Journal of Environmental Planning and Management

ISSN: 0964-0568 (Print) 1360-0559 (Online) Journal homepage: https://www.tandfonline.com/loi/cjep20

Measuring the welfare cost of air pollution in Shanghai: evidence from the housing market

Jie Chen, Qianjin Hao & Chamna Yoon

To cite this article: Jie Chen, Qianjin Hao & Chamna Yoon (2018) Measuring the welfare cost of air pollution in Shanghai: evidence from the housing market, Journal of Environmental Planning and Management, 61:10, 1744-1757, DOI: 10.1080/09640568.2017.1371581

To link to this article: https://doi.org/10.1080/09640568.2017.1371581

Published online: 10 Nov 2017.

Journal of Environmental Planning and Management, 2018
Vol. 61, No. 10, 1744–1757, https://doi.org/10.1080/09640568.2017.1371581

Measuring the welfare cost of air pollution in Shanghai: evidence from the housing market

Jie Chen[a], Qianjin Hao[b] and Chamna Yoon[c]*

[a]*School of Public Economics and Administration, Shanghai University of Finance and Economics (SHUFE), Shanghai, P.R. China;* [b]*Department of Environmental Science and Engineering, Fudan University, Shanghai, P.R. China;* [c]*Department of Economics, Sungkyunkwan University, Jongno-gu, Seoul, Republic of Korea*

(*Received 19 May 2016; final version received 31 July 2017*)

The purpose of this study is to quantify the marginal willingness to pay (MWTP) for clean air in China. We provide the first estimate of MWTP for clean air by implementing a hedonic method using housing price and air quality data from Shanghai. Our estimates imply that air pollution has a significant and negative impact on housing price. We also find that the willingness to pay for better air quality varies significantly across different income groups. This paper helps to deepen our understanding of the economic impacts of air pollution in emerging Asian metropolises where residents are suffering from the most severe respiratory health problems.

Keywords: air pollution; housing market; hedonic method; welfare cost

1. Introduction

The increased demand for energy, a growing vehicular fleet, and industrial expansion have led to serious deterioration of air quality in China. Furthermore, with the rapid improvement of living standards, Chinese residents are increasingly concerned with the environmental quality of life, especially clean air. However, to discuss efficient government policy intervention strategies, which incur substantial costs, we need to quantify the economic value of air quality. Kan and Chen (2004) estimate the total economic cost of health impacts owing to air pollution in urban areas of Shanghai in 2001 as roughly 1% of the city's GDP. Nonetheless, the health cost is just a part of total welfare costs incurred by air pollution. Further, the situation of air pollution, as well as people's willingness to pay for clean air, has changed dramatically over the last decade. The purpose of this study is to quantify the marginal willingness to pay (MWTP) for clean air in China using the latest available data.

We implement hedonic methods using housing price and air quality data from Shanghai. The MWTP for clean air cannot be directly measured because it is not traded in the market. However, we can indirectly infer the MWTP using the relationship between air quality and housing price (Rosen 1974). Residents' location choices reflect their demand and MWTP for environmental quality. By measuring residents' MWTP for air quality, we can also compute the welfare cost of air pollution, or equivalently, the welfare benefits of clean air. In China, because residents' location choices have been largely freed and housing has become the primary asset for households since

*Corresponding author. Email: chamnayoon@skku.edu

the market-oriented development of the housing sector in 1998, the property market is suitable to measure residents' willingness to pay for environmental amenities including air quality.

We collected data on air quality from 23 ambient air quality monitoring stations in Shanghai for 2010. This data includes the monthly mean of daily concentrations of SO_2, NO_2, and PM_{10}. We also obtained data on 20,109 units of reselling apartments from 602 residential real estate projects in the downtown area (within the outer ring, or city area) of Shanghai in September 2010. Housing variables include, among others, the listing price, structural characteristics (such as construction space, number of bedrooms, level of furnishing, and year of completion), and neighborhood characteristics (such as the greening rate and the floor area ratio of projects, as well as the distance to the central business district (CBD), sub-center, subway station, and supermarket). The neighborhood characteristics of the projects are constructed based on the geographic information system (GIS) data using the ArcGIS program.

Our estimates imply that air pollution has a significant and negative impact on housing price. Ceteris paribus, a 1 microgram per cubic meter ($\mu g/m^3$) reduction in the mean concentrations of SO_2 and PM_{10} results in a 0.6% and 0.9% increase in property value, respectively.[1] We also find that the MWTP for better air quality varies significantly across different income groups.

This study primarily contributes to the literature that assesses residents' MWTP for clean air. Previous studies on economic values of clean air and welfare costs of air pollution almost exclusively focus on the USA and other developed countries (Chay and Greenstone 2005). Recently, however, researchers have begun to investigate this issue in developing countries.[2] A few studies have attempted to quantify the impact of air pollution on health in China (Saikawa *et al.* 2009; Matus *et al.* 2012). We provide an estimate of MWTP for clean air in China using housing price and air quality data in Shanghai.[3] Furthermore, we quantify the differences in MWTP for clean air across different income groups.

The remainder of this paper is organized as follows. Section 2 introduces the hedonic method of measuring economic values of air quality. Section 3 provides a brief overview of the background of air pollution in China along with a description of the data. Section 4 discusses the econometric model. Section 5 discusses the main findings of the empirical research. Section 6 estimates the welfare cost of air pollution in Shanghai. Finally, Section 7 provides the primary conclusion of the research as well as policy proposals.

2. The hedonic method

We use the hedonic price method to measure residents' MWTP for better air quality. The hedonic price framework is an appropriate modeling strategy to indirectly estimate the relationship between a marketable good, such as housing, and the associated non-marketable services it contains, such as landscape or clean air. According to the literature (see, for example, Rosen 1974), when an individual visits the real estate market to acquire a residence, he/she acquires a quantity of property with a certain quality, after considering the location and environmental characteristics of the asset. Thus, his/her perception of these characteristics in making a decision indicates that the individual is somehow valuing these particularities of a residence. In this context, changes in the parameters of environmental quality, such as poor air quality, owing to pollutant emissions by industrial units or to bad smells exhaled from landfills or sewage treatment plants, are captured by the real estate market through property prices.

Outdoor air pollution in cities results primarily from emissions from road transport, industry, heating, and commercial sources. Because the distribution of factories, roads, population, and city traffic is extremely uneven, and weather conditions can significantly influence the adsorption, migration, and diffusion of air pollutants, the air quality of different regions' inner-city areas may have significant differences. The housing character of spatial fixity implies that when residents choose the location of a property, they simultaneously express their preferences for environmental quality.

In conditions of deteriorating air quality and increasing environmental awareness, residents prefer to live in areas with better air quality to overcome/minimize the potential health risks posed by air pollution. However, property with better air quality also has a high housing price. Therefore, residents must make a trade-off between better air quality and higher housing prices, which is known as the theory of housing choice (Rosen 1974).

Within the hedonic price model framework, it is assumed that consumers' utility depends on the consumption of a differentiated good that can be represented by a vector $Z = (z_1, z_2, z_3, \ldots, z_n)$ of structural characteristics and a vector $A = (a_1, a_2, a_3, \ldots, a_n)$ of amenities (Epple 1987).

When choosing a residential property, households choose a vector A of amenities (i.e., air quality) and a vector Z of characteristics. They also choose the amount of expenditure on a (non-housing) composite good X. Households face a budget restriction Y, which can be used either for housing expenditure or to buy the composite good X. Housing expenditure is a function of the property's hedonic price $P(Z, A)$, which measures the equilibrium relationship between the price of a property, Z, and A. Households also have a vector α of socioeconomic characteristics; therefore, their preferences can be represented by a utility function,

$$U = U(Z, A, X;\ \alpha) \tag{1}$$

The households' maximization problem of the utility is as given below:

$$\max_{Z,A,X} U = U(Z, A, X;\ \alpha) \tag{2}$$

$$\text{s.t. } P(Z, A) + X = Y \tag{3}$$

From the solution to this problem, we have the consumers' bid function $\varphi(Z, A, Y, \mu, \alpha)$, which represents the MWTP for a property with characteristics Z and amenities A, with a given income and utility level. The bid function can be implicitly defined as $U\ (Z, A, Y - \varphi) = \mu$.

As income changes, the bid would also change. Moreover, the derivative of the bid function, $\frac{\partial \varphi(Z,A,Y,\mu,\alpha)}{\partial Z_i}$, gives the rate at which a household would be willing to change housing expenditure, given the increases in the characteristics and a constant utility level.

3. Background and data

3.1. Air pollution in China and Shanghai

As China continues its three decades of unprecedented growth, there has been an increasing concern that its economic miracle has come at a substantial cost to the

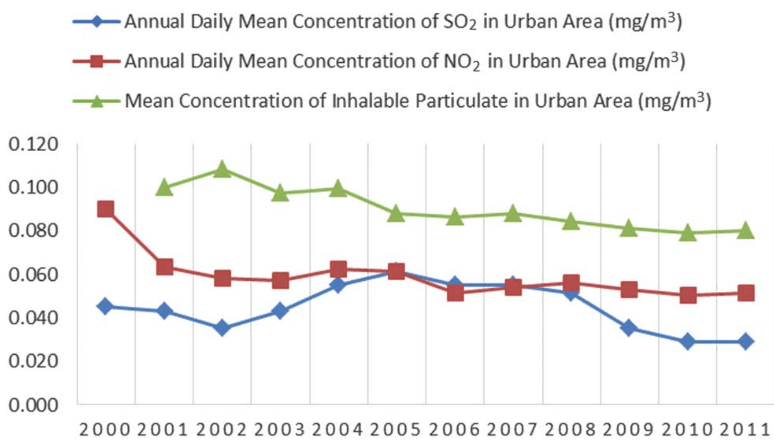

Figure 1. Air quality in Shanghai 2000–2011.

environment, both nationally and internationally. Currently, China faces severe challenges relating to its environment, including air pollution, the availability of clean water, and desertification (Matus *et al.* 2012). In particular, the increased demand for energy, the growing vehicular fleet, and industrial expansion have led to serious air quality deterioration in China. Less than 1% of the 500 largest cities in China meet the air quality standards recommended by the World Health Organization (WHO), and seven cities are ranked among the 10 most polluted cities in the world (Zhang and Crooks 2012).

We focus on air quality surrounding residential properties. Figure 1 shows the annual mean of daily concentrations of SO_2, NO_2, and PM_{10} from 2001 to 2011. The daily concentration of SO_2 for different monitoring sites in Shanghai in 2010 ranges between 22.21 and 42.80 $\mu g/m^3$ (average 30 $\mu g/m^3$), that of NO_2 ranges between 43.57 and 67.69 $\mu g/m^3$ (average 52 $\mu g/m^3$), and that of PM_{10} ranges between 62.77 and 95.78 $\mu g/m^3$ (average 80 $\mu g/m^3$). However, the mean concentrations of SO_2, NO_2, and PM_{10} in winter

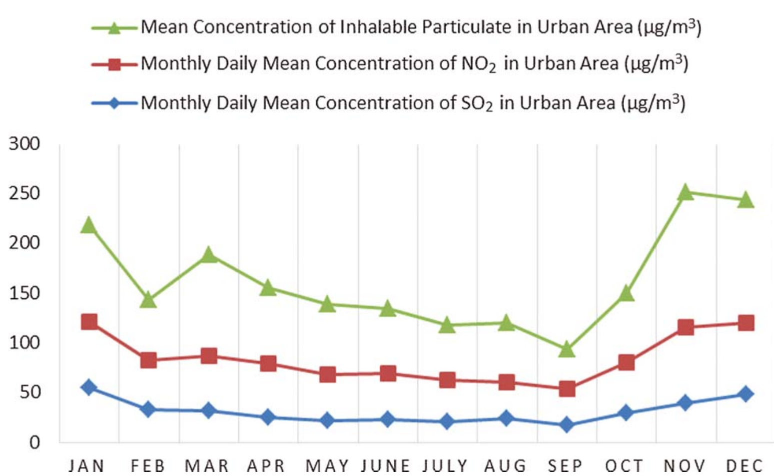

Figure 2. Air quality in Shanghai from January to December 2012.

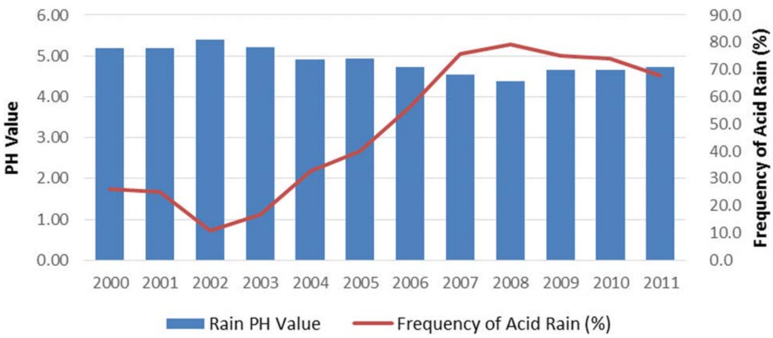

Figure 3. Acid rain condition in Shanghai 2000–2011.

are 44.71 μg/m^3, 70 μg/m^3, and 93.23 μg/m^3, respectively, which are higher than the annual mean concentrations (Figure 2). The highest mean concentrations of SO_2 and PM_{10} even reach 65.56 μg/m^3 and 104.93 μg/m^3, respectively, which are beyond the national air quality level 2 standard.[4] Figure 3 shows the average rain pH values and the frequency of acid rain[5]. in Shanghai. The average rain pH value is even lower than 5 and the frequency of acid rain has been higher than 70% since 2007. All evidence indicates severe air pollution in Shanghai, especially during the winter.

On the other hand, with the rapid improvement in living standards, Chinese residents are increasingly concerned with the environmental quality of life, such as clean air, clean water, and a clean city. In order to improve the air quality in Shanghai, the government began to increase investment in environmental protection since 2002, and this investment has always been maintained at approximately 3% of the GDP (Figure 4).

3.2. Data description

From the data collected based on 20,109 sets of houses, we estimated the average level of housing price as 26,440 RMB[6]/m^2, the lowest price being 5,337 RMB/m^2 and the highest price reaching 59,942 RMB/m^2 (Table 1).

We obtained data for air quality from 23 ambient air quality monitoring stations in Shanghai for 2010. Figure 5 shows the distribution of property projects and air quality

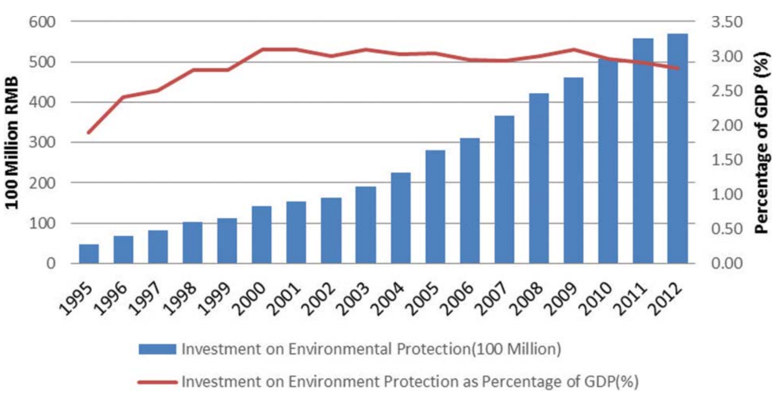

Figure 4. Investment in environmental protection in Shanghai.

Table 1. Statistical descriptions of housing characteristics.

Variable	N	Mean	Std. Dev.	Min	Max
Price	20,109	26,440.18	9,753.55	5,337.18	59,942.52
SO_2	20,109	44.62	4.55	35.93	65.56
NO_2	20,109	61.80	7.15	52.16	77.29
PM_{10}	20,109	93.43	5.81	79.96	104.93
dis_CBD	20,109	7.30	3.18	0.46	17.96
dis_subcenter	20,109	5.67	2.58	0.17	15.35
dis_rail	20,109	2.15	1.93	0.04	13.03
dis_supermarket	20,109	1.10	0.71	0.05	6.48
dis_road	20,109	0.96	0.67	0.02	3.00
Tfa	20,101	17.32	26.71	0.22	330
Green	19,958	0.43	0.09	0.15	0.73
Far	20,001	2.47	0.95	0.29	8
unit_2bed	20,109	0.52	0.50	0	1
unit_3bed	20,109	0.41	0.49	0	1
unit_material	20,109	0.91	0.28	0	1
unit_devor1	20,109	0.04	0.19	0	1
unit_devor2	20,109	0.12	0.33	0	1
Age	20,109	5.25	2.57	0	20
Abnormal	20,109	0.85	0.35	0	1

Note: This table provides statistical descriptions of housing characteristics.

Figure 5. Distribution of air monitoring sites and property projects in Shanghai.

Figure 6. Distribution of NO_2 ($\mu g/m^3$) in Shanghai.

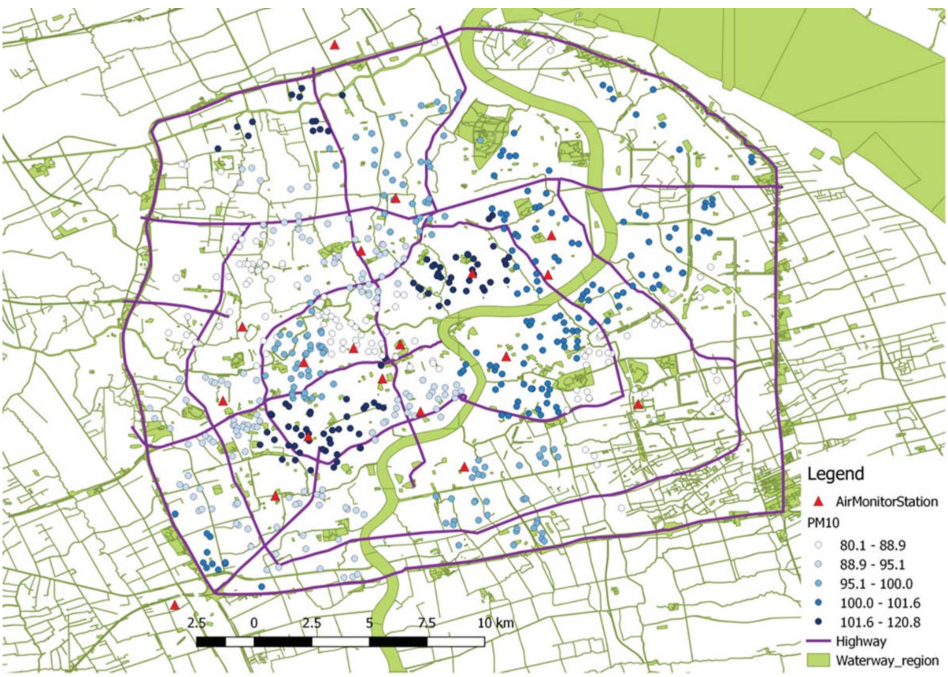

Figure 7. Distribution of PM_{10} ($\mu g/m^3$) in Shanghai.

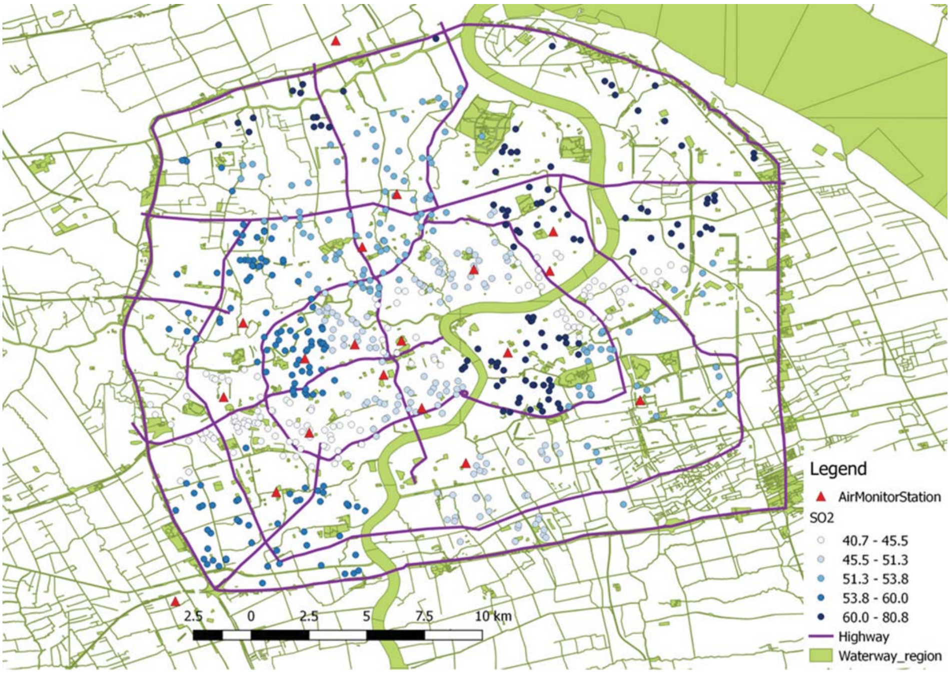

Figure 8. Distribution of SO_2 ($\mu g/m^3$) in Shanghai.

monitoring stations in the outer-ring area. This data includes the monthly mean daily concentrations of SO_2, NO_2, and PM_{10}.[7] We used the data from the nearest air monitoring station in winter to measure the housing attribute of air quality because the air pollution in winter is severe, and thus, residents could easily note the difference in air quality within urban areas.

Figures 6–8 show that air pollutants are unevenly distributed within Shanghai. Air pollution is mainly concentrated in specific local areas close to industrial zones. For example, the areas with the highest mean concentrations of SO_2 and PM_{10} are the Baoshan district, Yangpu district, and Jinqiao industry area in Pudong district, because these areas are characterized by a large number of pollutant factories such as power plants and steel mills. The areas with the highest mean concentration of NO_2 are mainly located in the inner-ring areas because of the high population and high level of traffic congestion.

4. Econometric model

As mentioned earlier, we use the hedonic price method to measure residents' MWTP for better air quality. In the hedonic price framework, housing is treated as a composite commodity in the sense that its market value is dependent on the vector of its characteristics (Lancaster 1966). In general, the characteristics that are important to assess in the market value of housing are classified into three categories: (1) structural attributes, i.e., building material, floor space, number of bedrooms and bathrooms, inner structure, age of dwelling, floor level, direction, and external appearance; (2) neighborhood attributes, i.e., dwelling maintenance and management service, parking, safety, surrounding parks and leisure facilities, and composition of neighbors in terms of age and ethnic, racial, and educational backgrounds; (3) location attributes, i.e., distance to CBD, travel and shopping convenience, and accessibility to subway/underground and public transport systems.

In its general form, the hedonic price model can be expressed as follows:

$$P = f(\mathrm{Z}_1, \ldots, Z_\mathrm{i}, \mathrm{A}_1, \ldots, \mathrm{A}_\mathrm{m}, \mathrm{u}_1) \tag{4}$$

where P denotes the price of the house, Z represents housing attributes (such as living area and number of bedrooms), A represents geographical accessibility and the neighborhood characteristics, and u_1 represents a stochastic disturbance term. However, the exact functional form of the hedonic price model varies from case to case. Usually, since prices are considered as log-normally distributed, the log-transformed price is used as a dependent variable, and we follow this procedure. For this study, we use the various distance measures as proxies of the accessibility and neighborhood characteristics. We follow the hedonic price model specification that has been widely adopted in previous studies (see, for example, Kim, Phipps, and Anselin 2003).

Because we focus on residents' willingness to pay for air quality, we include the variables of SO_2, NO_2, and PM_{10} in the hedonic price model. Our primary econometric model is based on the following equation:

$$\begin{aligned}\ln(\mathrm{price_i}) = \beta_0 &+ \beta_1 \mathrm{SO_2} + \beta_2 \mathrm{NO_2} + \beta_3 \mathrm{PM_{10}} + \beta_4 \mathrm{dis\_CDB} + \beta_5 \mathrm{dis\_subcenter} \\ &+ \beta_6 \mathrm{dis\_rail} + \beta_7 \mathrm{dis\_supermarket} + \beta_8 \mathrm{dis\_road} + \beta_9 \mathrm{tfa} + \beta_{10} \mathrm{green} \\ &+ \beta_{11} \mathrm{far} + \beta_{12} \mathrm{unit\_2bed} + 1\beta_{13} \mathrm{unit\_3bed} + \beta_{14} \mathrm{unit\_material} \\ &+ \beta_{15} \mathrm{unit\_decor1} + \beta_{16} \mathrm{unit\_decor2} + \beta_{17} \mathrm{age} + \beta_{18} \mathrm{abnormal} + \varepsilon_\mathrm{i}\end{aligned} \tag{5}$$

The detailed description of each housing attribute is provided in Table 2.

5. Empirical results

5.1. OLS results

As shown in Table 3, the basic findings of OLS regression are as follows: First, air pollutants SO_2 and PM_{10} have a significant and negative impact on housing price. Moreover, the impact of PM_{10} on housing price is higher than those of SO_2 and NO_2 because PM_{10} pollutant is more visible and more harmful than SO_2 and NO_2. Fine particulates in the air, which cause respiratory and cardiovascular diseases, are one of the key pollutants that account for a large proportion of damage to human health (Kan and Chen 2004). However, the impact of NO_2 on housing price is not significant, presumably because the concentration of NO_2 is relatively lower than the national air standard level 2, or residents are not sensitive to NO_2 pollution. This result for NO_2 is consistent with Kim, Phipps, and Anselin's (2003) finding.

Second, the implicit values of other housing characteristics are consistent with the theoretical expectation. The farther a residential property is from CBD, the lower the housing price, which is consistent with Chen and Hao (2008); the closer it is to the urban subway station and supermarket, the higher the traffic convenience and housing prices; residents show preference for houses characterized by a large floor area, high greening rate, and low housing age. What is different from our intuition is that floor area ratio

Table 2. Definition of housing characteristic variables.

Variable	Definitions
Price	Unit price, RMB/m^2
SO_2	Daily mean SO_2 concentration around a house in Winter ($\mu g/m^3$)
NO_2	Daily mean NO_2 concentration around a house in Winter ($\mu g/m^3$)
PM_{10}	Daily mean PM_{10} concentration around a house in Winter ($\mu g/m^3$)
dis_CBD	Distance to central business district (km)
Dis_subcenter	Distance to nearest sub-center (km)
dis_rail	Distance to nearest subway station (km)
dis_supermarket	Distance to nearest supermarket (km)
dis_road	Distance to nearest elevated road (km)
tfa	Total floor area (10 million square meter)
green	The green ratio is the amount of land space covered by green plants in the project.
far	The floor area ratio is the ratio of total construction space to the land area. It indicates the density of building in the project.
unit_2bed	Including 2 bedrooms? (If yes, the value is 1; if no, the value is 0)
unit_3bed	Including 3 bedrooms? (If yes, the value is 1; if no, the value is 0)
unit_material	reinforced concrete structure (If yes, the value is 1; if no, the value is 0)
unit_decor1	Simple decoration (If yes, the value is 1; if no, the value is 0)
unit_decor2	High decoration (If yes, the value is 1; if no, the value is 0)
Age	Dwelling age of property
abnormal	A house is classified as abnormal if it satisfies one of the following conditions 1) the size of house is larger than 140 m^2, 2) the price of house is higher than 2450 000 RMB and the house is within 1st city ring, 3) the price of house is higher than 1400 000 RMB and the house is outside the 1st city ring.

Note: This table provides detailed descriptions of housing attributes.

actually contributes positively to housing price, presumably because houses with higher floor area ratio have superior building quality and are more likely to have elevators, thus attracting people from higher social classes to live in them than houses with a low floor area ratio. The implied values of housing characteristics in the model are all theoretically consistent, which reflects the significant explanatory power of the model.

5.2. *Further analysis*

The literature shows that implicit prices of housing attributes may vary across different income groups (Malpezzi 2003). The MWTP for better environment will increase consistently with income (Carlsson and Johansson-Stenman 2000). In order to analyze heterogeneous MWTP for better air quality and check whether the implicit price of housing attributes is steady in different submarkets, we implement a quantile hedonic analysis on Shanghai's housing market. Whereas baseline hedonic analysis results in estimates that approximate the conditional mean of the implicit price of housing attributes, quantile hedonic analysis aims at estimating the quantiles of the implicit price of housing attributes. By testing the equivalence of the quantile estimates across quantiles, we can check whether the implicit price of housing attributes is substantially

Table 3. Regression results of hedonic price model.

Variable	Coefficient	Standard error
SO_2	-0.006^{***}	0.001
NO_2	-0.000	0.000
PM_{10}	-0.009^{***}	0.000
dis_CBD	-0.090^{***}	0.004
dis_CBD2	0.004^{***}	0.000
dis_subcenter	-0.037^{***}	0.001
dis_rail	-0.004^{**}	0.002
dis_supermarket	-0.020^{***}	0.003
dis_road	0.014^{***}	0.003
Tfa	0.00027^{***}	0.000
Green	0.253^{***}	0.025
Far	0.015^{***}	0.003
unit_2bed	-0.132^{***}	0.007
unit_3bed	-0.171^{***}	0.007
unit_material	0.016^{**}	0.007
unit_devor1	-0.034^{***}	0.010
unit_devor2	0.053^{***}	0.005
Age	-0.017^{***}	0.001
abnormal	0.319^{***}	0.005
constant	11.583^{***}	0.068

Note: This table shows the regression results of hedonic price model. Robust standard errors are in parentheses; ***stands for significance at 1% level, **stands for significance at 5% level, *stands for significance at 10% level. Number of observation is 19,922 and R-squared value is 0.579.

different across submarkets. Since higher income households choose more expensive houses, we can indirectly test whether the MWTP for better environment can vary across different income groups. The results are shown in Table 4.

Based on the coefficients of SO_2, NO_2, and PM_{10}, we observe that the MWTP for better air quality varies significantly across different quantiles. We find significant differences in MWTP for PM_{10} (the F-test value is 13.56) between high- and low-quantile, while there appear to be no significant differences for SO_2 ($F = 0.83$) and NO_2 ($F = 0.28$). Furthermore, the MWTP for reduction of the mean concentration of PM_{10} increases with

Table 4. The results of the quantile hedonic model.

Variable	q20	q40	q60	q80
SO_2	-0.007^{***}	-0.007^{***}	-0.008^{***}	-0.009^{***}
	(0.001)	(0.001)	(0.000)	(0.001)
NO_2	-0.001^{*}	-0.002^{***}	-0.002^{***}	-0.001^{***}
	(0.001)	(0.001)	(0.000)	(0.000)
PM_{10}	-0.007^{***}	-0.009^{***}	-0.010^{***}	-0.011^{***}
	(0.001)	(0.000)	(0.000)	(0.001)

Notes: This table shows the regression results of the quantile hedonic model. The estimation results for other variables besides the air quality are available upon request; *** stands for significance at 1% level, ** stands for significance at 5% level, * stands for significance at 10% level.

the improvement in housing price. Ceteris paribus, the 80th percentile housing price group pays 1.1% of the housing price, while the 20th percentile group only pays 0.7% when PM_{10} concentration reduces by 1 $\mu g/m^3$. It is interesting to note that the coefficient of NO_2 becomes significant in the quantile regression. The results above are consistent with the research by Carlsson and Johansson-Stenman (2000) and Wang *et al.* (2006).

6. Welfare cost of air pollution from Shanghai's housing market

Regarding the absolute impact of air pollution on Shanghai's housing market, our regressions suggest that the property value would drop by 159 RMB/m^2 and 238 RMB/m^2 when the mean concentrations of SO_2 and PM_{10} rise by 1 $\mu g/m^3$ (the average housing price is 26,440 RMB/m^2).

Based on these estimates, we attempt to compute the welfare loss of air pollution in Shanghai from the perspective of asset value depreciation in the whole Shanghai housing market. Since the total construction floor area space of housing stock in Shanghai in 2010 is 526.4 million m^2, we put the total estimated loss for the whole Shanghai housing market as 83.7 billion RMB and 125.3 billion RMB when mean concentrations of SO_2 and PM_{10} rise by 1 $\mu g/m^3$, respectively. The latter estimate is roughly 7.3% of the city's GDP in the same year.[8] The estimates are much larger with the results based on the method of illness cost by Kan and Chen (2004), who estimate the total economic cost of health impacts owing to particulate air pollution in urban areas of Shanghai in 2001 as approximately 625.40 million US dollars, accounting for 1.03% of the city's GDP. The two estimates are not directly comparable since they are addressing issues from different perspectives. Nonetheless, our work may still provide evidence that the residents in Shanghai are very sensitive to air pollution when they choose home locations and thus the marginal impact of air quality on property is significant.

7. Conclusion and policy implication

Under the conditions of poor air quality and growing environmental protection awareness in China, residents' demand for better air quality is increasing with improvement in income. However, previous studies on the economic value of clean air and the welfare costs of air pollution almost exclusively focus on the USA and other developed countries (Chay and Greenstone 2005). Most existing studies on the impacts of air pollution in China mainly focus on the direct effects, such as health impacts (Kan and Chen 2004) but little work has been conducted on measuring the socio-economic costs of air pollution. The main purpose of this paper is to address this gap. We implement hedonic methods using housing price and air quality data from Shanghai to quantify the marginal willingness to pay (MWTP) for clean air in China.

Based on this empirical study, we found that a 1 $\mu g/m^3$ reduction in mean concentrations of SO_2 and PM_{10} is associated with a 0.6% and 0.9% increase in the housing price in Shanghai, respectively; this approximates to 159 RMB/ m^2 and 238 RMB/m^2, respectively. Our results also show that the rich have a higher MWTP for better air quality than the poor. We also attempted to calculate the imputed welfare cost of air pollution in Shanghai from the perspective of housing market value. In 2010, this amount was estimated as 3.13 billion RMB and 4.68 billion RMB when the mean concentrations of SO_2 and PM_{10} rise by 1 $\mu g/m^3$, respectively. Overall, this paper suggests that residents in prosperous Chinese cities have high willingness-to-pay for better air quality and the

Chinese government would continuously face substantial pressure to tighten regulations and increase investment in environmental improvement.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the City University of New York [grant number TRADA-46-27]; NSFC [grant number 71203031], [grant number 7161101095], [grant number 71573166], [grant number 71173045].

Notes

1. Chay and Greenstone (2005) find that a 1 μg/m^3 reduction in TSP increases the value of housing by 0.2%–0.4%.
2. See, for example, Alberini and Krupnick (2002), Gonzalez, Leipzig, and Mazumder (2013), Kim, Phipps, and Anselin (2003), Kwak and Chun (1996), Lavín, Dresdner, and Aguilar (2011), Yang (1996), and Yusuf and Resosudarmo (2009).
3. Zheng and Kahn (2008) estimate a hedonic regression model using land parcel price and air quality in Beijing.
4. Prior to 2012, the Chinese Government used ambient air quality standards, within which the air quality level 2 standard required that the annual daily mean concentrations of SO_2, NO_2, and PM_{10} must not be higher than 60 μg/m^3, 80 μg/m^3, and 100 μg/m^3, respectively. However, since 2012, the national standard of level 2 specifies that the annual daily mean concentrations of SO_2, NO_2, and PM_{10} must not be higher than 60 μg/m^3, 40 μg/m^3, and 70 μg/m^3, respectively.
5. Rainwater with a PH value below 5.6 is considered as acid rain. 'Frequency of acid rain' means the fraction of rainfalls (per year) that are classified as acid rain.
6. The exchange rate of RMB to USD is roughly 6.4:1 in 2010.
7. The most visible air pollutant in China is the suspended particulate matter (PM_{10}). Over one-third of the monitored cities reported concentrations of PM higher than the Class II standard, which is much higher than the proportion of cities with SO_2 and NO_2 concentrations exceeding the relevant standards. SO_2 and nitrogen oxides (NOx) emitted into the atmosphere can be transformed through chemical reactions into sulfate and nitrate particles. This form of fine particulate ($PM_{2.5}$), or particulate matter that measures 2.5 μm or less in diameter, is fine enough to enter deeply into the lungs and bloodstream and cause serious health problems. The pollutant that most closely tracks developments in an industrializing and urbanizing economy is SO_2, which is primarily a combustion product of materials such as coal, fuel oil, gasoline, and diesel. (Zhang and Crooks 2012)
8. The GDP in Shanghai is 1716.6 billion RMB in 2010.

References

Alberini, A., and A. Krupnick. 2002. "Cost-of-Illness and Willingness-to-Pay Estimates of the Benefits of Improved Air Quality: Evidence from Taiwan." *Land Economics* 76 (1): 37–53.

Carlsson, F., and O. Johansson-Stenman. 2000. "Willingness to Pay for Improved Air Quality in Sweden." *Applied Economics* 32 (6): 661–669.

Chay, K. Y., and M. Greenstone. 2005. "Does Air Quality Matter? Evidence from the Housing Market." *Journal of Political Economy* 113 (2): 376–424.

Chen, J., and Q. Hao. 2008. "The Impacts of Distance to CBD on Housing Prices in Shanghai: A Hedonic Analysis." *Journal of Chinese Economic and Business Studies* 6 (3): 291–302.

Epple, D. 1987. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products." *Journal of Political Economy* 95 (1): 59–80.

Gonzalez, F., M. Leipnik, and D. Mazumder. 2013. "How Much are Urban Residents in Mexico Willing to Pay for Cleaner Air?" *Environment and Development Economics* 18 (3): 354–379.
Kan, H., and B. Chen. 2004. "Particulate Air Pollution in Urban Areas of Shanghai, China: Health-Based Economic Assessment." *Science of the Total Environment* 322 (1): 71–79.
Kim, C. W., T. T. Phipps, and L. Anselin. 2003. "Measuring the Benefits of Air Quality Improvement: A Spatial Hedonic Approach." *Journal of Environmental Economics and Management* 45 (1): 24–39.
Kwak, S., and L. G. Chun. 1996. "Estimation of the Benefit of Air Quality Improvement: An Application of Hedonic Price Technique in Seoul." In *The Economics of Pollution Control in the Asia Pacific*, edited by R. Mendelssohn and D. Shaw, 171–181. Cheltenham: Edward Elgar.
Lancaster, K. J. 1966. "A New Approach to Consumer Theory." *Journal of Political Economy* 74 (2): 132–157.
Lavín, F. V., J. Dresdner, and R. Aguilar. 2011. "The Value of Air Quality and Crime in Chile: A Hedonic Wage Approach." *Environment and Development Economics* 16 (3): 329–355.
Malpezzi, S. 2003. "Hedonic Pricing Models: A Selective and Applied Review." In *Housing Economics and Public Policy*, edited by T. O'Sullivan and K. Gibb, 67–89. Oxford: Blackwell Science.
Matus, K., K. Nam, N. Selin, L. Lamsal, J. Reilly, and S. Paltsev. 2012. "Health Damages from Air Pollution in China." *Global Environmental Change* 22 (1): 55–66.
Rosen, S. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82 (1): 34–55.
Saikawa, E., V. Naik, L. W. Horowitz, J. Liu, and D. L. Mauzerall. 2009. "Present and Potential Future Contributions of Sulfate, Black and Organic Carbon Aerosols from China to Global Air Quality, Premature Mortality and Radiative Forcing." *Atmospheric Environment* 43 (17): 2814–2822.
Wang, X. J., W. Zhang, Y. Li, K. Z. Yang, and M. Bai, 2006. "Air Quality Improvement Estimation and Assessment Using Contingent Valuation Method: A Case Study in Beijing." *Environmental Monitoring and Assessment* 120 (1–3): 153–168.
Yang, C. 1996. "Hedonic Housing Values and Benefits of Air Quality Improvement in Taipei." In *The Economics of Pollution Control in the Asia Pacific*, edited by R. Mendelssohn, and D. Shaw, 150–170. Cheltenham: Edward Elgar.
Yusuf, A. A., and B. P. Resosudarmo. 2009. "Does Clean Air Matter in Developing Countries' Megacities? A Hedonic Price Analysis of the Jakarta Housing Market, Indonesia." *Ecological Economics* 68 (5): 1398–1407.
Zhang, Q., and R. Crooks. 2012. *Toward an Environmentally Sustainable Future: Country Environmental Analysis of the People's Republic of China*. Mandaluyong City, Philippines: Asian Development Bank.
Zheng, S., and M. Kahn. 2008. "Land and Residential Property Markets in a Booming Economy: New Evidence from Beijing." *Journal of Urban Economics* 63 (2): 743–757.