Impacts of Air Pollution on Property Values: an Economic Valuation for Bogotá, Colombia.

By Fernando Carriazo-Osorio. [1]

Summary

This study attempts to value air quality (a non marketable good) from the urban housing market in Bogotá (a marketable good). Furthermore, the study examines the impacts of air pollution on housing values. By means of a Geographical Information System (GIS), the housing market is characterized from a random sub-sample of 1006 observations that correspond to properties within the 19 localities of the Capital District of Bogotá. Total of Suspended Particles (TSP) is used as the pollution variable. The methodological framework for estimations is based on a hedonic price model. This approach establishes a relationship between the price of a marketable good (e.g., housing) and the amenities and characteristics this good contains (e.g., air quality, presence of parks, and structural features such as built area, residential or commercial use, etc.). Therefore, if variations in air pollution levels occur, then households would change their behavior in an economic way by offering more money for housing located in highly improved environmental areas.

In the final analysis, estimations suggest that an increase of 1 per cent in the emission level of TSP decreases property values in 0.123 per cent. For the average housing price of Col.$37,506,800 (US$24,322), the marginal willingness to pay for a reduction of 1% in the emission levels is Col.$47,731 (US$31). In the aggregate of the Capital District of Bogotá, this reduction would mean benefits of more than Col.$47.348 million. (US$30,703,387) (All numbers in 1998 prices). This would indicate that a control pollution policy brings as a result substantial monetary benefits for both house owners and local government authorities. The results of this study are likely to be sub-valued since the monetary valuation of health-related problems and other impacts of air pollution are not taken into account.

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Introduction

Environmental amenities such as air quality can be considered as resources with monetary value. Those resources represent a flow of goods and services generating costs and benefits. Air pollution, for example, leads to social costs because fewer availability of clean air deteriorates human health and has negative impacts on species and physical goods. Air pollution's detrimental consequences are inevitably tied to the analysis and design of environmental policy.

From an economic point of view, air quality is a public good that embodies both positive and negative externalities. The lack of prices of environmental services related to air quality is a market failure that does not allow to allocate them efficiently. Moreover, incomplete information, uncertainty, irreversibilities, transfrontier impacts, and the possibility of catastrophic environmental changes, among others, complicate the decision process for policymakers. Nonetheless, recent developments for estimating economic values for nature are likely to provide guidelines to policymakers. Resources that once were considered as non valuable or of few importance, such as landscape or air quality, today are considered as a significant source of value and can be monetarily quantified. This estimated valuation for natural resources and environmental goods has been considered as an expansion of the cost-benefit analysis.

The task of estimating economic values to environmental goods is based on the assumption that the individuals' welfare depends not only on the marketable goods and services that they consume, but also on a flow of non marketable goods and services. Furthermore, in their preferences, individuals can substitute income for environmental goods and services. In economic theory, all value measures based on this assumption can be expressed as the willingness to pay (WTP) or willingness to accept compensation (WTA). The WTP and the WTA are welfare measures that can be estimated in terms of the compensatory variation (CV) or equivalent variation (EV). The CV or EV can be calculated in terms of a good (such as money) that the individual would be willing to substitute by the good or service that is being valuated.

This study attempts to determine the marginal willingness to pay for a cleaner air among housing owners in Bogota, Colombia. Moreover, improvements in the environmental quality in Bogotá (a non marketable good) are valued from the housing values in the city (a marketable good). By doing so, air pollution impacts on housing values are examined. A characterization of the property stock is carried out by using a Geographical Information System GIS. Total Suspended Particles (TSP) is taken as a variable to estimate the air pollution impacts on property values.

Estimations are made within the hedonic price model framework. In this model, the price of a marketable good (i.e, housing) is a function of the amenities and structural characteristics that it contains. This means, for example, that the environment (i.e., pollution levels in a location) is considered as a component of the marketable good. The hedonic method can be used as an approximation to measure the benefits of environmental improvements. By considering variations in pollution levels, households could perceive different air qualities at different sites. Consequently, when choosing a place of residence, families would be willing to pay more for less polluted areas. Therefore, it is possible to establish a relationship between the environmental improvements (or deterioration) and changes in property values.

This document develops as follows: Section I summarizes the theoretical foundations of hedonic models. Section II presents the empirical implementation of the model for Bogotá. In section III, results are discussed and Section IV offers some concluding remarks.

I. Theoretical Issues.[2]

The hedonic price framework is a good modeling strategy to indirectly estimate the relationship between a marketable good such as housing and the associated non marketable services it contains such as landscape or clean air. Since in the hedonic analysis of an heterogeneous good such as housing we do not have direct observations on the price of amenities, the value of the non marketable amenities can be estimated from the observable price changes of the marketable good.

The choosing of a place to live depends on preferences, household income, and the price difference of amenities that characterize each property. Therefore, a consumer examines an implicit market where there is a production process as well as an exchange and consumption of goods that are traded in "bundles" (Sheppard S., 1997). On the contrary, in an explicit market, one observes the prices and the trades of the bundles per se. For the housing market, properties are traded in a single market; however, they are heterogeneous goods. For this reason, the demand of housing is modeled based, not on the built units as a whole, but on its characteristics. Due to this heterogeneous nature of properties, the housing market cannot be modeled with the traditional supply and demand framework used in the standard economic analysis. Housing markets do not have a single price, but a range of prices that depend on the characteristics or on the quality of the houses. Thus, the hedonic analysis takes the heterogeneous goods with more or less homogeneous aggregate components. While the aggregate bundle does not have a single price, the amenities and characteristics that compose it does; or at least, they have a common price structure.

Within the hedonic price model framework it is assumed that consumers′ utility depends on the consumption of a differentiated good that can be represented by a vector $Z = (z_1, z_2, z_3, ..., z_n)$ of structural characteristics (i.e., constructed area), and a vector $A = (a_1, a_2, a_3, ..., a_n)$ of amenities (i.e. air quality). The price of the good is a function of its characteristics and amenities. This is the hedonic price function,

$$P = P(Z, A).$$

The hedonic equilibrium results from the maximization problem of both consumers and producers and the interaction of these two agents of the economy.

When choosing a place to live, households are choosing a vector A of amenities and a vector Z of characteristics. They also choose the amount of expenditure in a composed good X of the economy different from housing. Households also face a budget restriction Y, which can be used for housing expenditure or to buy the composite good of the economy X. Housing expenditure is a function of the property hedonic price $P(Z, A)$ which measures the equilibrium relationship between the price of a property, Z and A. Households also have a vector α of socio economic characteristics; therefore, their preferences can be represented by an utility function,

$$U(Z, A, X; \alpha)$$

The households' maximization problem of the utility is:

$$\text{Max}_{Z, A, X}\ U(Z, A, X; \alpha) \ \text{ s.a } \ P(Z, A) + X = Y .$$

From the solution of this problem we have the consumers' bid function $\phi(Z, A, y, u; \alpha)$ which represents the willingness to pay (WTP) for a property with characteristics Z and amenities A, with a given income and utility

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[2] For a further discussion on hedonic price models and applications, see for example Gottlieb (1996), Nourse (1967), Rosen (1974), Smith, K. (1995), Palmquist (1991), Freeman (1993) among others.

level. The bid function can be implicitly defined as $U(Z,A,Y-\phi)=u$. Therefore, if income changes, the bid would also change. Moreover, the derivative of the bid function $\frac{\partial\phi(Z,A,y,u;\alpha)}{\partial z_i}$ gives the rate at which a household would be willing to change housing expenditure, given increases in characteristics and holding a constant utility level.

From the first order conditions of the households' maximization problem, the marginal rate of substitution between one characteristic and the composite good X equals the marginal (hedonic) price of the characteristic i.

$$\frac{\frac{\partial U(Z,A,X;\alpha)}{\partial z_i}}{\frac{\partial U(Z,A,X;\alpha)}{\partial x_i}}=\frac{\partial P(Z,A)}{\partial z_i}=\frac{\partial\phi(Z,A,y,u;\alpha)}{\partial z}$$

Similarly, the marginal rate of substitution between an amenity and the composite good equals the marginal price of the amenity which at the same time equals the marginal bid for the amenity.

Summarizing, as a result of the consumer problem, in the optimum, the slope of the bid function equals the hedonic price for each characteristic i. If it is possible to observe (or estimate) the hedonic price for one characteristic, under the assumption of maximizing behavior, this observation gives us information on consumer´s preferences and the willingness to pay for the amenities of the observed chosen unit.

On the other hand, urban developers choose both the quantity and the type of housing they build. The producer's cost function can be represented as $C(Z,A,N,\beta)$, where N is the number of produced units and β represents a vector of suppliers' attributes such as specific technology and others that describe differences in the cost functions among suppliers. Then, taking prices as given, the profit-maximization problem that building developers face is:

$$\text{Max}_{Z,A,N}\ \pi = NP(Z,A)-C(Z,A,N;\beta).$$

From the solution of this problem, the offer function $\rho(Z,A,N,\beta)$ is obtained representing the price that a housing seller can accept for one unit with characteristics Z and attributes A.

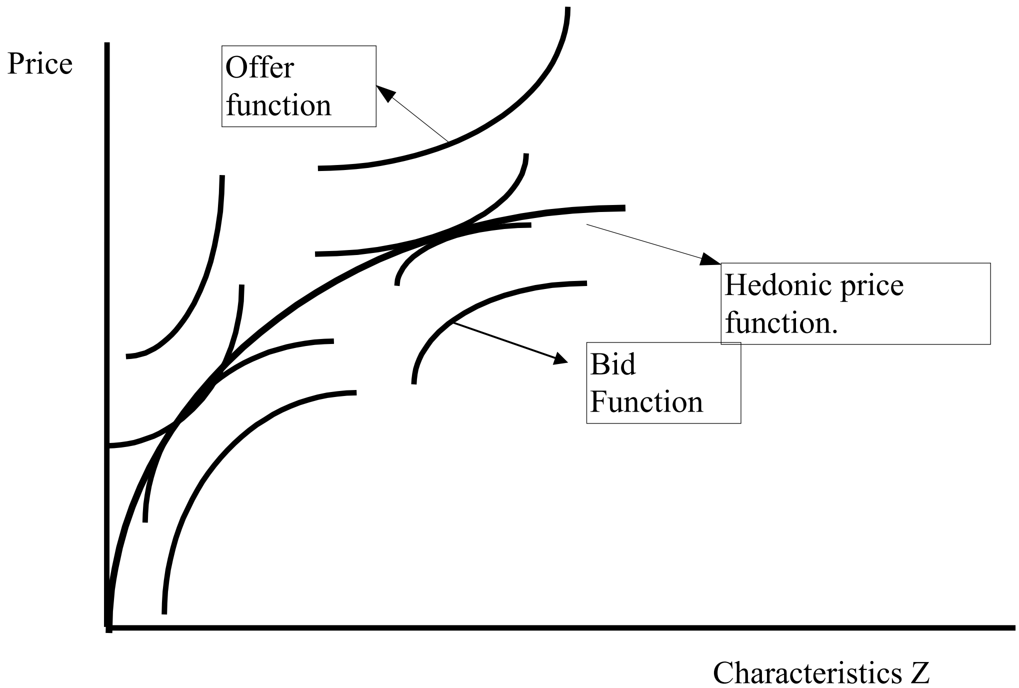
From the first order conditions of this maximization problem, the marginal price for each characteristic must equal its marginal cost. The offered level of characteristics should balance its price with its marginal cost. This is:

$$\frac{\partial P}{\partial Z_i}=\frac{\partial C}{\partial Z_i}$$

The equilibrium set can be determined by the interaction between consumers and producers. To see it in an intuitive way, this interaction can be seen as an auction where the producer offers characteristics and the consumer bids for the price of each differentiated good. On the one hand, consumers want to have the lowest willingness to pay so that they can maximize their utility. On the other, producers maximize their offer (the price they accept) and, by doing so, they maximize their profits. Market reconciles the agents' interests avoiding consumers to increase their utility by choosing a different product and firms to increase their profits by varying the quantity or the version of the product they supply.

In equilibrium, the offer and bid functions are tangent and the hedonic price function is given by the locus of the tangency points of the offer and bid functions (Figure1).

Figure 1. Hedonic equilibrium.



Source : Palmquist (1991).

Economists have faced some econometric difficulties for the estimation of the hedonic price function. The most common obstacle has been, among others, the choosing of both the functional form and the variables to avoid multicollinearity problems, potential heteroscedasticity or the violation on the assumption of the normality of the random term.

Box Cox transformations on hedonic prices and non dichotomous variables have been usually applied to estimate the most appropriate functional form of the hedonic equation. However, for a product such as housing, theoretical considerations do not determine the functional form of hedonic equations. For this reason, the functional form must be determined empirically. A very flexible and general form that has been used is the so called quadratic Box-Cox:

$$P^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i z_i^{(\lambda)} + \frac{1}{2}\sum_{i}^{m}\sum_{j}^{m} \gamma_{ij} z_j^{(\lambda)} z_i^{(\lambda)}$$

where,

$$P^{(\theta)} = \frac{(P^{\theta} - 1)}{\theta} \quad \text{if } \theta \neq 0 \text{, y } P^{(\theta)} = \ln P \text{ if } \theta = 0$$

$$Z^{(\lambda)} = \frac{(Z^{\lambda} - 1)}{\lambda} \text{ if } \lambda \neq 0 \text{, y } Z^{(\lambda)} = \ln Z \text{, if } \lambda = 0 .$$

The well known forms doblelog, log-lineal, lineal, semilog, among others, are special cases of the general form.

All theoretical considerations of hedonic price models are still topics of discussion and research among economists. Therefore future research shall be continued in order to cope with theoretical problems of hedonic models and to improve not only their prediction capacity but also the theoretical basis of applied models.

II. Empirical Implementation.

A. Data

From a total of 1,473,935 properties in the Capital District of Bogotá, those of residential use were selected. The sample included houses and apartments. A total of 661,393 houses and 338,117 apartments were obtained. From this total, a random sub sample of 1066 observations was selected[3]. This random sample was taken within the 19 localities of the Capital District of Bogotá[4]**.** Table 1 shows a comparison between the sample and the total housing units.

Table 1. Sample vs Total residential properties in Bogotá.

RESIDENTIAL UNIT	SAMPLE		BOGOTA	
	QUANTITY	%	QUANTITY	%
HOUSES	624	62.07	661.393	66.17
APARTMENTS	382	37.93	338.117	33.83
TOTAL	**1006**	**100**	**999.510**	**100**
STRATUM 1	35	3.48	36286	3.63
STRATUM 2	330	32.80	316743	31.69
STRATUM 3	369	36.68	403877	40.42
STRATUM 4	142	14.12	136.537	13.66
STRATUM 5	66	6.56	57461	5.74
STRATUM 6	64	6.36	48606	4.86
TOTAL	**1006**	**100**	**999.510**	**100**

From DADC database.

[3] Number of observation with 3% error.

[4] For Bogota's urban planning, the Capital District is divided in 19 zones : Usaquén, Chapinero, Santa Fe, San Cristobal, Usme, Tunjuelito, Bosa, Kennedy, Fontibón, Engativá, Suba, Barrios Unidos, Teusaquillo, Mártires, Antonio Nariño, Puente Aranda, Candelaria, Rafael Uribe, Ciudad Bolívar.

From the data set used in this study, it was possible to exploit its spatial nature to make a brief characterization of the housing stock (Table 2).

Table 2. Descriptive statistics of the variables used in the model.

VARIABLE	MEAN	STANDARD DEVIATION
PRICE	37.5068	39.0059
SCORE	42.8111	17.4855
ARTE	98.3111	153.5312
ARCO	129.2694	98.2722
USE	0.3797	0.4856
ROAD	0.7555	0.4300
DUST	0.0611	0.0229
WATER	0.2624	0.4402
ESTR	3.0656	1.2002
PARK	4.6913	6.3371

The average price of housing in 1998 pesos was Col.$37,506,800 (US$24,322). According to the average score (42.8/100) most housing has just an acceptable quality. Regarding the *use* variable, 37.9% of housing units are apartments and 62.03% are houses. The average constructed area / terrain area ratio is only 1.31. This could indicate a "horizontal" urbanization pattern rather than a "vertical" one which is associated with the great extension of the urban area.

Standard deviation of variables are likely to indicate the great range of intrinsic characteristics among housing and therefore the heterogeneous nature of the property stock as well.

Regarding the location amenities, 75% of neighborhoods are crossed by main roads and only 26.2% by rivers or wetlands. The average density of green areas is 4.69% and only 35.59% of total neighborhoods have a density of green areas higher than the average density. This could indicate the presence of small green areas within the city.

The average pollution level of TSP for the 19 locations of the Capital District of Bogotá is 0.06162 ppm. A negative correlation between the pollution and density of parks was identified. (See correlation Matrix in Annex).

B. Empirical Specification of the Hedonic Model.

This study hypothesizes that air pollution, while being a negative externality, leads to lower property values in Bogotá. The hedonic framework explained in the theoretical issues was used to corroborate this hypothesis. Some regressions were run with different functional forms that relate property values with the housing amenities and characteristics. The housing stock of the urban fringe was characterized by means of a Geographical Information System (GIS). The GIS links alpha-numeric data so that information is geo-coded in a map at the property level.

The attributes of housing have been traditionally divided in structural characteristics and location amenities. In this study, the following characteristics were incorporated in the analysis:

- Score: It summarizes the physical and structural characteristics of the building such as material of the structure, finishes and particularities of bathrooms and kitchen[5].
- Built area: measured in m^2, it does not include the area of terrain.
- Terrain area: area in m^2 on which the construction is built.

The location amenities are represented by:

- Environmental amenities: Presence of rivers, wetlands, green areas and pollution.
- Access amenities: roads.

These variables measure the quality of the neighborhood; in other words, they represent location externalities that affect property values at a local level.

Specifically, the following hedonic equation was estimated (see table 3 for definition of variables):

$$Price^{(\theta)} = \beta_0 + \beta_1 score^{(\lambda)} + \beta_2 arte^{(\lambda)} + \beta_3 arco^{(\lambda)} + \beta_4 use^{(\lambda)} + \beta_5 road^{(\lambda)} + \beta_6 dust^{(\lambda)} + \beta_7 water^{(\lambda)} + \beta_8 park^{(\lambda)} + \beta_9 estr^{(\lambda)} + \varepsilon_i \qquad (1)$$

Table 3. Definition and names of the variables used in estimations

Price	=	Price of housing in 1998 Col $, according to DACD.
Score	=	Score calculated according to IGAC. This variable ranges from 0 to 100 and is used as a "proxy" of the housing quality.
Arte	=	Terrain area on which the edification is built.
Arco	=	Constructed area .
Use	=	Dichotomous variable. 1 if the housing is an apartment and 0 if it is a house.
Road	=	Dichotomous variable. 1 if housing belongs to a neighborhood which is intercepted by one or more main roads, otherwise it is equal to 0.
Dust	=	Housing's locality average pollution level. ($\mu g/m^3$ of Total Suspended Particles).[6]
Water	=	Dichotomous variable. 1 if housing belongs to a neighborhood which is intercepted by one or more rivers or wetlands, otherwise is equal to zero.
Park	=	Density of green areas within the housing's neighborhood.[7]
Estr	=	Socio-economic stratum of the neighborhood. It takes discrete values (1,2,3,4,5,6), where 1 represents the lowest stratum and 6 the highest. As defined by Colombian government.
ε_i	=	random term with $N\sim(0,\sigma^2)$.

[5] This score is calculated according to the Manual de Reconocimiento Predial (Instituto Geográfico Agustín Codazzi, IGAC).

[6] Pollution data was taken from DAMA's (local environmental authority) net for the monitoring of the environmental quality. An average pollution level was calculated for each locality according to the location of the air pollution's monitoring station.

[7] This density is defined as: area of green zones within the neighborhood / total area of the neighborhood.

In order to determine the appropriate functional form of the model given by (1), restricted Box –Cox regressions were run and they were compared with unrestricted ones. By using the likelihood ratio test the appropriate functional form was chosen.[8] The following functional forms were tested (Table 4):

Table 4. Functional forms

FUNCTIONAL FORM	VALUE OF PARAMETERS.	ESTIMATOR
Lineal	$\theta = \lambda = 1$	Ordinary Least Squares
Doble log	$\theta = \lambda = 0$	Ordinary Least Squares
Semi log (log-lin)	$\theta = 0, \lambda = 1$	Ordinary Least Squares
Semi log inversa (lin-log)	$\theta = 1, \lambda = 0$	Ordinary Least Squares
Box Cox no restringida1[9]	$\theta = \lambda \neq 0$	Maximum Likelihood
Box Cox no restringida2[10]	$\theta \neq \lambda \neq 0$	Maximum Likelihood

The goodness of fit of this models were tested by using the likelihood ratio test.

III. Results.

First, an analysis of the robustness of variables is presented. Second, a comparison of models is carried out in order to choose the most appropriate functional form. Last, the estimated marginal willingness to pay for housing characteristics and amenities are discussed.

A. Stability of variables.

Table 5 presents the estimation results for various functional forms of the hedonic equation.

In terms of the stability of variables, results showed in table 4 can be summarized as follows.

[8] Likelihood ratio test is given by :

$$-2.\ln\left(\frac{L_{\theta R}}{L_{\theta NR}}\right) = 2.\left(\ln L_{\theta NR} - \ln L_{\theta R}\right) \rightarrow \chi^2_{igl}$$

where, LθR ,LθNR is the restricted and unrestricted likelihood functions respectively. The null hypothesis is that the hedonic equation has a known functional form (i.e lineal, log, doble log, etc..) and the alternative hypothesis indicates that the appropriate functional form corresponds to the non restricted Box-Cox regression.(BCNR).

[9] Corresponds to model No 3 in LIMDEP7 for the Box Cox regressions; the value of Theta and Alfa are the same for both left hand side variables and right hand side variables. Theta y Alfa are found by greed search within the interval (-1,1).

[10] Corresponds to model No 4 in LIMDEP7 for the Box Cox regressions. Dependent and independent variables have different transformations. Theta and Alfa are found by greed search within the interval (-1,1).

Table 5. The dependent variable is price.

	LINEAL	DOBLE LOG	LOG-LIN	LIN-LOG	NON RESTRICTED BOX COX 1(2)*	NON RESTRICTED BOX COX 2. (3)*
Constant	-52.138 (-9.814)**	-3.5117 (-22.050)**	1.3698 (21.598)**	-237.39 (-14.491)**	4.0460 (-21.575)**	-1.9259 (-8.573)**
Score	0.57594 (7.550)**	0.34960 (6.340)**	0.0117 (8.178)**	14.723 (5.650)**	0.36325 (15.417)**	0.1711 (10.073)**
Arte	0.07421 (3.713)**	0.30592 (10.732)**	0.0009 (4.933)**	20.831 (7.780)**	0.30498 (22.318)**	0.0984 (7.674)**
Arco	0.17438 (11.768)**	0.61780 (24.254)**	0.0042 (21.859)**	15.961 (7.002)**	0.54029 (24.049)**	0.1664 (8.265)**
Use	1.6138 (0.708)	0.54328 (15.336)**	0.1575 (4.630)**	16.219 (6.417)**	0.66474 (15.154)**	0.5692 (15.286)**
Road	-0.31132 (-0.254)	0.0964 (5.474)**	0.1117 (5.023)**	-0.8580 (-0.576)	0.11146 (4.793)**	0.1085 (5.111)**
Dust	-21.870 (-0.847)	-0.14528 (-5.826)**	-1.950 (-3.726)**	-5.3383 (-2.997)**	-0.2188 (-5.430)**	-0.3603 (-5.082)**
Water	-1.7096 (-1.273)	0.0211 (1.319)	0.0261 (1.349)	-1.8077 (-1.192)	0.0198 (0.952)	0.0202 (1.068)
Park	-0.15001 (-1.439)	-0.00955 (-0.950)	-0.0015 (-1.359)	-0.1532 (-1.263)	-0.0014 (-0.974)	-0.0014 (-1.062)
Estr	12.1550 (10.727)**	0.2224 (18.908)**	0.2464 (16.005)**	12.9530 (10.676)**	0.2883 (13.454)**	0.2634 (13.557)**
Log-likelihood function	-4456.55	57.99 (1)* NA	-151.94	-4562.40	-165.94	-72.70
Ln Función de verosimilitud Restringida.	-5112.64	-5112.64	-5112.64	-5112.64	-5112.64	-5112.64
Razón verosimilitud.	1312.18	10341.27 NA	9921.39	1100.48	9893.40	10079.86

Estimated in LIMDEP7.
T statistic in parenthesis .
** indicates significance at 99% level.
(1) *this model does not present statistical adjustment since a positive value of the log-likelyhood function was obtained.
(2)* Lambda = 0.070707 for dependent and independent variables.
(3)* Theta = 0.56707E-01 for the dependent variable, and Lambda = 0.30379 for the independent variables.

The *Score*, *Arte,* and *Arco* variables (indicating respectively, quality, area of terrain, and constructed area of the housing units) are significant in all estimated functional forms. As expected, there is a positive correlation between these characteristics and the housing price. Since the signs of the coefficients accompanying these variables do not change with the functional form, it could be concluded that these variables are robust.

The *Use* variable presents stable signs; however, it is not significant for the lineal specification. The coefficient's positive sign explains the higher average willingness to pay of housing consumers for apartments.

Summarizing, all structural characteristics present stable signs of coefficients for the various specifications of the hedonic equation.

The socio-economic variable *Stratum* is robust. The coefficient's sign is always positive.

Regarding the location amenities, *Road* and *Water* are not robust since the coefficient's signs vary depending on the functional forms. The remaining variables of the location amenities keep the same coefficients' sign. A possible explanation for the instability and non significance of these variables relies on the way they were defined. For example, concerning the water variable, a subjective perception of housing consumers is not so much the presence of rivers or wetlands but rather the quality of this variables[11]. A more accurate measure for this variable would be, for example, the pollution level (measured as OBD) of rivers or wetlands which was not possible to test due to information restrictions. A priori, the general perception of rivers for Bogotá are likely to be associated with negative externalities and, therefore, it would have a negative impact on property values. Furthermore, this variable is not significant in the model.

Regarding the accessibility variable (*Road*), a more accurate measure would be the distance from the house to the main road as well as quality of road. Although not robust, the coefficient of this variable is positive and significant for the chosen functional form. This could indicate that housing consumers are likely to give a higher value to the positive externalities associated with accessibility than the negative externalities of roads associated with noise or air pollution from vehicles.

The sign of the coefficient of park density is contrary to the expected. A better definition of the variable (i.e an index of quality of parks or distance to the park) would correct for a more accurate perception of it by housing consumers. Not surprisingly, this variable is not significant for any of the tested specifications.

The pollution variable (Dust) is a stable variable; it always maintains a negative sign for all functional forms.

In conclusion, the air pollution variable is the only stable and significant variable among the location amenities in the model. Furthermore, the sign that accompanies this variable is always negative, as it was hypothesized before.

B. Functional Form

In order to choose the appropriate functional form, comparisons of the estimated Box Cox regressions were made by using log likelihood ratio tests. Table 6 presents hypothesis test's results to determine the appropriate functional form of the hedonic equation.

As a result of the hypothesis tests, it can be concluded that there is no sufficient statistical evidence to affirm that the hedonic price function in this model has a known functional forms as those specified in table 4. Therefore, the most appropriate functional form is the specified as a non restricted Box-Cox, in which theta takes the value of 0.056707 and lambda takes the value of 0.30379. With these values the maximum value of the likelihood function is obtained. Therefore, this model was chosen as the most appropriate to estimate the marginal willingness to pay for housing characteristics and amenities.

[11] Many Bogota's superficial waterways are highly polluted and some of them are used as served waters.

Table 6. Hypothesis test´s results for determining the appropriate functional form

Model Vs BCNR.	Hypothesis	Log-likelihood function		Statistic	Conclusion regarding Ho.
Lineal	Ho: $\lambda=\theta=1$	For lambda and for theta	-4456.5522	8767.6906	Reject
BCNR : (Non restricted BoxCox Model)	Ha: $\lambda\neq\theta\neq1$	For lambda For theta	-72.7069 -3201.65551	8767.6906 2509.79338	
Doble log	Ho: $\lambda=\theta=0$	For lambda For theta	*** -3259	114.68898	Reject
BCNR	Ha: $\lambda\neq\theta\neq0$	For lambda For theta	-72.7069 -3201.65551	*** 114.68898	
Log Lin	Ho: $\lambda=0$, $\theta=1$	For lambda For theta	-151.9415 -3468.99056	158.4692 534.6701	Reject
BCNR	Ha: $\lambda\neq0$, $\theta\neq1$ ($\lambda\neq\theta$)	For lambda For theta	-72.7069 -3201.65551		
Lin Log	Ho: $\lambda=1$, $\theta=0$	For lambda For theta	-4562.4167 -4562.42172	8979.4196 2721.53242	Reject
BCNR	Ha: $\lambda\neq1$, $\theta\neq0$ ($\lambda\neq\theta$)	For lambda For theta	-72.7069 -3201.65551		

***For the double log function was not found statistical adjustment since the value likelyhood function does not belong to the [0;1] interval, presenting similar problems of the lineal probability models.

C. Marginal Willingness to pay for housing characteristics and amenities

An analysis of elasticity was made in order to determine the marginal willingness to pay for an increase (or decrease) for housing characteristics or location amenities,. This elasticity measures the relationship between a relative increase of the variable and a relative increase in the property value. Elasticities are calculated in the means of variables and the mean of the housing price. [12]

Table 7 presents the estimation results for the continuous variables used in the model.

The coefficient of the *score* variable is positive indicating that an increase in housing quality leads to an increase of property price. The Marginal Willingness to Pay for this variable is Col.$345,200 (US$ 225). According to the elasticity analysis, an increase of 1% in this variable leads to a housing value's increase of Col.$164,000 (US$ 106).

[12] Formally, for the Box Cox model, the elasticity can be expressed as:

$$\eta_{pz} = \frac{\partial \mathbf{ln} p}{\partial \mathbf{ln} z} = \frac{\dfrac{\partial p}{\partial z}}{\dfrac{\bar{p}}{\bar{z}}} = \frac{\beta(z^{\lambda})}{p^{\theta}}$$

Table 7. Non-restricted Box-Cox model: hedonic price function. Dependent variable is price. θ = 0.056707, λ = 0.30379.

VARIABLE	MEAN	COEFFICIENT (T ESTADÍSTICO)	MARGINAL (WTP) (MILLONS)	ELASTICITY	WTP FOR 1% CHANGE IN Z.(MILLONS)
PUNT	42.8111	0.1711** (10.073)	0.3452	0.4389	0.164
ARTE	98.3111	0.0985** (7.674)	0.1114	0.3252	0.122
ARCO	129.2694	0.1665** (8.265)	0.1556	0.5973	0.224
DUST	0.0611	-0.3604** (-5.082)	-69.5896	-0.1263	-0.047
DPARC	4.6913	-0.0014 (-1.062)	-0.0394	-0.0055	-0.002

**Significant at a 99% level.

The variables for terrain and constructed areas are significant in the model and indicate a positive relationship with the properties` prices. The marginal willingness to pay for the area of terrain variable is Col.$111,400 (US$72)and $155,600 (US$ 101) for the constructed area.

Summarizing, all structural characteristics are very significant in the chosen hedonic equation and explain a positive relationship with the hedonic price of properties.

Since the location amenities represented by the Use, Road and Water variables and the socio-economic variable are dichotomous and discrete, an interpretation of elasticities or the marginal willingness to pay leads to some theoretical complexities. However, the sign of the coefficients accompanying the variables can be analyzed in order to determine the consumers' perception of amenities as positive or negative externalities:

The coefficient of the *use* variable (indicating if house or apartment) is positive. This would suggest that housing consumers perceive the apartment ownership as a positive externality. The result could be associated with better security conditions of apartments with respect to houses in Bogotá.

The coefficient of the Road variable is positive. This would suggest that roads can be perceived as positive externalities associated with accessibility and not as negative externalities, associated with noise, traffic jams or air pollution from vehicles as it was mentioned before.

The presence of water bodies is likely to be perceived as a positive externality. However, as it was previously mentioned, this variable is not robust, and seems not to be relevant in the non restricted Box-Cox model (See t-statistc in table 5).

The socio-economic variable stratum is positively correlated with property prices. As expected, houses located in upper stratum areas present a higher value than those in lower stratum areas. This variable is very significant in the model.

Contrary to the expected, the sign of the coefficient accompanying the park density variable is negative. Sometimes, location amenities are essentially measures of externalities and very often, a single location attribute can represent both positive and negative externalities. In this model, housing consumers are likely to weight more the negative externalities associated to green areas (i.e presence of garbage or insecurity problems) than the convenience that green areas represent for different residents in a location. Nonetheless, as defined, this variable is not significant in the model.

For the air pollution variable (Dust) the elasticity analysis suggest that an increase of 1% in the emission level of Total Suspended Particles brings as a result a decrease of 0.1263% in its price. For the mean property price of Col.$37'506.800 (US$ 24,322) , this increase in pollution brings as a result a decrease of Col.$47,731 (US$31). Aggregating this value for the total stock of residential properties of the Capital District of Bogotá, a 1% reduction policy would mean benefits of more than Col.$47,348 million. (US$30,703,387) (All numbers in 1998 prices).

In brief, among the location amenities, the only significant variables used in the model are Road and Dust. Therefore, as estimation results suggest, air pollution is likely to be perceived as a negative externality and contributes to the explanation of lower property values in the presence of poor air quality.

IV. Concluding remarks.

An hedonic model has been applied to explain property values in Bogota from an environmental perspective. Data used allowed to characterize housing stock. From this characterization, the lack of some environmental amenities such as green areas was determined. Only 35.6% of neighborhoods have a density of green areas above the average. Among the location amenities, roads are likely to be perceived as positive externalities. In other words, as estimations suggest, housing consumers seem to put a higher weight to accessibility and a lower one to congestion, noise or other negative externalities associated with the presence of roads within a neighborhood. Amenities such as the presence of water bodies (rivers or wetlands) or higher green areas are likely not to be significant in the estimated model. However, with more information available, a better definition of these variables would help to improve the predictive capability of the estimated model.

From the estimated hedonic function, the air pollution variable is very significant in the model that explains property values. This variable represents a negative externality, suggesting that an increase of 1% in the TSP emission levels, produces a reduction of 0.1263% in the property value. This would indicate that an air pollution reduction policy brings as a result significant monetary benefits for both housing consumers and local authorities. Estimated social benefits for a reduction policy might be as high as US$30,703,387 and are likely to be sub-valued since the monetary valuation of health related problems and other impacts of air pollution are not taken into account.

Finally, local environmental authorities can use this type of valuation as guidelines to implement cost-effective environmental policies. The accuracy and predictive capacity of this model depends on a great extent on the quantity of the available information in data bases. Support of governmental and private sectors in a multidisciplinary effort is highly recommended to improve the accuracy of variable measures and overcome information restrictions.

BIBLIOGRAPHY

Braden, John B.; Kolstad, Charles D., eds. *Measuring the demand for environmental quality.* Contributions to Economic Analysis, no. 198, Amsterdam, Oxford and Tokyo: North-Holland; distributed in the U.S. and Canada by Elsevier Science, New York, 1991.

Corporación Misión Siglo XXI "*Localización de la actividad económica en Bogotá".* Santa Fe de Bogotá, 1998.

Department of the Environment, Transport and the Regions, (DETR). *An Economic Analysis of the NationalAir Quality Strategy Objective An Interim Report*, *Non-Health Benefits.* Publicado 5 de Febrero, 1999. Chapter 5.

Figueroa B., Eugenio; Rogat C., Jorge; Firinguetti L., Luis *An Estimation of the Economic Value of an Air Quality Improvement Program in Santiago de Chile* Estudios de Economía, Special Issue 230: 99-114, 1996.

Gat, Daniel. *A Compact Hedonic Model of the Greater Tel Aviv Housing Market* Journal of Real State Literature 42: 163-72, July 1996.

Gottlieb, Peter *Hedonic Models: Valuation of Urban Parks.* Unpublished document, Department of Agricultural and Resource Economics. University of Maryland, 1996.

Graves, Phil et al. *The Robustness of Hedonic Price Estimation: Urban Air Quality* Land Economics, 643: 220-33, August 1988.

Harrison, David, Jr.; Stock James H. *Hedonic Housing Values, Local Public Goods, and the Benefits of Hazardous Waste Cleanup* Harvard Energy & Environmental Policy Center, Discussion Paper Series: E:84-09, November 1984.

Hugh O. Nourse. *The Effect of Air Pollution on House Values*. Land and Economics, 43: 181-189, 1967.

Hughes, William T., Jr.; Sirmans, C. F. *Traffic Externalities and Single-Family House Price* Journal of Regional Science, 324: 487-500 November 1992.

Mas-Collel, A et al. *Microeconomic Theory*. Oxford University Press, New York, 1995, Chapter 11.

Orford Scott. *Valuing Location in an Urban Housing Market* Ed. School of Geografphical Sciences, University of Bristol. Bristol, UK, 1999.

Ostro, B. *The health effects of air pollution: a methodology with applications to Jakarta.* Working Paper Series No. 1301. The World Bank, Washington, DC. May, 1994.

Pamquist Raymond. *Hedonic Methods*, en Measuring the Demand for Environmental Quality. Edited by John Braden y Charles D. Kolstad. Ed. Elsevier Science Publishers. B.V North-Holland , 1991.

Polinsky, M and Shavell, S. *The Air Pollution and Property Value Debate,* The Review of Economics and Statistics (57), 1: 100-104, Feb, 1974.

Ramsey. *A Note on Air Pollution, Property Values and Fiscal Variables.* Land Economics (52) 2, May, 1976.

Ridker, R.G, and J.A Henning, *The Determinants of Residential Property Values with Special Reference to Air Pollution*. The Review of Economics and Statistics, 49: 246-256, 1967.

Sheppard, S. *Hedonic Analysis of Housing Markets* Ed. Oberlin College, 1997.

Sherwin Rosen. *Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition.* Journal of Political Economy 82: 34-55, Jan, 1974.

Small Keneth *Air Pollution and Property Values.* .The Review of Economics and Statistics (57) 1: 105-107, Feb 1975.

Smith, V. Kerry; Huang, Ju Chin. *Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models.* Journal of Political Economy, 1031: 209-27, February 1995.

ANNEX

Correlation Matrix:

	PREC	PUNT	ARTE	ARCO	USO	VIA
PREC	1.000					
PUNT	0.4813	1.000				
ARTE	0.4338	-0.1305	1.000			
ARCO	0.5570	-0.7985E-01	0.4039	1.000		
USO	0.7750E-01	0.6292	-0.3024	-0.4341	1.000	
VIA	0.2128	0.3421	-0.4495E-01	-0.1068E-01	0.2688	1.000

	PREC	PUNT	ARTE	ARCO	USO	VIA
DUST	-0.3937	-0.5589	0.6366E-02	-0.2885E-01	-0.3426	-0.2828
AGUA	0.1724E-03	0.2907E-01	-0.2728E-01	0.1265E-01	0.2679E-01	0.1028
PARC	0.1731	0.2724	-0.2265E-01	0.4556E-02	0.1628	0.1427
ESTR	0.6135	0.7585	0.6450E-02	0.7417E-01	0.4677	0.3781
DPARC	0.9563E-01	0.2221	-0.3896E-01	-0.4330E-01	0.1599	0.1132

	DUST	AGUA	PARC	ESTR	DPARC
DUST	1.000				
AGUA	0.6162E-01	1.000			
PARC	-0.2417	0.9682E-02	1.000		
ESTR	-0.5972	0.4083E-01	0.3505	1.000	
DPARC	-0.1944	0.1211E-01	0.7063	0.2353	1.000

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