La granja: Revista de Ciencias de la Vida
pISSN:1390-3799; eISSN:1390-8596
http://doi.org/10.17163/lgr.n36.2022.08

Scientific paper/ Artículo científico
Environmental Sciences

Contrasting effects of air pollution asessment in two areas of the Quito Metropolitan District, Ecuador

Efectos contrastivos de la evaluación de la contaminación ambiental en dos zonas del Distrito Metropolitano de Quito, Ecuador

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Received on May 11th, 2020. Accepted, after review, on October 29th, 2021.

Abstract

One of the main factors of air contamination within urban areas is burning gasoline by cars, light trucks and motorcycles. Gasoline burning liberates pollution gases such as Nitrogen dioxide, Sulfur dioxide, Carbon monoxide, benzene, besides others. Among these, Nitrogen dioxide (NO_x) is the one that stands out for the people's awareness of such contamination. We used the Hedonic Price Method (HPM) in order to determine people's perception of air quality as a proxy and estimate the effect of gases on the housing market. We selected two areas of Quito Metropolitan District in order to evaluate contamination effects on properties. One with a higher concentration of gases located within the historic district of Quito. The other with better air quality called the Bellavista district. The results of three different models indicated that a reduction of 1 ($\mu g/m^3$) of NO_x would increase an average of 4.54% of the housing market value, which it represents 2,032,326.24 USD in value for sample properties. A decrease of 5 $\mu g/m^3$ will increase in 22.7% of properties value.

Keywords: Greenhouse gases, hedonic price, housing value, air contamination, Quito.

Resumen

Uno de los principales factores de contaminación del aire dentro de las zonas urbanas es la quema de gasolina por parte de autos, camiones ligeros y motocicletas. La quema de gasolina libera gases contaminantes como el dióxido de nitrógeno, el dióxido de azufre, el monóxido de carbono y el benceno, entre otros. Entre ellos, el dióxido de nitrógeno (NO_x) es el que destaca por la concienciación de la gente sobre dicha contaminación. En esta investigación se utilizó el Método de los Precios Hedónicos (MPH) para determinar la percepción de la gente sobre la calidad del aire como indicador y estimar el efecto de los gases en el mercado inmobiliario. Se seleccionaron dos zonas del Distrito Metropolitano de Quito para evaluar los efectos de la contaminación en los inmuebles. Una con mayor concentración de gases ubicada dentro del casco histórico de Quito, y la otra con mejor calidad de aire conocida como el sector Bellavista. Los resultados de los tres modelos diferentes indicaron que una reducción de 1 (μg/m^3) de NO_x aumentaría un promedio de 4,54 % el valor del mercado inmobiliario, lo que representa un valor de USD 2.032.326,24 para las propiedades de la muestra. Una disminución de 5 (μg/m^3) aumentaría en un 22,7 % el valor de las propiedades.
Palabras clave: Gases de efecto invernadero, precio hedónico, valor de la vivienda, contaminación del aire, Quito.

Suggested citation: Cornejo-Vásconez, D., Rodríguez-Espinosa, F., Guasumba, A., and Toulkeridis, T. (2022). Contrasting effects of air pollution asessment in two areas of the Quito Metropolitan District, Ecuador. *La Granja: Revista de Ciencias de la Vida.* [Early Access] http://doi.org/10.17163/lgr.n36.2022.08.

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1 Introduction

Clean air is considered as one of the most basic requirements of human health and well-being (World Health Organization, 2016). Its relative purity or contrarily its pollution may determine different social and economic problems (Panayotou, 2016; Gulia et al., 2015; Victor, 2017). An estimation of physical damages can be done by estimation visibility impacts, acid rain impacts, crop and other vegetation damages, property value impacts, corrosion and soiling impacts, recreation effects, and health effects. Poor air quality is associated with the incidence of short and long-term diseases, particularly neurologic and of the the respiratory system, as mentioned by several authors like Zivin and Shrader (2016); Calderón-Garcidueñas et al. (2016); Perera (2017).

Organization (WHO) estimated that in 2014, 82 % of the population in developing countries may be subject to levels that tend to exceed minimum quality standards as stipulated in their guidelines on air-quality (World Health Organization, 2006, 2016). This issue has a greater incidence in large cities on all continents (Smith and Huang, 1993; Bayer et al., 2009; Kennedy et al., 2007). Nevertheless, the impact on health of air pollution is difficult to assess. Several studies have used the value of statistical life (VSL) as a method to estimate marginal reduction in the risk of premature death (Sanchez Martinez et al., 2018; World Bank, 2016; Franchini and Mannucci, 2015; World Health Organization, 2016). However, these studies required a complete data of premature deaths to estimate its potential cost. In this particular study, we did not consider the effects of pollution on health because we did not have access to premature deaths information due to such information is restricted to health centers and health governmental offices that do not facilitate it.

Instead, we estimate the impact of physical damages on the property value. Several studies have demonstrated that it also allows to affect the price of homes, impacting on the value of the private patrimony of citizens (Bajari et al., 2012; Cebula, 2009; Neupane and Gustavson, 2008; Égert and Mihaljek, 2007; Chau et al., 2006; Kiel, 2006; Jackson, 2001; Harrison Jr. and Rubinfeld, 1978; Rodriguez et al., 2017). These investigations have been based on the classic study of Rosen (1974), who developed the theoretical basis of the hedonic model, and later on the studies of Freeman III (1974) as well as Harrison Jr. and Rubinfeld (1978) when performing empirical studies of the theory. These pioneering works determined the demand and benefits for clean air in urban areas. Air pollution is a problem originated of anthropogenic activities and has been directly related to the different particular and economic activities of citizens (Toulkeridis et al., 2020). This concern arises within the open urban spaces according to the intensity of the burning of fossil fuels either by industrial activity or by the use of vehicles (World Health Organization, 2016). Therefore, the reduction of pollution automatically allows citizens of any given city to breathe less contaminated or strictly better air (World Bank, 2016; World Health Organization, 2016), or improve the value of a property. This becomes an environmental service, whose monetary valuation enhances fundamentally as a guide to appropriate policy measures that protect health as well as the economic situation at a heritage level. Hereby, in a complementary way to the health benefits, the relative quality of the air affects the (de-) valorization of real estate due to the contamination levels of its location (Del Giudice et al., 2017; Saaty and De Paola, 2017).

In this sense, pollution represents a negative externality and the Hedonic Pricing method suits as a technique that allows the economic valuation of air quality as an environmental service. Consequently, it supports to infer the willingness to pay agents in order to receive better air quality from its impact on the real estate market. The underlying central assumption pursues individuals will pay a higher price for a house, apartment or office, which may be located in an area with less air pollution, compared to a property with similar characteristics in an area with higher contamination (Harrison Jr. and Rubinfeld, 1978; Echegaray-Aveiga et al., 2020; Robayo et al., 2020; Poma et al., 2021). With the support of the aforementioned methodology, the current study may estimate the economic value of the air quality in the city of Quito in central Ecuador, by contrasting the effects of air pollution in two exemplary areas such as Bellavista and the Historic District. This purpose will be based on their geographic location, geomorphological content, vehicle access, and house distribution, which may indicate different levels of average pollution (Toulkeridis et al., 2016; Nugra et al., 2016; Guanochanga et al., 2018, 2019; Fuertes et al., 2019; Borja-Urbano et al., 2021).

1.1 The case study of the city of Quito

The Metropolitan District of Quito (DMQ), in central Ecuador (Figure 1) is a large city at a considerable altitude, where an evaluation of the particular air quality situation has not been conducted yet. Nowadays, the city of Quito has approximately three million inhabitants, being the most populated in the country. Despite this, it is the city with the highest general industrial activity in the country with a Gross Value Added (GVA) of 23.7 billion USD according to the Central Bank of Ecuador Regional Accounts (BCE, 2015). Simultaneously, the vehicle fleet has grown by 57 % since 2012, placing the city above the national average (INEC, 2016), increasing the air contamination in the DMQ.

According to the Air Quality Report of the Secretary of Environment of Quito (SAQ) in the DMQ (SAQ, 2017), the main source of air pollution of the DMQ is the transport that uses diesel fuel and gasoline, worsen by vehicular congestion caused by private vehicles. Additionally, there is a severe impact of the use of bunker fuel and fuel oil by thermoelectric plants and other industries in specific areas of the DMQ. Such activities are responsible for the concentration of pollutant particles in the air, such as Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Sulfur Dioxide (SO_2) Particulate Matter (PM_{10}), $PM_{2,5}$, Ammonia (NH_3) or Benzene among others of lower amounts based on the Ecuadorian Standard of Air Quality (NECA). According to Baca (2014) main source of pollution is mobile sources such as private vehicles and public transportation, area sources of pollution such as waste disposal facilities are the second source of air pollution in the DMQ and in less degree stationary sources.

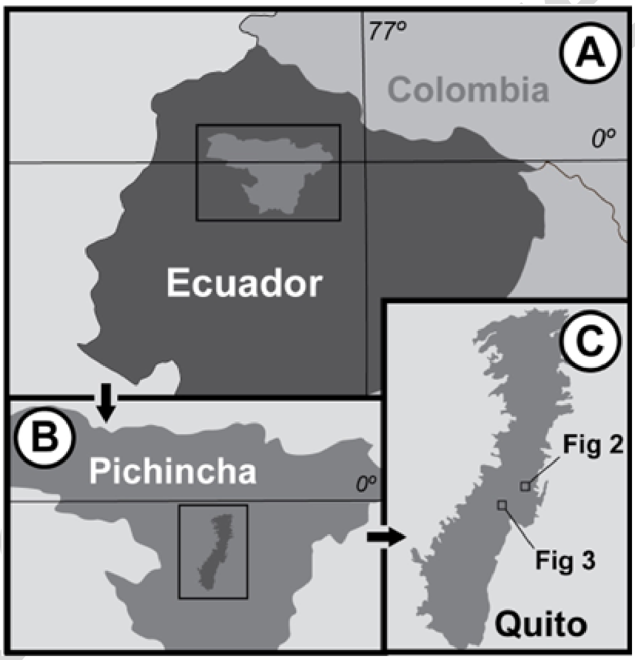

Figure 1. Study area.

Air quality is considered as an environmental service by The Economics of Ecosystems and Biodiversity Initiative (The Economics of Ecosystems and Biodiversity, 2013), and its economic or monetary valuation results, fundamental as guidance for policymakers in order to improve the health of citizens. Reasonably and as complementary to health benefits, the relative air quality impact on real estate property value or devaluation of a property due to air contamination levels as a negative externality may demonstrate air quality economic value. The hedonic price method allowed to value the impact of this externality estimating buyers' willingness to pay for a better air quality through the housing market. It is assumed that buyers would pay an additional value for properties located in areas with less contamination (Harrison Jr. and Rubinfeld, 1978).

The current study tries to estimate the air quality economic value of Quito by contrasting the impact of contamination in two areas, Bellavista and the Historic District, which represent two different levels of contamination. The choice of these two sectors seeks to capture the effect of air purification by nearby forest ecosystems. Bellavista's neighborhood borders the Metropolitan Park of Quito, which is a forested recreational park, where pollution degrees certainly are relatively low. The Historic District of Quito represents some spatial characteristics such as narrow streets, constant traffic flow and traffic jams, public transport flow close to industrial establishment areas besides other air contaminating issues that allow an understanding that the environmental pollution estimates exceed the city average for this area.

Due to Quito's Metropolitan Atmospheric Monitoring Network (REMMAQ), which determines the air quality of the city, we have been able to quantify the air quality of both focused areas. The RENMAQ appraised air quality since 2003 with some 39 stations throughout the urban area, surrounding valleys as well as regional and street level (SAQ, 2017). It has been expected to allow transparency about the economic fees assumed by the citizens of Quito on the price of their homes. Therefore, we consider that the results of the current study may serve to present the benefits that they may represent for the city and, specifically to the heritage of the people of Quito. Additionally, the adoption of policy measures may improve air quality and protect the ecosystem that supports its purification.

Air purification is an environmental service provided by ecosystems. Within the classification of the Economics of Ecosystems and Biodiversity Initiative TEEB, which divides environmental goods and services by categories (supply, regulation, life support, and culture), air quality has been conceived as an ecosystem regulation service (The Economics of Ecosystems and Biodiversity, 2013). Meanwhile, in Ecuador, the NECA establishes polluted air as the presence of substances in the atmosphere, resulting from human activities or natural processes, present in sufficient concentration, for a sufficient time and under circumstances such as to interfere with comfort, the health or well-being of human beings or the environment (Ministerio del Ambiente del Ecuador, 2011). For NECA and the SAQ, the most representative substances in the atmosphere are mainly SO_2, CO, NO_2, O_3 and benzene and in lesser quantity M_{10}, $PM_{2,5}$, Cadmium and Inorganic Mercury. The review of preliminary studies on the assessment of air quality indicates a particular interest in the NO_2 variable as a proxy for contamination (Smith and Huang, 1993), while others suggest that the pollution variables are strongly correlated. If this is the case then it is recommended to use NO_2 as a proxy, as it is linked to the most visual pollution, being the product of combustion processes (Harrison Jr. and Rubinfeld, 1978).

1.2 Context of the Hedonic Pricing Method

The Hedonic Pricing Method (HPM) identifies the environmental service flow as characteristics that describe in a particular way a market good, typically being real estate (Hanley and Barbier, 2009). The theoretical validity of the method has been based on the Theory of Value from the proposed approach (Rosen, 1974; Lancaster, 1979), which indicates that a unit of good or service (hi) within the group of goods and services of the same market has been to be described by a vector of its characteristics, being named as Z (Hanley and Barbier, 2009). In this sense, the price of this unit of good or service ($p(h_i)$) may be seen as a function of the characteristics. Formally, the relationship is defined as follows:

$$p(h_i) = f(Z_i) \tag{1}$$

Already in practice, based on the proposed definition of the HPM, it has been established that the value of a house belonging to the set of houses of the universe of interest depends on two main conditions. The first is a vector of characteristics (number of rooms, square footage, neighborhood, criminality, etc.), while the second is a vector of environmental variables such as proximity to parks. By differentiating the price for the quantity of any characteristic, the implicit price is obtained in relative terms. The implicit price documents the average willingness to pay given a certain quantity or quality of one of its characteristics (Hanley and Barbier, 2009).

If one seeks to adequately identify the magnitude of the effect of environmental good and service on the market price of the real estate, the theory allows the characteristics to be disaggregated and all those with the exception of the environmental variable to be kept constant; i.e., where the *ceteris paribus* condition applies (Schiffer, 1991; Boumans and Morgan, 2001). The logic underlying the concept of implicit price establishes that agents look forward to maximizing their utility, so they adapt their purchases to the condition of rationality and their perception of good qualities, leading to the point when the marginal rate of substitution (MRS) equals the implicit price of a certain characteristic (Hanley and Barbier, 2009).

This argument is important as it validates two fundamental assumptions: 1) the agents are in the ability to reflect and consider factors such as air pollution and other characteristics of a house when having to choose; 2) It is allowed to establish the principle that agents make an offer "on the margin". This implies that the money they are willing to pay is equal to the benefit generated by the set of characteristics of the house. In fact, this is a necessary condition for the existence of exchange. In this context, it is intuitive to think that the price of a house reflects, in part, the marginal willingness to pay for better air quality as a desirable feature.

1.3 Hedonic price function for the case of air quality

Here we intend to define the theoretical functional form between the price of the real estate and the environmental variable of interest, specifically the quality of the air. In addition, the relevant explanatory variables are proposed. A hedonic price function may be estimated by establishing the relationships between the price of the property and its particular characteristics:

$$p_i = f(CS_i, CN_i, CE_i + \varepsilon_i) \quad (2)$$

Where, following the categorization of Égert and Mihaljek (2007) and Hanley and Barbier (2009):

p_i = property price i.
CS_i = characteristics of the site (number of rooms, no bathrooms, surface, no garages, antiquity and green areas).
CN_i = characteristics of the neighborhood (crime and distance to the nearest park).
CE_i = environmental characteristics (in this case, contamination in the location zone is of interest).
ε_i = error term.

The proposed hedonic price function allows obtaining the implicit price. Hereby, the marginal change in the price of the property associated with the marginal change of any of the proposed characteristics may be obtained. Regarding the relationship of interest between price p_i and air pollution, it is expected that it does not follow a linear pattern. Following the argument of Rosen (1974) air quality is desirable as it is directly related to the price of housing but at a decreasing rate. Therefore, it is expected that $\frac{\partial p_i}{\partial CE_i} > 0$, but $\frac{\partial^2 p_i}{\partial {CE_i}^2} < 0$: the marginal cost of air quality, its implicit price, falls while the level of air quality increases. This appreciation is intuitive. When there are low levels of contamination, people are expected to value proportionally less such attribute compared to a scenario with severe contamination problems.

2 Methodological Procedure

The current study considers two zones whose levels of contamination differ substantively. The first zone is the Historic District of Quito (HDQ) (Figure 2) and the second zone is Bellavista in the North Center of the city. It is fundamental to consider that a criterion of choice of the Bellavista zone is its location that circuits the extreme south-west of the Metropolitan Park of Quito (Figure 3), which allows continuous processes of air purification. Based on the limits of Figure 2, the following geographical map has been constructed according to the information of the Quito Open Government (GAQ). It is interesting to compare the geographical map of the HDQ (Figure 3) with that presented with the Bellavista zone (Figure 2). It results that there is no greater presence of park-like green areas in the Historic District. In addition, there is a higher density of housing construction. Based on these results according to a geographical division of the chosen zones, the following information matrix of the sample may be defined according to the information of the amount (N) of houses (Table 1).

Figure 2. Geographical map of the Bellavista area.

Table 1. Matrix of the number of housing for the sample.

Zone	No. Properties (N=)	Confidence level (%)	Error range (%)	Sample size
Bellavista	3.056	95%	5%	342
Historic Center	15.456	95%	5%	375

The results of the sample size are obtained based on the following calculation method:

$$n = \frac{\frac{z^2 * \sigma^2}{e^2}}{1 + \left(\frac{z^2 * \sigma^2}{e^2 N}\right)} \tag{3}$$

Where,
e = error range (= 5%)
z = score (at a 95% level of significance)
N = population size

In the current study, a focal sample has been taken for reasons of information availability. The total sample has a total of n = 149 observations, of which 80 correspond to the Historical District and 69 to the Bellavista area. The sample needs to include information on the value of the real estate and air pollution in the area where it is located. Additionally, it requires to collect data on other determinants of the price of the property that have been considered significant as control variables. Table 2 presents and defines the variables related to pollution levels in the HDQ or Bellavista, and those with additional control characteristics that potentially affect the price. Additionally, the information source for each variable is listed.

2.1 The Hedonic Pricing Method

2.1.1 Hedonic Price Model (HPM)

The hedonic price model (HPM) has been defined further below. Two basic HPM's are presented: I and II, considering the theoretical reflections presented in the previous sections. The HPM I demonstrates a linear evolution between the evolution of environmental variables and the price of housing. The difference between model II and I is the application of the assumption of the relationship to decreasing rates between the price of a property and environmental quality in the real estate market. In this sense, an exponential correction factor is applied. The transformation of the variable rooms, surface, and age are also considered, elevating them to the square in both zones for the general model II. Models are obtained with or without the application of the

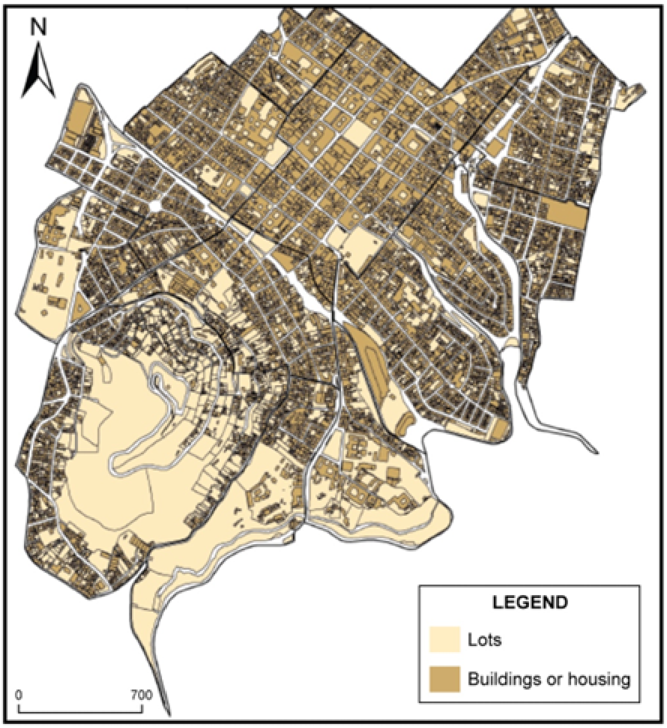

Figure 3. Geographical map of the Historical Center.

Table 2. Matrix of variables of the hedonic model. Sources: (a) Plusvalia.com, (b) Vive1.com, (c) OLX.com, (d) Secretaria de Ambiente del DMQ, (e) Fiscalia General del Estado

Concept	Variable	Definition	Unit	Source
Price	Market price	Market price of real estate (at the study date)	USD	a, b, c
Price m^2	Price m^2	Price m^2 of the real estate (at the study date	USD/m^2	a, b, c
Contamination	SO_2	Average annual concentration (= year 2016) of zoned sulfur dioxide	µm/m^3	d
Contamination	CO	Average annual concentration (= year 2016) of Zoned Carbon Monoxide	mg/m^3	d
Contamination	NO_2	Annual average concentration (= year 2016) of zoned Nitrogen Dioxide	µm/m^3	d
Contamination	O_3	Average annual concentration (= year 2006) of zoned ozone	µm/m^3	d
Contamination	Benzene	Average annual concentration (= year 2016) of zoned Benzene	µm/m^3	d
Rooms	No. of rooms	Number of rooms available	room	a, b, c
Bathroom	No. of bathrooms	Number of bathrooms available	bathrooms	a, b, c
Surface	Surface m^2	Surface extension	m^2	a, b, c
Garage	No. of garages	Number of own garages available	posts	a, b, c
Antiquity	Years of antiguaty	Number of years since the construction of the property	years	a, b, c
Green areas	Green areas	Availability of green areas such as gardens, green terraces, etc	0=no 1=yes	a, b, c
Crime	Criminality	Zoned sum of complaints of crimes against people and private property year 2016	complain	e

natural logarithm in the dependent variable. In this sense, Log-Log (elasticities) and Semi-Log (semi-elasticity) models are obtained, which also provides information of interest in this study. In general, the models are defined as follows:

Definition HPM I:

$$\ln(p_i) = \beta_0 + \beta_j \sum_{j=1} \ln\left(contamination_i^j\right) + \beta_k \sum_{k=5} \ln\left(characteristics_i^k\right) + \varepsilon_i \quad (4)$$

Definición del MPH II:

$$\ln(p_i) = \beta_0 + \beta_j \sum_{j=1} \ln\left(contamination_i^j\right) + \beta_k \sum_{k=5} \ln\left(characteristics_i^k\right) + \beta_l \sum_{l=13} \ln\left[\left(contamination_i^l\right)^{0,5}\right] + \beta_{19} rooms_i^2 + \varepsilon_i \quad (5)$$

Where,

$\ln(p_i)$ = property price i
$\ln\left(contamination_i^j\right)$ = natural logarithm of the variable $j = 1 \ldots 5$, of the set of pollution variables: { SO_2,CO_2,NO_2,O_3 and Benzene }
$\ln\left(contamination_i^l\right)^{0,5}$ = natural logarithm of the variable $l = 6 \ldots 10$, of the set of variables of the square root of contamination: {$SO_2^{0,5}$,$CO_2^{0,5}$,$NO_2^{0,5}$,$O_3^{0,5}$ and Benzene^{0,5} }
$\ln\left(características_i^k\right)$ = natural logarithm of the variable $k = 11 \ldots 18$, of the set of characteristic variables of the property: {rooms,ban,sup,garag,antiq,green areas and crime }
$rooms_i^2$ = number of rooms squared
ε_i = error term

3 Results and discussion

Air pollution between the Historic District of Quito and Bellavista differs when considering pollution variables resulting from the anthropogenic activities. Below are the results of the measurements of the concentration SO_2, CO, NO_2, O_3 and Benzene (Figure 4).

The results indicate that for all pollutants, the HDQ maintains lower levels of air quality compared to Bellavista. This corroborates the assertion about the existence of higher levels of pollution related to the result mainly of combustion processes (CO, NO_2, SO_2 and Benzene), and, indirectly, reflected in higher levels of O_3 between both zones. On the side of housing prices and price per square meter, the following information is obtained in the housing focus group.

The results of other house features were as anticipated. Variables such as construction area, parcel size, number of bedrooms, number of bathrooms, house's age, and presence of a garden were significant at 99%. Among neighborhood characteristics, only garage was significant at 95%, while green areas were insignificant. We selected all significant variables with the environmental variables and ran again the final regression model.

The average price of the Bellavista area exceeds that of the Historic District in USD 47,267 (Figure 5). The cases of properties on the average in the Historical District are reduced even though in this zone the most expensive property of the sample is offered with a price of USD 1,480,000, being almost USD 900,000 higher than the most expensive property in Bellavista. When this information is complemented with respect to the minimum prices obtained, it is concluded that there is greater variability in the price sample in the case of the Historic Center versus Bellavista. A further way to have a more accurate understanding of the real estate market in both sectors is by evaluating its price per square meter.

Figure 6 illustrates that the real estate market in the Bellavista area is more expensive compared to the Historic Center. Hereby, the average square meter is almost three times larger. This occurs even considering the maximum or minimum price per square meter. In general, the Bellavista area is more attractive from the point of the valuation that is yielded to the real estate offered there. This turns out to be a positive result based on the objectives of the current study, as there are clear differences between the Historic District and Bellavista regarding per square meter housing price.

In order to obtain the results of the empirical models of the hedonic price function, the average annual concentration of milligrams per cubic meter of NO_2 has been taken into consideration, since the pollution variables are highly correlated, avoiding multicollinearity issues. An intuitive reason for this problem is the close relationship among contamination sources, such as combustion processes of CO, NO_2, SO_2 and Benzene. A potential solution might be seen in the extension to further study areas, giving a greater variability to pollution measures, as stated as a particular case of this study. However, we found the most optimal functional form that allows the goodness of fit and greater possible significance for what different modeling proposals are composed of.

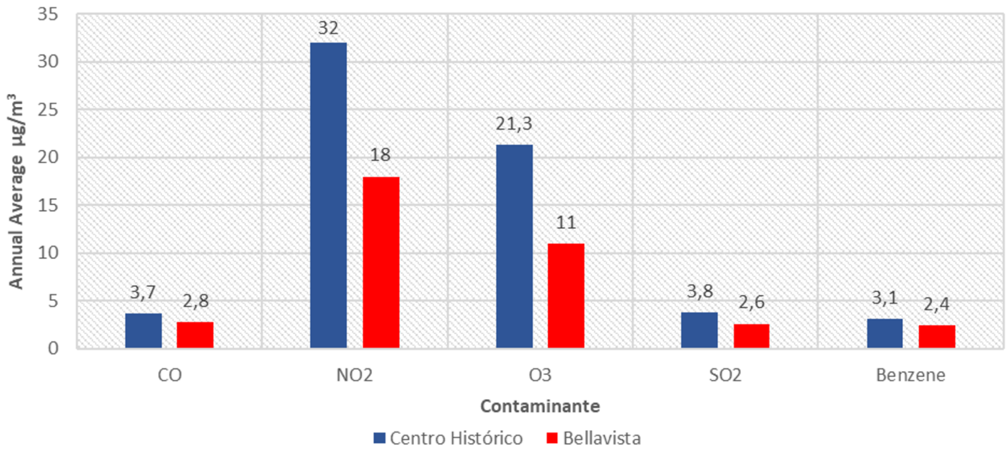

Figure 4. Comparison of pollutants by study area.

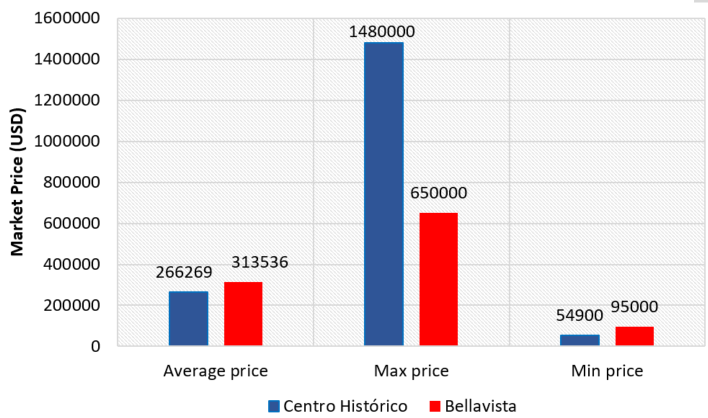

Figure 5. Comparison of housing market price according to study area. Adapted from Real estate websites.

In this sense, the results of the models in the semi-log version fit these specifications in a better way. The models that considered the relationship at decreasing rates between NO_2 and housing prices indicated a lack of improvement in the specification of the model. The estimation of adequate exponential value is more appropriate when studying a greater number of zones. Therefore, this may explain not giving a significant contribution to the explanation of the model despite having a theoretical validation. The models are corrected by heteroscedasticity. Particularly some variables such as the price per square meter (m^2) or housing age, for example, documented this issue. The results of the modeling in Table 3 are presented below.

We obtained high levels of R^2 values (91 %), which have been similar to those yielded in Cebula (2009) of about $R^2 = 87\,\%$, Chau et al. (2006) $R^2 = 87\,\%$, and Jackson (2001) with $R^2 = 81\,\%$, indicating that the variables in the equation manage to explain to a considerable extent the variation of the housing price in the sample research. The variable NO2 has a negative sign and turns out to be highly significant, even at a 99 % confidence level in the three proposed models. Additionally, considering Model III, it decreases by 1 $\mu g m^{-3}$ in the average annual concentration of NO_2 increase with the average price of homes by 4.54 %. With such data, we have been able to assess the quality of the air as documented in Table 4, while considering the results of Model III.

Table 3. Results of Models I, II and III. Statistics t are in parentheses; *Exceeds 95 % confidence level (t>1,96); **Exceeds 99 % confidence level (t>2,58).

Variable	Model I	Model II	Model III
Dependent	Log (pm)	Log (pm)	Log (pm)
Constant	8.99	6.30	1.217
	(9.72)	(12.02)	(0.44)
Log (Price (m2))	0.5288	0.8389	2.44
	(5.81)**	(15.26)**	(2.84)**
Log (Price (m2))2			-0.1227
			(-1.87)
Room	0.0852	0.0694	0.0677
	(3.86)**	(4.05)**	(4.00)**
Room2	-0.0029	-0.0022	-0.00213
	(-5.17)**	(-4.64)**	(-4.54)**
Bathrooms	0.0530	-0.0106	-0.011
	(3.28)**	(-0.88)	(-0.96)
Garage	0.0394	0.0106	0.008
	(2.25)*	(0.85)	(0.67)
Surface	0.0012	0.0039	0.0039
	(7.71)**	(11.87)**	(11.86)**
Surface2		-1.35e-06	-1.32e-06
		(-6.05)**	(-6.04)**
Antiquity	0.0045	0.0076	0.0063
	(2.76)**	(3.45)**	(2.87)**
Antiquity2		-0.00005	-0.00004
		(-2.58)**	(-2.38)*
Green areas	0.9188	0.0338	0.0336
	(1.40)	(0.71)	(0.44)
NO2	-0.0546	-0.0430	-0.0454
	(-3.79)**	(-4.99)**	(-5.08)**
R2	0.77	0.90	0.91

The estimates demonstrated that a decrease in the annual average of one milligram per cubic meter of NO_2 increases the price of housing by 4.5%. Likewise, a decrease of five milligrams per cubic meter of NO_2 increases by 22.7% the price of the homes of the research sample. In the first case, there is an increase in equity of 2,032,326.24 USD considering the 148 homes in the study area. In the second case, the equity increases, in aggregate terms, by 10,161,632.22 USD. The average price of the 148 homes increases between 13,731.93 and 68,659.67 USD, as air pollution decreases between one and five milligrams per cubic meter of NO_2. Obviously, a decrease of more than five (μgm^{-3}) of NO_2 would result in greater economic benefits. Thus, according to the reduction in the average annual levels of milligrams per cubic meter of NO_2, owners will benefit from an improved value of their properties, and therefore, their assets. Ultimately, their economic situation improves due to the relative quality of the air in the area where the real estate is located.

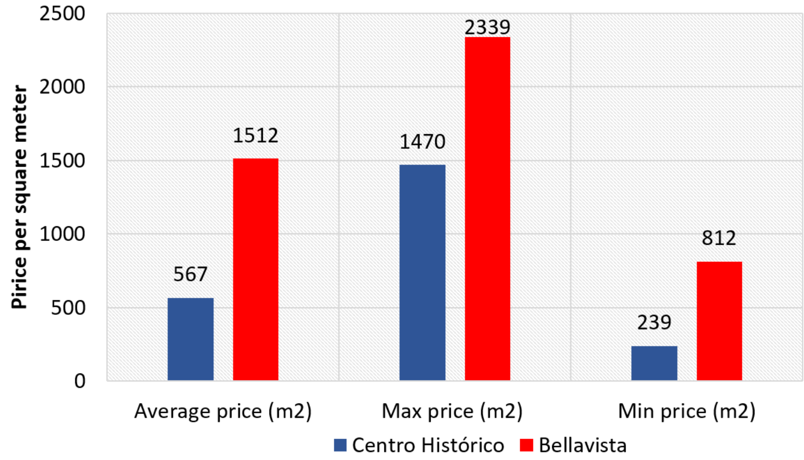

Figure 6. Price comparison m^2 of homes according to study area. Source: Real estate websites.

Table 4. Air Quality Assessment.

Variations		**Focal sample**				
Δ^- (NO_2) (μm/m3)	Δ^+ (Price) (%)	Average price (USD)	Amount households (n)	Δ Heritage (USD)	Δ Average price (USD)	Difference of average prices (USD)
1	4.5%	302 465.51	148	2'032 326.24	316 197.44	13 731.93
2	9.1%	302 465.51	148	4'064 652.49	329 929.38	27 463.87
3	13.6%	302 465.51	148	6'096 978.73	343 661.31	41 195.80
4	18.2%	302 465.51	148	8'129 304.98	357 393.24	54 927.74
5	22.7%	302 465.51	148	10'161 631.22	371 125.18	68 659.67

4 Conclusions

The two different studied zones of the city of Quito, are directly affected (being understood as a negative externality) by different economic activities that generate pollution. Our results demonstrate that NO_2 (32 μgm^{-3}) has the highest value among city pollutants. There is a significant difference between the Historic District and Bellavista, being 32 μgm^{-3}, and 23 μgm^{-3}, respectively. These levels of contamination have a direct effect on real estate price as it has been indicated. Differences in housing prices have been partially due to the varying levels of contamination between both zones.

Econometric models stated that a decrease in the annual average of one milligram per m^3 of NO_2 increases the price of housing by 4.5%, meaning an increase in equity of 2,032,326.24 USD. The average price of the 148 homes increases of about 13,731.93 USD if air pollution declines in one milligram per cubic meter of NO_2. Obviously, a higher pollutant reduction will result in higher economic benefits.

These results may help to establish policies that intend to improve air quality. Policies such as promoting green areas in sites with high levels of pollution may correct the unfair penalties in owners' properties. Additionally, the obtained results indicate the importance of maintaining forested areas that play an important role in purifying the air, allowing people to benefit directly from qualitatively adequate air.

The current study considers a focal sample and this leads to limitations when inferring the results at population levels. However, the R^2 (0.91) is very high, allowing to generalize our results and justify more extensive research in the DMQ regarding air pollution and its effects on property. In addition, the study concentrated only on the NO_2 pollutant, thus it is necessary to measure the other 3 pollutants.

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