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

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November 13, 2015 at IGC Energy Conference
Air pollution is very severe in developing countries

Global Annual Average PM$_{2.5}$ Grids from MODIS and MISR Aerosol Optical Depth (AOD), 2010

Satellite-Derived Environmental Indicators

Global Annual PM$_{2.5}$ Grids from MODIS and MISR Aerosol Optical Depth (AOD) data sets provide annual “snap shots” of particulate matter 2.5 micrometers or smaller in diameter from 2001–2010. Exposure to fine particles is associated with premature death as well as increased morbidity from respiratory and cardiovascular disease, especially in the elderly, young children, and those already suffering from these illnesses. The grids were derived from Moderate Resolution Imaging Spectroradiometer (MODIS) and Multi-angle Imaging SpectroRadiometer (MISR) Aerosol Optical Depth (AOD) data. The raster grids have a grid cell resolution of 30 arc-minutes (0.5 degree or approximately 50 sq. km at the equator) and cover the world from 70°N to 60°S latitude. The grids were produced by researchers at Battelle Memorial Institute in collaboration...
Research question: How much are people willing to pay for clean air in developing countries?

- Severe air pollution $\Rightarrow$ Health and economic costs
  - Significant health and economic costs of pollution (Jayachandran 2009; Greenstone and Hanna 2014; Hanna and Oliva 2015)
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- High costs of pollution ⇔ Current env. regulations are not optimal
  - Willingness-to-pay is a key parameter to determine optimal environmental regulation (Greenstone and Jack, 2014)
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- Severe air pollution $\Rightarrow$ Health and economic costs
  - 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
In this paper

- **Goal**: Provide revealed preference estimates of WTP for clean air
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- **Idea**: Estimate demand for home-use air purifiers in Chinese cities
  - Home-use air purifier ⇒ main defensive investment for households
  - Estimate demand for air purifiers in relation to air pollution
  - 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)

- Government built coal-based centralized heating in the North
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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

空气净化器
CADR 360 m³/h, PM2.5 去除率 > 99%
AC4090/00 查找相似产品

长久保护，持久健康
具有健康空气保护锁

建议零售价:
¥5,999.00

从飞利浦购买 从零售商处购买

电话订购: 4008 800 008
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 $j$
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 $j$

- Conditional indirect utility of consumer $i$ who purchases purifier $j$

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

- $\beta'$: 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
- We assume that $z_{0ct} = z_{ct}$
Standard Logit Demand Approach

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  - 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:

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

$$= \beta(z_{0ct} - z_{jct}) + \alpha p_{jct} + \xi_j + \epsilon_{jct}$$

  - $\beta (= -\beta')$: 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 = \( \Delta z_{jct} = (z_{0ct} - z_{jct}) \)

\[ \Delta z_{cjt} = z_{ct} \cdot HEPA_j = \begin{cases} z_{ct} & \text{if } HEPA_j = 1 \\ 0 & \text{if } HEPA_j = 0. \end{cases} \]
Standard Logit Demand Approach

\[
\ln s_{jct} - \ln s_{0ct} = \beta \Delta z_{cjt} + \alpha p_{jct} + \xi_j + \epsilon_{jct}
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\end{cases}
\]

- \(-\frac{\beta}{\alpha}\) = a lower bound of MWTP for a reduction in indoor pollution
  
  - e.g. Indoor pollution level (with no purifier) is likely to be lower than outdoor pollution level → We may underestimate MWTP
Standard Logit Demand Approach

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- \(-\frac{\beta}{\alpha} = \text{a lower bound of MWTP for a reduction in indoor pollution}\)
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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

<table>
<thead>
<tr>
<th></th>
<th>PM10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>North</td>
<td>19.1739***</td>
</tr>
<tr>
<td></td>
<td>[1.5948]</td>
</tr>
<tr>
<td>Quadratic latitude</td>
<td>Yes</td>
</tr>
<tr>
<td>Product FE</td>
<td>Yes</td>
</tr>
<tr>
<td>City controls</td>
<td>Yes</td>
</tr>
<tr>
<td>Longitude decile FE</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>4,940</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.4154</td>
</tr>
</tbody>
</table>

- **Strong first stage**: North of the river $\rightarrow$ 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)

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Distance to factory/port</td>
<td>3.8659***</td>
<td>3.2786***</td>
<td>3.4478***</td>
</tr>
<tr>
<td></td>
<td>[0.7511]</td>
<td>[0.7609]</td>
<td>[0.7700]</td>
</tr>
<tr>
<td>Distance^2</td>
<td>-0.1040***</td>
<td>-0.0878**</td>
<td>-0.0912**</td>
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<tr>
<td></td>
<td>[0.0377]</td>
<td>[0.0385]</td>
<td>[0.0390]</td>
</tr>
<tr>
<td>Quadratic latitude and</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quadratic latitude*HEPA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Yes</td>
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</tr>
<tr>
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<td>0.9553</td>
<td>0.9563</td>
<td>0.9565</td>
</tr>
</tbody>
</table>

- Strong first stage: Longer distance → higher prices
- Relationship between price and distance is concave
3) Reduced form: HEPA purifiers’ market share
3) Reduced form (Price is instrumented)

<table>
<thead>
<tr>
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<th>Log(market share)-Log(outside option)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>North*HEPA</td>
<td>0.5786**</td>
</tr>
<tr>
<td></td>
<td>[0.2250]</td>
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<tr>
<td>North</td>
<td>0.2065</td>
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<tr>
<td></td>
<td>[0.1684]</td>
</tr>
<tr>
<td>Price</td>
<td>-0.0256***</td>
</tr>
<tr>
<td></td>
<td>[0.0031]</td>
</tr>
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<td></td>
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WTP to reduce the amount of pollution generated by Huai River Policy:
0.5517/0.0263=$21 USD
### 2SLS

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<tr>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>PM10*HEPA</td>
<td>0.0370**</td>
<td>0.0284**</td>
<td>0.0278**</td>
</tr>
<tr>
<td></td>
<td>[0.0160]</td>
<td>[0.0111]</td>
<td>[0.0121]</td>
</tr>
<tr>
<td>PM10</td>
<td>0.0161</td>
<td>-0.0145</td>
<td>-0.0023</td>
</tr>
<tr>
<td></td>
<td>[0.0110]</td>
<td>[0.0094]</td>
<td>[0.0105]</td>
</tr>
<tr>
<td>Price</td>
<td>-0.0332***</td>
<td>-0.0234***</td>
<td>-0.0270***</td>
</tr>
<tr>
<td></td>
<td>[0.0053]</td>
<td>[0.0035]</td>
<td>[0.0037]</td>
</tr>
<tr>
<td>Quadratic latitude and Quadratic latitude*HEPA</td>
<td>Yes</td>
<td>Yes</td>
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**MWTP for 1 unit reduction in PM10:**

\[
\frac{0.0278}{0.0270} = \$1.03 \text{ USD}
\]
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, etc.)

- 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?

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