AN ESTIMATION OF THE ECONOMIC VALUE OF AN AIR QUALITY IMPROVEMENT PROGRAM IN SANTIAGO DE CHILE*

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ABSTRACT

There is no doubt regarding the negative effects of air pollution on human health, economic property and the environment. The almost five million inhabitants living in Santiago, Chile, are exposed to high levels of air contamination, especially during winter time when the level of pollution is at its worst. In this paper, a hedonic price model is used to first, estimate the effect of air pollution on house prices in Santiago and second, to estimate the willingness to pay (WTP) for a program that reduces air contamination by 50 percent. The data consists of 992 observations containing market prices for houses and their characteristics. The average WTP for the air quality improvement program was estimated in $567,000 (US$1,626), and the aggregated WTP for Santiago in almost 600 billion pesos (US$1.7 billion).

SINTESIS

No hay duda acerca de los efectos negativos de la contaminación del aire sobre la salud humana, propiedad económica y el medio ambiente. Los casi cinco millones de habitantes que viven en Santiago de Chile están expuestos a altos niveles de contaminación atmosférica, especialmente durante el invierno cuando el nivel de contaminación está en sus peores niveles. En este trabajo, un modelo de precios hedónicos se usa, primero, para estimar el efecto de la contaminación atmosférica sobre el precio de las viviendas en Santiago y, segundo, para estimar la disposición a pagar (WTP) por un programa que reduce la contaminación del aire en un 50 por ciento. Los datos consisten de 992 observaciones que contienen precios de mercado para viviendas y sus características. El WTP promedio para el mejoramiento de la calidad del aire fue estimado en $567.000 (US$1.616), y el WTP agregado para Santiago en casi 600 mil millones de pesos (US$1.7 mil millones).

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1. INTRODUCTION

Characteristic of Santiago, as well as of other highly polluted cities in Latin America, such as Sao Paulo and Mexico City, is the large amount of gas emissions that buses, trucks and cars account for. These have long been linked to smog and pollution, and are today the main contributors of carbon monoxide, nitrogen oxides, lead and particulate matter. High concentrations of particulate matter have been one of the most serious problems in Santiago. According to the health service, the 24-hour average standard of particulate matter of $150\mu g/m^3$ is continuously exceeded (Aranda et al., 1994). Most of these emissions are provided by natural dust from unpaved streets, but also a large amount of small size particulate matter (PM10) is generated by diesel buses. Particulate matter, which appears as visible smoke, affects the respiratory system and, if it is of a small enough size to bypass the respiratory system's mucous filtering mechanism and penetrate the lungs, it may slow down the ciliary function. This inhibits the removal of harmful substances in the mucus flow and causes bronchitis.

The purpose of this study is twofold; first, to look at the influence that particulate matter pollution has on house market prices in Santiago; and second, to estimate the willingness to pay (WTP) among people living in Santiago for an air quality improvement program that reduces the level of pollution by 50%. The hedonic price method is used, since it provides the theoretical basis to use econometric tecniques in estimating non-observed economic values of non-market goods from observed house market prices. Following the tradition of Lancaster (1966), Ridker y Henning (1967), Rosen (1974), Harrison and Rubinfeld (1978a and 1978b), Blomquist and Worley (1981), Freeman (1982) and Palmquist (1984), it is assumed here that consumers consider the level of air quality as well as the other characteristics of houses when deciding on their location for living. Therefore, it is

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expected that house prices will differ depending on the level of air quality at their city location.

2. THE HEDONIC PRICE MODEL

The theoretical origin of the hedonic price model is a seminal paper by Rosen (1974). The main novelty presented by Rosen was the way of looking at a market's functioning for heterogenous goods. The central assumption made is that heterogeneous goods are valued for the bundle of utility bearing attributes and not for the good per se. This implies that, when the amount or the quality of one of the attributes embodied in a particular heterogeneous good changes, the value of the good will change for both consumers and producers as well.

In a competitive market, the various equilibrium prices of an heterogeneous good are determined by the interaction of consumers and producers. Consumers and producers demand and offer house attributes in a number of implicit non-observed markets. When the observed market for the heterogeneous good is in equilibrium, all the implicit non-observed markets for the different attributes are also in equilibrium, and there exists an equilibrium implicit market price for each attribute of the good (Rosen, 1974).

Hedonic price methodologies consist of econometric techniques that use the observed market prices of an heterogeneous good to estimate (reveal) the non-observed equilibrium implicit prices of the different characteristics (attributes) of the good. The estimated competitive equilibrium implicit price of a given attribute represents the market's willingness to pay for the marginal unit of the attribute bought and sold in the implicit market. This information can then be used to estimate market and/or individual demand curves for the attribute which, in turn, allow to estimate the economic benefits of changes in the quantity of the attribute.

Typical examples of heterogeneous goods are houses, automobiles and factors of production such as land and labor. Houses have been the heterogeneous goods most used in hedonic environmental studies[1]. In this context, a house is viewed as a bundle of structural characteristics (number of rooms, size of lot, constructed area, building materials, etc.), neighbourhood characteristics (socio-economic level, public infrastructure, zoning, etc.), and environmental characteristics such as air quality, noise levels, amenities availability, etc. From the observed market prices for houses, the implicit market price of an evironmental attribute of interest (air quality, for example) is estimated, and willingness to pay functions for the attribute are obtained.

[1] See for instance Ridker (1967), Harrison and Rubinfeld (1978a) and Nelson (1978).

In this study, the ith housing unit is completely described by a vector Z_i cointaning all the structural, neighbourhood and environmental attributes, formally:

$$Z_i = (S_{1i},\ldots,S_{si}, N_{1i},\ldots,N_{ni}, E_{1i},\ldots,E_{ei})' \quad (1) \tag{1}$$

where,

S_{mi} = the mth structural characteristic, with m = 1,..., s;
N_{ki} = the kth neighbourhood characteristic, with k = 1,..., n;
E_{li} = the lth environmental characteristic, with l = 1,...,e.

The hedonic price function describing the competitive equilibrium market price P_i of the ith housing unit is:

$$P_i = h(Z_i) \tag{2}$$

Since there is only one environmental characteristic of interest in this study, namely air quality, the number of environmental attributes, e in equation (l), is one; thus, vector Z_i describing the ith housing unit (a house or an apartment) and the hedonic function describing its competitive equilibrium market price become:

$$P_i = h\,(Z_i) \;=\; h\,(S_{1i},\ldots,S_{si}, N_{1i},\ldots,N_{ni}, E_{1i}) \tag{3}$$

Since the hedonic price function in (3) can be estimated, the implicit marginal purchase price of air quality attribute (E_1) is given by:

$$P_{E_1} = \frac{\partial \hat{P}_i}{\partial E_1} = \frac{\partial \hat{h}(\cdot)}{\partial E_1} \tag{4}$$

where the hat symbol represents estimated values.

It is assumed that each one of the j consumers (households) in the housing market solves the following utility maximization problem:

$$Max\ U_j = U_j(X_j, Z_{ij}) \tag{5}$$

subject to its budget constraint:

$$Y_j = X_j + P_i \times Z_{ij} \tag{6}$$

where,

Y_j = disposable income of the jth consumer;
X_j = the vector of all private goods consumed by the jth consumer, which price is normalized to one.

The first-order condition for the representative maximizing consumer is:

$$MWTP(E_1) = \frac{\partial U_j}{\partial E_1} = \frac{\partial P_i}{\partial E_1} = P_{E_1} = IMP(E_1) \qquad (7)$$

where,

$MWTP(E_1)$ = marginal willingness to pay for air quality;
$IMP(E_1)$ = implicit marginal price of air quality.

Equation (7) states that, in equilibrium, the consumer's willingness to pay for a marginal improvement in air quality is equal to the implicit marginal price of air quality, i.e., the equilibrium price of the air quality attribute in its implicit market.

Estimation of the hedonic price function in equation (3) allows to obtain the implicit marginal price function of air quality in equation (4) for each consumer.

If it is assumed that willingness to pay is an appropriate measure of benefits, that consumers are able to perceive changes in air quality, and that consumers are willing to pay for air quality changes - since these changes affect the future net benefit stream of housing units (houses and/or apartments), then it is possible to estimate the benefits (or costs) of changes in air quality. In fact, under these assumptions, the MWTP function of a consumer provides estimates of benefits (costs) from changes in air quality. From the second equality in equation (7), the MWTP for a change in air quality can be obtained from the implicit marginal price fuction obtained from the estimated hedonic price function. For a linear functional form of the hedonic price function ($h(\cdot)$ in equation (3)), the equality between the MWTP and the implicit marginal price always hold, since they are a constant. Thus, this equality allows the calculation of benefits (costs) even in the case of non-marginal changes in air quality.

However, since repacking is not possible in the housing market, at least in the short run, the hedonic price function is not linear (Rosen, 1974). This implies that MWTP and the implicit marginal price diverge markedly from the point of estimation, and they are equal only at that point. For this reason, the implicit marginal price function can approximate the benefits (costs) of only marginal changes in air quality, and will give biased estimates of the benefits (costs) of non-marginal changes in air quality. Then, in the case of non-marginal changes in air quality it will be necessary, in general, to estimate the MWTP functions of the consumers.

An estimation of the benefits (costs) of a change in air quality for a given consumer can be obtained calculating the area under (integrating) its MWTP function between the initial and final levels of air quality. The sum across consumers of these benefits provides an estimation of the total benefits (costs) generated in the market by a change in air quality.

Estimation of the hedonic price function in equation (3) requires data on the market price of housing units (P_i), and on the s structural, the n neighbourhood and the unique environmental attributes of each property. Estimation of the MWTP function of each household requires additional information on each household´s characteristics (Freeman, 1979). Unfortunately, this information was not available for this study. Thus, following Brown and Pollakowski (1977), the assumptions of equal preferences and incomes accross households is imposed to allow benefits (costs) calculation only by estimating the hedonic price (non-linear) function and deriving the underlying implicit marginal price function. Though these assumptions are quite restrictive, they are useful to get an estimation that, at least, provides an idea of the order of magnitude of the expected benefits from improving air quality in Santiago.

3. THE DATA

The data was collected from the offer section in the local newspaper "El Mercurio", on May 26th, 1991[2]. In this section a large number of housing units are listed every weekend. Houses and apartments located at different places in Santiago are included, and it can be said that they comform a representative sample in the sense that no specific areas of Santiago are selected. In this case, the sample was taken from a randomly chosen day, which should reinforce the randomness assumption.

This study is based on a data base containing 2,980 observations. A number of interviewers were provided with a questionnaire, which they used to obtain the required information on the characteristics of each house or apartment. When all the interviews were carried out, 992 observations were considered valid. One of the reasons for the omission of observations was the unwillingness of the brokers to provide the required information[3]. Another reason was inconsistencies in the answers given by the brokers. When the valid and final sample was obtained, complementary information, such as distances from each housing unit to principal avenues, to downtown Santiago, to underground railroad stations, and to police stations were added. Four more variables corresponding to level of emissions for nitrogen oxides,

[2] A similar (but older) data set was used in Figueroa and Lever (1992) in an hedonic price estimation of the determinants of the price of urban lots in Santiago.

[3] The common argument not to give the required information was that this type of information is considered confidential.

carbon monoxides, sulfur oxides and particulate matter were also added. The data on the level of emissions for these variables correspond to annual averages obtained from the monitoring agency in Santiago for 1989. The levels of emissions corresponding to each housing unit was determined by mapping isopleth curves for the various different pollutants under study. These isopleth curves were obtained from a model of emission's dispersion by INTEC Chile-Universidad de Chile (1990) and Ulriksen et al. (1992).

4. ECONOMETRIC ESTIMATION OF THE HEDONIC PRICE MODEL

Given the theoretically expected non-linearity of the hedonic price function, a Box-Cox transformation (3) was estimated. By using the Box-Cox transformation, the functional form is dictated by the transformation parameters λ, estimated in the regressions.

The Box-Cox transformation of the hedonic price function estimated was:

$$P_i^{(\lambda)} = \alpha_0 + \alpha_1 S_{1i} + \ldots + \alpha_s S_{si} + \alpha_{s+1} N_{1i} + \ldots + \alpha_{s+n} N_{ni} + \alpha_{s+n+1} E_{1i} + \epsilon_i \qquad (8)$$

where,

$P_i^{(\lambda)} = (P_i^{\lambda} - 1)/\lambda$ for $\lambda \neq 0$; and
$P_i^{(\lambda)} = \ln P_i$ for $\lambda = 0$.

5. EMPIRICAL RESULTS

The original set of variables considered to be included in the econometric model is presented in Appendix 1. The criteria to determine the final model specification were the significance level of the explanatory variables, and the degree of multicollinearity between variables. As it is usual in hedonic price estimations, some right hand side variables did not have any explanatory power and, therefore were not included in the final equation. The correlation analysis showed, for instance, a large correlation between number of bedrooms and number of bathrooms, and not surprisingly, between the four variables measuring air pollution (EPTS, ESOX, ECO and ENOX) that were considered at the beginning.

EPTS is the pollution variable most commonly and better perceived by people, and it also was the best econometrically behaved of the four pollution variables considered. Thus ETPS was the independent variable used in the final regression model. The explanatory variables included in the final hedonic equation are presented with the results of its econometric estimation in Table 1.

TABLE 1

ESTIMATED HEDONIC PRICE EQUATION

Variables	Parameter estimate (Box-Cox transformation) N = 992 R^2 adjusted = 0.83 Lambda value = 0.09 T-value for lambda = 67.4 Dependent variable: PHOUSE	T-values
Intercept	2.77437	26.64
THOUSE	0.09973	3.07
M2LOT	0.00015	6.63
M2LIV	0.00299	14.20
BATHROOM	0.15128	7.13
RODS	0.16940	4.99
GARAGE	0.13098	4.64
ROCB	0.11905	2.29
TELEPHONE	0.12578	4.83
DSUBW	0.03739	3.05
DPOLIS	-0.00689	-3.89
SEI	0.09548	9.54
PGREENA	0.07707	1.86
GREENA	0.00727	6.91
PSERVICE	0.00247	2.44
PINVEST	0.00576	3.93
EPTS	-0.00639	-2.20

All the estimated coefficients of the explanatory variables are significant at more than 95 percent level of significance. All explanatory variables, except DPOLIS and EPTS, have a positive influence on the house price. THOUSE, which is a dummy variable that takes a value of 1 for houses and of 0 for apartments, has a positive influence on property value. M2LOT has a small and positive influence on the property value. M2LIV has positive influence on the house value. BATHROOM is positively related to the value of the property, a relation which is quite significant. This variable was chosen instead of number of bedrooms, which was less significant and closely correlated with number of bathrooms. The existence of a room for the domestic servant in the house has a positive influence on the price of the house. GARAGE, which is also a dummy variable, has, as expected, a positive influence on the value of the property. ROCB, which is a dummy variable representing the existence of a special room used as a commercial office for commercial business purposes, has also a positive influence on the value of the property.

The variable TELEPHONE is, not surprisingly, another attribute having a positive influence on the value of the house. As it is theoretically expected, DSUBW has a negative influence on the value of the property, as the greater the distance to the nearest underground railroad station, the smaller the price of the house is (ceteris paribus).

The coefficient for DPOLIS, the distance to the nearest police station, is negative and significant, which could mean that people value more the calmness of being farther away from it, than the security associated with living closer to it. Not surprisingly, SEI has a positive influence on the property value which is also quite significant. The index variable for green areas (GREENA) is positively related to the property value and significant. PSERVICE has a positive influence on the property value and is significant. PINVEST, has also a positive influence on the property value. This value is, however, less significant than the level of public service, and the reason can be that both variables partly explain the same thing. The concentration of particulate matter (ETPS) in the air has, as expected, a negative influence on the value of the property, meaning that air quality improvements increase the price of the house (ceteris paribus).

6. WILLINGNESS TO PAY FOR AIR QUALITY IMPROVEMENT

The main interest of this paper is to study the economic value of a program that causes a non-marginal (50%) change in air pollution. As it was mentioned above, given the assumption of equal preference and income across households, the marginal price function provides the willingness to pay (or demand) function for different levels of air pollution.

Mean values of the attributes embodied in the hedonic price equation were used to obtain the mean property value in the sample, a value which was very close to the mean property value observed in the sample. By changing then the level of particulate matter emissions and keeping the rest of the attributes constant, the mean willingness to pay value for a 50 percent decrease in the particulate matter emissions was obtained. In order to get an estimate of the total willingness to pay for a 50 percent air quality improvement, the results obtained were extended to the total number of house units in Santiago, which is 1.056,781[4]. The results are presented in Table 2.

[4] Information provided by Santiago's Housing Census.

TABLE 2

WILLINGNESS TO PAY ESTIMATION

Estimated mean house value at the present level of pollution:
$ 16,724, 094 = US$ 42, 609

Bootstrap confidence interval (95% level):
Lower limit : $ 16,289,526 = US$ 41,502
Upper limit : $ 17,206,570 = US$ 43,838

Estimated mean house value with a 50% decrease in pollution:
$ 17,291, 558 = US$ 44, 055

Bootstrap confidence interval (95%):
Lower limit : $ 16,605, 427 = US$ 43, 307
Upper limit : $ 17,946,911 = US$ 45,725

Estimated willingness to pay of the representative household:
$ 567,464 = US$ 1, 626

Estimated aggregate willingness to pay for a 50% decrease of pollution
(1,056,781 households) :
$ 599,685,173,384 = US$ 1,718 million

The change in the value of Santiago's total house inventory as a consequence of implementing a program to reduce the air pollution in the city by fifty percent is calculated at US$1,7 billion. This amount necessarily overestimates the benefits of the program, due to the assumption made that all households have equal preferences and income. However, it is also necessary to notice that this amount represents the present value of all benefit flows derived from the proposed air quality improvement program from the present to an infinite horizon of time. Among others, these benefits include declines in pollution-related mortality and morbility, other health improvements, reductions in property deterioration, increases in the availability of environmental amenities, improvements in visibility, etc. Thus an estimation of US$1.7 billion for the present value of all benefits derived from a better air quality from the now to ever can be perfectly compatible with previous partial estimations of benefits, as the one made by the World Bank (1994) for the annual health avoided costs of air pollution which amounted to US$100 per capita per year. Finally, it is important to keep in mind that the relevant contribution of this estimation is to provide an order of magnitude of the expected benefits and not an exact figure.

7. CONCLUSIONS

This paper has estimated the aggregated willingness to pay for an air quality improvement program aimed at reducing the air pollution in Santiago by fifty percent. The calculation has been made using a hedonic price model of house values for the capital city.

The estimated coefficients have the expected signs and all are significant at more than 95 percent level of confidence. The impact of an air quality improvement program on property values is of considerable magnitude; the aggregate WTP for a 50 percent reduction in air pollution in Santiago was estimated at aproximately US$1.7 billion. This figure overestimates the benefits due to the restrictive assumpion made of equal households, but it still provides a useful estimate of the order of magnitude of the benefits resulting from an air quality improvement program. The estimated order of magnitude clearly implies that there is large room for implementing air quality improvement measures in Santiago that could have positive welfare effects on the population, i.e., they would make it possible to attain better states in a Paretian sense.

APPENDIX 1

DEFINITION OF VARIABLES

PHOUSE:
house price (dependent variable)

THOUSE:
type of housing. Dummy variable taking the value 1 for house and 0 for apartments.

M2LOT:
area of lot in square meters.

M2LIV:
living area in square meters.

BEDROOM:
number of bedrooms

BATHROOM:
number of bathrooms

RODS:
room for domestic servant, Dummy variable taking the value 1 for housing having this type of room.

GARAGE:
dummy variable taking the value 1 for housing with the existence of garage.

ROCB:
room for office or commercial business purposes. Dummy variable which takes the value 1 for houses having this type of room.

TELEPHONE:
dummy variable for housing having telephone.

SOLID:
dummy variable, which takes the value 1 for houses constructed with solid materials.

DSUBW:
distance to the nearest underground railroad station. This takes values from 5 to 1, depending on whether the house is located between 1 and 3 blocks, 4 and 6 blocks, 7 and 12 blocks, 13 and 24 blocks and 25 or more blocks from the nearest underground railroad station, respectively.

DPOLIS:
distance in blocks to the nearest police office.

DSTGO:
distance to downtown Santiago. This takes values from 1 to 10, where 10 corresponds to housing located in the middle of down town Santiago.

PAV:
dummy variable taking the value 1 if the housing is located on a principal avenue.

CALT:

dummy variable, which takes the value 1 if the corresponding municipality allows to construct in altitude.

SEI:

socio economic index. This variable takes values from 1 to 12, depending on the level of income where the house is located.

GREENA:

this variable takes values from 1 to 100, depending on the number of square meters of green areas where the house is located.

DENS:

index of density. This variable takes values from 6 to 1, depending on the level of density prevailing in the area.

PGREENA:

dummy variable taking the value 1 if the housing has a view to a green area (park) at no more than two blocks from the house or apartment.

PSERVICE:

index for the degree of public service. Takes values from 1 to 100, depending on the degree of public service in the corresponding municipality, such as education and health.

PINVEST:

index for the level of public investment takes values from 1 to 100, depending on the amount of money invested in paved streets and drinking water.

EPTS:

suspended particulate matter. g/s annual average.

ESOX:

sulphur oxides. g/s annual average.

ECO:

carbon monoxides. g/s annual average.

ENOX:

nitrogen oxides. g/s annual average.

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