Willingness to pay for clean air in China

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Figure1: Environmental Performance Index-Air Quality in 2014

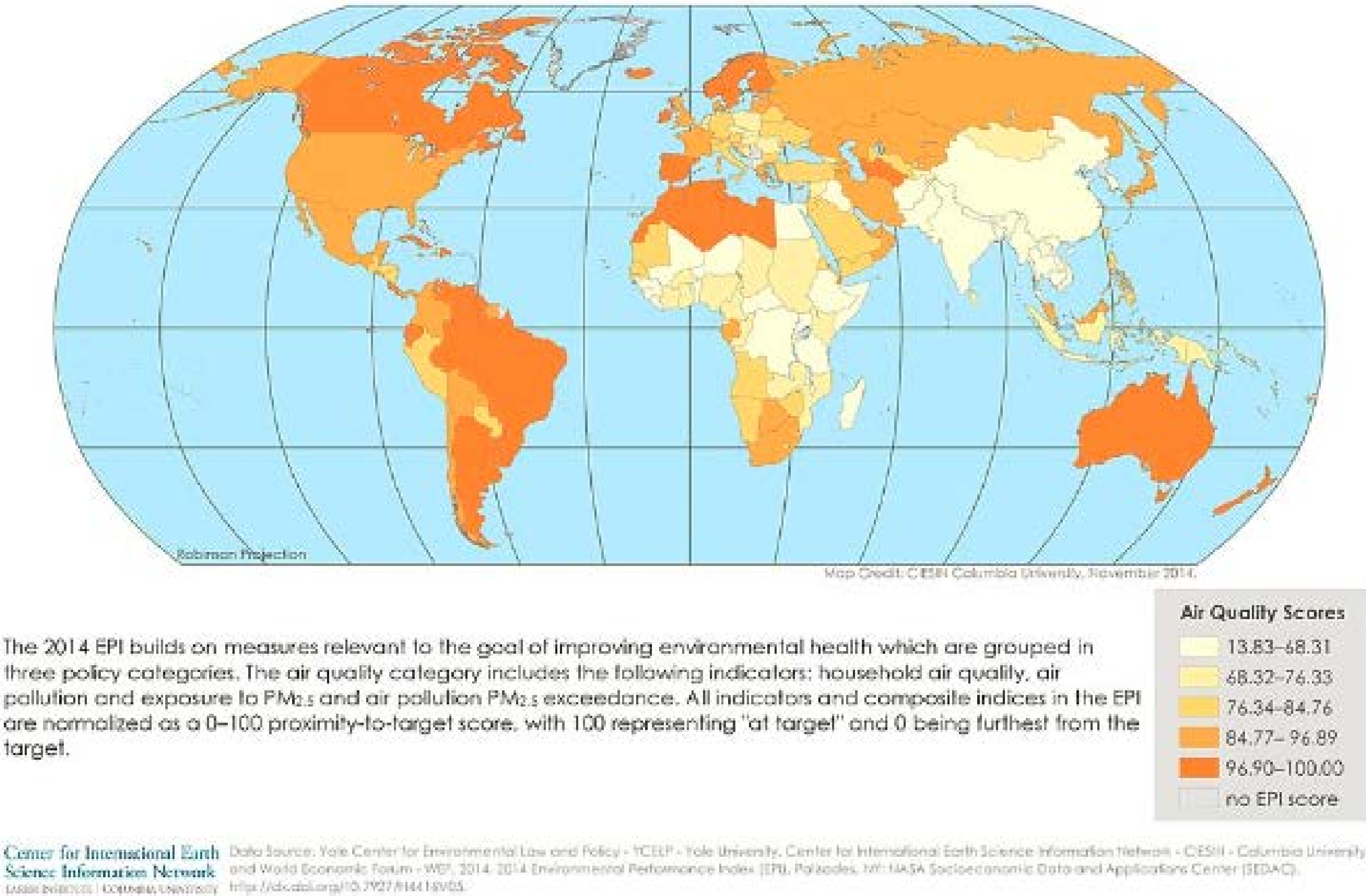


Figure2: China’s Provincial level PM2.5 in 2014

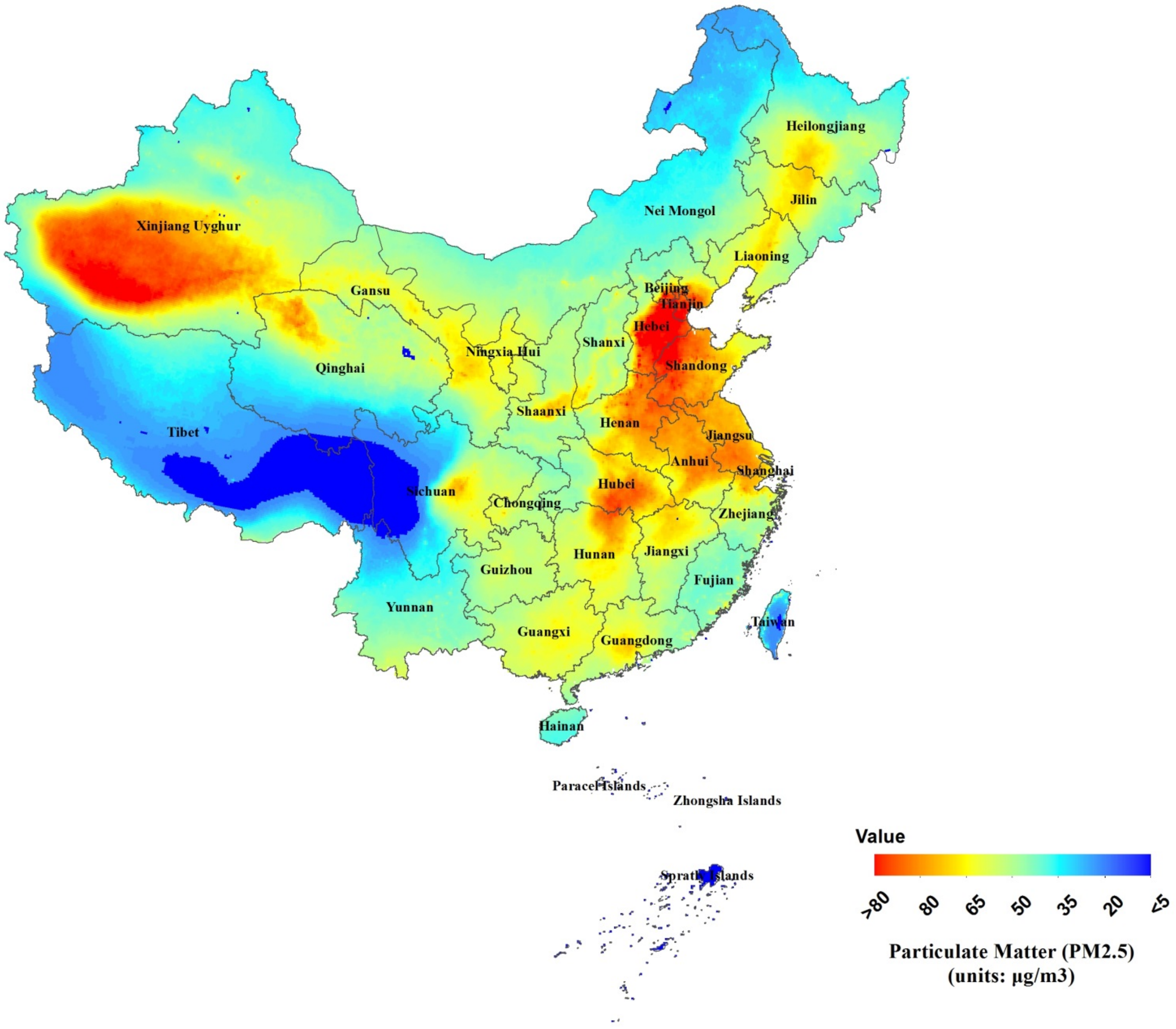
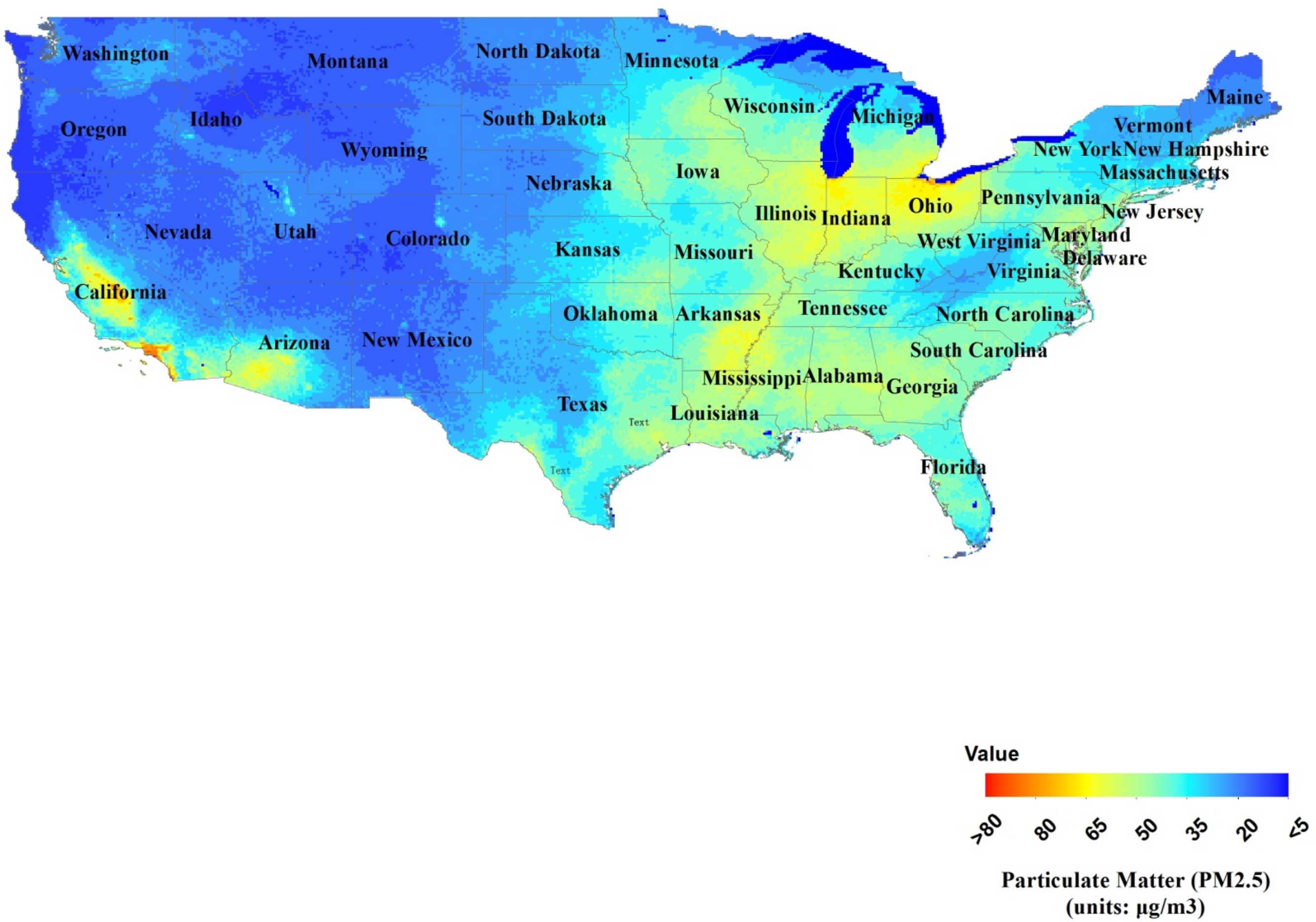


Figure3: U.S. State level PM2.5 in 2014



The central puzzle in environmental and development economics

The central puzzle at the intersection of environmental and development economics (Greenstone and Jack, 2015):

- Severe environmental pollution generates substantial health and productivity costs in developing countries.

- MWTP for environmental quality improvement is low in developing countries.

Three identification problems in hedonic models：

Table1: Identification problems in hedonic framework

Identification problems in hedonic model	Reality in developing countries
Free mobility across locations	Mobility costs are high.
Continuous joint distribution of all amenities	Regional distribution of amenities is discrete and out of balance.
Endogeneity problem	Regional distribution of air pollution is highly consistent with unobservable characteristics.

Why China？

China provides a great opportunity for the study of pollution induced sorting process, incorporating high migration costs.

- The largest developing country and second largest economy in the world
- Severe air pollution
- *Hukou* system (Household Registration) leads to high mobility costs
- Imbalanced spatial distributions of amenities and economic opportunities lead to non-random sorting.

Research Questions

- How much would the median household pay for one unit reduction in PM2.5 in China?
- Demonstrate the importance of modeling sorting process, incorporating migration costs and addressing endogeneity in the estimation of MWTP for non-market amenities in developing countries.

The contributions of our research

- **First, we provide new evidence on MWTP for clean air in developing countries, and the first application of equilibrium sorting model to the valuation of non-market amenities in China**

- The few existing studies found that households’ willingness to pay for environmental quality is extremely low in developing countries.
- So far, no study use equilibrium sorting model to estimate MWTP for non-market amenities in China, due to the unavailability of data.

The contributions of our research

- **Second, our study is conducted with the most comprehensive and detailed data available on air pollution and internal migration in China**

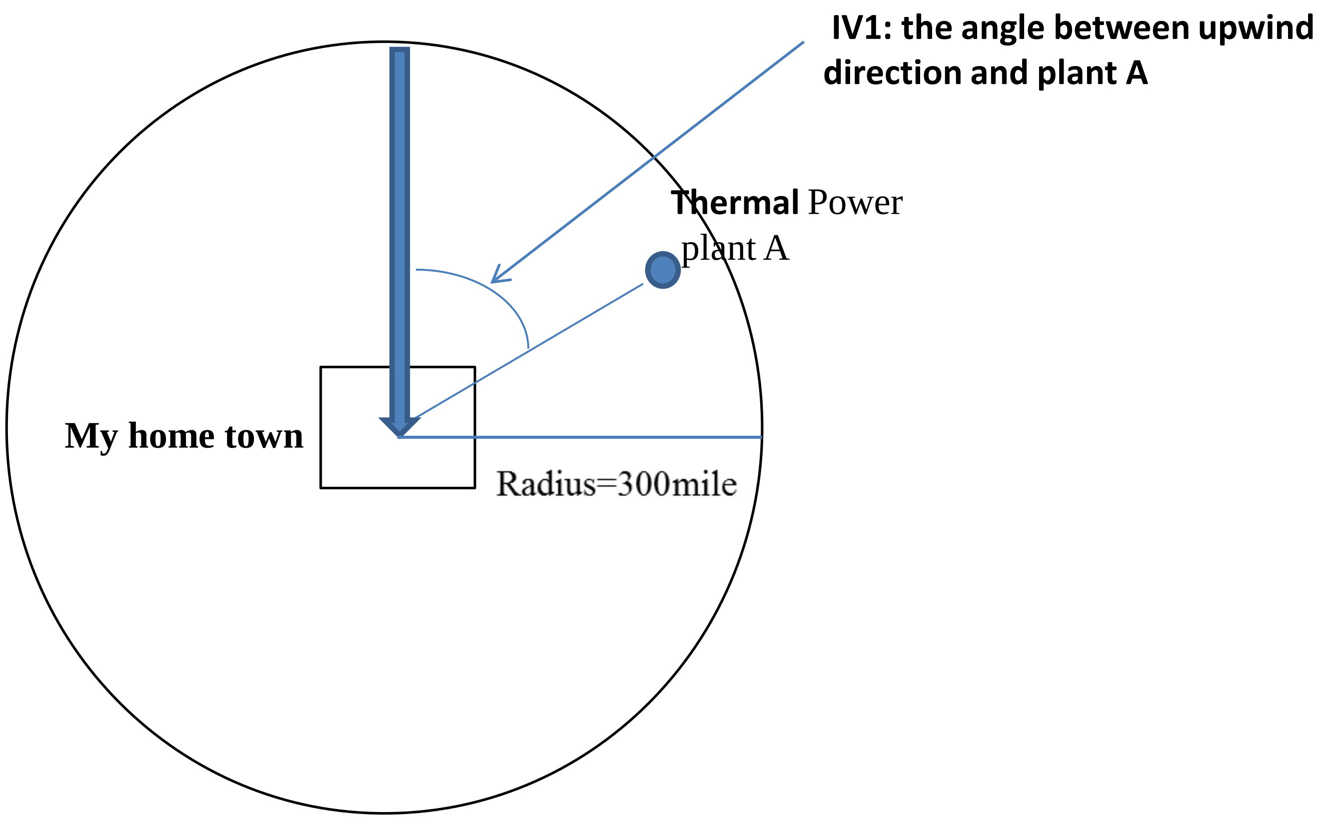
- PM2.5 data from NASA covers all the cities in China.
- China 1% National Population Sample Survey 2005 provides city level *Hukou* location and residential location, along with a wide range of sociodemographic and housing characteristic variables. **It is the only national census data that records household income in China.**

The contributions of our research

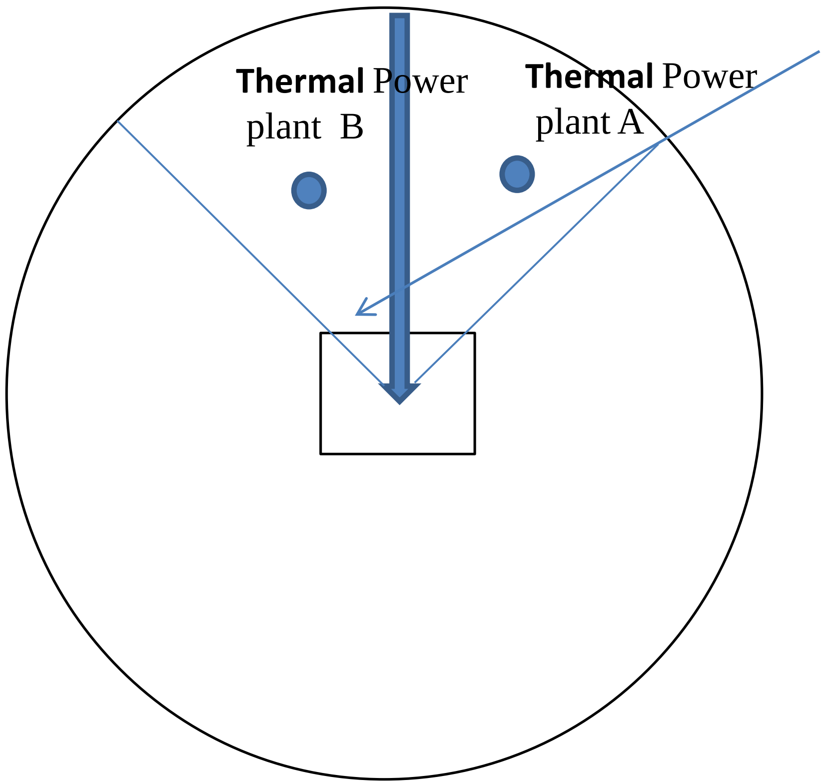
- **Third, our instrumental variable strategy contributes to the studies which identify the causal effect of air pollution.**

- Air pollution is likely to be correlated with unobservable local characteristics such as economic activity (Bayer et al., 2009).
- **IV1:** The smallest angle between the large-scale thermal power plants (genarating capacity>1million KW) and the annual dominant wind direction of the city
- **IV2:** The total coal consumption of the large-scale thermal power plants which located at upwind direction area of the city.

Our instruments



Our instruments



Upwind area of my home town

IV2: coal consumption of A + coal consumption of B

Why our instruments are exogenous?

- The wind direction is strictly exogenous.
- The large thermal power plants supply electricity to vast areas of China, some don't supply electricity to nearby cities.
- The allocation of electricity supply from large scale thermal power plants is determined by central government.
- The spillover effect of large thermal power plants on local economic activity is extremely small, but the pollutants from these plants affect the local air quality significantly.

2. A model of residential sorting

$$\max_{\{C,H,X_J\}} C_i^{\beta_c} H_i^{\beta_H} X_j^{\beta_X} e^{M_{i,j}+\xi_j+\eta_{i,j}} \quad s.t. C+\rho_j H = I_j \tag{1}$$

$$H_{i,j}^{*} = \frac{\beta_H}{\beta_H+\beta_C}\frac{I_{i,j}}{\rho_j} \tag{2}$$

$$V_{i,j} = I_{i,j}^{\beta_I} e^{M_{i,j}-\beta_H \ln\rho_j+\beta_X \ln X_j+\xi_j+\eta_{i,j}}, \quad \beta_I = \beta_H+\beta_C \tag{3}$$

$$\ln V_{i,j} = \theta_j + \beta_I \ln I_{i,j} + M_{i,j} + v_{i,j}, v_{i,j} = \beta_I \varepsilon_{i,j}^{I} + \eta_{i,j} \tag{5}$$

$$\theta_j = -\beta_H \ln\rho_j + \beta_X \ln X_j + \xi_j \tag{6}$$

$$MWTP_i = (\beta_X / \beta_I)(I_{i,j} / X_j) \tag{7}$$

A model of residential sorting

The probability that household i settles in location j can be written as

$$P(\ln V_{i,j} \geq \ln V_{i,l}, \forall l \neq j) = \frac{\exp(\theta_j + \beta_I \ln I_{i,j} + M_{i,j})}{\sum_{q=1}^{J} \exp(\theta_j + \beta_I \ln I_{i,q} + M_{i,q})} \quad (8)$$

Following Dahl et al. (2002), we deal with Roy's sorting problem in the estimation of counter-factual income.

3. Econometric Specification: measure migration costs

Consider the heterogeneities of the barriers to obtain local *Hukou* and economic opportunities available for migrants across cities of different administrative ranking, we assume:

$$M_{ij} = \mu_1 D_{1,ij} + \mu_2 D_{2,ij} + \mu_3 D_{3,ij} + \mu_4 D_{1,ij} \times D_{4,ij} + \mu_5 D_{1,ij} \times D_{5,ij} + \mu_6 D_{1,ij} \times D_{6,ij} \qquad (9)$$

$D_{1,ij}$： Whether city *j* is outside household *i*'s *hukou* city

$D_{2,ij}$： Whether city *j* is outside household *i*'s *hukou* province

$D_{3,ij}$： Whether city *j* is outside household *i*'s macro regions

$D_{4,ij}$： Whether the city *j* is Bejing or Shanghai.

$D_{5,ij}$： Whether the city *j* is *sub*-provincial level cities (including Tianjin and Chongqing).

$D_{6,ij}$： Whether the city j is provincial capital.

3. Econometric Specification: first-stage discrete choice model

$$L\left(\theta_j, \beta_I, \mu_{Dis}, \mu_{Hukou}\right) =$$

$$\prod_i \prod_j^J \left[\frac{\exp(\theta_j + \beta_I \ln \hat{I}_{i,j} + \mu_1 D_{1,ij} + \mu_2 D_{2,ij} + \mu_3 D_{3,ij} + \mu_4 D_{4,ij} + \mu_5 D_{3,ij} + \mu_6 D_{4,ij})}{\sum_{q=1}^{J} \exp(\theta_q + \beta_I \ln \hat{I}_{i,q} + \mu_1 D_{1,ij} + \mu_2 D_{2,ij} + \mu_3 D_{3,ij} + \mu_4 D_{4,ij} + \mu_5 D_{3,ij} + \mu_6 D_{4,ij})} \right]^{\chi_{i,j}} \quad (10)$$

$$\theta_j + \beta_H \ln \rho_j = \beta_X \ln X_j + \xi_j \quad (11)$$

IV1: The smallest angle between the large scale thermal power plants (generating capacity>1million KW) and the annual dominant wind direction of the city.

IV2: The total coal consumption of the large scale thermal power plants which located at upwind direction area of the city.

4. Data：pm2.5 data from NASA

- Existing studies on China's air pollution issue typically use Air Pollution Index (API) and PM10 data from the Ministry of Environmental Protection in China.

- API and PM10 data can only be obtained in large and medium-sized cities in China , and PM2.5 data was not published until 2014.

- A potential concern of the official air quality data is that it may be manipulated by local government (Chen et al., 2013, Ghanem and Zhang, 2014)

- We collect annual average city level PM2.5 using Global Annual PM2.5 Grids from NASA .The raster grids of this ground calibrated PM2.5 data have a high grid cell resolution of 0.01 degree.

4. Data：Migration data

- China 1% National Population Sample Survey 2005 was conducted by the National Bureau of Statistics in China. The sample size is 2,585,481.

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- The variables contains age, gender, *Hukou* type (rural/ urban), *Hukou* location, current residencial location, educational level, marital status, employment status , occupation, income, housing costs, housing characteristics etc .

- Drop the observations if the age of household head is more than 35 or the house was built before 1990, and there are 59,008 households in our sample.

5. Estimation results

Table 2：Results from conventional hedonic regression

Dependent Variable	OLS			IV	
	(1)	(2)	(3)	(5)	(6)
Average household income	0.004	0.191***	0.185***	-0.012	0.027
	(0.054)	(0.039)	(0.037)	(0.109)	(0.110)
The price of housing service	0.110	0.436**	0.481**	-0.305	-0.371
	(0.127)	(0.191)	(0.197)	(0.597)	(0.599)
Other local amenities	No	Yes	Yes	Yes	Yes
Local Industrial Emission	No	No	Yes	No	Yes

5. Estimation results

Table 3：Estimated MWTP for clean air from hedonic regression

MWTP($)	No covariates	No control for industrial emission	Full specification
OLS	-0.467	-9.052	-9.115
2SLS		1.298	3.033

5. Estimation results

Table4: First stage discrete choice model of residential location decision

Variable	Coefficient
ln(Counter-factual Income)	1.621***
Out of *hukou* city dummy ($D_{1.ii}$)	- 6.846 ***
Out of *hukou* province dummy ($D_{2.ii}$)	-2.102***
Out of *hukou* macro region dummy ($D_{3.ii}$)	-1.991 ***
Out of *hukou* city dummy ($D_{1.ii}$) $\times$ Beijing/Shanghai dummy ($D_{4.ii}$)	4.558 ***
Out of *hukou* city dummy ($D_{1.ii}$) $\times$ Sub-provincial city dummy ($D_{5.ii}$)	2.364***
Out of *hukou* city dummy ($D_{1.ii}$) $\times$ provincial capital dummy ($D_{6.ii}$)	1.587 ***
City fix effect	Yes

Table 5: Second stage estimation: OLS regression

Dependent variable: $\theta_j + \beta_h \ln \rho_j$	(1)	(2)	(3)
ln (PM25)	-0.459***	-0.671***	-0.622***
	(0.149)	(0.168)	(0.167)
ln (The number of public school per capita)		0.690***	0.692***
		(0.123)	(0.129)
ln (The area of road per capita)		-0.063	-0.080
		(0.179)	(0.180)
ln (Environmental infrastructure		0.051	0.065
expenditure per capita)		(0.055)	(0.056)
ln (GDP per capita)		0.690***	0.782***
		(0.190)	(0.201)
ln (Population)		-0.242**	-0.167
		(0.108)	(0.132)
ln (The minimum distance to three largest		-0.573***	-0.551***
sea ports)		(0.123)	(0.122)
ln (Industrial SO2 emission)			-0.094
			(0.074)
ln (Industrial waste water emission)			-0.023
			(0.087)
Constant	2.169***	0.481	0.039
	(0.522)	(2.227)	(2.219)
Obs.	285	280	280
R2	0.019	0.398	0.404

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: The correlation between PM2.5 and the instrumental variables

Dependent variable: ln (PM2.5)	(1)	(2)	(3)
The smallest angle between the large thermal power plants and the upwind direction	-0.060***	-0.043***	-0.042***
	(0.013)	(0.013)	(0.012)
The coal consumption of thermal power plants located at upwind direction area	0.009***	0.005***	0.005***
	(0.002)	(0.002)	(0.002)
ln (The number of public school per capita)		-0.174***	-0.146***
		(0.042)	(0.045)
ln (the area of road per capita)		0.076*	0.075*
		(0.045)	(0.044)
ln (Environmental infrastructure expenditure per capita)		-0.023	-0.027
		(0.019)	(0.019)
ln (GDP per capita)		-0.036	-0.089*
		(0.048)	(0.046)
ln (Population)		0.160***	0.088**
		(0.034)	(0.038)
ln (The minimum distance to three largest sea ports)		-0.079***	-0.080***
		(0.024)	(0.024)
ln (Industrial SO2 emission)			0.021
			(0.021)
ln (Industrial waste water emission)			0.071**
			(0.034)
Constant	3.603***	3.676***	3.785***
	(0.039)	(0.563)	(0.549)
Obs.	280	280	280
R2	0.204	0.391	0.414

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table7: Result from second stage regression, 2SLS regression using IV1 and IV2

Dependent variable: $\theta_j + \beta_h \ln \rho_j$	(1)	(2)
ln(PM25)	-1.202**	-1.125*
	(0.611)	(0.619)
ln (The number of public school per capita)	0.599***	0.617***
	(0.155)	(0.156)
ln (The area of road per capita)	0.000	-0.019
	(0.185)	(0.188)
ln (Environmental infrastructure	0.042	0.053
expenditure per capita)	(0.056)	(0.058)
ln (GDP per capita)	0.647***	0.711***
	(0.197)	(0.216)
ln (Population)	-0.146	-0.113
	(0.156)	(0.151)
ln (The minimum distance to three largest harbor)	-0.639***	-0.617***
	(0.171)	(0.172)
ln (Industrial SO2 emission)		-0.076
		(0.077)
ln (Industrial waste water emission)		0.006
		(0.092)
Constant	2.701	2.211
	(3.482)	(3.572)
Obs.	280	280
R2	0.380	0.388

Note: Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 8：Estimated marginal willingness to pay for air quality

MWTP($)		No covariates	No control for local industrial emission	Full specification
Hedonic model	OLS	-0.467	-9.052	-9.115
	2SLS		1.298	3.033
Sorting model incorporating mobility costs	OLS	9.805	14.345	13.286
	2SLS		25.680	24.026

Table 9：Interpretation of our results

	WTP($)	The share of WTP in household income
1 unit reduction in PM2.5	24.026	1.622%
1 SD reduction in PM2.5	354.970	23.964%

Table 10：Estimated marginal willingness to pay for air quality:
using different distance to construct instrumental variables

MWTP($)	No control for industrial emission	Full specification
Distance<250 mile	22.235	21.487
Distance<275 mile	24.839	23.922
Distance<300 mile	25.680	24.026
Distance<325 mile	23.136	21.166
Distance<350 mile	29.386	27.615

Conclusion:

- The median household would pay $24.026-$25.680 for one unit reduction in PM2.5?
- Ignoring sorting process and mobility costs will likely misrepresent the economic benefits of environmental quality improvement in developing countries.

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Thank you so much!
谢谢大家！