

Rodríguez-Sánchez, José Iván

**Article**

## Do Mexicans care about air pollution?

Latin American Economic Review

**Provided in Cooperation with:**

Centro de Investigación y Docencia Económica (CIDE), Mexico City

*Suggested Citation:* Rodríguez-Sánchez, José Iván (2014) : Do Mexicans care about air pollution?, Latin American Economic Review, ISSN 2196-436X, Springer, Heidelberg, Vol. 23, Iss. 1, pp. 1-24, <https://doi.org/10.1007/s40503-014-0009-z>

This Version is available at:

<https://hdl.handle.net/10419/108954>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<http://creativecommons.org/licenses/by/2.0/>

# Do Mexicans care about air pollution?

José Iván Rodríguez-Sánchez

Received: 28 August 2013 / Revised: 18 February 2014 / Accepted: 15 April 2014  
© The Author(s) 2014. This article is published with open access at Springerlink.com

**Abstract** Mexico has many major problems such as corruption, poverty, illiteracy, unemployment, pollution, etc. Regarding pollution, politicians have established some programs trying to improve air quality in Mexico. But they do not know if Mexicans care about air pollution or they prefer that government faces other problems. This paper answers this question and in fact, we conclude that Mexicans do care about air pollution (measured by Particulate Matter) and they agree to pay to reduce it. This paper follows a residential sorting model to calculate marginal willingness to pay for a reduction in air pollution. Our estimates imply that the household head in Mexico would pay \$443.66 to \$2,682.92 (in constant 2000 Mexican pesos) or 46.90–283.61 (2000 dollars) for a one-unit reduction in Particulate Matter emissions per year. Therefore, there are benefits to reduce this problem in Mexico and the government and private firms must face this problem since the costs are lower than those benefits.

**Keywords** Particulate matter · Migration costs · Discrete choice models · Valuation of air quality in Mexico

**JEL Classification** D1 · Q2 · Q5 · R1

## Abbreviations

CO Carbon monoxide  
CONAPO Consejo Nacional de Población

---

J. I. Rodríguez-Sánchez (✉)  
Instituto de Ciencias Sociales y Humanidades, Universidad Tecnológica de la Mixteca,  
Carretera a Acatlima Km. 2.5, C.P. 69000 Huajuapam de León, Oaxaca, Mexico  
e-mail: rodrigji@colorado.edu

J. I. Rodríguez-Sánchez  
Departamento de Economía, Universidad de las Américas Puebla, Ex Hacienda Santa Catarina  
Mártir s/n, C.P. 72810 San Andrés Cholula, Puebla, Mexico

COV	Volatile organic compounds
CV	Contingent valuation
ENIGH	National survey of household income and expenditure
EPA	Environmental protection agency
IIA	Independence of irrelevant alternatives
iid	Independently and identically distributed
INECC	Instituto Nacional de Ecología y Cambio Climático
INEGI	Instituto Nacional de Estadística y Geografía
ML	Maximum likelihood
MWTP	Marginal willingness to pay
NH <sub>5</sub>	Ammonia
NIE	National inventory of emissions
NO <sub>x</sub>	Nitrogen oxide
PM <sub>2.5</sub>	Particulate matter 2.5
PM <sub>10</sub>	Particulate matter 10
PNUD	Programa de las Naciones Unidas para el Desarrollo
SO <sub>x</sub>	Sulfur oxide
US	United States of America
WTP	Willingness to pay

## 1 Introduction

In the last decades, economists have used hedonic methods as an important tool in economics. Hedonic models characterize the pricing of differentiated goods, viewed as bundles of characteristics or attributes, and the demand and supply of those goods (attributes) under different assumptions about preferences and technology (Heckman et al. 2004). They allow for a systematic economic analysis of the demand and supply of a quality of the attributes of the good. That is, they evaluate the impacts of the improvement of the attributes of a good, or the amenities offered by an environmental improvement. For example, in the case of a home purchase, the idea is that the consumer buys environmental quality through the house. His utility or satisfaction will depend not only on the consumption of market goods (C), but also on the consumption of nonmarket goods (X). Although the consumer pays a price for the house, he is in fact paying for all the individual attributes of the house. Cornerstone works related to the hedonic method include Rosen's seminal paper (1974), Graves et al. (1988), Sattinger (1993), Boyle et al. (1999), Palmquist and Smith (2001). This method has been applied to explain the behavior of many different markets such as housing, labor, paintings, and classical music.

One of the most important objectives of using hedonic models is to calculate Willingness to Pay (WTP) to avoid or reduce disamenities. For example, if researchers want to know how much a citizen is willing to pay to reduce air pollution, they may use a hedonic approach. The main goal is to obtain an indicator of the possible response of citizens by reducing air pollution. However, this benefit is biased. The reason, first mentioned in Bayer et al. (2009), is that people cannot

move freely from one city to another (as the traditional hedonic approach assumes) and they face a mobility or migration constraint. That is, an individual living in a polluted city will prefer to move to another city with a better air quality, but in reality this person will face some mobility or migration costs to move there and this person must stay in the polluted city for personal, familial or economic reasons. This finding is important since the result given by traditional hedonic methods is biased and eliminating this bias will allow policy makers to make better decisions on the public's willingness to pay. This is especially important in developing countries, such as Mexico, where the government faces a more stringent budget constraint and must choose where to allocate their scarce resources.

Mexico faces many major problems such as corruption, poverty, illiteracy, and pollution. Regarding pollution, the capital of Mexico is one of the most polluted cities in the world. In fact, Forbes (2008) ranks Mexico City in the number 5 of the world's dirtiest cities. This is the result of industrial and automobile emissions that affect the air quality and these emissions cause higher levels of sulfur dioxide, nitrogen oxide, carbon monoxide, fine particulate matter and organic compounds like benzene. Some compounds like nitrogen oxygen and volatile organic compounds cause air pollution problems in stagnant air, as the reaction between these elements form ozone and other oxidants. Ozone and particulate matter are the most serious pollutants in developing and developed countries. In Mexico City, the ozone levels fail to meet World Health Organization standards at least 300 days of the year. These levels of pollution affect residents with health problems and their negative externalities have an impact in the economy too. In Mexico, the government provides health services for almost all people. As a consequence, the government must offer medicines and health care to the residents if they are sick due to pollution. Also, there is an obvious productivity loss since workers cannot be in their jobs. However, if there is a reduction in the emissions of pollutants, people have a higher probability to be healthy and the government can save money. Of course, to achieve this goal at first the government must spend some money to reduce pollution, but at the end the benefits (resulting from decreased cost of health care and increased productivity) would be greater than the costs.

Air pollution is a major problem and one of its impacts is on health. There are no many researches of this area in Mexico and those are focused on Mexico City. However, these papers could give us an idea of the severity of the problem. Loomis et al. (1999) conducted a time series study of infant mortality in the southwestern part of Mexico City due to high levels of fine particles. They found that there is a positive relationship between concentrations of  $PM_{2.5}$  and infant deaths. Holguín et al. (2003) found that ambient levels of  $PM_{2.5}$  and ozone can reduce the high-frequency component of heart rate variability in elderly subjects living in Mexico City. Hence, there are major impacts on health because of the particulate matters and the reductions of these should be a priority in any country. Of course, it is important to measure the benefits people have to decrease the air pollution in Mexico. The main goal for this paper is to calculate WTP to reduce air pollution to know how Mexicans value their health by this figure.

Air pollution is also a problem issue in other large Mexican cities such as Guadalajara, Monterrey, Tijuana, Ciudad Juarez, and Puebla. Therefore, it is

important to evaluate the benefits to reduce air pollution for the whole country. The main objective of this paper is to calculate WTP to reduce air pollution in Mexico in dollars. To obtain the latter figure, we use a hedonic wage and property approach that allows us to eliminate the bias of no free mobility. Households cannot move freely from one state to another state since they have reasons to stay there such as their jobs and the neighborhood where they live.

In Mexico, there are only a few papers that evaluate what people are willing to pay to avoid air pollution<sup>1</sup>. This situation is understandable since for many years Mexico did not have an Inventory of Emissions and good data bases to calculate that figure by hedonic methods. However, researchers faced this problem using a different approach, called contingent valuation (CV), to obtain this WTP, but they apply it only to the Mexico City Metropolitan Area. Hammitt and Ibarra (2006) used a CV method to estimate the value of reducing health risks by improving air quality in that area. Therefore, they collected data by in-person survey and they followed Viscusi's (1993) approach to calculate the value per statistical life, which is the total amount that the inhabitants would be willing to pay to prevent one unidentified random fatality in the next year.

Other way researchers inferred WTP for Mexico City Metropolitan Area is using estimates from other countries (World Bank 2002). World Bank estimates the levels of emissions for the period 2000–2010 and the benefits from reducing the concentrations in PM<sub>10</sub> and Ozone under different scenarios. This study analyzed a wide range of health benefits of reducing air pollution, such as reduced cost of illness, reduced losses in productivity, WTP for reduce acute and chronic exposure. A big problem that his study faced was the estimation of WTP, since there was no information about this estimate in Mexico. Hence, they decided to use WTP obtained in the US to forecast that figure in Mexico. They used the below equation to predict WTP in Mexico:

$$WTP_{\text{Mexico}} = WTP_{\text{Country A}} \left[ \frac{\text{Income}_{\text{Mexico}}}{\text{Income}_{\text{Country A}}} \right]^{\varepsilon}$$

where  $\varepsilon$  represents the income elasticity of WTP, that is the percentage change in WTP corresponding to a 1 % change in income and Country A is the US. Basically, since income in the US is higher than in Mexico and assuming that  $\varepsilon$  is one, WTP in Mexico must be lower than WTP in the US.

In the studies described before, the researchers focused only on Mexico City. This paper is more ambitious and the WTP obtained here is for the whole country. Also, this value is calculated correctly, eliminating all possible problems related to the bias of the WTP. Therefore, the goal in this paper is to obtain the marginal WTP to reduce air pollution in Mexico. This is the first paper that obtains this figure for a developing country and this could encourage the research in other countries in this area too.

The hedonic method has been used widely on many important issues where it is hard to determine the value of a good. Basically, goods that do not have a specific market need to calculate their value by this method. In the case of WTP to reduce air pollution, there is no market for this figure, so it is necessary to use the hedonic

<sup>1</sup> In the literature air pollution is measured by PM<sub>10</sub> (Particulate Matter) or Ozone emissions.

**Table 1** State-wise percent by residence location in 2000 (Census Data)

	States	Percent of household heads that stay in their birth's state
1	Aguascalientes	79.82
2	Baja California	53.68
3	Baja California Sur	66.89
4	Campeche	77.04
5	Coahuila de Zaragoza	85.94
6	Colima	72.54
7	Chiapas	96.73
8	Chihuahua	81.96
9	Distrito Federal	78.26
10	Durango	88.52
11	Guanajuato	91.53
12	Guerrero	94.49
13	Hidalgo	87.54
14	Jalisco	86.53
15	México	59.28
16	Michoacán de Ocampo	91.50
17	Morelos	71.04
18	Nayarit	83.22
19	Nuevo León	78.02
20	Oaxaca	94.10
21	Puebla	91.11
22	Querétaro de Arteaga	79.40
23	Quintana Roo	43.10
24	San Luis Potosí	90.46
25	Sinaloa	87.93
26	Sonora	83.68
27	Tabasco	90.48
28	Tamaulipas	74.75
29	Tlaxcala	85.69
30	Veracruz de Ignacio de la Llave	90.82
31	Yucatán	93.11
32	Zacatecas	90.62

Source: Own calculations using Mexican Census of 2000

method. However, since there are migration costs to get this value for air pollution, the traditional hedonic approach must be changed and it must incorporate these costs as Bayer et al. (2009) did in their paper.

This paper is based on the study by Bayer et al. (2009). They incorporate migration or mobility costs into the hedonic approach using a “residential sorting model”. This constraint is not taken into account by the traditional hedonic method and the outcomes obtained by this approach will be biased, as it was stated before. They fix this problem using a two-stage model. In the first stage, they use a discrete

**Table 2** Region-wise percent by residence location in 2000 (Census Data)

Regions	Percent of household heads that stay in their birth's region
Northwest	76.01
North	83.39
Northeast	75.07
West Central	86.45
South Central	70.48
Pacific	92.96
Gulf of México and Yucatan Peninsula	85.99

Source: Own calculations using Mexican Census of 2000

Regions are based on INEGI definition of economic areas. Regional definitions: Northwest (Baja California, Baja California Sur, Sinaloa, Sonora, Nayarit), North (Chihuahua, Coahuila, Durango, Zacatecas), Northeast (Nuevo Leon, Tamaulipas), West Central (Aguascalientes, Jalisco, Guanajuato, Colima, Michoacan, Queretaro, San Luis Potosi), South Central (Hidalgo, Mexico, Puebla, Tlaxcala, Morelos, Distrito Federal), Pacific (Chiapas, Guerrero, Oaxaca), Gulf of Mexico and Yucatan Peninsula (Veracruz, Tabasco, Campeche, Quintana Roo, Yucatan)

choice model to obtain the probability for a person to choose any location to live constrained on the migration costs, the income this individual could earn in any location and the quality of life in every location (the country fixed effects). In the second stage, they regress these country fixed effects on air pollution concentrations to recover the WTP for air amenity in metropolitan areas throughout the US. Their estimations are much larger than the comparable estimate from the conventional hedonic model. This implies that there is a bias in the estimations using the latter approach and that mobility costs are important. Therefore, this paper follows that approach, calculating the marginal WTP to reduce air pollution in Mexico avoiding this bias. The reason is that in Mexico there are migration costs too. Tables 1 and 2 relate birth location and current residency, as it is shown that the majority of household heads in Mexico stay not only in their birth state but also in their birth region. Hence, they will prefer not to migrate since there is a tradeoff between their location (familiar or personal reasons) and rents and wages in other places.

This paper is organized as follows: Sect. 2 describes the methodology; Sect. 3 presents the data used in this paper; Sect. 4 defines the econometric specification; Sect. 5 discusses the main results and Sect. 6 gives the conclusion.

## 2 Methodology

This paper seeks to estimate the WTP to reduce air pollution in Mexico using a residential sorting model. This model, based on Bayer et al. (2009), is described below in detail. The main outcome in Bayer's paper is that a WTP incorporating mobility costs is almost four times greater than one derived from the traditional hedonic technique for the US.

This residential sorting model is a structural model choice based on a discrete choice model. In contrast, the traditional hedonic model is a reduced form model.

Bayer et al. showed that both models have the same results in the case that there are no migration costs<sup>2</sup>. However, when there are mobility costs, the results are different and the bias is given by those costs.

Following Bayer et al. (2009), this paper assumes the following utility function:

$$U_{i,j} = C_i^{\beta_C} H_i^{\beta_H} X_j^{\beta_X} e^{M_{ij} + \xi_j + \eta_{ij}}$$

where  $U_{ij}$  is the utility obtained by the household head or individual  $i$  to live in sate  $j$ ;  $C_i$  is the quantity consumed by  $i$  of the numerarie good;  $H_i$  is the quantity consumed by  $i$  of the housing characteristics,  $X_j$  is local air quality (measured by  $PM_{10}$  concentrations<sup>3</sup>);  $M_{ij}$  is the disutility of migrating from  $i$ 's birth place to his currently residency  $j$ ;  $\xi_j$  are the unobservable factors at location  $j$ ; and  $\eta_{ij}$  is the individual idiosyncratic error of the utility.

Since it is assumed that individuals are rational and therefore, they desire to maximize their utility, individuals solve the following problem:

$$\text{Max} U_{ij} = C_i^{\beta_C} H_i^{\beta_H} X_j^{\beta_X} e^{M_{ij} + \xi_j + \eta_{ij}} \quad \text{s.t. } C + \rho_j H = I_{ij}$$

where the price of the numerarie is 1;  $\rho_j$  is the price of housing services in location  $j$ ;  $I_{ij}$  is individual  $i$ 's income in location  $j$ . Therefore, individuals maximize utility subject to their budget constraint and solve the following maximization problem:

$U_{i,j} = (I_{ij} - \rho_j H_i)^{\beta_C} H_i^{\beta_H} X_j^{\beta_X} e^{M_{ij} + \xi_j + \eta_{ij}}$ , taking first-order condition for  $H_i$ , we obtain the following result:  $H_i = \left( \frac{\beta_H}{\beta_H + \beta_C} \right) \left( \frac{I_{ij}}{\rho_j} \right)$ . Plugging it in the budget constraint and substituting for H into the utility function give us the following indirect utility function:

$$V_{i,j} = I_{ij}^{\beta_C + \beta_H} e^{M_{ij} + \xi_j + \eta_{ij} + \beta_X \ln X_j + \beta_H \ln \rho_j}$$

To find the marginal WTP (MWTP) for the amenity  $X_j$ , it is needed to take partial derivative of the indirect utility function with respect to  $X$  and  $I$ , and these derivatives will help us to construct the marginal rate of substitution between  $X$  and  $I$ :

$$\text{MWTP} = \frac{\frac{\partial V_{ij}}{\partial X_j}}{\frac{\partial V_{ij}}{\partial I_{ij}}} = \frac{(1/X) \beta_X I^{\beta_1} e^{M_{ij} + \xi_j + \eta_{ij} + \beta_X \ln X_j + \beta_H \ln \rho_j}}{\beta_1 I^{\beta_1 - 1} e^{M_{ij} + \xi_j + \eta_{ij} + \beta_X \ln X_j + \beta_H \ln \rho_j}} = \frac{\beta_X I_{ij}}{\beta_1 X_j}$$

where  $\beta_1 = \beta_H + \beta_C$ .

Regarding the income it is known how much money the household head is earning in his current residency, but in reality we do not know the income that this individual would earn in any other location. Hence, we have to estimate the income this person would obtain in any other place. Therefore, we have to separate the income into a predicted mean income and an idiosyncratic error term as follows:  $I_{ij} = \hat{I}_{ij} + v_{ij}$ . In the case of the housing variable, we do not have to separate it into a predicted mean housing and an error, since in this case the calculations are more

<sup>2</sup> For the traditional hedonic model, they use a simple version of Roback's model.

<sup>3</sup>  $PM_{10}$  means particulate matter or fine particles smaller than 10  $\mu\text{m}$  in diameter.



precise and the error for this case is approximately zero. In fact, we did this exercise and the results show that the housing variable and its predicted mean value were basically the same.

Using this last equation and plugging into the indirect utility function, we obtain the following:

$$\ln V_{ij} = \beta_I \ln \hat{I}_{ij} + M_{ij} + \theta_j + v_{ij}^1 \tag{1}$$

$$\text{where } \theta_j = \beta_X \ln X_j - \beta_H \ln \rho_j + \zeta_j \tag{2}$$

$$\text{and } v_{ij}^1 = \beta_I \ln v_{ij} + \eta_{ij}$$

$\theta_j$  is defined as the utility relevant attributes of location  $j$  (location fixed effects) or the “quality of life” in that state; and  $v_{ij}^1$  is an error term.

It could be possible that an individual decides to live in a polluted city, because the price of a house is lower than in cities with higher quality of air, and this individual does not care about pollution at all. Hence, there is a possibility to have the self-selection problem that Chay and Greenstone (2005) mentioned in their paper. That is, household heads with lower valuation for air quality could locate in areas with worse air quality and this will affect the estimates of the MWTP since there will be a bias. In this case, we can avoid this problem by finding the probability that the household head  $i$  sorts any location  $j$  given by Eq. (1). The location the individual  $i$  will choose depends on the income this person could earn in any place, the migration cost facing by the household head, and the quality of life in that location. Basically, we want to obtain the choice probability of individual  $i$  to settle in location  $j$ ; hence, assuming that the idiosyncratic city preferences  $v_{ij}^1$  are independently and identically distributed (iid) Type 1 Extreme Value, we have a Logit specification with the following closed form:

$$P[\ln \tilde{V}_{ij} \geq \ln \tilde{V}_{il}, \forall l \neq i] = \frac{e^{\sigma(\ln \tilde{I}_{ij} + \tilde{M}_{ij} + \tilde{\theta}_j)}}{\sum_q e^{\sigma(\ln \tilde{I}_{iq} + \tilde{M}_{iq} + \tilde{\theta}_q)}} \tag{3}$$

where we divide Eq. (1) by  $\beta_I$ , so the tildes denote that, for example,  $\tilde{\theta} = \theta/\beta_I$ , and  $\sigma = 1/\beta_I$  is a logit scaling parameter.

The big advantage of the Logit estimation is its closed form; however, this specification allows for independence of irrelevant alternatives (IIA) and it cannot represent random taste variation. But because of its closed form, it is easy to estimate. Equation (3) will define the first-stage estimation for the residential sorting model, and this part is estimated by maximum likelihood (ML). In the same equation,  $\tilde{M}_{ij}$  is the migration cost function and is defined latter in Sect. 4.

In many situations where IIA are exhibited, the choice probabilities are an accurate representation of reality. Luce in 1959 established IIA to be a property of specific choice probabilities. In fact, he derived the Logit model directly from an assumption that choice probabilities exhibit IIA (Train 2009). However, the Logit model exhibits independence from IIA and in this paper, due to the nature of the model we do not have to worry about IIA.

Hence, using ML we obtain the estimates of  $\tilde{\theta}$ , and we use them in the second stage. This second stage is defined by Eq. (2), so we regress these “state area utilities” on local air pollution emissions and other local amenities. However, in the second stage we can face two econometric problems. First, there may be a correlation between the price of housing services and the unobserved local characteristics, hence moving the term with housing services to the left-hand side avoids this problem, that is

$$\tilde{\theta}_j + \tilde{\beta}_H \ln \rho_j = \tilde{\beta}_X \ln X_j + \tilde{\xi}_j \quad (4)$$

The above equation eliminates the correlation mentioned above, and this is possible because the estimate of the share of income spent on housing ( $\tilde{\beta}_H$ ) is really close to the value obtained in our data. Therefore, we can substitute the value given by our data and do not have to estimate it.

Second, there may be a correlation between amenity levels and local unobservable attributes in the same region. Even though local emissions (correlated with local economic activity) are the key determinants of local air quality, pollution comes from other distant sources. Emissions from other locations outside the one we are analyzing are likely to be uncorrelated with local economic activity. Therefore, to avoid this problem of endogeneity, we construct a new variable that is not related to the unobservable term. This new variable is related to the exposure a resident has to the emissions of  $PM_{10}$  in a specific state given only the emissions of  $PM_{10}$  outside that state. This variable will give us a “Lower Bound” to the MWTP in Mexico.

### 3 Data

The data used in this research come from several Mexican sources. For the first stage, the discrete choice model, we use the Mexican Census 2000 to estimate the Logit model. I draw a random sample of 80,000 observations of the Census. The Census has important information about demographic characteristics of the household heads such as gender, age, marital status, level of education, total income earned from employment and migration status comparing the current location of the household head and his birth’s location.

For the second stage, we use the National Survey of Household Income and Expenditure (ENIGH) 2004, 2005, and 2006 (58,275 observations). This survey provides information on income and expenditure for a household head in Mexico and the characteristics of the house in which the household is living. The key variables for this stage are related to the characteristics of the house and characteristics of the location or state. The following variables are used to obtain the housing index: number of rooms, number of bedrooms, dwelling with kitchen (if the house has a kitchen or not), dwelling with plumbing facilities, dwelling owned (if the house is rented or owned), number of years of the dwelling, and dwelling with electricity. Other sources that we use in this stage to obtain information about local amenities were obtained from the Instituto Nacional de Estadística y Geografía

(INEGI), Consejo Nacional de Población (CONAPO) and Programa de las Naciones Unidas para el Desarrollo (PNUD).

In this model, it is assumed that the household head is the decision maker, and that those household heads over 35-year old are excluded to make sure that location decisions are driven by current local attributes<sup>4</sup>. This paper assumed this due to the fact that households with heads  $\leq 35$ -year old are more mobile than the rest of the population. Also, the decision makers live in any of the 32 states and in any of the 2,445 municipalities that comprise Mexico.

Another important source is the Instituto Nacional de Ecología y Cambio Climático (INECC), an agency similar to the Environmental Protection Agency (EPA) in the US. One of its main objectives is to improve the air quality in Mexico. Mexico did not have a National Inventory of Emissions (NIE) until 2006 when INECC completed this task with the first NIE. This inventory measures the emissions by states and municipalities for  $\text{NO}_x$  (Nitrogen Oxide),  $\text{SO}_x$  (Sulfur Oxide), COV (Volatile Organic Compounds), CO (Carbon Monoxide),  $\text{PM}_{10}$  (Particulate Matter 10),  $\text{PM}_{2.5}$  (Particulate Matter 2.5), and  $\text{NH}_3$  (Ammonia). This paper uses the emissions of  $\text{PM}_{10}$  to calculate the marginal WTP to avoid pollution in Mexico. Since the level of emissions is aggregated we calculate the emissions of  $\text{PM}_{10}$  per area, depending on the size per state.

### 3.1 Air quality measures

In this paper,  $\text{PM}_{10}$  emissions' levels indicate the level of air pollution. Problems due to the inhalation of  $\text{PM}_{10}$  are major in humans and animals.  $\text{PM}_{10}$  emissions can cause health problems since they settle in the bronchi and lungs. They can cause asthma, lung cancer, cardiovascular harm and a higher probability of dying at a young age. Therefore, the reduction of the emissions of this particulate matter in the air is beneficial for the whole population in Mexico and it is important to know those benefits.

The emissions of  $\text{PM}_{10}$  are taken from the NIE 1999 and we use the total emissions produced by all sources for the 32 states and all the municipalities. However, since there could be enormous difference among states due to the size, we decided to divide the emissions by the state's area. This is one of the covariates that we use in the second stage of this paper.

A major issue in this model is that in the second stage it is plausible to have a relationship between state  $\text{PM}_{10}$  and the unobservable term in location  $j$ . If that is the case, a problem of endogeneity appears and the outcome of the WTP will be biased. Therefore, we decided to construct a new variable that avoids this problem and it can be used as a covariate in this state. This new variable is based on the exposure an individual faces in a specific state to the emissions of  $\text{PM}_{10}$  originated outside that state. For example, if you are living in Nuevo Leon, and other things equal, the emissions produced in other states will affect you. Abstracting for the

<sup>4</sup> This paper assumes that the household heads is the one to decide where to live, because they are providing money and food to their families by their jobs. They have to decide to migrate or not first because the job they have and the possibility to get a better job in another place. Of course, there are other personal reasons to decide to migrate, but here we assume that the household head is the decision maker.

emissions inside the state, we use only the exposure an individual faces in that specific state given by the neighboring states' emissions. However, we have municipality information for each state regarding the emissions of PM<sub>10</sub>, so we can use that information to construct this new variable. A specific state has many municipalities so each of these municipalities will be affected by other municipalities that are outside this state and belong to other states. Suppose we want to calculate individual's exposure to PM<sub>10</sub> in Nuevo Leon: first, we have to compute the exposure per municipality in all the municipalities that belong to Nuevo Leon given by all the municipalities that are close to them and are not located in Nuevo Leon. Therefore, we define the following equation:

$$\text{Exposure municipality } j = \sum_{i=1}^k \left( \frac{1}{D_{ij}} \right) \text{PM}_{10_i} \tag{5}$$

where  $D_{ij}$  is the distance between the center of municipality  $j$  and the center of the municipality that is close to it but is not in the same state as municipality  $j$ .  $\text{PM}_{10_i}$  is obtained from the NIE and it is for the  $k$  neighbor municipalities<sup>5</sup>.

Once we calculate the exposure in all the municipalities for Nuevo Leon, we have to calculate the exposure to PM<sub>10</sub> in that state. We define the following equation:

$$\text{Exposure state 1} = \sum_{c=1}^m \left( \frac{\text{Population municipality}_c}{\text{Population State 1}} \right) \text{Exposure municipality}_c \tag{6}$$

The above equation tells us that the exposure in state 1, for example Nuevo Leon, depends on the exposure per municipality in that state and how large this municipality is in relation to the whole state. It is important to emphasize that we are assuming that the exposure in Nuevo Leon depends on the emissions of the neighboring states and not its own emissions. Of course, this will tell us how the emissions outside the state will affect the residents in that state. Also, we expect that the closest the municipalities are, the more exposure the individuals will have to PM<sub>10</sub>. In the calculation of this variable we use municipality information, but the whole analysis is based on state information.

In the empirical analysis, we use four possible scenarios for the above new variable. First, using the map, we locate the closest municipalities that are not in the same state as the municipality we are interested in. We then calculate the above equations and the new variable. However, since these calculations are based on the map without any specific distance, it is likely that in some cases the neighboring municipality is, in fact, far from the municipality we measured. To avoid this problem, we also use the square distance in Eq. (5) and this equation is now:

$$\text{Exposure municipality } j = \sum_{i=1}^k \left( \frac{1}{D_{ij}^2} \right) \text{PM}_{10_i} \tag{7}$$

<sup>5</sup> To calculate the exposure municipality for a municipality in Nuevo Leon, we add all PM<sub>10</sub> emissions from municipalities that are close to each one of the municipalities in Nuevo Leon. Depending on the distance we use, we include some municipalities outside Nuevo Leon that can affect each of the municipalities in Nuevo Leon.

The above equation is used in the second scenario and it is the only change we did since Eq. (6) does not change to calculate the total emissions in a specific state.

The third scenario is based on a specific distance from the center of each municipality to the center of the receptor municipality  $j$ . For this case, if the distance is less than 80 km ( $D \leq 80$ ), then neighboring municipality will affect the individuals in municipality  $j$ . After that, we have to calculate the exposure per state using Eqs. (5) and (6). Finally, the last scenario is based on Eqs. (6) and (7). In the last two scenarios the outcome obtained by them must be basically the same, since we have a specific distance between the municipalities. Therefore, we can conduct a sensitive analysis using the different scenarios and find the range where the WTP to reduce air pollution in Mexico will be.

#### 4 Econometric specification

There are many intermediate steps to get the main result in this research. First, we have to estimate housing prices and incomes in each state. Second, we use these estimates and the migration cost function in the Logit specification to estimate the state fixed or “quality of life” in that state. The last step is to regress those fixed effects on local attributes and the WTP is obtained using this regression.

Hence, we have to calculate the housing prices first using data given by the ENIGH. These prices can be obtained from data on observed rent or house values and housing characteristics. The following functional form is used:

$$\ln P_{i,j} = \ln \rho_j + \lambda_j \Omega_i + h'_i \phi + \varepsilon_{i,j}^H \tag{8}$$

where  $P_{i,j}$  is a measure of house rent by individual  $i$  in location  $j$ ;  $\Omega_i$  is a dummy variable of the house ownership ( $\Omega_i = 1$  if house is owned and 0 if it is rented);  $\rho_j$  represents the housing services in each locations;  $h'_i$  represents the attributes of the house; and  $\varepsilon_{i,j}^H$  is the error term. The estimates of the  $\rho$ 's are used in Eq. (4) and they measure the “price of housing services” in a specific state<sup>6</sup>.

As was stated before, for the first stage of the residential sorting model we need to predict the income that a household head could earn in any state. The equation to estimate this structure is the following:

$$\begin{aligned} \ln \text{INCTOT}_{i,j} = & \alpha_{0,j} + \alpha_{\text{SINGLE},j} \text{SINGLE}_i + \alpha_{\text{MALE},j} \text{MALE}_i + \alpha_{\text{AGE},j} \text{AGE}_i \\ & + \alpha_{\text{AGE}2,j} \text{AGE}2_i + \alpha_{\text{JH},j} \text{JH}_i + \alpha_{\text{HS},j} \text{HS}_i + \alpha_{\text{COLLEGE},j} \text{COLLEGE}_i \\ & + \alpha_{\text{UNIVERSITY},j} \text{UNIVERSITY}_i + \alpha_{\text{HIGHER},j} \text{HIGHER}_i \\ & + \alpha_{P1,j} P(R_B, R_D | \text{ED}) + \alpha_{P2,j} \{P(R_B, R_D | \text{ED})\}^2 + \varepsilon_{i,j}^1 \end{aligned} \tag{9}$$

where  $\text{INCTOT}_{i,j}$  is the income from employment that household head  $i$  obtains in location  $j$ ; the other variables are demographic characteristics of that household

<sup>6</sup> This equation is commonly used in the hedonic housing price literature. A good paper that uses this equation is Harrison and Rubinfeld (1978).

head such as age, education, and marital status. The last two terms before the error term are defined as follows:

$$\begin{aligned}
 P(R_B, R_D|ED) &= JH_i P(R_B, R_D|JH) + HS_i P(R_B, R_D|HS) \\
 &+ COLLEGE_i P(R_B, R_D|COLLEGE) \\
 &+ UNIVERSITY_i P(R_B, R_D|UNIVERSITY) \\
 &+ HIGHED_i P(R_B, R_D|HIGHED)
 \end{aligned}
 \tag{10}$$

This measures the observed percentage of individuals with education level, born in region  $R_B$ , that are found to be living in region  $R_D$ . The idea behind these terms is to control individuals that are migrating from one region to other region due to their levels of education. Equation (9) is estimated using the Census and then the estimates are used to predict the income each individual would earn in any state. These predictions are introduced in Eq. (3).

Finally, the migration variable is calculated from data describing the household’s state of birth and the household’s location in 2000. It is a dummy variable with 1 if the household head migrates from his birth’s residency to his current location and 0 otherwise. We use a migration cost matrix with some flexibility where  $dummystate_{i,j} = 1$  if location  $j$  is outside  $i$ ’s birth state (=0 otherwise);  $dummyregion_{i,j} = 1$  if location  $j$  is outside  $i$ ’s birth region (=0 otherwise)<sup>7</sup>; and  $dummymacroreg_{i,j} = 1$  if location  $j$  is outside  $i$ ’s macro-region (=0 otherwise)<sup>8</sup>.

The above structure is represented by the following migration cost:

$$\tilde{M}_{ij} = \tilde{\mu}_S d_{ij}^S + \tilde{\mu}_R d_{ij}^R + \tilde{\mu}_{MR} d_{ij}^{MR}
 \tag{11}$$

Equation (11) is also plugged into Eq. (3) and we can estimate the parameters for the first stage:  $\{\tilde{\mu}_S, \tilde{\mu}_R, \tilde{\mu}_{MR}, \sigma, \tilde{\theta}\}$ . In the second stage, the thetas estimated in the first stage are regressed on local air pollution emissions and other local amenities. Therefore, the estimating equation in this stage must be

$$\tilde{\theta}_j + 0.20 \ln \rho_j = \tilde{\beta}_{PM} \ln PM_j + \tilde{\beta}_Z Z_j + \tilde{\xi}_j
 \tag{12}$$

The estimate of 0.20 corresponds to the share of income spent on housing in the sample given by ENIGH, and the results are robust to other choices of this parameter. On the other hand, since a higher value of  $PM_{10}$  translates into a worse air quality it is expected to have  $\tilde{\beta}_{PM} < 0$ , if and only if a household head is willing to pay for better air quality. To avoid the endogeneity problem, we use as a covariate the exposure to  $PM_{10}$  per state described in Sect. 3.1 instead of  $PM_{10}$  emissions per area. The explanatory variables in  $Z_j$  contain crime per capita, employment rate, government expenditure per capita, population, life expectancy, rankings of art, and number of firms in location  $j$ .

<sup>7</sup> We use the regions given by INEGI: Northwest, North, Northeast, West Central, South Central, Pacific, Gulf of Mexico, and Yucatan Peninsula.

<sup>8</sup> We use three macro-regions: North, South, and Center.

## 5 Results

### 5.1 Housing price and income regressions

Tables 3 and 4 describe the key variables used in the analysis and their means and standard deviations. Table 3 tells us that the average age of this sample is 40, almost 89 % of the household heads are male, 5 % are single, and 12 % graduated from university. As shown in the third table, 3.5 % of the houses do not have a kitchen, 4.8 % of the houses do not contain plumbing facilities, and 1.5 % of the houses do not have access to electricity.

Table 5 reports the results of the housing index regressions. As we can see, results are as expected and are intuitive, the price of a house will be high if it has more rooms, bedrooms, and it has more housing services. That is, if a house has no kitchen, no plumbing facilities or no electricity, for example, its price is lower than a house that has those services. Almost all the estimates are statistically significant at the common levels of significance.

Table 6 shows that men earn more than women, more education causes household heads to earn more, and there is no statistical evidence that single individuals earn less compared to the excluded groups (married, separated and divorced). As it was expected, income increases with age, but at a decreasing rate. All the estimates are statistically significant at the usual levels.

### 5.2 Results from the residential sorting model

Table 7 is based on McFadden's choice model; where individual  $i$  chooses where to live among all states constrained by the income and the migration costs. Table 8 summarizes the results presented in Table 7. As shown by Table 8, estimates are statistically significant and have the expected signs. There is a major utility cost ( $-4.63$ ) associated with leaving one's birth state. Also, the costs continue to rise with leaving one's birth region and macro-region, but at a decreasing rate ( $-6.56879$ ) and ( $-7.65025$ ). Finally, the estimate of the scaling parameter  $\sigma$  is 1.36, or the estimate of the income parameter is 0.7301. Therefore, the results show that there is a migration cost or disutility to leave the birth's state and settle in another state as Tables 1 and 2 suggested. Also, people have a higher utility in major states, that is, they will prefer to stay there since the quality of life is better compared to other states.

The estimates of the state fixed effects are used as the dependent variables in the second-stage estimation given by Eq. (12). Tables 9, 10, and 11 report the results for all the scenarios discussed in Sect. 3. In all these cases, the share of income spent on housing is 0.20 obtained by the ENIGH. However, all the results are robust for different values of this share.

Table 9 shows the result using emissions of  $PM_{10}$  per area and there is a negative relationship between the "quality of life" and this variable using the state data. Also, a state has a better quality of life if it is more populated and if there are not many firms established in that state. States that have higher government expenditure per capita have a lower quality of life. This could be plausible since the government

**Table 3** Data summary

Variable	Mean	SD	Description
Demographic characteristics			
Male	0.8876	0.3158	1 = male, 0 = female
Age	40.24	12.59	Age of the household head
JH	0.2071	0.4052	Junior High graduate
HS	0.0931	0.2906	High-School graduate
College	0.0439	0.205	Not 4-year degree
University	0.1217	0.3269	University graduate
HighEd	0.0113	0.1057	Master or PhD graduate
Inctot	45,069.49	135,072.70	Total income from employment (yearly) in pesos
Single	0.0546	0.2273	1 = single, 0 = otherwise
PM10 area	0.8032	0.9485	Emissions PM10 per area <sup>a</sup>
Exp_State	33.8797	42.1383	Exposure to PM10 emissions (without a specific distance) <sup>a</sup>
Exp_State2	1.6454	3.9947	Exposure to PM10 emissions (without a specific distance and distance square) <sup>a</sup>
Exp_State<80	128.8414	227.916	Exposure to PM10 emissions (distance less than 80 km) <sup>a</sup>
Exp_State<80_2	3.8361	8.5314	Exposure to PM10 emissions (distance less than 80 km and distance square) <sup>a</sup>



**Table 3** continued

Variable	Mean	SD	Description
Economic variables and other main variables			
Employment	0.5658	0.0242	Fraction of population employed <sup>b</sup>
Crime	2.2031	0.9502	Crime per capita <sup>b</sup>
Population	3.0762	2.6508	Population (millions) <sup>c</sup>
Gov. Exp.	8.119	1.8797	Government expenditure per capita (\$000) <sup>b</sup>
Rank art	16.5	9.3808	Arts rankings <sup>b</sup>
Firms	134,065	106,595.80	Number of firms establishments per state <sup>b</sup>
Life exp.	75.19	1.1754	Life expectancy (years) <sup>d</sup>

Source: Mexican Census 2000

Source calculations were needed in some cases to get the values

<sup>a</sup> Own calculations using NIE

Source: <sup>b</sup> INEGI (2005a, b, 2006, 2007, 2009); <sup>c</sup> CONAPO (2009); <sup>d</sup> PNUD (2007)

**Table 4** Data summary

Housing characteristics			
Variable	Mean	SD	Description
ROOM1	0.0620	0.2411	1 Room in dwelling
ROOM2	0.1468	0.3539	2 Rooms in dwelling
ROOM3	0.2198	0.4141	3 Rooms in dwelling
ROOM4	0.2501	0.4331	4 Rooms in dwelling
ROOM5	0.1741	0.3792	5 Rooms in dwelling
ROOM6	0.0805	0.2721	6 Rooms in dwelling
ROOM7	0.0350	0.1840	7 Rooms in dwelling
ROOM8	0.0172	0.1303	8 Rooms in dwelling
ROOM9	0.0140	0.1176	9+ rooms in dwelling
BED1	0.3096	0.4623	1 Bedroom dwelling
BED2	0.4120	0.4922	2 Bedroom dwelling
BED3	0.2176	0.4126	3 Bedroom dwelling
BED4	0.0487	0.2154	4 Bedroom dwelling
BED5	0.0118	0.1083	5+ Bedroom dwelling
YR1	0.0180	0.1332	0- to 1-year-old dwelling
YR2	0.1443	0.3514	2- to 5-year-old dwelling
YR3	0.2126	0.4091	6- to 10-year-old dwelling
YR4	0.3067	0.4611	11- to 20-year-old dwelling
YR5	0.1778	0.3823	21- to 30-year-old dwelling
YR6	0.1013	0.3018	31- to 40-year-old dwelling
YR7	0.0389	0.1935	41+ year-old dwelling
NOKITCHEN	0.0355	0.1852	Dwelling does not contain complete kitchen facilities
NOELECTRIC	0.0156	0.1240	Dwelling without electricity
NODRENAJE	0.1102	0.3131	Dwelling does not contain access to safe drinking water
NOPLUMBING	0.0485	0.2149	Dwelling does not contain complete plumbing facilities
OWNER	0.7081	0.4545	Dwelling owned
POORFLOOR	0.0930	0.2904	Dwelling's floor is made of sand, soil, and mud
POORCEIL	0.2788	0.4484	Dwelling's ceiling is made of cardboard, discards, or palm-tree

Source: ENIGH 2004, 2005, 2006

expenditure per capita is not translated into a benefit for the state, but on the contrary, the government could spend the money on other “things”, for example corruption, but not on the improvement of the state. However, the last result is not robust for other scenarios and is counter intuitive, and further work is needed to figure this out.

Table 10 presents the results for the cases of exposure without a specific distance. As shown in column 2, the coefficient of the exposure to  $PM_{10}$  per state is not statistical significant. In this case, a more populated state has a better quality of life. States with a higher life expectancy have a better quality of life, and states with fewer firms have also a better quality of life. As was pointed out before, the first result

**Table 5** Housing services index parameters

Variable	Average parameter estimate	Standard errors
Constant	9.4883***	0.0545
ROOM2	0.0237	0.0201
ROOM3	0.0976***	0.0214
ROOM4	0.1728***	0.0227
ROOM5	0.2725***	0.0243
ROOM6	0.4027***	0.0271
ROOM7	0.5308***	0.0323
ROOM8	0.6240***	0.0393
ROOM9	0.8481***	0.0425
BED2	0.1435***	0.0118
BED3	0.2741***	0.0151
BED4	0.3049***	0.0236
BED5	0.2807***	0.0417
YR2	-0.0570*	0.0316
YR3	-0.0102	0.0311
YR4	0.0484	0.0308
YR5	0.0768**	0.0315
YR6	0.0621**	0.0326
YR7	0.0310	0.0366
NOKITCHEN	-0.2052***	0.0236
NOELECTRIC	-0.7428***	0.0363
NODRENAJE	-0.1700***	0.0165
NOPLUMBING	-0.2088***	0.0228
OWNER	-0.4274***	0.0094
POORFLOOR	-0.2348***	0.0171
POORCEIL	-0.2160***	0.0116
Adjusted $R^2$	0.3715	
$N$	58,275	

For this regression we use municipality fixed effects

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

(about exposure not statistically significant) seems feasible, because we could have a measurement error. Since we use only the map to choose the closest neighbor municipalities, it is possible that in some cases the neighbor municipality is too far from the receptor municipality. That is, if the municipality is too far, this municipality will not affect the other municipality at all, and the exposure given by this municipality must be zero. To fix this problem, we use the square of the distance and the results are in columns 3 and 4. In this case, the estimate of the exposure to  $PM_{10}$  per state using the square distance becomes statistically significant. The estimated coefficient represents the elasticity of WTP with respect to air pollution exposure and its value is equal to  $-0.216$ . The value given by the first case using the

**Table 6** Income regression

Variable	Average parameter estimate	Standard errors
Constant	8.6619***	0.02853
Male	0.3588***	0.00933
Age	0.0416***	0.00127
Age2	-0.00048***	0.00001
JH	0.4182***	0.00712
HS	0.7292***	0.01000
College	0.8749***	0.01321
University	1.3982***	0.00950
HighEd	1.9147***	0.02969
Single	-0.0172	0.01237
$R^2$	0.3618	
$N$	75,426	

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

emissions of  $PM_{10}$  per area (-0.590) is nearly twice in magnitude than the latter value. However, the only conclusion here is that there is a bias in the first case, and it is expected that the correct value must be close to -0.21. Hence, this value is the minimum value the elasticity of WTP can get. The other conclusions about population, firms established and life expectancy remain the same.

The last scenarios are presented in Table 11. The estimated coefficient of the elasticity of WTP has again the expected sign and the elasticity of WTP ranges from -0.215 to -0.199 in both cases. Since in these cases we have a specific distance ( $D < 80$  km) among the municipality in state  $m$  and the municipalities in other states, the result in both cases must be basically the same, that is, we do not have a measurement error. Again, we have the same results as before. States with more people are significantly more appealing. States with higher life expectancy can attract more residents and states with a bigger local economy (given by the firms established) are not a very good option for living. All these results are robust. In the case of the latter result, a higher level of economic activity has some negative externalities to some states due to air pollution. Therefore, people in those places could have a negative impact in their quality of life.

The last step in this research is to calculate the marginal WTP. Therefore, we need to multiply the elasticity of WTP by the income and dividing by the air pollution emissions. Table 12 reports the results of the estimates of marginal WTP for air quality. Those figures represent the median household's willingness to pay for a 1 Mg/year reduction in ambient  $PM_{10}$  emissions. We use the median values of household income (\$25,716.00 pesos) and  $PM_{10}$  emissions in our sample as the measures of income (I) and air pollution (X)<sup>9</sup>. However, we want to

<sup>9</sup> The median values of air pollution depend on the scenarios given by Tables 9, 10, and 11, and they are 0.4706, 0.4518, 33.0609, and 0.6878. For example, 0.4706 is the median value if the variable is emissions of  $PM_{10}$  per area.

**Table 7** Conditional logit

Variable	Average parameter estimate	Standard errors
LnIncPred_State	0.7301***	0.0720
dummysstate	-3.3867***	0.0153
dummyregionec	-1.4091***	0.0201
dummymacroreg	-0.7895***	0.0200
theta1	0.1023	0.0660
theta2	1.2495***	0.0697
theta3	0.0850	0.0766
theta4	0.2522***	0.0768
theta5	0.4443***	0.0568
theta6	-0.2227***	0.0722
theta7	0.1870***	0.0702
theta8	0.8597***	0.0575
theta9	0.4945***	0.0515
theta10	0.2704***	0.0631
theta11	0.4830***	0.0581
theta12	-0.3005***	0.0623
theta13	0.4104***	0.0581
theta14	1.1600***	0.0565
theta15	2.4229***	0.0493
theta16	0.5540***	0.0558
theta17	0.7889***	0.0611
theta18	0.3536***	0.0736
theta19	1.6059***	0.0576
theta20	-0.0191	0.0615
theta21	0.7392***	0.0544
theta22	0.2734***	0.0612
theta23	1.1315***	0.0626
theta24	0.0615	0.0591
theta25	0.3848***	0.0599
theta26	0.9948***	0.0587
theta27	0.2685***	0.0677
theta28	1.1403***	0.0588
theta29	0.3911***	0.0617
theta30	0.2660***	0.0561
theta31	0.5803***	0.0666

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

Theta  $j$  represents the state fixed effect for state  $j$ . We need a normalization to estimate the above regression, in this case  $\vartheta_{32} = 0$

compare the different values of WTP obtained in each scenario. Therefore, we normalize these results and multiply them by its one standard deviation. The standard deviations are obtained as the exposure per municipality since we use

**Table 8** First-stage maximum likelihood parameter estimates

Variable	Parameter	Coefficient	t Statistic
Migration cost			
State	$\tilde{\mu}_S$	-4.63878***	-220.84
Region	$\tilde{\mu}_R$	-1.9300***	-69.81
Macro-region	$\tilde{\mu}_{MR}$	-1.08147***	-39.45
Logit Scale Parameter	$\sigma$	1.369671***	10.14

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level. Recall that  $\sigma = \frac{1}{\beta_1}$

**Table 9** Results from second-stage regressions

Dependent variable $\psi + 0.20\ln\rho$	OLS (1)	OLS (2)
LnPM10_Area	-0.2257	-0.5906***
Crime_Rate		0.2107
Employment_rate		4.7263
Ln_population		2.8624***
Gov_Expenditure		-0.1027**
Life_Expectancy		0.1827
Rank_art		-0.106
Ln_Firms_State		-2.5515***
Constant	2.3271***	-25.9163**
Regional Dummies	Yes	Yes
R <sup>2</sup>	0.3690	0.8765
Observations	32	32

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

municipality information to calculate the exposure per state<sup>10</sup>. The final figures are presented in Table 12.

The estimated MWTP for air quality ranges from \$443.66 to \$2,682.92 Mexican pesos. The first case has a MWTP equal to \$1,818.27 and has a bias due to the endogeneity problem. However, in the other cases we eliminate this bias and the results are correct. As shown in the table, the results for the case with a specific distance are really close as it should be. Finally, as was stated before, it could be possible to use the exposure variable as an instrument and calculate the marginal WTP avoiding this bias. However, this instrument is not strictly a good one and it is better to use only the results with the exposure variables. Therefore, we expect that the MWTP must be greater than \$443.66 and lower than \$2,682.92.

<sup>10</sup> The SD are 0.0563, 0.2175, 2.6418, and 0.0798.

**Table 10** Results from second-stage regressions

Dependent variable $\vartheta + 0.20\ln\rho$	OLS (1)	OLS (2)	OLS (3)	OLS (4)
LnExpos_Dist	-0.2475	-0.2079		
LnExpos_Dist2			-0.1517	-0.2167*
Crime_Rate		-0.0930		-0.0456
Employment_rate		-1.8992		-0.3372
Ln_population		2.3307**		2.3942**
Gov_Expenditure		-0.0969		-0.1001
Life_Expectancy		0.3355*		0.3086*
Rank_art		0.0064		0.0061
Ln_Firms_State		-2.1378**		-2.1310**
Constant	3.2288***	-29.1162*	2.3208***	-29.908*
Regional Dummies	Yes	Yes	Yes	Yes
$R^2$	0.3775	0.7699	0.3631	0.7901
Observations	32	32	32	32

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

**Table 11** Results from second-stage regressions

Dependent variable $\vartheta + 0.20\ln\rho$	OLS (1)	OLS (2)	OLS (3)	OLS (4)
LnExpos_Dist < 80	-0.2257*	-0.2159**		
LnExpos_Dist2 < 80			-0.2050*	-0.1998**
Crime_Rate		-0.1108		-0.0931
Employment_rate		-1.1470		-0.9288
Ln_population		2.4458**		2.3551**
Gov_Expenditure		-0.1035		-0.1008
Life_Expectancy		0.2782		0.2889*
Rank_art		0.0125		0.0115
Ln_Firms_State		-2.1183**		-2.0106**
Constant	3.0748***	-27.1765*	2.2279***	-28.8781**
Regional Dummies	Yes	Yes	Yes	Yes
$R^2$	0.4092	0.8054	0.4079	0.8059
Observations	32	32	32	32

Asterisks denote significance at \* 10 % level, \*\* 5 % level, and \*\*\* 1 % level

## 6 Conclusions

This paper uses a residential sorting model to avoid the bias obtained by the traditional hedonic approach when we calculate MWTP to reduce air pollution.

**Table 12** Estimated marginal WTP for air quality

	Residential sorting model			
	(1)	(2)	(3)	(4)
MWTP elasticity	0.5906	0.2167	0.2159	0.1998
WTP (2000 pesos)	\$1,818.27	2,682.92	443.66	596.01
WTP (2000 USD)	192.21	283.61	46.90	63.00

The coefficients are taken from the Tables 9, 10, and 11. WTP is calculated by multiplying the coefficients by the median household income per year in 2000 (\$25,716.0 pesos) and dividing by the median X. Then, we multiply them by its standard deviation to get WTP

The main goal in this paper is to calculate MWTP for a reduction in air pollution measured by the emission of PM<sub>10</sub> and since we face a problem of endogeneity, we implement a new variable to successfully measure the tradeoff between a better quality of life and a lower exposure to the emission of PM<sub>10</sub>. Our estimates imply that the household head in Mexico would pay \$443.66 to \$2,682.92 (in constant 2000 Mexican pesos) or 46.90–283.61 (2,000 dollars) for a one-unit reduction in PM<sub>10</sub> emissions. This value is very important since if we aggregate individual WTP and compare this figure to the cost of pollution mitigation, we can clearly state that the benefits of reduction of air pollution are higher than its costs. Therefore, a public policy that helps to improve air quality in Mexico would be important and beneficial for all Mexicans<sup>11</sup>.

Since we get a lower bound for the WTP when using the exposure variables, we can assure that the minimum value for the WTP to reduce air pollution in Mexico is \$443.66 and it is expected that the figure combining emissions in the state and outside the state must be higher than the latter value. Therefore, these results point out that in reality Mexicans do care about air pollution and there are benefits to decrease this disamenity. Hence, policy makers in Mexico must face this major problem and spend money to reduce the emissions of PM<sub>10</sub> to improve the quality of life of the Mexicans.

This lower bound value of WTP to reduce air pollution in Mexico is lower than the WTP obtained by Bayer et al. (2009). They obtained a value of 149–185 dollars for this reduction. It seems that because of the lower income per capita in Mexico, we should have a lower value and that is the case. However, we have here some evidence that this is the case, but we need to research more on this topic, so we can conclude this asseveration.

**Acknowledgments** JI thanks Prof Randall Walsh at University of Pittsburgh in drafting the manuscript and Prof. Michael Greenwood, Prof. Francisca Antman at University of Colorado for their comments in writing this manuscript. JI thanks his beautiful princess and son for all their support and love in these years.

<sup>11</sup> If we use the average of WTP and the population in Mexico given by the Census 2000, the aggregate WTP would be on average 152,394,843,145 pesos, and if we estimate the costs using the results from PROAIRE 2011–2020, there would be nearly 244,315,782. The latter value is an estimation of the benefits and costs and as we can see, we have greater benefits than costs (SEMARNAT 2010).



**Conflict of interest** The author declares that he has no competing interests.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution License which permits any use, distribution, and reproduction in any medium, provided the original author(s) and the source are credited.

## References

- Bayer P, Keohanie N, Timmins C (2009) Migration and hedonic valuation: the case of air quality. *J Environ Econ Manag* 58(1):1–14
- Boyle K, Poor J, Taylor L (1999) Estimating the demand for protecting freshwater lakes in eutrophication. *Am J Agric Econ* 81:1118–1122
- Chay K, Greenstone M (2005) Does air quality matter? Evidence from the housing market. *J Polit Econ* 113(2):376–424
- Consejo Nacional de Población (CONAPO) (2009) Población en México. <http://www.conapo.gob.mx/es/CONAPO/Proyecciones> Accessed 1 Aug 2010
- Forbes (2008) The World's Dirtiest Cities [http://www.forbes.com/2008/02/26/pollution-baku-oil-biz-logistics-cx\\_tl\\_0226dirtycities.html](http://www.forbes.com/2008/02/26/pollution-baku-oil-biz-logistics-cx_tl_0226dirtycities.html). Accessed 15 Aug 2013
- Graves P, Murdoch J, Thayer M, Waldman D (1988) The robustness of hedonic price estimation: urban air quality. *Land Econ* 64(3):220–233
- Hammitt J, Ibarra E (2006) The economic value of reducing fatal and non-fatal occupational risks in Mexico City using actuarial- and perceived-risk estimates. *Health Econ Lett* 15:1329–1335
- Harrison D, Rubinfeld D (1978) Hedonic housing prices and the demand for clean air. *J Environ Econ Manag* 5:81–102
- Heckman J, Matzkin R, Nesheim L (2004) Simulation and estimation of hedonic models. In: *Frontiers in applied general equilibrium modeling*. Cambridge University Press
- Holguín F et al (2003) Air pollution and heart rate variability among the elderly in Mexico City. *Epidemiology* 14:521–527
- INECC (2006) *Inventario Nacional de Emisiones de México 1999*. Publicación Oficial Instituto Nacional de Ecología
- INEGI (2005a) Censo General de Población y Vivienda 2000 <http://www.inegi.org.mx/sistemas/olap/proyectos/bd/consulta.asp?c=10252&p=14048&s=est>. Accessed 15 Aug 2013
- INEGI (2005b) Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH). Publicación Oficial INEGI
- INEGI (2006) Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH). Publicación Oficial INEGI
- INEGI (2007) Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH). Publicación Oficial INEGI
- INEGI (2009) Consulta interactiva de datos <http://www.inegi.org.mx/est/contenidos/proyectos/cubos/>. Accessed 15 Aug 2013
- Loomis D et al (1999) Air pollution and infant mortality in Mexico City. *Epidemiol Resour Inc* 10:118–123
- Palmquist R, Smith K (2001) The use of hedonic property value techniques for policy and litigation. *International yearbook of environmental and resource economics*, vol 6
- Programa de las Naciones Unidas para el Desarrollo (PNUD) (2007) Informe sobre Desarrollo Humano México 2006–2007 <http://www.undp.org.mx/desarrollohumano/informes/index.html>. Accessed 15 Aug 2013
- Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. *J Polit Econ* 82:34–55
- Sattinger M (1993) Assignment models of the distribution of earnings. *J Econ Literature* 31:831–880
- SEMARNAT (2010) Programa para Mejorar la Calidad del Aire de la Zona Metropolitana del Valle de México 2011–2020 (PROAIRE)
- Train K (2009) *Discrete choice methods with simulation*. Cambridge University Press, Cambridge
- Viscusi K (1993) The value of risks to life and health. *J Econ Literature* 31:1912–1946
- World Bank (2002) Improving air quality in metropolitan Mexico City. *World Bank Report*, 1–62