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REVIEW ARTICLE

MEASURING BENEFITS OF AIR QUALITY IMPROVEMENT: EVIDENCE BASED ON RESIDENTIAL PROPERTY PRICES IN KERALA, INDIA

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ABSTRACT

Environmental amenities and other site specific characteristics can affect the price and productivity of residential property in a variety of ways. An analysis of the demand for air quality in Cochin industrial agglomeration in India is presented using the survey data from 600 households. Hedonic property value model is used to identify and monetarize the benefits in the value of residential property due to an improvement in air quality. Incorporating a number of structural, neighborhood, environmental and socio economic variables as the determinants of the consumer's willingness to pay for reduced air quality, it is hypothesized that the major environmental variable SO_2 was inversely related to the residential property values. Estimated implicit prices for different sites in different locations correspond to the individual willingness to pay (WTP) for a marginal unit of environmental good purchased. Adopting a two-stage estimation procedure to estimate these relationships, it is found that, on an average, an increase in the level of SO_2 reduced property prices in the study area by 0.45 percent. Estimates further revealed that the households are willing to pay an additional amount of 1.48 percent for a reduction in SO_2.

INTRODUCTION

Environmental quality, such as, reduction in air pollution may affect the productivity and price of residential property which has everlasting consequences to settlement patterns and the growth of urban property market. Price of residential land property could be influenced by local environmental quality, location, size and other number of neighborhood or structural variables.

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In most of the industrial cities the, consumers express their strong preference for environmental amenities such as improved air quality and are even willing to pay for such improvements. Consumer's Willingness to Pay (WTP) in turn has been influenced by structural characteristics like size of the plot, number of rooms, garage space, central heating, public and local socio economic characteristics like access to services, social security, quality of schools, racial composition, wage differentials. and environmental quality. (Ridker and Henning 1967; Pearce and Markandya 1989; Garrod, 1992; Parikh *et al.*, 1994; Mahan *et al.*, 2000; Murty and Surendar Kumar, 2002). In a developing country like India, the policy of rapid industrialization led to the growth of many big industrial cities. At the same time, however, air pollution has been constantly growing in these agglomerations due to concentration of industries and increased use of vehicles and its level has exceeded critical limits in many cities. Environmental economists, who examined the impacts of air pollution on natural environment have raised these contradictions of industrialisation and argued for their immediate redressal through appropriate legal, fiscal and institutional regimes (Shaman, D., 1996; Kuik, *et al.,* 1997; Sankar, 1998; Murty, 2000) and the Government has formulated a number of policies and enacted legislations. Despite these initiatives, the process of industrialisation continues to inflict damages to property values in many parts of the country (Parikh *et. al.,* 1994) including the State of Kerala which was believed to be least affected by industrial pollution[1]. The primary concern of this inquiry is to unearth how the quality of air influences residential property values in the context of a state in India, where, environmental concerns were not yet stemmed well. This paper is divided into IV sections. In section I we present a short review of air pollution and property prices studies. Section II provides the hedonic price model, which is used to estimate this relationship. Section III is the estimation of the model. The last section offers a discussions summary of results.

Air Pollution and Land Price

Residential land value has received extensive research attention in neo-classical economic frame work because land, unlike other factors, simultaneously performs many public and private functions (Xu, Feng, *et al*., 1993). This, along with the advances in economic theory and regression techniques, paved the way for numerous enquiries in which land values were attributed as a function of various factors such as presence of building, distance to town and likewise. Ronald Ridker (1967) was the first economist, who attempted to use residential property value data as the basis for estimating the benefits of changes in environmental quality, such as air pollution. Since the publication of Ridker's article (Ridker and Henning, 1967) an extensive literature had developed to interpret the data on air pollution and property value. The basic principle of this model is that, for many environmental goods, it is often possible for individuals to choose their level of consumption through their choice of related market goods. For example, one could consider the levels of air quality in the decision to purchase a residential property (Anderson and Crocker, 1971; Schanare 1976). In such a decision, there is an 'implicit market' in environmental quality, and the demand for non-market environmental good, such as air pollution would contribute to observed prices and consumption of market goods.

Rosen, (1974) provided a theoretical model of hedonic regression. The Rosen model assumed that various characteristics of a differentiated product could be represented by a vector, $z = (z_1, z_2 ..... z_n)$. Its sales price (*P*) was represented as a hedonic function, of vector *z*. i.e., $P = p(z)$. The hedonic price schedule in the market could then be estimated by considering the behaviour of the consumers and firms. Consumers differ according to socio economic characteristics. This procedure is followed in most empirical applications. Some economists (Mailer, 1977; Freeman, 1979b) had raised questions regarding the application of Rozen's model and a number of variants of the original model have developed in connection with the nature of good valued and it's applications (Cassel and Mendelsohn, 1985; Epple, 1984, 1987; McConnell and Phipps, 1987; Palmquist, 1988). Some of the environmental hedonic studies assumed that the markets are segmented (Freeman 1979b) according to, income, race, accessibility, geographical variations and other environmental variables. Halvorsen and Pollakowski (1981); Spitzer (1982) proposed a

[1] The state of Kerala, the southern tip of India, is rich in natural resources and poor in industrial performance. It is generally accepted by the authorities that, Kerala is not highly polluted, compared with other states. Spenger, Thom, team leader of Indo Dutch project, Kerala State Pollution control Board, argued that based on the available data, the state's overall environmental status is acceptable. (State Pollution Control Board, Ernakulam Public hearing, 1999).

quadratic Box-Cox. Giannias (1988) used the model to estimate people's willingness to pay (WTP) for better air quality. Different arguments exist regarding the validity of environmental datasets used in housing hedonic equations. Almost all studies dealing with the effects air pollution on property values have used single objective measures of air pollution. Some researchers have begun to include more than one pollutant in their hedonic studies (Palmquist, 1982, and 1983, Garves *et al*, 1988; Murdoch Thayer, 1988; Mason and John, 1989). Another optional is to estimate and inverse demand curves for the environmental quality variable (Garrod and Willis, 1992; Brookshire *et al*., 1982; Allen, Marcus *et al*., 1995).

There exist several empirical studies interpreting the relationship between air pollution and residential property values (Zabel and Kiel, 2000; Taylor and Smith, 2000; Chattopadhyay, 1999; Palmquist *et al.,* 1997; Kerry Smith and Huang, Ju Chin, 1995; Levesque and Terrence, 1994). Ridker (1967) and Ridker and Henning (1967) provided the first empirical evidence that air pollution affects property values by regressing median census trade property values on a measure of sulphate air pollution. Following this seminal work, a number of theoretical and practical interpretations were observed on pollution property relationship. Harrison and Rubinfield (1978) measured the marginal WTP as a percentage of income for an improvement in air quality at designated high levels of nitrogen oxides. They concluded that home buyers would be willing to pay up to 19 percent of their yearly income for a given improvement in air quality.

Harrison and James (1984) estimated households' implicit willingness to pay to locate, farther from hazardous waste sites. In a review of air pollution hedonic price model studies, Pearce and Markandya (1989) demonstrated that a 1 percent increase in sulphation levels resulted in a fall in property values between 0.06 and 0.12 percent, a 1 percent increase in particulates lowered property values by 0.05 to 0.14 percent, while a 1 percent increase in a variable, which picked up a number of measures of air pollution property prices.

In a pioneering work on property valuation in India, Parikh *et al.* (1994) estimated a hedonic property price equation and made certain illuminating observations on the effects of air pollution on property values in Mumbai. The data was taken from 'the metropolitan household survey' of Bombay Metropolitan Region Development Authority. The rent values reported by the households were used for analysis along with neighbourhood, structural and ethnic characteristics. The concentration of SPM in a given locality was taken as a measure of air quality. The results showed that air pollution affected the rent negatively in the hedonic price model, that is, an 8 percent drop in rent per a 100 ppm increase in SPM. The mean value of SPM was greater than the Indian and World Health Organisation standards. The hedonic price model predicted positive benefits for the urban dwellers in Bombay for a reduction in SPM from the currently observed levels to the national air quality standards in India.

The hedonic regression models have been used for the purpose of estimating the influence of environmental good (or bad) on the price of housing[2]. Most of the theoretical and empirical applications listed above were based mainly on the experiences of industries of the developed countries while the nature of industrial pollution produced by the third world industries remains unexplored for long. In developing countries like India, air pollution has been consistently growing during the last few decades and is extremely complex. Policy makers have a tendency to borrow the principles and solutions offered by western economists to mitigate pollution in developing countries without examining in detail the possible local solutions to such issues. However, the basic evidence that comes from the review is that,

[2] Freeman (1974) and Small (1975) were the first to show that the hedonic equation could be used to measure peoples marginal willingness to pay for an environmental improvement. Individuals could choose level of consumption of local public goods through their choice of the jurisdiction to reside in. If air quality varied in different areas, individuals might choose their exposure to air pollution through their location choices.

pollution in general.

Model

Following the general principles of consumer's behavioural theories[3], the basic hedonic property model can be explained as given below. Let the price of i^{th} residential location (*Phi*) be

$$Phi = Ph(Si, Ni, Qi) \quad \text{------------------------ (1)}$$

where,

S_i is structural characteristics
N_i is neighbourhood characteristics
Q_i is environmental characteristics

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

$$u(X, Si, Ni, Qi) \text{ ---------------------------------- (2)}$$

where, *X* represents 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,

$$M = X + Phi \text{ ----------------------------- (3)}$$

the first order condition for the choice of environmental amenity *qj* is given as,

$$\frac{\partial u}{\partial qi} \Big/ \frac{\partial u}{\partial x} = \partial Phi / \partial qj \quad \text{----------- (4)}$$

The partial derivative of (1) with respect to one of the environmental quality characteristics *qj*, (air quality), give the implicit marginal price of that characteristic. In the second stage, MWTP for environmental quality is expressed as a function of *qj*, given *Si, Ni*, *Qi** and *Gi*, where *Qi** ins the vector of other environmental characteristics and *Gi* is socio- economic characteristics.

Equation (5) gives the individual's MWTP for the improvement in environmental quality *qj*. If there is an improvement in environmental characteristic from qj^0 to qj^1, the value individuals place on such improvement (*Bij*) could be estimated by integrating (5) with respect to *qj*.

$$Bij = \int_{qjo}^{qj1} bij(qj, Qi^*, Si, Ni, Gi)\partial qj \text{ ------------- (6)}$$

The value obtained by integrating the inverse demand function with respect to the implicit price is interpreted as the consumer surplus.

Estimation of the Model

In order to estimate a hedonic price function, it is necessary to gather data on all characteristics that are relevant to choices including the sales prices of the residential property. The explained variable, price of the residential property (*Phi*), is considered as a function of environmental (*Qi*), structural (*Si*) and neighbourhood variables (*Ni*) and these data sets relate to the residential areas of Cochin industrial agglomeration, Kerala, India. Data from 600 households were collected using a structured questionnaire. Cochin Industrial agglomeration is a geographical space, consisting of the Cochin Corporation, the Kalamassery Municipality and three panchayaths, viz, Vadavucode- Puthercruz, Thiruvankulam and Eloor. This area has been identified as the industrial capital of Kerala and hence inhabits a large number of factories both in the private and public domain. The Central Pollution Control Board in collaboration with the State Pollution Control Board identified Cochin as one of the problem areas in the country. The households chosen to participate in the survey were selected using a two stage sampling procedure. In the first stage, the agglomeration is divided into six strata according to the distribution of air quality monitoring stations of the State Pollution Control Board. Among these stations, Eloor and Irumpanam are assumed as high polluted, Ernakulam North and CSIR Complex as medium polluted and Port Trust and Ambalamugal as low polluted areas. From each region, 100 households were selected for intensive survey.

[3]The hedonic price theory assumes that as environmental quality changes, property prices would also change, indicating a scope for estimating an implicit demand function for the environmental goods by observing the property price variations. So hedonic prices are defined as the implicit prices of the attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them (Bhattacharya, 2002).

Estimation of the hedonic model was undertaken in two stages. In the first stage, the hedonic property price function was estimated and the implicit prices were computed for all the observations. In the second stage, implicit demand function or the marginal willingness to pay function was derived from the hedonic price function for given sets of environmental characteristics.

(a) *Estimation of the Hedonic Price Function*

The hedonic price function relates sales price of residential property to different characteristics of the property and is estimated using a simple least square regression model.[4] Following this general specification and refining it by dropping insignificant variables, the hedonic price function is estimated as follows.

$$\ln priceh = \alpha_0 + \alpha_1 \ln trees + \alpha_2 \ln plotarea + \alpha_3 hstypdum + \alpha_4 \ln area + \alpha_5 \ln discit + \alpha_6 \ln dis\_ind + \alpha_7 \ln SO_2 + \varepsilon \quad \text{-------- (7)}$$

where,

ln *priceh*	Natural log of land price
ln *trees*	Natural log of number of trees
ln *plotarea*	Natural log of plot area
ln *area*	Natural log of plinth area of house
ln *discit*	Natural log of distance from city
ln *dis_ind*	Natural log of distance from industry
ln SO_2	Natural log of SO_2
hstypdum	Dummy variable for type of house

In the estimation of hedonic price equation, it is assumed a negative relationship between environmental characteristic SO_2 and the residential land price; where as, number of tree coverage is assumed to have a positive influence. All the structural parameters included in the model, like plot area, type of house, etc are expected to have positive relations with the land price. Neighbourhood characters like distance from industry and city are inversely related with pollution. It is normally expected that as distance from city increases land price decrease, where as distance from industrial location increases, land price also increases. Applying these assumptions on the model specified above, the parameters are estimated using the method of ordinary least squares and is given in Table 1. The results confirm that as the level of SO_2 increases by one per cent residential property price on the average decreases by about 0.45 per cent. Among the neighbourhood characteristics, tree coverage is positively related to property price. Distance from city is negatively related to house price, showing that the plots nearer to the city have high property values. Distance form industry is positively related, showing that when distance increases, property prices increase. Total area of the plot is also positively related to property value. The regression results of the hedonic price function shows that all the significant estimated variables follow the expected relationship patterns. Hence the estimated equation could be written as:

$$\ln priceh = 13.958 + 2.502E^{-02} \ln trees + 0.775 \ln plotarea - 2.566E^{-02} hstypdum - 3.953E^{-02} \ln areal - .312 \ln discit + .210 \ln dis\_ind - 456 \ln SO_2 + \varepsilon \quad \text{----------- ----(8)}$$

The partial derivative of this function with respect to air quality gives its implicit marginal price. This price is the additional amount which the household would be willing to pay for choosing a house with reduced amounts of air pollution, other things remaining the same. The marginal implicit price is estimated as follows.

$$implicit\ price = priceh.(1/SO_2).\alpha_7 \quad \text{------------- (9)}$$

(b) *Estimation of the Implicit Demand Function*

Estimated implicit prices for different sites correspond to the individual willingness to pay (WTP) for a marginal unit of environmental good purchased. The individual chooses the level of

[4] The model is specified as follows:

$$LnPh_i = \beta_0 + \sum \beta_j S_{ij} + \sum \beta_k Q_{ki} + \sum \beta_l N_{li} + \varepsilon_i ,$$

Where, i= 1, 2, …n

S_i is structural characteristics, N_i is neighbourhood characteristics , Q_i is environmental characteristics characteristic at which their Marginal Willingness to Pay (MWTP) for that characteristic is equal to its implicit marginal price (Murty and Surender Kumar 2002). The inverse demand function is then obtained by regressing implicit price as a function of air quality, SO_2, and other socio economic features of individuals along with a demand shift variable, such as, income. The regression equation for inverse demand function is:

$$\ln imprice_i = \beta_0 + \beta_1 Y + \sum \beta_j G_{ij} + \sum \beta_k S_{ik} + \sum \beta_l N_{il} + \sum \beta_m Q_{im} + \varepsilon \quad \text{--------- (10)}$$

Where,

Y is the annual income of the house hold,
G_i is the socio economic characteristics
S_i is the structural characteristics
N_i is the neighbourhood characteristics
Q_i is environmental characteristics

After leaving out the insignificant variables through trial and error method, the implicit price function considered for final estimation is:

$$\ln imprice = \beta_0 + \beta_1 \ln anlinc + \beta_2 \ln fmemb + \beta_3 \ln ptarea + \beta_4 \ln discit + \beta_5 \ln dis\_ind + \beta_6 \ln SO_2 + \varepsilon \quad \text{-------------------- (11)}$$

Where,

Variable name	Description
ln *imprice*	Natural log of implicit price
ln *anlinc*	Natural log of annual income
ln *fmemb*	Natural log of family members
ln *plotarea*	Natural log of plot area
ln *discit*	Natural log of distance from city
ln *dis_ind*	Natural log of distance from industry
ln SO_2	Natural log of SO_2

The first derivative of the hedonic price function can be interpreted as the implicit marginal price function for the environmental good. Descriptive statistics of implicit prices for 600 observations is given in Table 2. Hence the marginal implicit price for reducing SO_2 is calculated as Rs. 5154. This result clearly identifies air quality as an important factor, along with structural and neighbourhood characteristics, in determining demand for residential property in Cochin. As mentioned earlier, second stage estimation of inverse demand curve is done by regressing the implicit marginal price on the quantity of environmental good purchased and other socio economic features including income of the individuals. The results are given in Table 3.

The first derivative of the implicit marginal price function with respect to SO_2 is negative (-1.488) signaling decreasing marginal implicit prices for increasing environmental quality, implying that, a reduction in SO_2 by one percent leads to 1.48 percent increase in property values in Cochin. The welfare gains for a change in environmental quality (Q_i^0 to Q_i^1) could be estimated by integrating implicit price with respect to Q_i. Pearce and Markandya (1989) point out that hedonic price model identifies consumer's marginal WTP for a change in level of pollution. If the consumer moves from higher polluted area to lower polluted area, the consumer's WTP for an extra unit of environmental quality is greater than the associated increase in the value of the property. Since change in environmental quality affect consumer welfare or his willingness to pay at two levels, the measure of consumer surplus would give an estimate of welfare change. Summing the changes in consumer surplus for all households affected by the particular environmental improvement would give an estimate of it's over all value.

(c) Estimation of Consumer Surplus

Consumer surplus is calculated by integrating the inverse demand curve with respect to environmental quality and calculating definite integral observed between the old and new levels of SO_2, planned by the policy makers (Freeman, 1993).

Accordingly, the consumer surplus is calculated as:

$$\int imprice = \int e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5}.SO_2^{a6} \quad \text{------- (12)}$$

$$= e^{a0}.anlinc^{a1}.fmemb^{a2}.ptarea^{a3}.discit^{a4}.dis\_ind^{a5}.\frac{1}{a_6+1}.\left[\left(lower\lim^{a6+1}\right) - SO_2^{a6+1}\right] \quad \text{---- (13)}$$

Where, *lower*lim is the improvement in environmental quality by a reduction in SO_2. Consider the case where, the level of SO_2 has

(CS) is calculated as follows:

Table 1. Regression Results of Hedonic Price Function

Variable	Coefficients	Std. Error	t	Sig.
(Constant)	13.958*	.329	42.366	.000
LNSO2	-0.456*	.034	-13.568	.000
LNTREES	2.502E-02***	.014	1.727	.085
LNPTAREA	0.775*	.020	38.090	.000
HSTYPDUM	-2.566E-02	.029	-.890	.374
LNAREA	-3.953E-02	.044	-.894	.372
LNDISCIT	-.312*	.010	-32.235	.000
LNDISIND	.210*	.013	16.714	.000
R^2	0.875	*Adjusted* R^2	0.874	
F	583.901	Sig.	.000	

***, **, * Significant at 10 percent, 5 percent, and 1 percent level respectively
Source: survey data, 2001-02

Table 2. Descriptive Statistics of Implicit Prices

Descriptive statistics	***Implicit price*** **(in Rs.)**
Mean	5154.26
Median	2553.97
Mode	8290.91
Standard Deviation	9379.52
Minimum	285.71
Maximum	148251.60
Count	600.00
Confidence Level(95.0%)	752.02

Source: Source: survey data, 2001-02

Table 3. Estimation of Inverse Demand Function

Variable	Coefficient	Std. Er	t	Sig.
(Constant)	13.065	0.391	33.415	.000
LNANLINC	-2.203E-	0.028	-0.783	.434
LNFMEMB	0.152*	0.050	3.059	.002
LNSO2	-1.488	0.032	-45.95:	.000
LNPTAREA	0.785*	0.018	43.343	.000
LNDISCIT	-0.303	0.009	-35.20(	.000
LNDISIND	0.211*	0.011	18.765	.000
R^2	0.923	*Adjusted* R^2	0.922	
F	1177.6‹	*Sig*	0.000	

**, * Significant at 5 percent, and 1 percent level respectively
Source: survey data, 2001-02

Table 4. Consumer Surplus per Households

Descriptive statistics	*consumer surplus* (in Rs.)
Mean	53006.49
Median	30122.03
Mode	8903.69
Standard Deviation	74450.38
Minimum	3849.64
Maximum	606003.30
Count	600.00
Confidence Level (95.0%)	5969.22

Source: survey data, 2001-02

$$CS = e^{13.065} . anlinc^{-2.203E-02} . fmemb^{0.152} . ptarea^{0.785} . discit^{-0.303} . dis\_ind^{0.211} . \frac{1}{-1.488+1} . \left[\left(lowerlim^{(-1.488+1)} \right) - \left(SO_2^{(-1.488+1)} \right) \right]$$
-------- (14)

The Average Consumer Surplus for Cochin, calculated from this equation is given in table 4. The average consumer surplus per person, for Cochin, for a ten percent reduction in SO_2 is Rs.53,006. For 600 individuals the amount of consumer surplus ranges between Rs. 3850 and Rs. 606003. The elasticity of land price with respect to SO_2 is -1.488, showing that a change in SO_2 will reduce house price considerably. The Hedonic property value model, thus predicts positive benefits for households residing in Cochin for a reduction in SO_2.

Conclusion

in this paper presents an analysis of changes and residential property values due to an improvement in air quality based on survey data from Cochin by estimating the hedonic property value model. In the model specification, I incorporated a number of structural, neighbourhood, environmental and socio economic variables as determinants of the consumer's willingness to pay for reduced air quality. It is hypothesized that the major environmental variable SO_2 is inversely related to the residential property values. Similarly, the major structural and neighbourhood variables, such as, tree coverage, distance from industry, plot area are positively related to property prices while distance from city and are negatively related. Adopting a two-stage estimation procedure, it is found that, on an average, an increase in the level of SO_2 reduced residential property prices in the study area by 0.45 percent. The estimated the marginal implicit price for reducing SO_2 was Rs. 5154. Estimates further revealed that the households are willing to pay an additional amount for a reduction in SO_2. The average consumer surplus per person, for a ten percent reduction in SO_2 is Rs.53, 006 and it ranges between Rs. 3850 and Rs. 606003. The elasticity of land price with respect to SO_2 is elastic, signaling definite a change in implicit prices for a small change environmental quality. The analysis, therefore, revealed a positive response of households in Cochin industrial agglomeration between air quality and property prices. This paper has provided ample evidence to establish the fact that air pollution has produced negative externalities on residential property values in the context of a developing country.

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