambda \neq 0$$

$$= \text{Ln } X_i \qquad \lambda = 0.$$

Imposing zero restrictions on θ and λ we can obtain the trans log form attributed to Christensen, Jorgenson and Lau (1971) given by:

$$LnP = \alpha_0 + \sum_{i=1}^{m} \alpha_i LnX_i + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \gamma_{ij} LnX_i LnX_j .$$

Adding a stochastic term to the quadratic model we get: -

$$P^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i X_i^{(\lambda)} + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \gamma_{ij} X_{i=1}^{(\lambda)} X_{j=1}^{(\lambda)} + \varepsilon_t \qquad (18)$$

The two equations of the hedonic prices model estimated in this paper with Box-Cox transformation of both dependent and independent variables are:

$$P_h^{(\theta_1)} = \alpha_1 + \sum \beta_i X_i^{(\lambda_1)} + u_h \quad (19)$$

$$Y_h^{(\theta_2)} = \alpha_2 + \sum \gamma_i X_i^{(\lambda_2)} + \sum \mu_j G_j^{(\lambda_2)} + v_h \quad (20)$$

h= 1…..H.

where X_i , i = 1…N and G_j , j = 1…S are respectively the characteristics of commodity and socio economic variables of the household , Y_k is the marginal willingness to pay for the environmental characteristic of the commodity and θ_1 ,θ_2 and λ_1, λ_2 are respectively Box-Cox transformations on dependent and independent variables in the two equations. Since these transformations apply only to positive values of P,Y ,X, and G, the constant and the dummy variables are not transformed.

3.2 Data

The data used for the estimation are obtained from a specially designed household survey of a sample of households in the cities of Hyderabad and Secunderabad and the secondary data is from the Andhra Pradesh State Pollution Control Board (APPCB) and the Central Pollution Control Board (CPCB). The twin cities have 20 air pollution monitoring stations regularly monitored by the APPCB and collecting data on the concentrations of RSPM, NO_x, and SO_2 in the atmosphere. The sample of 1250 households was distributed among the areas around 20 monitoring stations. The households within a one-kilometre radius of the monitoring station were chosen for the sample. The area around a monitoring station is divided as low income, middle income and higher income localities and a sub-sample of households earmarked for that area is drawn having a representation of each locality. Households earmarked for each locality are selected randomly for the survey. Thus a stratified random sample method is used for choosing a sample of households for the survey.

The present survey conducted during January - February, 2004 has collected data about the structural, neighbourhood, and environmental characteristics of houses, the travel characteristics of travel in the city by the members of the household, the job characteristics of working members of the household, and the socio-economic characteristics of households. Tables 1,2, and 3 provide the descriptive statistics of variables for which data were collected.

Table 1: Descriptive Statistics – Hedonic Property Price Model

Name of the Variable	Mean	Standard Deviation
House Ownership	2.5189	0.6745
Number of Floors	1.1977	0.4481
Number of Rooms	3.4723	1.5171
Number of Bathrooms	1.7623	0.9279
Air Cooler	0.4335	0.6855
Air Conditioner	0.1619	0.6579
Connect to Public Sewer	0.9211	0.2728
Water Quality	1.5386	0.5297
Ventilation	0.6944	0.8925
Cooking Fuel	0.9672	0.1781
Business / Salaried	0.3070	0.4615
Religion	0.8784	0.3270
Property Price Enhancing	0.3720	0.4835
Water logging	0.2924	0.4548
Green Cover	0.4366	0.4962
Exposure	0.0529	0.2241
House Age	17.6123	14.3579
Plot Area	1809.039	2155.723
Distance from Business Center	0.9595	0.66008
Distance from Shopping Mall	0.7445	0.4162
Distance from Slum	1.1076	0.4526
Distance from Industries	7.0931	4.1179
Area of Park	192507.6	167488.9
Electricity	23.8274	0.5726
Education	15.0486	7.0756
Income	164098.8	171804.5

Table2: Descriptive Statistics – Hedonic Travel Cost

Name of the variable	**Mean**	**Standard Deviation**
Mode of Transport	0.4852	0.5000048
Multiple Mode of Trans	0.1915	0.39363
Car AC or non AC	0.0457	0.20893
Distance Traveled	9.6106	10.2864
Time taken in commuting	0.5832	0.62288
En Route RSPM	84.7494	17.8476
Education	14.6709	4.0394

3.3 The Hedonic Property Value Model

Estimates of the hedonic property price equation for the twin cities of Hyderabad and Secunderabad are given in Table 3. The estimation is done with the Box-Cox transformation of dependent and independent variables since the null hypothesis of standard values of θ_1 and λ_1 is rejected in favour of unrestricted estimates of θ_1 and λ_1. The coefficients of most of the independent variables in the equation have required signs and are statistically significant. These variables represent the structural characteristics like number of rooms, number of floors, use of air conditioners, ventilation and connection to a public sewer, the distance characteristics like distance from market, and distance from industries, the neighbuorhood characteristics like majority religion, presence of business class and property price enhancing activities and the environmental characteristics like presence of air pollutants: RSPM, SO_2, and NO_x.

Table 3: Parameter Estimates of Hedonic Property Price Equation

Dependent variable: Annual Rent of House.		Theta = 0.029*, Lambda = 0.123	
Variables	Coefficient (Chi Sq)	Variables	Coefficient (Chi Sq)
Constant	5.599	Water logging (wlogg)	-0.083* (3.160)
House Ownership (hown)	0.030 (0.952)	Green Cover (gcover)	0.065 (2.212)
Number of Floors (nf)	0.065 (1.859)	Exposure (expos)	-0.088 (0.918)
Number of Rooms (nr)	0.101*** (35.103)	RSPM (rspm12)	-0.182*** (15.558)
Number Bathrooms (nb)	0.203*** (49.034)	SO2 (so12)	-0.432** (4.739)
Air Cooler (a)	0.219*** (38.920)	NOx (nox12)	0.199** (3.855)
Air Conditioner (ac)	0.270*** (38.625)	House Age (hage)	-0.024 (1.907)
Connected to Public Sewer (psew)	0.178*** (5.460)	Plot Area (pa)	0.145*** (95.802)
Water Quality (wq)	0.025 (0.307)	Distance from Business Center (dbs)	-0.336*** (19.148)
Ventilation (ven)	0.096*** (14.019)	Distance from Shopping Mall (dsm)	0.002 (0.001)
Cooking Fuel (fuel)	0.428*** (12.933)	Distance from Slum (dslm)	0.255*** (18.143)
Business or Salaried (bsal)	0.105** (4.140)	Distance from Industries (dia)	0.170*** (45.296)

Religion (rel)	0.250*** (8.446)	Area of Park (apark)	0.044*** (18.614)
Property Price Enhancing (eprop)	0.176*** (16.146)	Electricity (elec)	0.483 (0.818)
Hypothesis Testing against restricted functional forms			Log-likelihood = -2629.955 LR Stat: 1359.47*** $R^2 = 0.84$
Null-Hypothesis	Restricted Log-likelihood	Chi-Sq	Probability
Theta = Lambda = -1	-14253.983	3247.98	0.000
Theta = Lambda = 0	-12631.628	3.27	0.071
Theta = Lambda = 1	-14302.899	3345.81	0.000

Using the estimated hedonic property price equation, the implicit marginal price of environmental characteristic, RSPM is computed as follows:

$$\frac{\partial RENT}{\partial RSPM} = \frac{RSPM^{0.122-1}}{RENT^{0.029-1}} \,|\left(-0.182\right)| \tag{21}$$

The household marginal willingness to pay function for the environmental characteristic of house is estimated by considering the computed implicit marginal price as function of house characteristics and the socio-economic characteristics of households. Table 4 provides the estimated household marginal willingness to pay function for the reduction of RSPM in the local atmosphere. This is also called as inverse demand function for the

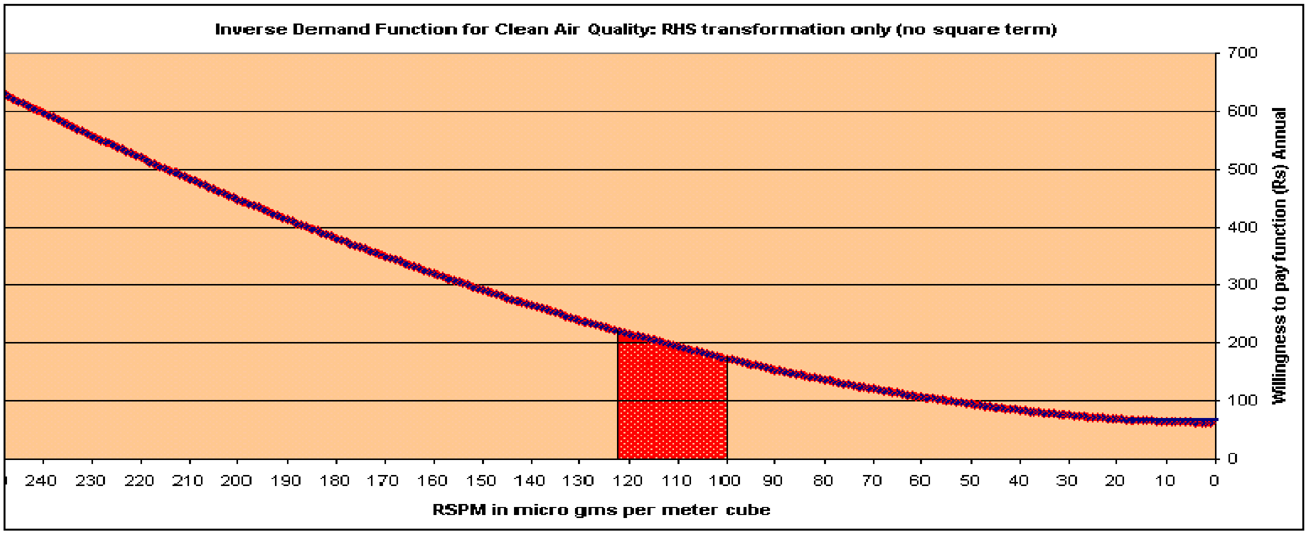
Table 5: Marginal Willingness to Pay Function for Environmental Characteristic of House

Dependent variable: Marginal Implicit Rent.			Lambda =1.803***
Variables	Coefficient (Chi Sq)	Variables	Coefficient (Chi Sq)
Constant	-502.57	Water logging	-0.9235 (0.001)
Ownership	15.79 (0.491)	Green Cover	-4.6157 (0.021)
Number of Floors	153.51*** (19.344)	Exposure	-24.7554 (0.136)
Number of Rooms	26.77** (4.717)	RSPM	0.0492* (2.650)
Number of Baths	55.89*** (6.780)	House Age	-0.0163 (0.057)
Air cooler	54.44** (4.754)	Plot Area	0.00003*** (14.856)
AC	177.33*** (28.921)	Distance from Business Centre	-50.2476** (4.584)
Connected to Public Sewer	25.07 (0.199)	Distance from Shopping Mall	87.6644* (3.279)
Water Quality	-8.86	Distance from Slum	-66.5810*

	(0.087)		(3.493)
Ventilation	-1.41 (0.006)	Distance from Industries	0.2008 (0.044)
Cooking Fuel	-59.59 (0.526)	Area of Park	5.46e-08*** (74.028)
Business or Salaried	-36.71 (0.966)	Electricity	0.1271 (0.004)
Religion	-16.18 (0.084)	Education (fedu1)	-0.0802 (0.186)
Property Price Enhancing	132.14 (17.680)	Income (fgross)	1.52e-08*** (35.746)
Hypothesis Testing against restricted functional forms			Log-likelihood = -8700.698 LR Stat: 771.42*** $R^2 = 0.67$
Null-Hypothesis	Restricted Log-likelihood	Chi-Sq	Probability
Theta = Lambda = -1	-8726.6183	51.84	0.000
Theta = Lambda = 0	-8740.074	78.75	0.000
Theta = Lambda = 1	-8715.1921	28.99	0.000

atmospheric quality revealed through house location choices. Diagram 1 provides the graph of this function for a representative household of the twin cities. The area under the demand curve provides an estimate of the welfare gains to a representative household from reducing air pollution to zero from the current level. An estimate of annual marginal willingness to pay of a representative household for the reduction of RSPM (reduction of one microgram at margin) at the current maximum level of pollution in the twin cities is obtained as Rs 220.67. The estimate of annual welfare to a typical household from the reduction in RSPM levels from current maximum to a safe level (100µg/C^3) is given as Rs 4,499.72.

Diagram 1: The Inverse Demand Function for Urban Air quality Revealed Through House Location Choices



3.4 Hedonic Travel Cost Model

The hedonic travel cost method could be used to estimate an individual marginal willingness to pay for improvement of urban air quality as revealed through their travel choices. This method that is probably not discussed in the literature on measuring benefits from reduction in urban air pollution so far is empirically interesting for finding the revealed environmental values by exploiting the information about individuals' choices of modes of transport, and travel routes to minimize their exposure to urban air pollution[2]. The per day travel cost of an individual is defined as a function of distance travelled, mode of transport, time taken, and air pollution en route.

The household survey of the twin cities of Hyderabad and Secunderabad described earlier provides data on the travel characteristics of all the working members in the family. There are some households in the sample, which have more than one working member. Table 2 provides the descriptive statistics of variables used for estimating the hedonic travel cost function. An individual's exposure to air pollution is measured as the average of ambient pollution concentrations at identifiable land marks en route. Given that the data on pollution concentration is available only for 20 monitoring stations, the pollution at a given land mark en route is taken as the pollution concentration at the monitoring station nearest to that land mark.

[2] Pendelson and Madelsohn (2000) have used the hedonic travel cost method for estimating demand for specific environmental characteristics of resource sites by making use of data for a number of sites.

Table 6 provides parametric estimates of the hedonic travel cost function. The Box-Cox transformation is done only on dependent variables since the null hypothesis of alternative transformations is rejected in favour of Box-Cox transformation in this case. The coefficients of all independent variables have the required signs and are significant at 1 percent level. As expected, the cost of travel is inversely related to the exposure to air pollution. The individual could be using a longer route or travelling by AC car to minimize exposure to pollution resulting in the higher travel cost.

Table 6: Parameter Estimates of Hedonic Travel Cost Function

Both sides transformation with same parameter where		Lambda = 0.268***	
Variables		Coefficients	
Constant		2.128	
Mode of Transport (amt)		1.032*** (124.487)	
Multiple Mode of Trans (ammt)		0.304*** (8.193)	
Car AC or non AC (aac)		2.445*** (125.979)	
Distance Travelled (adw1)		0.665*** (255.496)	
Time taken in commuting (atswt1)		-0.258** (5.407)	
En Route RSPM (arspmt)		-0.084*** (2.473)	
			Log Likelihood = -3733.149 LR Stat = 625.99*** R^2 = 0.61
Hypothesis Testing			
H_0	Rest. Log L.	Chi sq	P value
Lambda = -1	-5289.775	3313.25	0.000
Lambda = 0	-3817.815	169.33	0.000
Lambda = 1	-4240.971	1015.65	0.000

The implicit marginal cost of environmental characteristic of travel is estimated in the same way as it is done in the property value model. The marginal willingness to pay function for the air quality en route is estimated by expressing implicit marginal cost as a function of travel characteristics and socio-economic characteristics of the individual. Table 7 provides parametric estimates of marginal willingness to pay function or inverse demand function of air quality revealed through an individual's travel choices. The coefficients of most of the independent variables of this function have required signs and are significant at the 5 percent level. The derived demand function for air quality from the travel cost model is given as ,

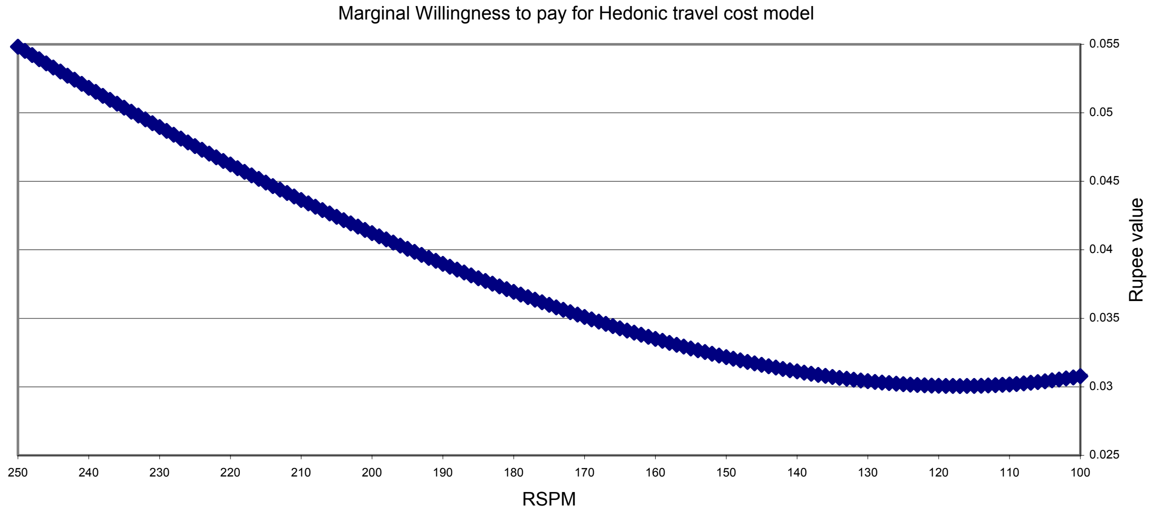
Marginal Travel Cost = 0.1566 –0.185*((arspmt$^{0.429516}$-1)/0.429516) + 0.0012*(arspmtsq$^{0.429516}$-1)/0.425916)). (22)

Table 7: Parameter Estimates of the Marginal Willingness to Pay Function of Environmental Characteristic of Travel

Only Right Hand Side transformation: Lambda = 0.268***	
Variables	Coefficients
Constant	0.121
Mode of Transport (amt)	0.008 (83.371)
Multiple Mode of Trans (ammt)	0.001 (1.538)
Car AC or non AC (aac)	0.030*** (140.126)
Distance Travelled (adw1)	0.003*** (121.263)
Time taken in commuting (atswt1)	-0.0008 (0.442)
En Route RSPM (arspmt)	-0.019*** (32.432)
RSPM square (arspmtsq)	0.001*** (3.712)
Wage (awage)	0.0001*** (87.442)
Education (awem1)	-0.001** (3.712)
	Log Likelihood = 2961.5281 LR Stat = 864.84*** R^2 = 0.84

Hypothesis Testing			
H_0	Rest. Log L.	Chi sq	P value
Lambda = -1	-5289.775	3313.25	0.000
Lambda = 0	-3817.815	169.33	0.000
Lambda = 1	-4240.971	1015.65	0.000

Diagram 2: Inverse Demand Function for Urban Air Quality Revealed Through Travel Choices



This function has required the curvature property in a certain range of the variable air pollution as shown in Diagram 2. By integrating the function in the range of maximum RSPM ($122\mu / C^3$) en route to the safe level ($100\mu / C^3$) an estimate of welfare gain to a representative commuter by reducing air pollution to the safe level in the twin cities could be obtained. A typical commuter gets a daily benefit of Rs7.27 due to the reduction of RSPM from the maximum level to the safe level and an annual benefit of Rs 2,108[3]. There are on the average 1.538 working members in the sample households. Therefore, a representative household in the twin cities gets an annual benefit of Rs 3243 from reducing exposure to air pollution to the safe level on travel of its members

3.5. Welfare Gains for Households in the twin Cities from Reduced Air Pollution to Safe Levels

The working members of a typical household in the twin cities spend 13.4 hours at home, 1.16 hours on travel and the remaining hours at the work place or in leisure activities. As explained in Section 2, household members are exposed to air pollution while staying at home, travelling in the city and working in office. The household willingness to pay for reduced pollution is the sum of its willingness to pay for reduction of pollution at all these places. In Section 3, estimates of the annual household willingness to pay for reduction of air pollution to the safe level at home and on travel are obtained as Rs 4,500

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[3] Annual benefits are estimated assuming that individuals work 290 days in a year.

and Rs 3,243, respectively. The data on job characteristics of working members of the family collected through the household survey does not explain any revealed values for air quality at the work place. Survey data shows that most of these members are have white collar jobs, the choice of which is not affected by the air quality at the work place. Therefore, the total annual willingness to pay of a typical household for reducing air pollution to the safe level is Rs 7,743. The gains for all the households in the twin cities as per the 2001 Census (provisional) are estimated as Rs 6,437 million. The damages from air pollution in the twin cities constitute 0.0423 percent of State Domestic Product (SDP) of Andhra Pradesh in 2003 and the SDP corrected for air pollution is given as Rs 15,12,523 million.

IV. Estimated Model with Interdependent Choices

A hedonic prices model considering that house location choices and travel choices of household members are interdependent is estimated. The model consists of the following two simultaneous equations representing the hedonic property price equation and hedonic travel cost equation.

P = P (H, T, C)

C = C (H, T, P).

Table 8 provides the descriptive statistics of variables used in the estimation. Table 9 provides parametric estimates of the model estimated using the method of the three stage least squares.

Table 8: Descriptive Statistics of Variables Used in Estimation

Variable	Mean	Std. Dev.	Variable	Mean	Std. Dev
House Price	46872.59	98934.95	Air Cooler	0.419512	0.650728
Number of Rooms	3.438049	1.389243	Air Conditioner	0.103415	0.447473
Number of Bathrooms	1.716098	0.879666	Public Sewage	0.921951	0.268379
Enhancement of Property	0.352195	0.477888	Ventilation	0.663171	0.879882
Travel Cost	19.45101	18.60234	Cooking Fuel	0.966829	0.17917
Distance to Working Place	9.883122	9.994428	Basic Salary	0.279024	0.448738
RSPM level in that Area	85.02303	18.2997	Religion	0.87122	0.33512
Mode of Transport	0.499512	0.500244	RSPM	79.42553	27.85361
Multiple Mode of Transport	0.189268	0.391913	AC Car	0.044878	0.207137

Table 9: Estimated Structural Equations of House Price and Travel Cost Using Three-Stage Least Squares (Number of observations – 1025)

Dependent Variable: House Price			
Variable	Coefficient	Variable	Coefficient
Constant	11.696	Cooking Fuel	0.498*** (3.726)
Number of Rooms	0.167*** (3.632)	Basic Salary	0.146** (2.804)
Number of Bathrooms	0.139*** (4.136)	Religion	-0.158 (2.209)
Air Cooler	0.129*** (3.407)	Enhancement of Property	0.142** (3.054)
Air Conditioner	0.206*** (3.493)	Travel Cost	0.039 (0.393)
Public Sewage	0.301*** (3.652)	RSPM	-0.750*** (6.259)
Ventilation	0.096*** (3.904)		
$\bar{R}^2 = 0.4734$ S. E. of Regression = 0.5883			
Dependent Variable: Travel Cost			
Constant	-3.488	Multiple Mode of Transport	0.167* (2.725)
Distance to Working Place	0.756*** (6.956)	AC Car	0.435** (3.203)
RSPM level in that Area	0.127 (0.436)	House Price	0.374*** (5.708)
Mode of Transport	0.528*** (6.683)		
$\bar{R}^2 = 0.3717$ S.E. of Regression = 0.7592			

note: *** 1%, **5%, *10% .

The coefficients of most of the independent variables are have the required signs and are significant at the 5 percent level. The coefficient of pollution variable RSPM is negative as expected and is significant at the 1 percent level in the hedonic property price equation. However, the coefficient of RSPM in hedonic travel cost equation is positive and is statistically not significant. The coefficient of travel cost is positive and significant at the one percent level in the hedonic property price equation while the coefficient of property price is positive but not statistically significant in hedonic travel cost equation. It shows the complementarity between house location choices and travel choices by the households.

V. Conclusion

Individuals are exposed to air pollution while staying at home, travelling in the city and working at a place. The hedonic property price model is used to estimate benefits individuals get from the reduced pollution at home and the hedonic wages model is used to the estimate benefits from reduced pollution at the work place. The paper suggests that the hedonic travel cost method could be used to estimate benefits to individuals from the reduced exposure to pollution in travel within the city. The individual's marginal willingness to pay for reduced pollution in the city is a sum of the marginal willingness to pay for reduced exposure at home, in travel and at the work place.

Hedonic property prices and the hedonic travel cost models are estimated using data collected through a survey of households in the twin cities of Hyderabad and Secunderabad. in the state of Andhra Pradesh in India. Since the survey collects data mostly for people engaged in white collar jobs, it is found that the air pollution at the work place has no effect on job choices. Estimates show that the annual willingness to pay for reducing air pollution to the safe level of a typical household revealed through its house location and travel choices is Rs 7,743. The damages from the current pollution level for all the households in the twin cities as per 2001 Census (provisional) are estimated as Rs 6,437 million which forms 0.0423 percent of State Domestic Product (SDP) of Andhra Pradesh in 2003.

This paper also takes note of the interdependence of an individuals' choices of location of house, location of work place and the travel route from the house to work place and provides a generalized method of hedonic prices. Individuals try to minimize the exposure to urban air pollution while making these choices.

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