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How much are urban residents in Mexico willing to pay for cleaner air?

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ABSTRACT. We estimate the marginal willingness-to-pay for PM10 abatement in the three largest Mexican cities. We use a unique data set with actual market transactions at the household level from January 2003 to May 2004 and observed PM10 concentrations. We follow an instrumental variable approach to mitigate bias from omitted variables. We exploit the seasonality in PM10 concentrations due to rainfall patterns in those cities to construct a valid instrument for PM10. We find the house price–pollution elasticity to be around −0.07 for Mexico City, −0.05 for Guadalajara, and −0.07 for Monterrey, implying that one unit reduction in PM10 levels is valued at US$41.73, 36.34 and 43.47, respectively. Our results indicate that urban residents of Mexico are willing to pay for cleaner air.

1. Introduction

The correct evaluation, design and implementation of air pollution regulations depend to a large extent on the empirical evidence of their costs and benefits. These regulations can be particularly controversial in developing countries because currently there are no reliable estimates on the benefits of improved air quality. Despite the lack of research, it is typically assumed that developing countries face far more urgent priorities than abating air pollution. This was one of the main reasons behind the absence of mandatory carbon emissions reductions for developing countries under the Kyoto Protocol. However, there is enough variation in terms of income and development within and across developing countries to challenge this assumption.

The primary purpose of this paper is to obtain precise and reliable estimates of the benefits of air pollution abatement as measured by the marginal willingness-to-pay (MWTP) for PM10 in the three largest cities in Mexico using a hedonic approach. PM10, a standard measure of particulate matter, is the most visible among all air pollutants and thus appropriate for hedonic methods. We use a unique data set consisting of 4,267 market-based housing sales along with PM10 concentrations from January 2003 to May 2004 for Mexico City, Monterrey and Guadalajara. The data set includes detailed physical characteristics of the housing units, socioeconomic characteristics of the household buying the house, date of purchase and financial terms of the mortgage. Our pollution data are constructed from hourly PM10 readings from monitoring stations located within the metropolitan boundaries of our three chosen cities. To our knowledge this is the largest and most complete data set for actual housing market transactions and air pollution measures in a developing country.

In addition to the uniqueness of our data set, this paper makes two other relevant contributions. First, our study contributes to the relatively non-existent literature on how much people in developing countries are willing to pay for clean air. Most of the prior hedonic literature has estimated values for clean air in urban cities of the developed world with an almost exclusive focus on US cities.[1] More recently, researchers have started to apply the hedonic method to cities in Asia such as Seoul (Kwak and Chun, 1996; Kim *et al.*, 2003), Taipei (Yang, 1996), and Jakarta (Yusuf and Resosudarmo, 2009). However, with the exception of Yusuf and Resosudarmo (2009), these studies also examine cities in developed countries, albeit in Asia.

Second, we use the instrumental variables (IV) technique to address the oft-cited issue of omitted variable bias in prior hedonic estimates. We exploit the unique interaction between rainfall and PM10 concentrations in Mexico to construct a valid instrument for PM10.[2] This provides reliability in our MWTP estimates and hence the foundation for reliable welfare calculations of a marginal change in air quality.

Our main results show that urban Mexicans do care to pay for PM10 abatement. The PM10 elasticities in our baseline IV regression are −0.05 for Guadalajara (the cleanest city in our sample), −0.06 for Mexico City and −0.07 for Monterrey (the city with the worst air quality in our sample). These estimates fall at the higher end and some lie outside the range of most prior hedonic estimates (Smith and Huang, 1995). However, unlike early hedonic estimates, all of our IV estimates are of the 'right' sign and significant at least at the 5 per cent level. A unit reduction in PM10 levels is

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[1] For a survey of the results from the early hedonic literature, see Boyle and Kiel (2001) and Zabel and Kiel (2000).

[2] We do not use daily rainfall data as our instrument because this information is not publicly available.

valued, on average, at US$41.73 in Mexico City, at US$36.34 in Monterrey and at US$43.37 in Guadalajara.

These results suggest that, in contrast to what is commonly assumed, urban people in developing countries may be willing to pay non-trivial monetary amounts for environmental amenities. Our findings of a positive willingness-to-pay for improved air quality imply that some level of air pollution abatement in cities of middle-income developing countries may increase welfare. According to the point estimates of our model and using a simple average across metropolitan statistical area (MSAs), at a PM10 30-day daily average of around 59 $\mu g/m^3$, a unit pollution of abatement is justified and welfare-improving if the marginal cost of abatement is less than US$40. Although caution is warranted in generalizing our results to other developing countries, policy makers and environmental economists in developing countries can use our estimates as one input in the evaluation of the benefits of air pollution regulation in cities similar to those in our study. This is important for developing countries since about 47 per cent of their population live in urban areas, according to the United Nations (UNDESA, 2012). Moreover, data from UNDESA (2012) also show that about 73 per cent of the world's urban population and seven of the 10 largest cities are located in developing countries.

The rest of the paper is organized as follows. Section 2 discusses the background literature. Section 3 describes our data set. Section 4 explains the fixed effect estimation and presents its numerical results. Section 5 explains the IV model and presents its numerical results, and finally section 6 concludes.

2. Background

Economists have estimated the association between housing prices and air pollution at least since Ridker (1967) and Ridker and Henning (1967). However, Rosen (1974) was the first to give this correlation an economic interpretation. In the Rosen model, a differentiated good is described by a vector of its characteristics, $Q = (q_1, q_2, \ldots\ldots\ldots, q_n)$. In the case of a house, these characteristics, q, may include structural attributes (e.g., number of bedrooms), provision of neighborhood public services (e.g., local school quality) and local amenities (e.g., air quality). Thus, the price of the ith house, P_i, can be written as

$$P_i = P(q_1, q_2, \ldots\ldots\ldots, q_n) \tag{1}$$

where $\partial P/\partial q_n$ is referred to as the marginal price of the nth characteristic implicit in the overall price of the house. Since equation (1) is the locus of tangencies between consumers' bid functions and suppliers' offer functions, the marginal price with respect to air quality gives the equilibrium differential that allocates individuals across locations. Thus, at each point of (1), the marginal price of air quality is a consumer's MWTP and a supplier's marginal cost of producing it. Since (1) reveals the MWTP at a given point, it can be used to infer the welfare effects of a marginal change in air quality. Estimating this MWTP constitutes the first stage of the hedonic method.

In principle, the second stage of Rosen's hedonic method recovers the structural parameters of the underlying demand (and supply functions) using the estimated marginal prices from the first stage. Brown and Rosen (1982), Bartik (1987) and Epple (1987) highlight the strong assumptions necessary to identify the structural parameters in the second stage. There is a consensus that empirical applications have not identified a situation where these assumptions hold and that the second-stage demand function for an environmental amenity has never been reliably estimated (Deacon *et al.*, 1998). Hence, the goal of this paper is to focus on the first stage of the hedonic method to find reliable estimates of MWTP for clean air for residents of urban Mexico. This goal is of practical importance as consistent estimation of the first stage is the foundation on which welfare calculation rests.[3]

Consistent estimation of the first stage of the hedonic price schedule is extremely difficult. One reason is due to unobserved factors that covary with both air pollution and housing prices. For example, areas with poorer air quality tend to be more urbanized and have higher per capita incomes, population densities and crime rates. Consequently, cross-sectional estimates of the housing price–air quality gradient may be severely biased because of omitted variables. Smith and Huang (1995) reviewed over 37 studies to provide 86 estimates of the MWTP for reducing air pollution as measured by total suspended particulates (TSP) in US cities between 1967 and 1988. A quarter of their reported estimates have perverse signs; i.e., they indicate a positive correlation between housing prices and pollution levels. More recently, Zabel and Kiel (2000) also estimate 80 coefficients for various pollutants, out of which only 19 were negative. Moreover, even if the early estimates had the 'right' sign, they were often not statistically significant (Wieand, 1973; Smith and Deyak, 1975; Li and Brown, 1980; Palmquist, 1982).

In the intervening years, this problem of measurement error in hedonic estimates has received little attention, with the exception of Graves *et al.* (1988) and Chay and Greenstone (2005), both of which focus on the United States. Other sources of misspecification arise from the functional form for the hedonic price function and theory offers little guidance on the matter. Hence, the price function could include linear, log-linear and log-log models. Cropper *et al.* (1988) find that certain versions of the Box–Cox model perform best, although the log and linear models do relatively well when the house price model is misspecified, as it often is in the case of omitted variables. Cassel and Mendelsohn (1985) point out that the Box–Cox specification may not be preferable when the goal is to obtain best estimates of the parameters in the hedonic equation rather than the best fit. Moreover, Palmquist (1991) claims that to allow the air quality variables in (1) to have their own Box–Cox parameters only adds to the complexity of the equation and is unlikely to increase the variance of the estimates. Thus, for our base regressions we use the log-log functional form and further test the sensitivity of our results with the log-linear and linear-linear models.

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[3] The econometric technique we use to estimate the first stage of the hedonic method requires two stages.

The size of our data set prevents use of complicated functions such as the Box–Cox.

Our paper contributes to the above literature in three important ways. First, we use a unique, individual level data set with actual house prices and a wide variety of housing models for three of the largest cities in Mexico. This is the largest and most complete data set to be used to estimate the MWTP for clean air in a developing country. Second, we construct a unique instrument for our pollution variable, using its seasonal variation to address the issue of measurement errors in the early hedonic studies to provide reliability in our MWTP estimate. Finally, most of the prior hedonic literature has estimated values for clean air in urban cities of the developed world, with an almost exclusive focus on US cities. As mentioned in section 1, more recently researchers have applied the hedonic method to cities in Asia but, with the exception of Yusuf and Resosudarmo (2009), these studies are also for cities in developed countries, albeit in Asia. Moreover, the estimates for particulate matter found by Yusuf and Resosudarmo (2009) for Jakarta are not statistically significant. Hence, to the best of our knowledge, no known reliable estimates exist for the MWTP for PM10 abatement in the developing world.

3. Data

Our data set is a cross-section of 4,267 house sales from January 2003 to May 2004 in the three largest cities of Mexico: Mexico City (1,546 sales), Guadalajara (1,141 sales) and Monterrey (1,580 sales). For each house sale we have four sets of variables: housing, household, location and air pollution. The set of housing variables contains information on the housing unit's sale price, date of transaction (day month, year), lot size, constructed size, and number of floors, bedrooms, full baths and half baths. The set of household data has the age, income, occupation, education level, marital status and number of dependents of the head of the household purchasing the house. The set of location variables contains the neighborhood, postal code, the MSA and the XY coordinates of the centroid of the postal code in which the housing unit is located. The set of air pollution variables contains PM10 measures that influence buyers' perceptions when house hunting.

The original data set for the housing, location and head of household variables comes from mortgage originations by Sociedad Hipotecaria Federal (SHF). All the mortgages and housing prices are market based, i.e., there is no government subsidy. In the rest of this section we describe our data in more detail, and provide relevant summary statistics in table 1. The monetary units in our data are originally in Mexican pesos (MXP). In table 1 we transform the peso values into US$ for exposition purposes using the period's average exchange rate of 10.902 MXP/US$. All regressions are performed using pesos.

3.1. Location variables

The three MSAs used in our analysis are the largest in Mexico with a combined population of 27 million in 2005, which represents approximately 26 per cent and 37 per cent of the country's total and urban population,

Table 1. *Descriptive statistics*

	Guadalajara		*Mexico City*		*Monterrey*	
	Mean	*Std*	*Mean*	*Std*	*Mean*	*Std*
Housing						
Housing value (US$)	33,394.4	16,267.9	35,957.3	13,080.9	43,608.1	16,209.6
Built size (m^2)	55.5	17.8	70.6	17.3	86.1	47.0
Lot size (m^2)	84.4	17.9	111.0	150.5	108.7	57.5
Bedrooms	1.8	0.9	2.6	0.6	2.8	0.4
Full baths	1.3	0.5	1.1	0.3	1.6	0.5
Half baths	0.1	0.3	0.3	0.5	0.5	0.5
Floors	1.4	0.6	2.2	1.0	1.9	0.6
Socioeconomic						
Household monthly income	1,819.9	1,214.5	2,077.1	1,193.7	2,266.4	1,210.4
Head of household age	37.0	9.3	37.7	8.6	34.5	8.0
Dependents	1.2	1.4	1.2	1.2	1.1	1.2
Male	59.3%		63.2%		71.3%	
Married	52.1%		55.6%		69.9%	
No education degree	1.2%		2.9%		1.2%	
Elementary	6.7%		2.8%		4.3%	
High school	36.3%		22.0%		11.7%	
Technical school	13.4%		16.2%		10.5%	
Bachelor and above	42.4%		56.2%		72.3%	
Salaried	86.3%		77.1%		86.0%	
Business	9.8%		14.5%		10.2%	
Professional	1.0%		2.3%		1.7%	
Informal	1.5%		2.2%		1.8%	
Other work	1.4%		3.9%		0.2%	
Pollution ($\mu g/m^3$)						
6-month lag	38.5	11.8	51.7	16.2	85.9	18.9
5-month lag	37.5	13.0	56.4	18.3	83.8	18.1
4-month lag	40.0	14.5	55.7	17.3	84.0	19.5
Observations	1,141		1,546		1,580	

respectively. Figure 1 shows a map of Mexico with state divisions and shaded areas representing the counties that compose each of the MSAs. Mexico City is the largest city in the country (and one of the largest cities in the world) with a population of 20 million, followed by Guadalajara and Monterrey with populations of 4 and 3.6 million, respectively.

The original loan data have information only on the neighborhood, municipality and the state where the housing unit is located. We use Conapo (2007) to assign each municipality in our data set to its respective MSA. Since there is no publicly available geographic information system (GIS)-determined location for neighborhoods in Mexico, we use the Mexican Postal Service (Sepomex, 2010) database to assign a postal code to each

Figure 1. *MSA of Mexico City, Guadalajara and Monterrey, 139 × 108 mm (300 × 300 dpi)*

neighborhood. Next, we use the database from GeoPostcodes to assign a geocoded XY (latitude and longitude) location to the centroid of each postal code. We use this information to create our PM10 measure for each postal code.[4]

3.2. *Housing and household variables*

The first part of table 1 reports the summary statistics on the housing variables of the three MSAs. Our data only include new housing units due to scarce financing for used houses in Mexico at the time, thus satisfying an underlying assumption of Rosen's framework which ignores second-hand markets. Official government statistics from Conafovi (2002–2004) report no mortgages for used housing in 2002 and 2003 and just 62 for the entire country in 2004.

The second part of table 1 describes the socioeconomic characteristics of the head of the household purchasing the house. We construct five categories for the highest degree obtained by the head of the household purchasing the housing unit: no degree; elementary; high school; technical school; and bachelor's and above. Our data set also has information on the main sources of income for the heads of household: salaried work, business, professional work, informal work, and other miscellaneous sources.

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[4] The total population data refer to 2005 data from Conapo (2007) since it is the closest available to our 2003–2004 sample period.

Our primary interest in these socioeconomic characteristics lies not in their individual influences on housing values. Rather, we follow Zabel (2004) and include them so that jointly they proxy for some missing neighborhood characteristics such as quality of schools and crime levels. Zabel and Kiel (1998) provide a rationale for using these variables.

Note that the households in our data set lie at the higher end of the socioeconomic scale and are thus not representative of populations in a developing country. However, they are an important socio-political group within a developing country context as their ways of living are often emulated by other demographic groups. Therefore, even if our sample of households constitutes a small proportion of the population, they have a relatively large circle of influence and represent an important faction for understanding the environmental preferences of developing country residents.

3.3. *Air pollution variable*

Our air pollution data come from the National Ecology Institute (INE). Pollution data for several pollutants are recorded on an hourly basis using automatic monitoring stations and the recordings are later validated and published. Mexico City has 15 automatic monitoring stations whereas Guadalajara and Monterrey have eight and five, respectively.

Economic theory offers little guidance regarding which measure of pollution is best to use in hedonic methods. Perspectives from sociology show that poor nations are most concerned with locally visible environmental problems and their direct experiences are important in influencing their perceptions (Brechin, 1999; Dunlap and York, 2008).[5] Hence, we choose PM10 concentrations to measure air quality in our paper because it is the most visible of air pollutants.

However, the question still remains as to what PM10 measure best captures buyers' perceptions through direct experience. Rosen (1974) states that house characteristics must be objectively measured such that consumers' perceptions of the amount of these characteristics embodied in the good are identical. To best approximate this description for our air quality measure, we construct – using the closing date recorded for each sale in our data – a PM10 measure that buyers experience when house hunting. Mortgage originators report that in Mexico it takes between 4 and 6 months to buy a new house from search to closing date. This time includes the actual search, the credit approval (which takes approximately 2 months) plus the appraisal and notary work on the title.[6] Hence, the direct exposure to PM10 levels occurs during visits to properties and is measured by 30-day pollution averages 4, 5 and 6 months before the closing date. For example, the relevant 6-month lagged pollution data for a house sale that closed on 20

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[5] However, the aforementioned studies in sociology also show that potential factors other than direct experiences could influence environmental values in a developing country.

[6] In Mexico the supply of notaries is regulated and they undertake the main role in the title process of the house.

December 2003 would be the 30-day pollution average starting on 20 June 2003 and ending on 20 July 2003. The differences in these 30-day pollution averages experienced by households during multiple property visits are capitalized in the negotiated price of the house. Given that each of our houses has a unique closing date, our 30-day averages 6, 5 and 4 months before this unique purchase date create a different PM10 measure for each housing unit even when houses are located in the same postal code.[7] Next, to create our 30-day PM10 averages, we obtain, from INE (2010), the GIS coordinates of each monitoring station used to compute, within each MSA, the distance between every monitoring station and the centroid of all postal codes. The formula to compute this distance takes into account the curvature of the earth. For each postal code in each MSA, we compute a daily PM10 average by weighting the pollution readings from all the monitoring stations in the MSA by the inverse of the square of the distance between the centroid of the corresponding postal code and each monitoring station.[8]

This interpolation method performs better in obtaining estimates of the house price–pollution gradient relative to alternatives such as Thiessen polygons.[9] Finally, we compute unique 30-day PM10 measures for each housing unit as the mean of the daily PM10 values.

The last part of table 1 presents the summary statistics on average 30-day PM10 concentrations lagged 6, 5 and 4 months by MSA. The 6-month lagged measure for Guadalajara lies below the 24-hour average standard of $50\,\mu g/m^3$ maintained by the World Health Organization (WHO). For Monterrey, all the PM10 averages violate the WHO standard consistently, which is partially explained by the large industrial base of Monterrey. For Mexico City, reported as the most polluted megacity in the world by the WHO and the UN in 1992 (WHO/UNEP, 1992), the averages are slightly above the WHO standard.

4. Fixed effect estimation

4.1. Fixed effects model

The fixed effect estimation consists of a cross-section ordinary least squares regression model with month and postal code fixed effects using dummy variables. The postal code fixed effects control for any postal code-specific conditions that do not vary during our sample time period. These could

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[7] Houses will have the same pollution readings only if they are sold in the same postal code on the same day.

[8] This interpolation method allots equal weights to sales that are relatively far from any monitoring station and those that are near at least one station. This works well as long as there exist no sales that are remotely located from all stations. Median distances in miles (with standard deviations in parentheses) to the nearest monitoring station for Guadalajara, Mexico City and Monterrey are 6.101 (2.51), 6.305 (3.372), and 3.422 (2.215), respectively.

[9] See Anselin and Gallo (2006). Another alternative is Krigging. However, this method is computationally more intensive and it is most effective when GIS coordinates are available for each housing unit.

include geographical characteristics such as distance to the different amenities, including proximity to the central business district, parks and major highways. The month fixed effects control for sources of seasonality at the MSA level in a given month that could affect housing prices such as weather conditions or holidays. The resulting fixed effect regression for each MSA is the following:

$$P^n_{j,t} = \alpha + \psi_t + \phi_j + \beta_1 \mathbf{H}^n_{j,t} + \beta_2 \mathbf{M}'_{j,t} + \beta_3 E_{j,t-l} + \varepsilon_{j,t} \tag{2}$$

where $n =$ housing unit, $t =$ date of the purchase (month, day and year), $j =$ postal code, α is the constant term and $i =$ household buying the housing unit n. The parameters ψ_t and ϕ_j represent the month and postal code fixed effects, respectively. Thus, $P^n_{j,t}$ is the amount paid for housing unit n located in the postal code j sold at date t. Similarly, $\mathbf{H}^n_{j,t}$ is the vector of physical housing characteristics of unit n and $\mathbf{M}^i_{j,t}$ are the household i characteristics, $E_{j,t-l}$ is the daily 30-day average PM10 concentrations l months before the purchase date t in postal code j, and $\varepsilon_{j,t}$ is the contemporaneous error term. In our fixed effect regression we take logs of the house price, built size, lot size, income and pollution levels.[10] The hedonic slope for pollution, β_3, represents the elasticity of housing price with respect to PM10 levels.

Anthropogenic PM10 emissions in these three MSAs come from road traffic, industrial processes, energy production, construction, and domestic and residential emissions. In particular, Querol *et al.* (2008) find that PM10 emissions changes in Mexico City are correlated with higher road traffic because of the combustion of diesel fuels (particularly by long-range and heavy transportation), combustion of gasoline and abrasion of tires and brake pads. Natural sources of PM10 emissions include erosion, burning, soil and urban dust.

4.2. *Fixed effects results*

In this section we present and analyze our results from the fixed effects regressions. We undertake separate regressions for every MSA since they represent different housing markets and use robust errors to ameliorate the effect of possible heterocedasticity in our model errors. Table 2 presents results for the baseline hedonic regression using the fixed effects estimator. Each column shows the results for each city, where MC, GUAD and MON represent Mexico City, Guadalajara and Monterrey, respectively. In this regression we take the logs of house prices and pollution levels. Regressions for each MSA and for each of the three different pollution measures, namely the '6-month-lag', the '5-month-lag' and the '4-month-lag', are done separately.

The fixed effects estimate for the 6-month lagged pollution elasticity for Guadalajara is negative and significant at the 5 per cent level, while

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[10] At the end of the results section we experiment with different specifications such as log-linear and linear-linear. We also performed a Hausman specification test to compare the fixed effects to a random effects model for each MSA. In all cases we accepted the null hypothesis in support of the fixed effects model.

Table 2. *Fixed effects hedonic regression with log of house values and pollution measures*

Variables	*MC*	*GUAD*	*MON*	*MC*	*GUAD*	*MON*	*MC*	*GUAD*	*MON*
Housing									
Lot size (m^2)	−0.21***	0.88**	0.19	−0.21**	0.88**	0.19	−0.21**	0.88**	0.18
Built size (m^2)	1.14***	0.20	0.58*	1.14**	0.20	0.58*	1.15**	0.21	0.58*
Bedrooms	−0.20***	−0.03	0.05	−0.20**	−0.03	0.05	−0.20**	−0.03	0.05
Full baths	0.23***	0.04	0.06	0.23**	0.07	0.06	0.23**	0.07	0.06
Half baths	0.06	0.16**	0.07	0.06	0.16**	0.07	0.06	0.16**	0.08
Floors	−0.44***	−0.01	0.02	−0.44**	−0.01	0.03	−0.44**	−0.01	0.03
Socioeconomic									
Monthly income	0.01	0.01	0.08**	0.01	0.01	0.08**	0.01	0.01	0.08**
Age	0.00	0.00	−0.003	0.00	0.00	0.00	0.00	−0.001	−0.002
Age squared	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Male	−0.001	0.00	0.001	−0.002	0.003	0.00	−0.001	0.004	0.001
Married	0.004**	0.00	0.01	0.005*	−0.002	0.01	0.004	−0.002	0.01
No degree	0.01	0.002	−0.04	0.01	0.001	−0.04	0.01	0.002	−0.04
Elementary	0.01	−0.002	−0.03**	−0.002	−0.003	−0.03*	−0.001	−0.003	−0.03**
High school	0.002	0.00	−0.004	0.002	0.00	−0.004	0.002	−0.001	−0.003
Technical school	−0.004	0.00	−0.03**	−0.004	0.00	−0.03**	−0.004	0.00	−0.03**
Salaried	−0.01*	−0.001	−0.01	−0.01	0.01	−0.005	−0.01	−0.001	−0.002
Informal	0.01	0.005	0.03	0.01	0.01	0.03	0.01	0.01	0.03
Business	0.002	0.003	0.01	0.001	0.004	0.01	0.002	0.003	0.01
Other work	0.01	−0.02	0.01	0.01	−0.02	0.02	0.01	−0.03	0.02
Dependents	0.002	−0.001	−0.004	0.002	−0.001	−0.003	0.002	0.00	−0.003

(*continued*)

Table 2. *Continued*

Variables	*MC*	*GUAD*	*MON*	*MC*	*GUAD*	*MON*	*MC*	*GUAD*	*MON*
Pollution									
6-month lag	0.034*	−0.04*	0.015						
5-month lag				0.03	−0.02	−0.07			
4-month lag							0.02	−0.01	−0.09*
Constant	8.98***	8.05**	8.51**	9.02**	7.97**	8.90**	9.02**	7.89**	8.97**
R-squared overall	0.64	0.80	0.67	0.64	0.78	0.66	0.79	0.79	0.66
Observations	1,546	1,141	1,580	1,546	1,141	1,580	1,546	1,141	1,580

Notes: ***, significant at 1%; **, significant at 5%; *, significant at 10%.
Each regression includes postal code and month fixed effects. Lot size, Built size and Monthly household income are in logs. The PM10 measures for the three cities are the 6-month lagged measure for Mexico City and Guadalajara and the 4-month lagged for Monterrey. The omitted categories are 'Bachelor's and above' and 'Professional'.
'R-squared overall' refers to the R-squared of the model in equation (2). 'R-squared overall' is computed as the square of the correlation between the actual values of the dependent variable and the predicted values, where the predicted values ignore the contribution of the fixed effects.
MC, Mexico City; GUAD, Guadalajara; MON, Monterrey.

those for Mexico City and Monterrey are positive and not statistically significant. For Guadalajara and Monterrey, while the 5-month and 4-month lagged pollution measures are negative, only the latter is significant at the 5 per cent level and only for Monterrey. Thus, the fixed effects estimates are erratic with regard to significance.

We briefly discuss the fixed effects coefficients of the house characteristics. House prices in Mexico City are significantly influenced by almost all of the physical characteristics of a house and the number of bedrooms has a significant but negative effect on housing values. This negative result might seem counterintuitive at first, but can be justified in the Mexican context. Conditional on the other variables, particularly lot and built sizes, it is possible that a higher number of bedrooms may reduce the size of some parts of the house such as living room, kitchen or bathrooms. Thus, the negative sign could be picking up this possible tradeoff. Contrary to Mexico City, the fixed effects results show little significance for most of the physical characteristics of houses for Monterrey and Guadalajara. Since we are not interested in these characteristics in themselves, we include them in each table for exposition purposes, but refrain from analyzing them any further.

Finally, the omitted category for education is that of 'Bachelor's and above', and that of 'Professional' for source of income. Only the few socioeconomic variables that are statistically significant are shown in table 2. As noted in section 3, the socioeconomic characteristics in our regressions merely act as a proxy for missing neighborhood attributes and are not important in themselves. Thus, we include them in the rest of the tables for exposition purposes, but we do not analyze them any further.

To correctly identify the marginal price for PM10 abatement, we need data on neighborhood characteristics such as proximity to traffic intersections or on the number of unpaved roads located near our housing units. Unfortunately, these data are not available for Mexico. Moreover, postal code fixed effects do not control for heterogeneity within postal codes that influence house prices and, despite using owner characteristics to proxy for missing neighborhood variables within postal codes, we see great variability in our fixed effects estimates. Hence, we employ the IV technique to address the potential bias from omitted factors.

5. Instrumental variable estimation

5.1. Instrumental variable model

A key factor in the success of the IV estimation is to find a valid instrument, Z_i, that is correlated with the pollution variable, E_i, but unrelated with house prices. Thus, Z_i is uncorrelated with omitted variables and the regression error, ε_i, thereby creating an exogenous source of variation in pollution levels. We use the month of closing the sale as the exogenous factor to create two groups of households, one facing higher PM10 levels, and thus lower house prices, relative to the other. The equilibrium price differential between these two groups of buyers captures the desired MTWP for PM10 abatement. We use the two-stage linear square instrumental variable (2SLS-IV) regression method to extract the MWTP estimate.

Next, we explain how we create the two groups of households experiencing different PM10 levels. We show that the natural seasonality existing in PM10 levels in Mexico can be exploited to create a valid instrument. We argue that the observed seasonality of PM10 concentrations in the MSAs in our sample is caused to some extent by the rain pattern observed in these MSAs. Mexico experiences a rainy season when, on average, about 67 per cent of all rainfall takes place (see Conagua, 2008). Ruijgrok and Römer (1993) show that rainfall is an efficient way to remove suspended particles from the atmosphere, particularly in the short run. Moreover, according to INE (2007), during the dry season (usually in the winter) there is a higher resuspension of PM10, increasing its level of concentrations. This observed seasonality in the concentrations of PM10 in the largest Mexican cities as well as their relationship with the rainy season has been widely documented (Mugica *et al.*, 2002; INE, 2003, 2007; Valle-Hernandez *et al.*, 2010).

We document the exogenous source of variation in PM10 patterns in two ways. The first is by showing the historical relationship between rainfall and PM10 levels, and the other is by showing that a similar relationship exists between the two variables over the period of our data. The graph on the left side of figure 2 shows the monthly normal rainfall over the period 1971–2000 for the three MSAs obtained from the National Meteorological System (SMN, 2011).[11] A strong seasonal pattern in rainfall exists in all three MSAs over this 30-year period, albeit at slightly different times. Mexico City and Guadalajara experience their rainy season in the summer months of June–August, while Monterrey gets its major bout of rainfall a little later, in the months of August–October. All three MSAs experience little or no rainfall in the winter months of December, January and February.

The graph on the right side of figure 2 displays the historical monthly average PM10 concentrations for our three MSAs obtained from INE (2003). This graph shows that PM10 concentrations tend to be lower in the aforementioned rainy months and higher in the dry, winter months of December–February.[12] Thus, figure 2 suggests that important differences exist in PM10 concentrations between the winter and rainy months, and that this difference is related to the rainfall observed in these months, a factor likely to be exogenous to housing prices.

In figure 3 we establish a similar connection between rainfall and PM10 levels for each MSA during the period of our data set. For each MSA the left y-axis of figure 3 measures the concentrations of PM10 in $\mu g/m^3$, while the right y-axis measures mm of rainfall. Although noisier than figure 2, the graphs in figure 3 also show that PM10 concentrations tend to be lower in

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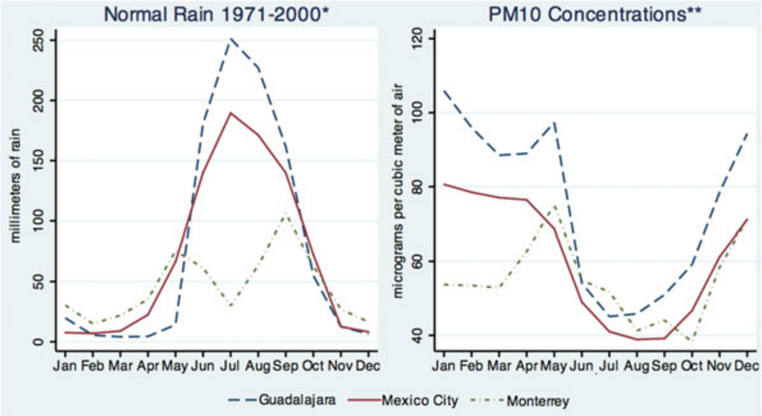
[11] Normal refers to the arithmetic average of a climate element (in this case rainfall) over a 30-day interval. The latest available normal is for the 1971–2000 period.

[12] Even though PM10 for all three MSAs starts to fall about a month before the rainy season starts, we are interested in selecting those months in the summer that fall within the reported rainy months in each of our three MSAs in order to avoid any ambiguity about the exogenous influence of our instrument.



*Normal refer to the arithmetic mean over the 1971-2000 period.

**PM10 averages for Guadalajara from 1996-2002, Mexico City 1995-2002 and Monterrey 1997-2002.

Figure 2. *Historic average monthly rainfall and PM10 concentrations, 180 × 109 mm (300 × 300 dpi)*

the reported rainy months and increase in the winter when rainfall tends to be lower. Hence, using the information in figures 2 and 3, we select June–August as the rainy months for Mexico City and Guadalajara, and those of August–October for Monterrey.[13] For all three MSAs we use the same winter months of December 2003, January 2004 and February 2004, as large differences exist in PM10 concentrations between these dry months and the aforementioned rainy months for each city.[14] Most importantly, this difference in PM10 levels is largely attributed to rainfall patterns, a factor that affects PM10 concentrations but is exogenous to housing prices. Table 3 summarizes the months selected for each MSA.

Since closing a house sale takes 4–6 months in Mexico, the group of buyers exposed to high PM10 levels during property visits close in the rainy months while those that experience low PM10 levels close in the dry, winter months. Thus, the season of closing a housing sale exogenously creates two buyer groups that experience radically different PM10 levels and the price differential between these two groups' offers captures the desired MTWP for PM10 abatement. Buyers in Mexico may be aware of the general air quality in different parts of their city due to daily announcements

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[13] Although in January/February of 2004 Monterrey experienced a large bout of rainfall, an aberration from historical patterns, PM10 levels in these winter months are still higher than those in the rainy months of August–October of 2003. However, these aberrant rains might have reduced PM10 levels by less than they would otherwise have fallen. Hence, our hedonic estimates for the pollution elasticity for Monterrey are likely to be underestimated.

[14] For instance, according to the 6-month lagged PM10 measure, we are comparing sales closing in December 2003 and experiencing the low PM10 levels of June 2003, with those that close in June 2003 and are exposed to high PM10 levels corresponding with December 2002.

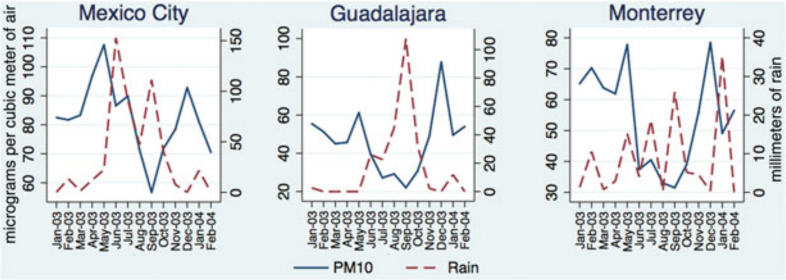

Figure 3. *Average monthly rain and PM10 concentrations (January 2003–February 2004), 105 × 39 mm (300 × 300 dpi)*

Table 3. *Selected 'rainy' and 'winter' months for each MSA*

MSAs	*Selected 'rainy' months*	*Selected 'winter' months*
Mexico City	June 2003, July 2003, August 2003	December 2003, January 2004, February 2004
Guadalajara	June 2003, July 2003, August 2003	December 2003, January 2004, February 2004
Monterrey	August 2003, September 2003, October 2003	December 2003, January 2004, February 2004

in the media. However, it is difficult to determine the air quality in the specific location of the house from these announcements alone, as they are done for large general areas (e.g., southwest, northwest). Direct exposure to PM10 at the location of the potential house makes this association easier in the mind of the buyers because PM10 is arguably the most visible of the common air pollutants. Our PM10 measures capture some of the effects of this direct exposure on buyers' perceptions during the house hunting process. Since the closing date of sale is not selected by households, it acts as a valid instrument for PM10.[15] Since the 2SLS-IV regression is restricted to the selected rainy and 'winter' months, our sample size reduces to 754 for Mexico City, and 719 each for Monterrey and Guadalajara.

A potential concern with using the natural seasonality in PM10 patterns as an instrument is that prices of property *j* could depend on unobserved variables such as sales frequency in areas proximate to it. If these variables exhibit a seasonality similar to that observed in our PM10 levels, then our instrument will not be orthogonal to the error term. However, we choose rainy and winter seasons, both being holiday months when schools are closed. Thus, seasonal factors of the housing market likely influence both seasons in similar ways, and are unlikely to affect our estimates. Hence, the

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[15] We are restricted to the months mentioned in table 3, as the period covered in our data set prevents any other meaningful comparisons.

relationship we observe between fluctuations in PM10 and house values is not spurious.

Lastly, we cannot use all of our lagged PM10 measures in the 2SLS-IV regression. For Mexico City and Guadalajara we only use the 6-month lagged PM10 because different lags will fall outside our selected rainy season. Similarly, for Monterrey, we only use the 4-month lagged measure.

The MWTP for the first stage of Rosen's hedonic method is estimated using a 2SLS-IV regression for each MSA separately. First, we regress our pollution variable against the physical characteristics of the house, the household characteristics and the season of closing (instrument) as follows:

$$E_{j,t-l} = \alpha + \psi_t + \phi_j + \gamma_1 \mathbf{H}^n_{j,t} + \gamma_2 \mathbf{M}'_{j,t} + \gamma_3 W_{j,t-l} + \xi_{j,t} \tag{3}$$

where W is the winter dummy (one in the winter months, zero otherwise). Hence, households closing their sale in the 'rainy' months constitute our omitted group. Since houses closing in 'winter' months experience lower PM10 levels relative to those closing in the rainy months, we expect γ_3 to be negative.

From (3) we compute the predicted value of the pollution variable, $\hat{E}_{j,t-l}$, to use as a regressor in the second stage of the 2SLS-IV regression, thus allowing us to extract the part of PM10 that varies mostly due to exogenous rainfall patterns. The second stage of the 2SLS-IV regression is:

$$P^n_{j,t} = \lambda + \psi_t + \phi_j + \delta_1 \mathbf{H}^n_{j,t} + \delta_2 \mathbf{M}^i_{j,t} + \delta_3 \hat{E}_{j,t-l} + \upsilon_{j,t} \tag{4}$$

where λ is the constant and $\upsilon_{j,t}$ is the error term. The estimated coefficient, δ_3, in (4) provides us with a reliable value of the elasticity of house price with respect to PM10.[16]

Finally, we test the robustness of our results with linear and logarithmic functional forms.

5.2. *Instrumental variable results*

In this subsection we present and analyze our results from the 2SLS-IV regressions and also show that, despite smaller sample sizes, the reliability of our estimates improves with the 2SLS-IV relative to the fixed effects. In addition, we test the robustness of our results by using different functional forms in the 2SLS-IV. We discard the postal codes with fewer than six observations in order to avoid using postal codes with too few observations. Although this is a somewhat arbitrary threshold, it allows us to have enough groups within each MSA. As in the fixed effect model, we undertake separate regressions for every MSA since they represent different housing markets, and use robust errors to ameliorate the effect of possible heterocedasticity.

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[16] Since all the houses in our data set are new, we do not expect to see any consistent structural problems such as flooding, roofs leaking, wetness, and the like. Moreover, we control for some neighborhood characteristics and also use a postal code dummy to consider the possibility of flood zones.

Tables 4 and 5 present results for three models under the 2SLS-IV approach. Model 1 uses the same explanatory variables as in the fixed effects model (with exception of the instrument). In Model 2, we perform the 2SLS-IV regression excluding only the socioeconomic variables that were statistically insignificant in the second-stage 2SLS-IV regression of Model 1. In Model 3, we exclude all statistically insignificant variables from the second-stage regression of Model 1. This allows us to determine if the results are substantially impacted by the statistically insignificant variables. We perform additional robustness checks on our results in section 5.3.

Table 4 shows the first-stage results from the 2SLS-IV regression where the dependent variable is the different PM10 measures: the '6-month lag' for Mexico City and Guadalajara, and the '4-month lag' for Monterrey. The coefficient of 'winter' is negative, as expected, and significant at the 1 per cent level for all models. Table 4 shows the F-statistic of our instrument ('winter') in the first-stage regression. The 'rule of thumb' is that values of 10 or less indicate a weak instrument. All our values are sufficiently large as to reject the hypothesis of a weak instrument. Given that our model is just identified, the F-statistics are much greater than 10, and the coefficients for the instrument in our first-stage regression are of the expected sign and statistically significant at 1 per cent. We do not find a clear indication that our model is not correctly specified.

Table 5 presents results from the second-stage 2SLS-IV-regression of the log of housing prices on various predicted measures of pollution from the first stage, run separately for each MSA and model. We find that the PM10 elasticities are negative and highly significant for all three cities and models as opposed to it being sporadically significant for some of the cities some of the time. The PM10 elasticities range from −0.056 to −0.074 for Mexico City, −0.050 to −0.052 for Guadalajara, and −0.071 to −0.072 for Monterrey. Monterrey has the largest pollution elasticity for all three models among the three cities. Note that while Monterrey experiences the worst PM10 levels in our sample, part of the larger elasticity could also be attributed to the use of the 4-month lagged PM10 measure for Monterrey while using the 6-month lagged PM10 measure for Mexico City and Guadalajara. Table 5 shows the F-statistic for the overall model. This value is sufficiently large, indicating that the overall model is statistically significant at the 1 per cent level.

The results of the second-stage regression across the three models for each MSA do not present substantial variations (e.g., no change in sign or major changes in magnitudes), particularly for the pollution variable. This indicates the low importance of the statistically insignificant variables of Model 1. Mexico City is the MSA with the largest change in the pollution estimate across the three models and also the MSA with the lowest number of statistically significant variables in Model 1. This suggests that in Model 3 the pollution estimate may be picking up some of the effects captured by the lot size and the half baths in Model 1.

Our 2SLS-IV estimates typically fall at the higher end of prior estimates in the hedonic literature as reported in Smith and Huang (1995) for developed cities with respect to TSP. These prior elasticities with respect to TSPs lie in the range of −0.04 to −0.07. However, most of these estimates focus

Table 4. *2SLS-IV first-stage regression with log of house price and PM10 measure*

	Mexico City			*Guadalajara*			*Monterrey*	
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*	*Model 1*	*Model 2 & 3*
Housing								
Lot size (m^2)	−0.042	−0.029		0.076	0.080**	0.009	−0.193***	−0.186***
Built size (m^2)	0.077**	0.053	0.024	−0.015	−0.018	0.027	0.132*	0.118
Bedrooms	−0.021	−0.010	−0.006	−0.007	−0.007	−0.011	0.035	0.038
Full baths	−0.086***	0.099***	0.099***	0.031	0.031	0.066***	−0.033**	−0.034**
Half baths	−0.006	−0.044		0.062***	0.062***	−0.036**	0.024*	0.024*
Floors	−0.045	−0.039	−0.028	−0.058***	−0.060***		0.003	−0.002
Socioeconomic								
Monthly income	−0.008*			0.002			0.003	0.007
Age	0.003**			−0.0002			0.002	
Age squared	−0.00004*			1.03E-06	−1.4E-06	−1.3E-06	−1.1E-05	
Male	0.002			0.003			0.0002	0.0004
Married	0.003			0.002			0.003	
No degree	0.003			0.003	−4.0E-06	−0.001	−0.001	
Elementary	0.010			−0.0004			−0.006	−0.005
High School	0.008*			−0.001			0.009	
Technical school	−0.004			−0.001			0.007	
Salaried	−0.001	−0.002	−0.001	0.001			0.038	
Informal	−0.018			0.001			0.032	−0.005
Business	−0.004			0.001			0.033	
Other work	0.025*			−0.026			0.106	0.073
Dependents	−0.002			0.001			−0.001	

(*continued*)

Table 4. *Continued*

	Mexico City			*Guadalajara*			*Monterrey*	
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*	*Model 1*	*Model 2 & 3*
Winter	−0.641***	−0.641***	−0.639***	−0.762***	−0.764***	−0.767***	−0.036***	−0.035***
Constant	4.131***	4.124***	4.085***	3.677***	3.686***	3.733***	4.574***	4.649***
R-squared	0.98	0.98	0.98	0.98	0.98	0.98	0.90	0.90
F(1, dof)	2410.0***	2329.5***	2459.8***	1288.9***	1346.4***	1358.4***	796.9***	805.3***
Observations	754	754	754	719	719	719	719	719

Notes: ***, significant at 1%; **, significant at 5%; *, significant at 10%.
Each regression includes postal code and month fixed effects. Lot size, Built size and Monthly household income are in logs. The PM10 measures for the three cities are the 6-month lagged measure for Mexico City and Guadalajara and the 4-month lagged for Monterrey. The omitted categories are 'Bachelor's and above' and 'Professional'. The *F*-statistic is for the instrument 'winter' and *dof* are the degrees of freedom that vary for each model and MSA.

Table 5. *2SLS-IV second-stage regression with log of house price and PM10 measure*

	Mexico City			*Guadalajara*			*Monterrey*	
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*	*Model 1*	*Model 2 & 3*
Housing								
Lot size (m^2)	−0.166	−0.168		0.944***	0.940***	0.906***	0.288***	0.285***
Built size (m^2)	1.325***	1.319***	1.151***	0.090***	0.095***	0.116***	1.149***	1.163***
Bedrooms	−0.349***	−0.343***	−0.321***	−0.058***	−0.056***	−0.058***	−0.155***	−0.157***
Full baths	0.390***	0.380***	0.379***	0.081***	0.074***	0.090***	0.052***	0.054***
Half baths	−0.026	−0.025		0.119***	0.117***	0.130***	0.090***	0.088***
Floors	−0.446***	−0.448***	−0.382**	−0.027	−0.029		0.259***	0.261***
Socioeconomic								
Monthly income	−0.007			0.003			0.065***	0.062***
Age	0.002			−0.0010			−0.002	
Age squared	−2.6E-05			2.1E-05*	−2.7E-06*	2.7E-06*	0.000	
Male	−0.004			0.001			0.015**	0.014**
Married	0.001			0.0005			0.002	
No degree	0.009			0.014*	0.006	0.005	0.016	
Elementary	0.005			0.002			−0.021*	−0.019*
High school	0.004			0.005			−0.015	
Technical school	−0.001			0.002			−0.017	
Salaried	−0.018*	−0.013***	−0.012***	−0.002			−0.013	
Informal	−0.010			−0.015			0.054**	0.068***
Business	−0.007			−0.004			−0.024	
Other work	−0.005			0.047			−0.051*	−0.054***
Dependents	0.0003			0.001			−0.003	

(*continued*)

Table 5. *Continued*

	Mexico City			*Guadalajara*			*Monterrey*	
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*	*Model 1*	*Model 2 & 3*
Pollution	−0.060***	−0.056**	−0.074***	−0.052***	−0.050***	−0.050***	−0.072**	−0.071**
Constant	9.075***	9.076***	8.872***	8.036***	8.140***	8.162***	6.761***	6.702***
R-squared	0.98	0.98	0.98	0.99	0.99	0.99	0.96	0.96
F	4630.7***	8765.0***	11396***	191160***	34154***	30114***	1778***	2751***
Observations	754	754	754	719	719	719	719	719

Notes: ***, significant at 1%; **, significant at 5%; *, significant at 10%.
Each regression includes postal code and month fixed effects. Lot size, Built size and Monthly household income are in logs. The PM10 measures for the three cities are the 6-month lagged measure for Mexico City and Guadalajara and the 4-month lagged for Monterrey. The omitted categories are 'Bachelor's and above' and 'Professional'. The *F*-statistic is for the overall model.

Table 6. *Sensitivity tests of 2SLS-IV regression with different functional forms*

	Mexico City	*Monterrey*	*Guadalajara*
2SLS-IV: log-log (baseline)			
Estimate (elasticity)	−0.06***	−0.07**	−0.05***
MWTP (US$)	41.73	36.34	43.37
2SLS-IV: log-linear			
Estimate	−0.001**	−0.0012**	−0.001**
Elasticity	−0.05	−0.10	−0.04
MWTP (US$)	35.96	52.33	33.39
2SLS-IV: linear-linear			
Estimate (MWTP in US$)	−46.50***	−59.39**	−57.07**
Elasticity	−0.07	−0.11	−0.07
N	754	719	719

Notes: ***, significant at 1%; **, significant at 5%; *, significant at 10%.
Each regression includes postal code and month fixed effects. The PM10 measures for the three cities are the 6-month lagged measure for Mexico City and Guadalajara and the 4-month lagged for Monterrey. The omitted categories are 'Bachelor's and above' and 'Professional'.

almost exclusively on cities in the US and are often of the 'wrong' sign or not significant. The use of the 2SLS-IV approach in our study vastly improves the precision and significance of our estimates. All of our 2SLS-IV estimates are of the 'right' sign and significant at least at the 5 per cent level. However, as expected, our estimated elasticities are smaller than the −0.2 to −0.35 range found by Chay and Greenstone (2005) using an IV approach for US counties. Nevertheless, our elasticities translate into non-trivial monetary amounts for the MWTP for PM10 abatement, particularly for a developing country.

To obtain monetary amounts (US$) for the MWTP, we multiply our respective elasticities by the corresponding averages of house prices, and then divide by the averages of the PM10 measures used. Thus, the marginal price for a unit reduction in PM10 levels is US$41.73 for Mexico City, US$43.37 for Guadalajara and US$36.34 for Monterrey. These estimates are by no means trivial and show that wealthy residents of a developing country living in cities with poor air quality do care enough to pay sufficiently high amounts for cleaner air.

5.3. *Robustness checks*

Following Cropper *et al.* (1988) we test the sensitivity of our 2SLS-IV pollution estimates to various functional forms. Cropper *et al.* (1988) shows that, in the presence of omitted variable bias, the log-linear and linear-linear functional forms perform better than those of the Box–Cox quadratic. We restrict our attention to using the log-linear and the linear-linear functional forms, as the size of our data set prevents the use of more complicated forms such as the Box–Cox quadratic. Table 6 shows the results on the pollution coefficient and its respective elasticity for different functional forms. We find that, while both functional forms slightly reduce significance levels of some of the estimates, the linear hedonic regression unambiguously increases the magnitudes of our MWTP estimates, as well as those of the elasticities derived from them. The PM10 elasticities under the linear-linear functional form relative to the baseline results rise from −0.05 to −0.07 for Guadalajara, from −0.06 to −0.07 for Mexico City, and from −0.072 to −0.11 for Monterrey. This coincides with the Cropper *et al.* (1988) finding that in the presence of omitted variables simpler functional forms for the hedonic regression perform the best.

We also check the robustness of our 2SLS-IV estimates by excluding postal codes with less than 10 and 15 observations and the results remain mostly unchanged. Only for Guadalajara and Monterrey does the significance decrease to the 10 per cent level when excluding postal codes with less than 15 observations. Thus, overall the results in this section strongly suggest that our 2SLS-IV elasticities are robust.

6. Conclusions

There is a dearth of studies that estimate the benefits of air pollution improvements in the urban areas of developing countries. This is particularly troublesome because, according to the UN (UNDESA, 2012), urban population represents 46 per cent of the total in developing countries. Furthermore, the vast majority of the world's urban population live in developing countries. We contribute to the literature by providing reliable estimates of the benefits from lower air pollution, as measured by MTWP for PM10, in a developing country.

We use a unique and detailed data set at the household level, consisting of actual market-based housing sales and measured PM10 concentrations from January 2003 to May 2004 for the three largest MSAs in Mexico: Mexico City, Guadalajara and Monterrey. We exploit the natural seasonality in PM10 patterns for Mexico to create an exogenous source of variation in potentially endogenous PM10 concentrations, using the season of closing as a valid instrument.

Our results show that urban Mexicans are willing to pay for PM10 abatement. Our estimates of the elasticity of house prices with respect to PM10 concentrations range from −0.06 to −0.07 for Mexico City, −0.05 to −0.07 for Guadalajara, and −0.07 to −0.11 for Monterrey. These elasticities translate into non-trivial amounts for the MWTP for a unit reduction in PM10 levels, particularly for a developing country: US$42–47 for Mexico City, US$43–57 for Guadalajara, and US$36–59 for Monterrey.

Our results can be particularly helpful to policy makers and researchers in developing countries in several ways. First, they provide empirical support for the notion that urban residents may be willing to pay for improved air quality. Second, our estimates may be used as one input in the calculation of benefits from air pollution abatement policies for similar cities in developing countries. A better estimation of benefits and costs can help reduce the controversy over these policies and potentially ease their implementation. Finally, caution is warranted when generalizing our results to similar cities, given that differences in income, housing and pollution types, among other variables, can affect the results.

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