Hedonic Housing Prices and Environmental Quality in Lebanon

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Abstract

Using a unique dataset from Lebanon, this paper applies a hedonic pricing approach to examine the impact of local air pollution on housing prices. To account for non-linearities in pricing, we use three different functional forms for the Hedonic Model Approach. We also deal with potential Omitted Variable Bias by estimating a Hedonic Frontier Specification. We find that, in all specifications, air pollution negatively and significantly affects housing prices. The estimated marginal willingness to pay for a one microgram per cubic meter change in PM10 concentration ranges between 2.88 and 3.18 percent of mean housing prices. We also provide evidence of a negative pricing gradient away from the city center, landing support for the monocentric urban development hypothesis.

Keywords: hedonic pricing, housing, air pollution, frontier models, Lebanon

JEL Codes: C31, Q51, Q52, R30

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1 Introduction

Estimating the cost of environmental degradation or the benefits of environmental quality improvements has often been a challenging task given the lack, in many instances, of explicit markets for environmental goods and services. A number of methods have been developed by economists to elucidate such implicit prices. Broadly, these methods follow one of the following two approaches. The first approach, known as the stated preferences approach, uses primarily survey or questionnaire data. The most popular techniques using stated preferences are contingent valuation and choice experiments. The second approach, known as revealed preference approach, elucidates implicit prices from market behavior. The most common revealed preferences techniques are the travel cost method and the hedonic pricing method (Perman et al., 2011). In this paper, we follow the latter approach by applying the hedonic pricing method to exploit the nature of our secondary data. We aim at estimating the implicit price of environmental pollution on housing prices in Lebanon. In addition to fitness to our data, a prime advantage of the hedonic pricing method is the use of actual rather than hypothetical behavior (Carson et al., 2001).

In the extant environmental economics literature, housing and land prices, be it rent or sale prices, are most commonly used by researchers to estimate the implicit price of environmental quality, given data ubiquity. These studies consider several pollution media, most notably noise (Wilhelmssonn 2000; Nelson, 2004; Affuso et al., 2019), water quality (Leggett and Bockstael, 2000; Lewis and Acharya, 2006; Bin el al., 2017; Singh et al., 2017) and air quality (Yusuf and Resosudarmo, 2009; Bajari et al., 2012). In our paper, we concentrate on the latter. While a large number of studies cover developed countries (Harrison and Rubinfeld, 1976; Nelson, 1978, 1979; Chattopadhyay, 1999; Bajari et al., 2012), fewer studies are found in developing countries such as Nigeria (Megbolugbe, 1989; Arimah, 1992), Brazil (Aryeetey-Attoh, 1992), Thailand (Crane et al., 1997), and Indonesia (Crane et al., 1997; Yusuf and Koundouri, 2005; Yusuf and Resosudarmo, 2009). To the best of our knowledge, no evidence from the Middle East and North Africa (MENA) region is reported. In our paper, we specifically study Lebanon, which is a middle-income, small-open economy located in the MENA region. The case of Lebanon is of interest especially in the aftermath of a widespread garbage crisis that erupted in 2015 and caused civil upheaval and social unrest.[1] This garbage crisis peaked in the summer of 2015 when municipal solid waste was left untreated and accumulated in makeshift landfills across the Lebanese territory. This has resulted in widespread negative environmental externalities related to odor and visual impairments, as well as water pollution (see for example Sonibare et al., 2019). In addition, this crisis increased airborne local pollution due to open air burning of garbage which is a prevalent method of dealing with garbage in Lebanon. This crisis received international media attention. Moreover, airborne pollution is found to increase respiratory and cardiovascular diseases in Lebanon (Nakhle et al. 2015; Salameh et al. 2018).

In this paper, we apply a First Stage Hedonic Approach on asking prices of all housing sales listings over the period ranging from September 2017 until June 2018 in all the Lebanese provinces. The data collected is for the post garbage crisis period, after environmental awareness was heightened among the public. We measure air pollution using Particulate Matter concentration (PM10), which is a local airborne pollutant. We apply the Hedonic Approach using three different functional forms: linear, log-linear, and log-log. To deal with the issue of the Omitted Variable Bias, we use a Hedonic Frontier Specification (Carriazo et al., 2013). We find a negative and highly significant effect of PM10 on housing prices in all our specifications. This supports the view that not only

[1] https://www.aljazeera.com/news/2016/09/lebanon-struggling-rubbish-collection-160923162318470.html
https://en.wikipedia.org/wiki/2015%E2%80%9316_Lebanese_protests

individuals in developed countries, but also those in developing countries, value environmental quality (Yusuf and Resosudarmo, 2009). Moreover, our results provide evidence that environmental quality is a normal good indicating that a society might care more about the environment as it develops (Copeland and Taylor, 2004).

Several methodologies have been used to estimate the effects of air pollution on housing prices such as the First Stage Hedonic Approach (Harrison and Rubinfeld, 1978; Nelson, 1978; Chay and Greenstone, 2005; Jim and Chen, 2006), the Second Stage Hedonic Approach (Carriazo et al., 2013; Carriazo and Gomez-Mahecha, 2018) and the spatial analysis (Kim et al., 2003; Cohen and Coughlin, 2008; Osland, 2010). The first approach uses data on prices, housing attributes and environmental quality to estimate the willingness to pay for the environmental variables. The Second Stage Hedonic Approach goes beyond the First Stage by using individuals' socio-economic characteristics to derive the demand function of environmental variables. Finally, the last methodology uses spatial statistics to account for spatial dependence. Due to data availability, we use the First Stage Hedonic Approach in our analysis. Mixed evidence has been reported on the effects of air pollution on housing prices. While some studies find a negative effect of airborne pollution on prices, others find no significant impact. Nonetheless, the majority finds negative effects on property prices, suggesting that individuals have a positive willingness to pay for environmental improvement. Smith and Huang (1995) perform a meta-analysis using studies published between 1967 and 1988 that tried to estimate the marginal willingness to pay for a reduction in particulate matter. They find that the annual marginal willingness to pay ranges from 0 to 98.52 US dollars measured in 1982-1984 dollars. Mixed evidence is also found in the meta-analysis of Boyle and Kiel (2001) on 12 US cities; however, most of the pollution effects are negative. Bui and Mayer (2003) find no effect of regulated pollutants in Massachusetts, while

Decker et al. (2005) find a negative effect of the same pollutants in Nebraska. Yusuf and Resosudarmo (2008) apply the hedonic pricing approach using data from Jakarta, Indonesia. The authors find a negative impact of local air pollution on housing rental prices with marginal willingness to pay ranging between 28 and 85 US dollars per rental unit per year. Le Boennec and Salladarre (2017) study the effect of both air pollution and noise on the housing prices in the French city of Nantes. They consider houses that have been sold between 2002 and 2008. They find that only noise, but not air pollution, affects sale prices.[2]

The paper continues as follows: Section 2 describes the data. We present the methodology in Section 3. Section 4 describes the results, and Section 5 concludes.

2 Data

Our cross-sectional data consists of a set of housing characteristics and prices, local air pollution concentration, and location characteristics.

We retrieve the housing characteristics and prices from the online repository Property Finder Lebanon.[3] We collect all housing sales listings in all the Lebanese provinces over the period ranging from September 2017 until June 2018.[4] The majority of these listings are apartment units. The listings provide the dwelling's asking price in US dollars (USD). Asking prices have been used in several studies on the housing market such as Cheshire and Sheppard (1998), Orford (2000), and Chasco and Le Gallo (2013). We use asking prices due to data limitation on

[2] While the hedonic pricing literature is extensive, providing a comprehensive overview of its results is beyond the scope of this paper.
[3] https://www.propertyfinder.com.lb/
[4] Although Lebanon has six provinces, this arrangement is purely administrative. The small size of the country and its interconnection make the housing market across the country a single market. Actual sale prices are proprietary data not available for researchers. Moreover, sale prices are distorted by misreporting for tax avoidance purposes.

equilibrium prices[5]. Asking price is systematically above the sale price indicating a consistent upward bias that affects the level of pricing but not the variation. In this paper, we report the marginal willingness to pay as a percentage of that price. In addition to the asking price, the listings include information about the dwelling's size in square meters, the number of bedrooms, bathrooms and parking spots, and the presence of a maid's room, balcony, view, artesian well, parking, furniture, terrace, built-in wardrobes, boiler, solar power, gymnasium, garden, storage, concierge, back-up electric generator, pool, central air conditioning and playground. Moreover, the listings specify whether the dwelling is part of a compound, is new, is located in a new building, and whether it is a single-floor flat in the case of apartment-listings. Our sample includes 7,320 listings.

Particulate Matter concentration (PM10) measures are taken from the air pollution database of the Lebanese Ministry of Environment.[6] The retrieved data contains daily averages measured in microgram per cubic meter over the period ranging from June 2017 until June 2018. Measurements are collected from air pollution monitoring stations spread across the Lebanese territory. For the purpose of our study, we use the yearly average concentration for each monitoring station. We match each dwelling to the closest air pollution monitoring station. The main sources of PM10 emissions in Lebanon are traffic and power plants.

We also collect several location and geographic characteristics for each listing. Distance from the economic center is proxied by the distance of the listed dwelling from the Lebanese Parliament, which is located in the city center of the capital Beirut. We also collect driving distances to major

[5] In the Lebanese context, actual transaction (equilibrium) data typically suffers from substantial and highly heterogeneous underreporting due to tax evasion purposes. Thus, using ask prices provides a more accurate cross-sectional representation of the housing market.

[6] http://www.moe.gov.lb/?lang=en-us

sources of disamenities including landfills (Costa Brava, Naameh, and Bourj Hammoud) and fossil fuel power plants (Zouk and Jieh).[7] All the distances are measured in kilometers and retrieved from Google Maps.[8] Moreover, we use Google Earth[9] to collect the altitude of the dwelling's locations measured in meters above sea level. Finally, we collect population density data, measured by person per square kilometer, for the different Lebanese towns and locations from the Center for International Earth Science Information Network (CIESIN).[10]

Table 1 describes the variable and table 2 provides summary statistics. Column 1 reports the number of observations. The mean and the standard deviation are reported in columns 2 and 3, respectively. Columns 4, 5 and 6 show the minimum, median, and maximum values, respectively. The listing prices range from USD 21,000 to USD 15 million, with a median value of USD 370,000. The average dwelling is 226.5 square meters in size and includes 2.94 bedrooms and 3.44 bathrooms. The PM10 concentration ranges from 19.16 to 48.75 microgram per cubic meter.

'Table 1 here'

'Table 2 here'

3 Methodology

We use a Hedonic Pricing approach first developed by Lancaster (1966), Griliches (1971), and Rosen (1974). An asset that is traded on the market has an equilibrium price, reflecting consumer's preferences and producer's costs. However, such an asset typically has a number of valuable attributes or characteristics. These attributes do not necessarily have an explicit price. Hence, if

[7] Even though these sources of disamenities may not be on a direct line of sight to all the housing units in our sample, they are widely recognized sources of negative externalities across Lebanon. Thus, we abstract from directly controlling for the visibility as suggested by Paterson and Boyle (2002)
[8] https://www.google.com/maps
[9] https://www.google.com/earth/
[10] http://www.ciesin.org/

the researcher is able to empirically control for these attributes, a set of implicit prices can be retrieved from the asset's equilibrium price. Most applications of the Hedonic Pricing approach are found within the Environmental Economics literature attempting to estimate the marginal willingness to pay for environmental quality. Since we are interested in the impact of air pollution on housing prices, we run the following regression in line with the recent work of Carriazo and Gomez-Mahecha (2018):

$$P_{ij} = \beta_0 + \beta_Z' Z_i + \beta_A' A_i + \beta_1 PM10_j + \lambda_j + u_{ij} \quad (1)$$

P_{ij} is the price of the dwelling i in town j, Z_i is a housing characteristics vector for each dwelling i, A_i is a location characteristics vector for dwelling i, $PM10_j$ is a measure of PM10 concentration in town j, λ_j are town fixed effects, and u_{ij} is the error term. β_Z and β_A are vectors of coefficients of the housing and location characteristics, respectively. β_1 is our coefficient of interest measuring the implicit price of a marginal change in environmental quality. All standard errors are clustered on the town level to correct for spatial autocorrelation. We use ordinary least squares (OLS) with three different functional forms to run the above regression: linear, log-linear, and log-log.[11]

Typically, models as described in equation (1) suffer from potential omitted variable bias due to the inability of the researcher to control for all pricing factors. Carriazo et al. (2013) argue that if an unobservable variable is correlated with environmental quality, then the above model will lead to biased results. To deal with this issue, they propose including two errors in the regression: a symmetric and an asymmetric one. The latter restricts errors to non-negative values reflecting unobserved changes in the omitted variable, while the former is the usual regression error component ~ $N(0,\sigma^2)$. Thus, we use the following Hedonic Frontier Specification:

[11] We use throughout robust standard errors to correct for possible heteroskedasticity problem.

$$\ln P_{ij} = \beta_0 + \beta_1 Z_i + \beta_2 A_i + \beta_3 lnPM10_j + \lambda_j + u_{ij} + v_{ij} \quad (2)$$

where v_{ij} in equation (2) is the asymmetric error term with variance specified as follows

$$\sigma_v^2 = exp(\delta_0 + \delta_1 lnZouk_i + \delta_2 lnPM10_j + \delta_3 lnZouk_i . lnPM10_j)$$

We use the variable with the highest correlation to PM10, which is the distance to the Zouk electric power plant that runs on heavy fuel oil resulting in substantial emission of airborne pollutants (Carriazo et al., 2013). The high correlation between PM10 levels and the source of air pollution is documented in several studies (Roorda-Knappe et al. 1999; Puett et al. 2014)

4 Results

4.1 OLS Results

Table 3 reports the results of the linear OLS regression. Column (1) includes PM10 and dwelling's characteristics. Column (2) adds distance variables to sources of amenities and disamenities. Lastly, column (3) adds geographic location characteristics including altitude and population density. For all three specifications, we find negative and highly significant effects of PM10 on prices at the 1 percent significance level. In addition, the dwelling's size, the number of bathrooms, the number of parking spots, the presence of a pool, being located in a new apartment building, and the distance from Bourj Hammoud landfill all have a positive and significant impact on prices. Interestingly, the distance from the city center has a negative effect that is significant at the 1 percent level. This lends support to the monocentric hypothesis stating that the price gradient is negative in all directions away from the economic center (Alonso, 1964). The capital Beirut is not only the economic center of Lebanon but also its geographic center. Surprisingly, we find that the presence of a maid's room and a generator negatively affect prices; however, the coefficients are only significant at the 10 percent level. Some of those results might be driven by the use of a linear hedonic model, which assumes that the marginal price is constant for all the characteristics (Taylor, 2017). In what follows, we relax this assumption by first running a semi-log regression and then a log-log regression.

'Table 3 here'

The results for the semi-log regression are reported in Table 4, where we take the logarithmic transformation of the prices. Again, PM10 is negative and significant at the 1 percent level for all three specifications. The following dwelling characteristics significantly increase the price: the size, the number of bathrooms and parking spots, the presence of a maid's room, storage, concierge, pool, central AC, being part of a compound, and being located in a new apartment building. Moreover, we find a negative effect of the distance from the city center that is significant at the 10 percent level in model 2. The positive effects of the distance from the Bourj Hammoud landfill, which were found in the linear model, still hold and is significant at the 10 percent level.

'Table 4 here'

In table 5, we also logarithmically transform all the non-dichotomous independent variables. In this log-log regression, the coefficients of the transformed variables are interpreted as elasticities. In all three specifications, PM10 is negative and significant at the 1 percent level. In line with the semi-log results, the same dwelling characteristics are positively related to the price at, at least, the 5 percent level. except for the presence of a maid's room. In addition, we find a negative effect for the number of bedrooms and the presence of a terrace significant at the 5 percent level. Our results suggest that, for two apartments of the same size, the one with more bedrooms will have a lower price. This could be due to the smaller size of bedrooms and/or the open area. The negative effect of the terrace could be explained by the fact that, in most Lebanese dwellings, the terrace is located on the ground floor. Our dataset does not specify the dwelling's floor number; thus, the terrace could be capturing the ground floor effect. In line with the monocentric hypothesis, the distance from the city center has a negative effect that is significant at the 1 percent level. We also find that the farther the distance from the Zouk power station and the Bourj Hammoud landfill, which are two major sources of negative environmental externalities, the higher the dwelling's price is. Those results are significant at the 1 percent and 5 percent levels, significantly. Lastly, we find a negative effect of altitude on prices significant at the 1 percent level. This effect can be explained by the geography of Lebanon, which features regions with a narrow coastal area adjacent to a mountainous area. Coastal areas have higher population densities and more concentrated economic activities. Thus, the negative effect of altitude on prices might be attributed to the distance from population and economic centers.

'Table 5 here'

4.2 Frontier Results

To deal with the potential omitted variable bias, we use the Frontier Hedonic approach suggested by Carriazo et al. (2013). Table 6 reports the results for the full specification of the log-log model, given that this specification provided the best fit in our OLS results with an R-squared equal to 0.9. In line with the OLS results, PM10 is negative and significant at the 1 percent level. Moreover, the coefficient is in the same order of magnitude as the one obtained in the OLS specification for the log-log model. Similar results are found for the dwellings' characteristics except for the presence of a pool. In addition, the monocentric hypothesis is confirmed in the Frontier Hedonic approach by the negative and highly significant effect at the 1 percent level of the dwelling's distance from the city center on prices. We also find a positive effect of the distance from the landfill of Bourj Hammoud that is significant at the 1 percent level. The negative and significant effect of altitude on prices, that we found in the OLS log-log specification, is also present in the Frontier Hedonic results and is significant at the 5 percent level. Lastly, we find a negative effect of population density on prices that is significant at the 1 percent level. Higher density neighborhoods typically include lower income households which is reflected in a lower willingness to pay for housing.

'Table 6 here'

4.3 Marginal Willingness to Pay

We use the above results to calculate the marginal willingness to pay for a one microgram per cubic meter change in PM10 concentration. The marginal willingness to pay is equal to β_1, the coefficient of PM10 in equation (1), in the linear model, β_1 x P in the semi-log model, and β_1 x (P/PM10) in the log-log model (Taylor, 2017). In order to compute the marginal willingness to pay, the researcher may choose the mean or median sample value of the price and PM10. A number of studies have used the mean such as Nelson (1978, 1979), Kryvobokov and Wilhelmsson (2007), Hoshino and Kuriyama (2010), and Carriazo et al. (2013, 2018). Others, such as Costello and Watkins (2002), advocate for the use of the mean or the median. In our study, we report the results using both the mean and the median of the price and PM10.

Panel A of Table 7 calculates the marginal willingness to pay for environmental quality using the mean values of the price and PM10 for the OLS linear, semi-log, and log-log models as well as the Hedonic Frontier model. Column 1 reports the results for the specification that includes the dwelling characteristics only. The specifications that add the distances and the geographic characteristics are reported in columns 2 and 3, respectively. Panel B of Table 7 reports the same results but using the median instead of the mean values to calculate the marginal willingness to pay.

‘Table 7 here’

The linear OLS estimates of the marginal willingness to pay are very high relative to the dwelling’s mean and median prices, which are, in our sample, USD 610,000 and USD 370,000, respectively. Indeed, the consensus in the hedonic pricing literature is that the linear OLS model does not capture the non-linearities in the pricing relationship (Brookshire et al., 1982; Haab and McConnell, 2002; Taylor, 2017). The OLS log-log estimates are more plausible and are in line with the Hedonic Frontier estimates. Using the mean, the estimated marginal willingness to pay is USD 17,548 in the log-log model and USD 19,378 in the Hedonic Frontier model. These estimated marginal willingness to pay values range between 2.88 and 3.18 percent of the mean housing price. When using the median, the marginal willingness to pay is USD 10,916 (2.95 percent) and USD 12,054 (3.26 percent) for the log-log and the frontier model, respectively. Our results are within the range found in the literature (Carriazo et al., 2018).

5 Conclusion

This paper uses a hedonic pricing approach to examine a unique dataset from Lebanon. Namely, detailed housing characteristics, location, and pollution observables are collated to examine various housing pricing specifications. We also correct for Omitted Variable Bias using the hedonic frontier specification and find a negative and highly significant effect of PM10 on prices in all specifications. The estimated marginal willingness to pay for a one microgram per cubic meter change in PM10 concentration ranges between 2.88 and 3.18 percent of mean housing prices. In addition, we provide evidence for the monocentric hypothesis by finding a negative and significant effect of the distance to the city center on housing prices.

The negative and highly significant effect of local airborne pollution on housing prices indicates that the Lebanese public highly values clean air. This finding is especially important given that the dataset covers the post garbage crisis (2015) era where environmental concerns were put at the forefront of public policy debates. This result indicates that there is genuine demand for environmental quality improvements by the Lebanese public, which might provide support for enhanced pollution regulation by the Lebanese government.

The evidence found for the monocentric hypothesis as reflected by the negative pricing gradient away from the City Center indicates that pressure exits, in terms of demand for housing, on Beirut and its suburbs, which are located in Mount Lebanon. This is indeed reflected in higher prices, as our study demonstrates. This centrally located geographic area hosts the unique passenger airport and largest port in the country. Moreover, it has the largest concentration of population and economic activity where most of universities, hospitals, and firms are based. Our results showing a steep pricing gradient are indicative of all these facts and show that there is a hedonic demand for convenience. Living close to the economic center is even more convenient due to the lack of public transportation and high traffic congestion. Indeed, only 6 percent of the Lebanese population use public transit for transportation in Beirut.[12] Moreover, car ownership in Lebanon, a middle income country, is comparable to that of high income countries.[13] The monocentric setup and the congestion challenges clearly demonstrate an urgent need for government interventions in

[12] https://www.numbeo.com/traffic/in/Beirut
[13] https://www.nationmaster.com/country-info/stats/Transport/Road/Motor-vehicles-per-1000-people

terms of investment in transportation infrastructure, especially public transit including dedicated bus lanes and light rail, both of which are currently absent (Marrouch and Mourad, 2019).

Finally, in this paper, we only consider the first stage hedonic model. When more data becomes available, future research can try to link household socioeconomic data to housing and environmental data in order to run a second stage hedonic model and calculate the willingness to pay for non-marginal changes in air pollution. Future research can also consider other sources of disamenities such as municipal solid waste and waterborne pollution.

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Table 1: Variable Description

Variable	Description
Price	asking price in USD
PM10	yearly average Particulate Matter concentration measured in microgram per cubic meter
Size	dwelling's size in square meters
Nbr of bedrooms	number of bedrooms
Nbr of bathrooms	number of bathrooms
Nbr of parking	number of parking spots
Maidroom	dummy variable equals to 1 if the dwelling has a maid's room
Balcony	dummy variable equals to 1 if the dwelling has a balcony
View	dummy variable equals to 1 if the dwelling has a view of a natural feature
Well	dummy variable equals to 1 if the dwelling has an artesian well
Furniture	dummy variable equals to 1 if the dwelling is furnished
Terrace	dummy variable equals to 1 if the dwelling has a terrace
Wardrobe	dummy variable equals to 1 if the dwelling has built-in wardrobes
Boiler	dummy variable equals to 1 if the dwelling has a central water boiler
Solar power	dummy variable equals to 1 if the apartment complex has solar power panels
Gymnasium	dummy variable equals to 1 if the apartment complex has a gymnasium
Garden	dummy variable equals to 1 if the dwelling has a garden
Storage	dummy variable equals to 1 if the dwelling has a storage room
Concierge	dummy variable equals to 1 if the apartment complex has a concierge
Generator	dummy variable equals to 1 if the apartment complex has a backup generator
Pool	dummy variable equals to 1 if the apartment complex has a swimming pool
Central AC	dummy variable equals to 1 if the dwelling has central air conditioning
Playground	dummy variable equals to 1 if the apartment complex has a kid's playground
New	dummy variable equals to 1 if the dwelling is new
Single	dummy variable equals to 1 if the dwelling is a single-floor flat
Compound	dummy variable equals to 1 if the dwelling is part of a gated compound
City center	driving distance in kilometers from the dwelling to the Lebanese Parliament in the capital
Zouk power plant	driving distance in kilometers from the dwelling to the Zouk power plant
Jieh power plant	driving distance in kilometers from the dwelling to the Jieh power plant
Costa Brava landfill	driving distance in kilometers from the dwelling to the Costa Brava landfill
Naameh landfill	driving distance in kilometers from the dwelling to the Naameh landfill
Bourj Hammoud landfill	driving distance in kilometers from the dwelling to the Bourj Hammoud landfill
Altitude	dwelling's location altitude measured in meters above sea level
Population density	town population density measured by person per square kilometers

Table 2: Summary Statistics

	N	Mean	Std Dev	Min	Median	Max
Dependent Variable						
Price	7320	610000	700000	21000	370000	15000000
Air Pollution						
PM10	7320	27.67	7.23	19.16	26.98	48.75
Dwelling Characteristics						
Size	7320	226.5	114.48	35	200	1701
Nbr of bedrooms	7320	2.94	0.66	0	3	6
Nbr of bathrooms	7300	3.44	1.15	0	3	8
Nbr of parkings	7084	1.33	0.9	0	1	8
Maidroom	7320	0.58	0.49	0	1	1
Balcony	7320	0.53	0.5	0	1	1
View	7317	0.63	0.48	0	1	1
Well	7317	0.07	0.25	0	0	1
Furniture	7318	0.12	0.32	0	0	1
Terrace	7314	0.12	0.33	0	0	1
Wardrobe	7318	0.24	0.43	0	0	1
Boiler	7318	0.03	0.18	0	0	1
Solar power	7315	0.06	0.23	0	0	1
Gymnasium	7316	0.05	0.21	0	0	1
Garden	7317	0.21	0.41	0	0	1
Storage	7318	0.33	0.47	0	0	1
Concierge	7314	0.56	0.5	0	1	1
Generator	7319	0.09	0.29	0	0	1
Pool	7319	0.04	0.2	0	0	1
Central AC	7319	0.33	0.47	0	0	1
Playground	7317	0.02	0.12	0	0	1
New	7246	0.42	0.49	0	0	1
Single	7313	0.25	0.43	0	0	1
Compound	7316	0.02	0.16	0	0	1
Location Characteristics						
City center	7320	18.26	19.18	0.1	14.2	131
Zouk power plant	7320	19.03	15.2	1	15.8	116
Jieh power plant	7320	47.3	20.53	2.2	43.4	164
Costa Brava landfill	7320	29.98	20.25	7.8	24.9	146
Naameh landfill	7320	37.82	20.63	5	33.9	155
Bourj Hammoud landfill	7320	17.06	17.91	1.8	10.4	127
Altitude	7320	273.34	269.44	4	170	1830
Population density	7320	15652.97	60751.44	0.78	3300.55	820000

Table 3: Linear OLS

VARIABLES	(1) price	(2) Price	(3) Price
PM10	-83,193***	-75,214***	-76,818***
	(1,012)	(14,402)	(15,244)
Size	3,241**	3,221**	3,208**
	(1,307)	(1,294)	(1,302)
Nbr of bedrooms	-56,205	-55,260	-55,621
	(47,768)	(46,351)	(46,390)
Nbr of bathrooms	58,992***	56,148***	57,582***
	(17,837)	(18,547)	(19,303)
Nbr of parking	130,695***	130,270***	130,187***
	(27,147)	(26,627)	(25,933)
Maidroom	-67,366*	-65,112*	-63,093*
	(35,360)	(34,607)	(35,311)
Balcony	-15,377*	-10,686	-9,618
	(7,507)	(9,887)	(10,721)
View	39,038	44,149	41,749
	(34,764)	(33,524)	(33,501)
Well	2,785	1,902	-144.4
	(21,148)	(22,427)	(22,003)
Furniture	-1,701	-7,874	-6,861
	(11,476)	(14,881)	(17,999)
Terrace	-92,753*	-90,583*	-90,302*
	(46,688)	(46,078)	(45,556)
Wardrobe	14,394	12,330	13,220
	(9,887)	(10,256)	(9,679)
Boiler	9,482	10,313	7,790
	(23,725)	(19,864)	(22,277)
Solar power	-5,673	-11,792	-9,417
	(20,736)	(20,789)	(22,690)
Gymnasium	-2,977	-18,022	-19,200
	(37,527)	(41,686)	(42,269)
Garden	-18,762	-9,726	-6,797
	(15,802)	(11,528)	(12,139)
Storage	10,484	14,127*	14,724*
	(8,637)	(8,069)	(7,403)
Concierge	-6,638	-9,390	-11,504
	(17,328)	(19,372)	(18,543)
Generator	-50,373**	-50,335**	-50,666**
	(19,111)	(18,517)	(17,560)

Pool	304,788*	302,355*	300,004*
	(162,019)	(154,326)	(154,673)
Central AC	-17,876	-15,993	-16,045
	(34,538)	(28,038)	(26,811)
Playground	44,263	35,662	37,363
	(45,594)	(46,997)	(46,561)
New	59,185**	57,024**	55,294**
	(24,901)	(22,935)	(22,075)
Single	6,181	14,836	18,024
	(82,281)	(86,130)	(84,520)
Compound	20,017	22,491	20,126
	(18,434)	(18,910)	(19,427)
City center		-71,544***	-68,346**
		(24,299)	(26,688)
Zouk power plant		7,368	9,846
		(8,012)	(7,143)
Jieh power plant		11,876	15,009
		(9,881)	(9,872)
Costa Brava landfill		1,268	-1,073
		(15,909)	(15,804)
Naameh landfill		5,668	5,608
		(12,222)	(12,943)
Bourj Hammoud landfill		43,498**	42,213**
		(17,331)	(17,089)
Altitude			-98.58
			(60.63)
Population density			-0.243
			(0.254)
Constant	2383000***	1430000	-667,904
	(258,166)	(911,810)	(713,817)
Observations	6,963	6,963	6,963
R-squared	0.698	0.706	0.707

Notes: Column 1 reports the results of the linear OLS regression for the specification that controls for the dwellings' characteristics only. Column 2 adds the distances, and column 3 adds the geographic characteristics. Standard errors clustered at the town level are reported in parentheses. Significance at the one, five, and ten percent levels is indicated by three, two, and one asterisks, respectively.

Table 4: Semi-log OLS

VARIABLES	(1) Ln Price	(2) Ln Price	(3) Ln Price
PM10	-0.060***	-0.055***	-0.058***
	(0.002)	(0.014)	(0.015)
Size	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)
Nbr of bedrooms	0.039	0.040	0.040
	(0.030)	(0.029)	(0.029)
Nbr of bathrooms	0.134***	0.133***	0.135***
	(0.014)	(0.015)	(0.016)
Nbr of parking	0.037***	0.037***	0.037***
	(0.011)	(0.011)	(0.011)
Maidroom	0.076***	0.078***	0.081***
	(0.021)	(0.021)	(0.021)
Balcony	-0.009	-0.003	-0.002
	(0.016)	(0.016)	(0.016)
View	0.002	0.008	0.004
	(0.031)	(0.029)	(0.027)
Well	-0.012	-0.011	-0.013
	(0.044)	(0.043)	(0.044)
Furniture	0.008	0.005	0.008
	(0.012)	(0.013)	(0.018)
Terrace	-0.022	-0.019	-0.018
	(0.020)	(0.022)	(0.023)
Wardrobe	-0.004	-0.005	-0.003
	(0.010)	(0.010)	(0.007)
Boiler	0.023	0.024	0.020
	(0.046)	(0.047)	(0.045)
Solar power	0.005	0.001	0.005
	(0.027)	(0.028)	(0.029)
Gymnasium	-0.022	-0.029	-0.031
	(0.031)	(0.028)	(0.031)
Garden	0.007	0.017	0.022
	(0.015)	(0.011)	(0.014)
Storage	0.044**	0.049***	0.050***
	(0.016)	(0.013)	(0.014)
Concierge	0.037**	0.037**	0.034**
	(0.018)	(0.016)	(0.016)
Generator	-0.009	-0.006	-0.007
	(0.036)	(0.038)	(0.038)
Pool	0.155*	0.156*	0.153*

	(0.086)	(0.081)	(0.079)
Central AC	0.071*	0.069**	0.069**
	(0.038)	(0.029)	(0.028)
Playground	-0.008	-0.010	-0.007
	(0.050)	(0.055)	(0.056)
New	0.031**	0.028**	0.026**
	(0.012)	(0.012)	(0.011)
Single	-0.057	-0.052	-0.047
	(0.047)	(0.052)	(0.048)
Compound	0.075***	0.072***	0.068***
	(0.011)	(0.004)	(0.006)
City center		-0.049*	-0.044
		(0.025)	(0.027)
Zouk power plant		0.007	0.011
		(0.008)	(0.008)
Jieh power plant		0.010	0.015**
		(0.007)	(0.006)
Costa Brava landfill		-0.014	-0.018
		(0.026)	(0.026)
Naameh landfill		0.014*	0.014
		(0.008)	(0.008)
Bourj Hammoud landfill		0.029*	0.027*
		(0.014)	(0.013)
Altitude			-0.0002
			(9.28e-05)
Population density			-2.62e-07
			(1.66e-07)
Constant	13.91***	13.16***	13.08***
	(0.046)	(0.504)	(0.530)
Observations	6,963	6,963	6,963
R-squared	0.869	0.872	0.873

Notes: Column 1 reports the results of the semi log OLS regression for the specification that controls for the dwellings' characteristics only. Column 2 adds the distances, and column 3 adds the geographic characteristics. Standard errors clustered at the town level are reported in parentheses. Significance at the one, five, and ten percent levels is indicated by three, two, and one asterisks, respectively.

Table 5: Log-log OLS

VARIABLES	(1) ln Price	(2) ln Price	(3) ln Price
ln PM10	-1.722***	-0.563**	-0.796***
	(0.062)	(0.210)	(0.217)
ln Size	1.091***	1.081***	1.076***
	(0.074)	(0.068)	(0.067)
ln Bedrooms	-0.205**	-0.178**	-0.172**
	(0.089)	(0.071)	(0.064)
ln Bathrooms	0.207***	0.195***	0.201***
	(0.018)	(0.028)	(0.031)
ln Parking	0.118***	0.109***	0.107***
	(0.024)	(0.026)	(0.024)
Maidroom	0.015	0.017	0.020
	(0.023)	(0.022)	(0.022)
Balcony	-0.011	-0.010	-0.010
	(0.015)	(0.013)	(0.012)
View	0.009	0.014	0.012
	(0.027)	(0.024)	(0.022)
Well	-0.017	-0.015	-0.015
	(0.038)	(0.038)	(0.038)
Furniture	-0.016	-0.023*	-0.022
	(0.010)	(0.011)	(0.015)
Terrace	-0.068**	-0.065**	-0.064**
	(0.025)	(0.027)	(0.027)
Wardrobe	-9.01e-05	-0.002	-0.001
	(0.012)	(0.012)	(0.011)
Boiler	0.043	0.044	0.046
	(0.034)	(0.036)	(0.035)
Solar power	0.003	0.005	0.011
	(0.016)	(0.019)	(0.019)
Gymnasium	0.017	-0.002	-0.001
	(0.024)	(0.019)	(0.018)
Garden	0.001	0.005	0.006
	(0.017)	(0.012)	(0.014)
Storage	0.042***	0.042***	0.045***
	(0.011)	(0.009)	(0.010)
Concierge	0.033***	0.034***	0.034***
	(0.009)	(0.008)	(0.007)
Generator	0.005	0.007	0.007
	(0.022)	(0.022)	(0.023)
Pool	0.137	0.116	0.106

	(0.080)	(0.075)	(0.076)
Central AC	0.064*	0.062**	0.062**
	(0.031)	(0.028)	(0.027)
Playground	0.009	-0.012	-0.016
	(0.047)	(0.050)	(0.050)
New	0.050***	0.049***	0.050***
	(0.010)	(0.010)	(0.009)
Single	-0.084*	-0.071	-0.069
	(0.048)	(0.055)	(0.055)
Compound	0.080***	0.075***	0.065***
	(0.019)	(0.020)	(0.014)
ln City Center		-0.248***	-0.198***
		(0.011)	(0.027)
ln Zouk		0.027***	0.054***
		(0.006)	(0.011)
ln Jieh		-0.099	-0.061
		(0.227)	(0.213)
ln Costa Brava		0.066	0.033
		(0.227)	(0.229)
ln Naameh		0.016	0.039
		(0.101)	(0.087)
ln Bourj Hammoud		0.096***	0.094**
		(0.023)	(0.039)
ln Altitude			-0.035***
			(0.007)
ln Density			-0.012
			(0.008)
Constant	13.30***	9.584***	10.40***
	(0.454)	(0.857)	(0.833)
Observations	6,085	6,085	6,085
R-squared	0.906	0.911	0.912

Notes: Column 1 reports the results of the log-log OLS regression for the specification that controls for the dwellings' characteristics only. Column 2 adds the distances, and column 3 adds the geographic characteristics. Standard errors clustered at the town level are reported in parentheses. Significance at the one, five, and ten percent levels is indicated by three, two, and one asterisks, respectively.

Table 6: Hedonic Frontier Specification

VARIABLES	(1) Ln Price	(2) Ln Price	(3) Ln Price
ln PM10	-1.633***	-0.663**	-0.879***
	(0.060)	(0.270)	(0.270)
ln Size	1.063***	1.056***	1.051***
	(0.084)	(0.079)	(0.076)
ln Bedrooms	-0.185**	-0.164**	-0.156**
	(0.093)	(0.077)	(0.069)
ln Bathrooms	0.218***	0.203***	0.206***
	(0.022)	(0.031)	(0.033)
ln Parking	0.123***	0.114***	0.113***
	(0.023)	(0.023)	(0.021)
Maidroom	0.018	0.018	0.020
	(0.024)	(0.023)	(0.023)
Balcony	-0.011	-0.010	-0.010
	(0.013)	(0.012)	(0.011)
View	0.009	0.014	0.012
	(0.026)	(0.024)	(0.022)
Well	-0.017	-0.017	-0.017
	(0.039)	(0.039)	(0.039)
Furniture	-0.015	-0.021**	-0.021
	(0.009)	(0.011)	(0.014)
Terrace	-0.073***	-0.069**	-0.068**
	(0.027)	(0.028)	(0.028)
Wardrobe	0.002	0.001	0.001
	(0.014)	(0.013)	(0.011)
Boiler	0.041	0.042	0.044
	(0.035)	(0.037)	(0.037)
Solar power	0.003	0.004	0.006
	(0.019)	(0.020)	(0.021)
Gymnasium	0.016	-0.003	-0.003
	(0.026)	(0.020)	(0.019)
Garden	-0.001	0.004	0.005
	(0.016)	(0.012)	(0.014)
Storage	0.045***	0.044***	0.046***
	(0.012)	(0.010)	(0.012)
Concierge	0.033***	0.034***	0.034***
	(0.009)	(0.009)	(0.009)
Generator	0.004	0.006	0.007
	(0.021)	(0.023)	(0.024)
Pool	0.131	0.112	0.102

	(0.082)	(0.077)	(0.078)
Central AC	0.060**	0.059**	0.060**
	(0.028)	(0.026)	(0.026)
Playground	0.002	-0.020	-0.022
	(0.052)	(0.053)	(0.053)
New	0.051***	0.051***	0.051***
	(0.012)	(0.011)	(0.010)
Single	-0.087*	-0.073	-0.070
	(0.052)	(0.059)	(0.059)
Compound	0.083***	0.076***	0.068***
	(0.022)	(0.023)	(0.018)
ln City Center		-0.243***	-0.185***
		(0.011)	(0.022)
ln Zouk		-0.101	-0.082
		(0.228)	(0.218)
ln Jieh		0.046	0.012
		(0.227)	(0.232)
ln Costa Brava		0.009	0.026
		(0.091)	(0.080)
ln Naameh		0.131***	0.123***
		(0.027)	(0.044)
ln Bourj Hammoud			-0.026**
			(0.010)
ln Altitude			-0.015**
			(0.007)
ln Density	12.95***	9.957***	10.88***
	(0.465)	(1.122)	(1.041)
Observations	6,085	6,085	6,085

Notes: Column 1 reports the results of the Hedonic Frontier Specification for the specification that controls for the dwellings' characteristics only. Column 2 adds the distances, and column 3 adds the geographic characteristics. Standard errors clustered at the town level are reported in parentheses. Significance at the one, five, and ten percent levels is indicated by three, two, and one asterisks, respectively.

Table 7: Marginal Willingness to Pay

	Panel A Mean			Panel B Median		
	(1)	(2)	(3)	(4)	(5)	(6)
OLS- linear	83,193	75,214	76,818	83,193	75,214	76,818
OLS- semi-log	36,783	33,428	35,075	22,311	20,276	21,275
OLS- log-log	37,962	12,412	17,548	23,615	7,721	10,916
frontier	36,000	14,616	19,378	22,395	9,902	12,054
Dwelling characteristics	x	x	x	x	x	x
Distance		x	x		x	x
Geographic characteristics			x			x

Notes: Panel A calculates the marginal willingness to pay using the mean values of housing prices and PM10. Panel B uses the median. In both panels, the first column reports the results for the specification that controls for the dwelling characteristics. The second column adds the distances variables, and the last column adds the geographic characteristics.