Willingness to Pay for Clean Air: Evidence from Air Purifier Markets in China

Koichiro Ito
University of Chicago & NBER

Shuang Zhang
University of Colorado Boulder

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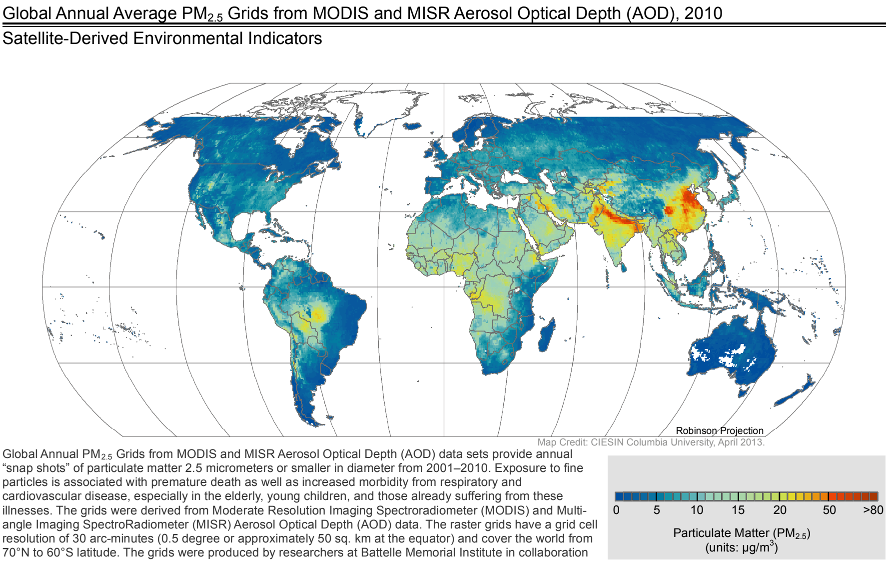
Air pollution is very severe in developing countries



Research question: How much are people willing to pay for clean air in developing countries?

- Severe air pollution $\Rightarrow$ Health and economic costs
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  - Significant health and economic costs of pollution (Jayachandran 2009; Greenstone and Hanna 2014; Hanna and Oliva 2015)
- High costs of pollution $\not\Rightarrow$ Current env. regulations are not optimal
  - Willingness-to-pay is a key parameter to determine optimal environmental regulation (Greenstone and Jack, 2014)
- Yet, limited evidence on WTP for clean air in developing countries
  - Data: Hard to obtain comprehensive data
  - Identification problems: Hard to find exogenous variation

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  - This enables us to provide a lower bound of WTP for clean air

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- Data: Air purifier sales and prices from scanner data in retail stores
  - Monthly data at the product-by-store level in 82 cities for 7 years
  - Key product attribute: Effectiveness of removing indoor air pollution

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- Quasi-experimental variation in pollution levels and purifier prices
  - The Huai River Policy ⇒ A natural experiment to air pollution
  - Distance to factory/port by city-brand ⇒ IV for purifier prices

Huai river policy created long-run variation in air pollution

- Government built coal-based centralized heating in the North
- Created plausibly exogenous, long-run variation in air pollution

A boiler house in an apartment complex (Shenyang)

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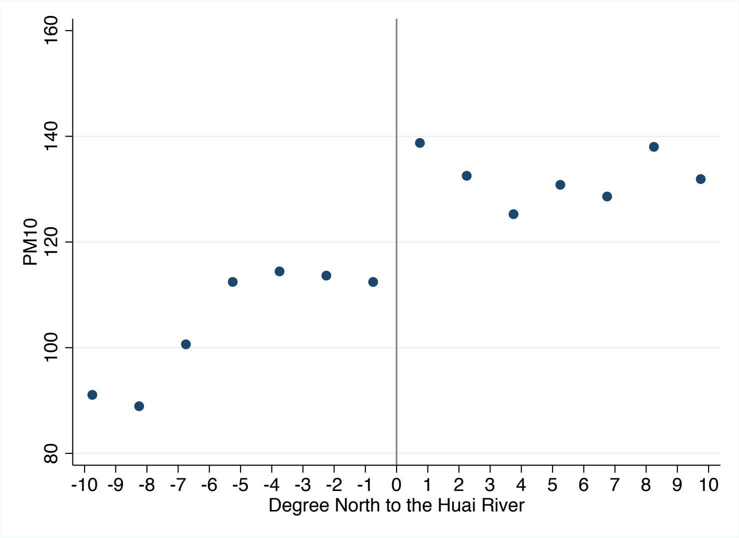
PM10 by degree of latitude relative to the Huai River (Raw)



- Note: Average PM10 in the U.S. was 55 in 2014 (it was 85 in 1990)

Our idea: Analyze demand for air purifiers to learn WTP

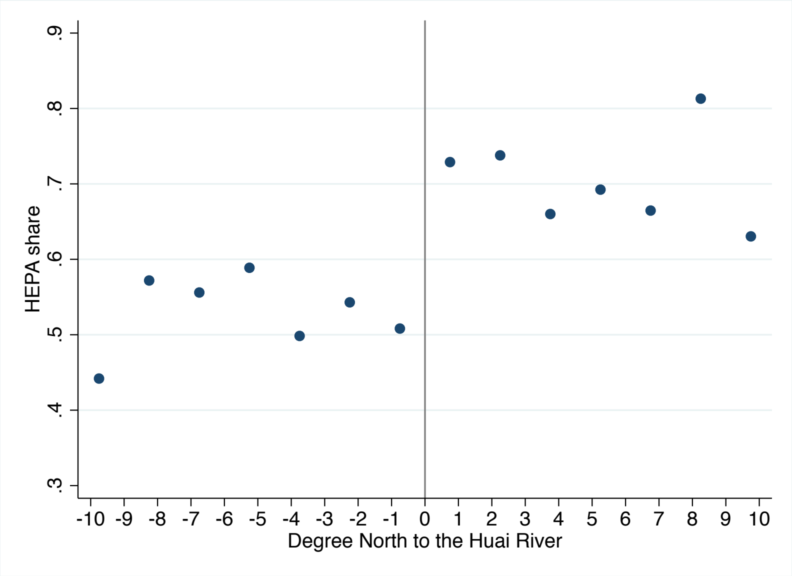
- Example: Philips AC4090/00

Air Purifier: HEPA vs. Non-HEPA filtration system

- High Efficiency Particulate Arrestance (HEPA):
  - The only one that removes PM (US EPA)
  - Efficiency (US EPA): it must remove 99.97% of particles in 0.3 micrometer in diameter or larger
  - Ads in Chinese market: it can remove >99% of PM2.5
  - Market share 60%

- Non-HEPA filtration systems do not remove PM
  - Remove Volatile Organic Compounds (VOC), gas and odors
  - Do not remove PM
  - Market share 40%

Market share of HEPA purifiers (raw data)



Demand Model

- z_{ct}: Ambient air pollution in city c at time t
- z_{jct}: Indoor air pollution conditional on the purchase of air purifier j

$$z_{jct} = z_{ct} \cdot (1 - e_j)$$

  - e_j: Effectiveness of purifier j

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- Conditional indirect utility of consumer i who purchases purifier j

$$u_{ijct} = \beta' z_{jct} + \alpha p_{jct} + \xi_j + \epsilon_{jct} + \epsilon_{ijct}$$

  - β': Marginal disutility for indoor air pollution

Standard Logit Demand Approach

- Assume that $\epsilon_{ijct} \sim$ extreme value type I distribution
- The market share for air purifier j in city c at time t is:

$$s_{jct} = \frac{\exp(\beta' z_{jct} + \alpha p_{jct} + \xi_j + \epsilon_{jct})}{\sum_{j'=1}^{J} \exp(\beta' z_{j'ct} + \alpha p_{j'ct} + \xi_{j'} + \epsilon_{jct})}$$

  - The outside option is not to buy any air purifier
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- The difference between log market share for product j and log market share for outside option:

$$\begin{aligned} \ln s_{jct} - \ln s_{0ct} &= \beta'(z_{jct} - z_{0ct}) + \alpha p_{jct} + \xi_j + \epsilon_{jct} \\ &= \beta(z_{0ct} - z_{jct}) + \alpha p_{jct} + \xi_j + \epsilon_{jct} \end{aligned}$$

  - $\beta \, (= -\beta')$: Marginal utility for reductions in indoor pollution

Standard Logit Demand Approach

$$\ln s_{jct} - \ln s_{0ct} = \beta \Delta z_{cjt} + \alpha p_{jct} + \xi_j + \epsilon_{jct}$$

- Reductions in indoor pollution $= \Delta z_{jct} = (z_{0ct} - z_{jct})$

$$\Delta z_{cjt} = z_{ct} \cdot HEPA_j = \begin{cases} z_{ct} & \text{if } HEPA_j = 1 \\ 0 & \text{if } HEPA_j = 0. \end{cases}$$

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  - e.g. Indoor pollution level (with no purifier) is likely to be lower than outdoor pollution level $\rightarrow$ We may underestimate MWTP

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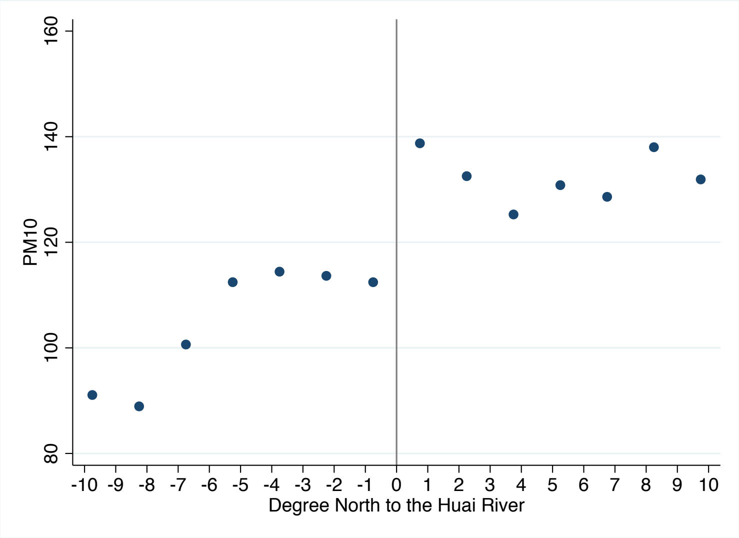
- Work in progress: Random-coefficient Logit ($\beta_i = \beta_0 + \beta_1 \cdot y_i + e_i$)

1) First stage on PM10



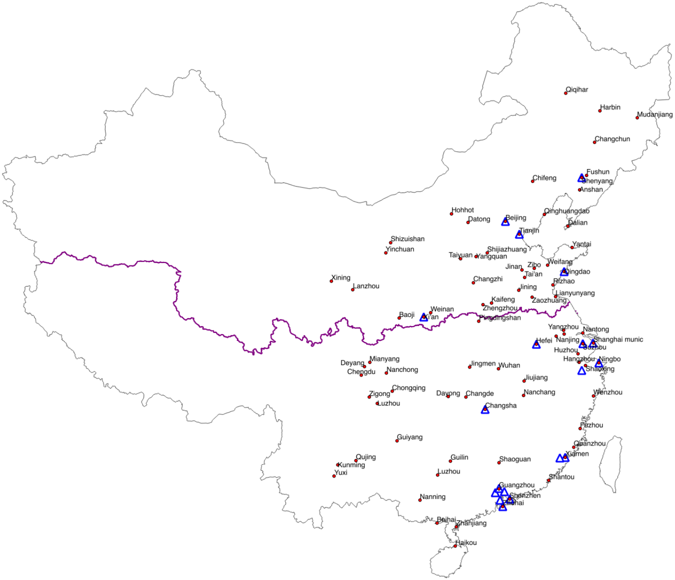
- Strong first stage: North of the river → higher PM10 levels

1) First stage on PM10

	PM10		
	(1)	(2)	(3)
North	19.1739*** [1.5948]	19.9383*** [1.7195]	21.6882*** [1.9423]
Quadratic latitute	Yes	Yes	Yes
Product FE	Yes	Yes	Yes
City controls		Yes	Yes
Longitude decile FE			Yes
Observations	4,940	4,940	4,940
R-squared	0.4154	0.6062	0.6647

- Strong first stage: North of the river → higher PM10 levels
- The amount of PM10 generated by Huai River Policy = 21.6 units

2) First stage on Price (distance to factory locations)



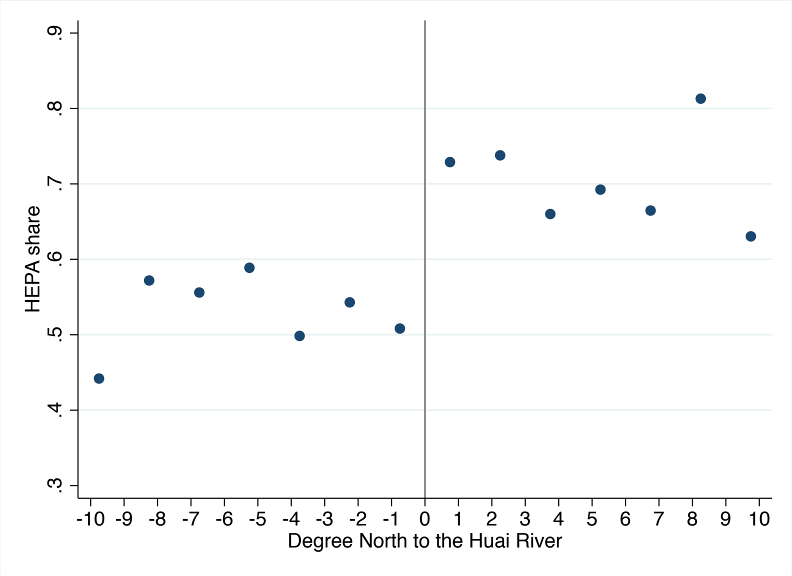
- For each product, we collected data on its factory/port location

2) First stage on Price (distance to factory locations)

	Price		
	(1)	(2)	(3)
Distance to factory/port	3.8659***	3.2786***	3.4478***
	[0.7511]	[0.7609]	[0.7700]
Distance^2	-0.1040***	-0.0878**	-0.0912**
	[0.0377]	[0.0385]	[0.0390]
Quadratic latitute and Quadratic latitude*HEPA	Yes	Yes	Yes
Product FE	Yes	Yes	Yes
City controls		Yes	Yes
Longitude decile FE			Yes
Observations	4,940	4,940	4,940
R-squared	0.9553	0.9563	0.9565

- Strong first stage: Longer distance $\rightarrow$ higher prices
- Relationship between price and distance is concave

3) Reduced form: HEPA purifiers' market share



3) Reduced form (Price is instrumented)

	Log(market share)-Log(outside option)		
	(1)	(2)	(3)
North*HEPA	0.5786**	0.5268***	0.5517**
	[0.2250]	[0.2020]	[0.2215]
North	0.2065	-0.2680	-0.0153
	[0.1684]	[0.1719]	[0.2026]
Price	-0.0256***	-0.0223***	-0.0263***
	[0.0031]	[0.0033]	[0.0035]
Quadratic latitute and Quadratic latitude*HEPA	Yes	Yes	Yes
Product FE	Yes	Yes	Yes
City controls		Yes	Yes
Longitude decile FE			Yes
Observations	4,940	4,940	4,940

WTP to reduce the amount of pollution generated by Huai River Policy: $0.5517/0.0263=$ $21 USD

4) 2SLS

	Log(market share)-Log(outside option)		
	(1)	(2)	(3)
PM10*HEPA	0.0370**	0.0284**	0.0278**
	[0.0160]	[0.0111]	[0.0121]
PM10	0.0161	-0.0145	-0.0023
	[0.0110]	[0.0094]	[0.0105]
Price	-0.0332***	-0.0234***	-0.0270***
	[0.0053]	[0.0035]	[0.0037]
Quadratic latitute and Quadratic latitude*HEPA	Yes	Yes	Yes
Product FE	Yes	Yes	Yes
City controls		Yes	Yes
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Observations	4,940	4,940	4,940

MWTP for 1 unit reduction in PM10:

0.0278/0.0270=$1.03 USD

Interpret the magnitude of MWTP from Huai River policy

- An air purifier depreciates in about 5 years, and manufactures advise consumers to replace HEPA filter every 6 months
  - We assume that households expect to use the purifier for 5 years and replace filters as instructed
  - We also consider various assumptions (fewer years of use, more replacements than instructed, ect.)

- We consider the average replacement cost for a filter, $50
- WTP for removing the average level of PM10 per year: ($103+$50*9)/5=$110
- MWTP for removing 1 unit of PM10 per year: $110/100=$1.1

Health valuation

- We borrow PM10-health estimates from Ebenstein *et al.* (2015)
  - An increase of 100 units of PM10 is associated with 2.3 years of loss in life expectancy at age 5
- Combined with our estimate from Huai River (local average)
  - WTP for an additional year of life for one person is $917
  - Smaller than estimates in the US but larger than previous estimates for developing countries
    - e.g. Kremer et. al (2011)'s estimate for households in Kenya is $24

Summary and discussion

- We analyze air purifier market data to estimate WTP for clean air
  - WTP for 1 unit reduction of PM10 = $1.1
  - WTP for an additional year of life expectancy = $917
- These findings suggest that WTP for clean air and valuation of health in China are substantially higher than previously understood for developing countries (e.g. Kremer et. al 2011)
- Should China implement more stringent environmental regulations?
  - More stringent environmental regulations can be justified if the marginal cost of regulation is below our MWTP estimate

Thank you!

Comments/suggestions?

Koichiro Ito
Assistant Professor, University of Chicago
ito@uchicago.edu