# Willingness to Pay for Clean Air

## Evidence from Air Purifier Markets in China

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# Overview



# About the authors

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- Research interest: Energy Economics, Environmental Economics, Industrial Organization, Public Economics
- Publication: AER(2), JPE, AEJ(2), REStat...

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# Introduction

- Air pollution causes negative impacts on various economic outcomes, including infant mortality, life expectancy, and labor supply.
- However, a great economic burden of air pollution does not necessarily imply that existing environmental regulations are not optimal.
  - Optimal environmental regulation depends on the extent to which individuals value air quality improvements—that is, their willingness to pay (WTP) for clean air (Greenstone and Jack 2013).
  - Obtaining a revealed-preference estimate of WTP for clean air is challenging in developing countries because of limited data and a lack of readily available exogenous variation in air quality.

# Introduction

- This paper provides among the first revealed-preference estimates of WTP for clean air in developing countries.
- Idea: Demand for home-use air purifiers provides valuable information for the estimation of WTP for air quality improvements.

# Air Pollution, Air Purifiers & Huai River Policy

## A. Air Purifiers

- A key advantage of analyzing air purifier markets is that one of the product attributes—HEPA—informs both consumers and econometricians about the purifier's effectiveness at reducing indoor particulate matter.
  - A HEPA air purifier removes at least 99.97% of particles that are 0.3 mm or larger in diameter.
  - In contrast, non-HEPA purifiers are not effective at reducing small particles, such as PM2.5 and PM10. Yet non-HEPA purifiers provide consumers utility gains through attributes other than HEPA because these attributes are effective in removing other indoor pollutants.

# Air Pollution, Air Purifiers & Huai River Policy

## B. Huai River Policy and Its Recent Reform

- The government provided citywide centralized heating to northern cities only (Almond et al. 2009). Northern and southern China are divided by a line formed by the Huai River and Qinling Mountains. The government used this line because the average January temperature is roughly 0°C along the line and the line is not a border for other administrative purposes (Chen et al. 2013).
- In July 2003, the Chinese government issued a heating reform, which changed the payment system from free provision to flat-rate billing (World Bank 2005).
- Our analysis focuses on the period from 2006 to 2014, after the 2003 reform on heating billing.

# Air Pollution, Air Purifiers & Huai River Policy

## B. Huai River Policy and Its Recent Reform

# Data

## Air Purifier Data

- This paper uses air purifier sales transaction data collected by a marketing firm in China (2006 - 2014) for 80 cities. Provided are monthly sales and monthly average price for each product by store, along with information on product attributes.
  - The data set covers in-store transactions in major department stores and electrical appliance stores, accounting for over 80% of all in-store sales.
  - During the period 2006–14, in-store sales made up 72% of overall purifier sales (including in-store and online sales).

# Data

## Air Purifier Data

- Because our data set does not cover 100% of purifier sales, we take **two approaches to defining sales volume**.
  - In the first approach, we simply ignore transactions outside the data set $\Rightarrow$ underestimate the sales volume;
  - In the second approach, we adjust sales volume proportionally to address this limitation. Specifically, we multiply the sales volume of each product by 1.73 $(= 1/(0.8 \cdot 0.72))$.
- We aggregate the transaction data to the product-city level.

# Data

## Air Pollution / Demographic / GIS Data

- **Air Pollution Data:** city-level annual average $PM_{10}$ from 2006 to 2014 (Ebenstein et al., 2017).
  - Source: *China's Environmental Yearbooks*; *China's Environmental Quality Annual Reports*.
- **Demographic Data:** city-year measures on population, urban population, and GDP per capita; individual-level microdata (income, education, housing)
  - Source: City Statistical Yearbooks in 2006–14; 2005 census
- **GIS Data & Map:** construct two distance variables
  - Distance between a city and the Huai River;
  - Road distance from a city's centroid to the factory or importing port locations of air purifiers.

# Summary Statistics and Testing for Balance in Observables

Summary Statistics of Air Purifier Data

| | All Purifiers (1) | HEPA Purifiers (2) | Non-HEPA Purifiers (3) | Difference in Means (4) |
|---|---|---|---|---|
| A. Air purifier attributes: | | | | |
| Price of a purifier ($) | 454.52 | 509.64 | 369.81 | 139.84*** |
| | (383.81) | (404.24) | (333.45) | [52.14] |
| Humidifying (0 or 1) | .164 | .177 | .143 | .034 |
| | (.370) | (.382) | (.351) | [.070] |
| Room coverage ($m^2$) | 41.85 | 44.97 | 36.50 | 8.47* |
| | (23.65) | (24.93) | (20.27) | [4.42] |
| Distance to factory or port (hundreds of miles) | 7.48 | 7.32 | 7.72 | −.39 |
| | (2.87) | (2.69) | (3.12) | [.45] |
| Price of replacement filter ($) | 46.38 | 56.39 | 34.92 | 21.47* |
| | (52.21) | (65.68) | (25.91) | [10.70] |
| Frequency of filter replacement (months) | 9.03 | 10.08 | 7.92 | 2.17 |
| | (5.93) | (6.55) | (4.97) | [1.37] |
| | | | | HEPA/Non-HEPA (Ratio) |
| B. Number of purifier sales/number of households (%): | | | | |
| Beijing (north) | 17.82 | 12.10 | 5.72 | 2.12 |
| Xi'an (north) | 6.20 | 4.38 | 1.82 | 2.41 |
| All northern cities | 4.70 | 3.16 | 1.54 | 2.06 |
| Shanghai (south) | 8.89 | 5.08 | 3.81 | 1.33 |
| Shenzhen (south) | 8.35 | 4.39 | 3.96 | 1.11 |
| All southern cities | 3.47 | 1.94 | 1.53 | 1.27 |

# Summary Statistics and Testing for Balance in Observables

Summary Statistics of Observables for North and South of the Huai River

| | North (1) | South (2) | Differences in Means (3) | RD Estimates (Local Linear) (4) |
|---|---|---|---|---|
| Population (millions) | 2.398 | 2.720 | −.323 | −.388 |
| | (2.266) | (3.189) | [.625] | [1.411] |
| Urban population (millions) | 1.773 | 1.974 | −.200 | −1.092 |
| | (1.770) | (2.436) | [.480] | [1.151] |
| Years of schooling | 9.30 | 8.64 | .667*** | −.101 |
| | (.88) | (1.12) | [.227] | [.671] |
| Fraction illiterate | .052 | .069 | −.016** | .003 |
| | (.022) | (.033) | (.006) | (.018) |
| Fraction completed high school | .338 | .286 | .051** | .018 |
| | (.107) | (.112) | [.025] | [.074] |
| Fraction completed college | .052 | .048 | .004 | −.019 |
| | (.033) | (.031) | [.007] | [.021] |
| Per capita household income (in 2005 dollars) | 527.52 | 698.10 | −170.58** | −134.54 |
| | (152.79) | (388.20) | [67.27] | [107.41] |
| House size (m²) | 75.24 | 92.04 | −16.80*** | −12.25 |
| | (13.32) | (17.52) | [3.51] | [9.34] |
| Residence built after 1985 | .691 | .718 | −.027 | −.040 |
| | (.083) | (.075) | [.018] | [.027] |
| Fraction of building materials include reinforced concrete (less insulated) | .668 | .729 | −.061 | .010 |
| | (.187) | (.147) | [.037] | [.107] |
| Fraction moved within city | .074 | .065 | .009 | −.002 |
| | (.030) | (.022) | [.006] | [.010] |
| Fraction of occupation involved with outdoor activities | .218 | .208 | .011 | .032 |
| | (.106) | (.099) | [.023] | [.074] |

# Random-Utility Model

- Our goal is to obtain a revealed-preference estimate of WTP for clean air by analyzing demand for air purifiers. Because air purifiers are differentiated products, start with a random-utility model.
- Intuition: the extent to which consumers value this characteristic, along with the price elasticity of demand, provides useful information on their WTP for indoor air quality improvements.

The **indirect utility** of consumer $i$ from buying air purifier $j$ at city $c$ is

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \eta_j + \lambda_c + \xi_{jc} + \epsilon_{ijc}, \tag{1}$$

where

- $x_{jc} = x_c \cdot e_j,\ e_j \in [0,1]$ means purifier $j$'s effectiveness at reducing indoor particulate matter;
- $p_{jc}$ represents the price of product $j$ in market $c$

# Some Assumptions

- Air purifiers usually run for 5 years and require filter replacement several times within that period. We assume that consumer $i$ considers utility gains from purifier $j$ for 5 years and $p_{jc}$ as a sum of up-front and running costs.
- We assume that the error term $e_{ijc}$ is distributed as a type I extreme-value function.
  - Standard logit model: preference parameters do not vary by $i \Rightarrow$ linear GMM
  - Random-coefficient logit model: preference parameters can vary by $i$ through observable/unobservable factors $\Rightarrow$ nonlinear GMM

# A. Standard Logit Model

Suppose $\beta_i = \beta$ and $\alpha_i = \alpha$. Consumer $i$ purchases purifier $j$ if $u_{ijc} > u_{ikc}, \forall k \neq j$. The market share for product $j$ in city $c$ is

$$s_{jc} = \frac{\exp(\beta x_{jc} + \alpha p_{jc} + \eta_j + \lambda_c + \xi_{jc})}{\sum_{k=0}^{J} \exp\left(\beta x_{kc} + \alpha p_{kc} + \eta_k + \lambda_c + \xi_{kc}\right)}. \tag{2}$$

How to construct market share $s_{jc}$ and outside option $s_{0c}$ empirically?

- $I_c$: number of households in city $c$
- $q_{jc}$: the total sales volume during the sample period of 9 years
- $s_{jc} = (q_{jc}/I_c) \cdot (5/9), \quad s_{0c} = 1 - \sum_{j=1}^{J} s_{jc}$

# A. Standard Logit Model

$$
\begin{aligned}
\ln s_{jc} - \ln s_{0c} &= \beta x_{jc} + \alpha p_{jc} + \eta_j + \lambda_c + \xi_{jc} \\
\Rightarrow \ln s_{jc} &= \beta x_{jc} + \alpha p_{jc} + \eta_j + \lambda_c + \xi_{jc}
\end{aligned}
\tag{3}
$$

The marginal willingness to pay (MWTP) for one unit of indoor air pollution reduction is $-\beta/\alpha$.

Define the pollution reduction by $x_{jc} = x_c \cdot H_j$, where $x_c$ represents ambient pollution and $H_j$ is an indicator variable for HEPA purifiers.

$$
\Rightarrow \ln s_{jc} = \beta x_c H_j + \alpha p_{jc} + \eta_j + \lambda_c + \xi_{jc} \tag{4}
$$

# B. Random-Coefficient Logit Model

Begin with

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \eta_j + \lambda_c + \xi_{jc} + \epsilon_{ijc}. \tag{1}$$

We allow $\beta_i$ and $\alpha_i$ to vary by comsumer $i$ through observable and unobservable factors. We model the two parameters by

$$\beta_i = \beta_0 + \beta_1 y_i + u_i, \quad \alpha_i = \alpha_0 + \alpha_1 + e_i$$

where $y_i$ is household $i$'s income, $u_i$ and $e_i$ are lognormally distributed unobserved heterogeneity.
Split the utility function into two parts:

- $\delta_{jc} = \beta_0 x_{jc} + \alpha_0 p_{jc} + \eta_j + \lambda_c + \xi_{jc}$
- $\mu_{jci} = (\beta_1 y_i + u_i) x_{jc} + (\alpha_1 y_i + e_i) p_{jc}$

# B. Random-Coefficient Logit Model

The market share for product $j$ in city $c$ can then be evaluated using Monte Carlo integration assuming a number of individuals $n_c$ for city $c$ by

$$s_{jc} = \frac{1}{n_c}\sum_{i=1}^{n_c} s_{jci} = \frac{1}{n_c}\sum_{i=1}^{n_c}\frac{\exp(\delta_{jc}+\mu_{jci})}{\sum_{k=0}^{J}\exp(\delta_{kc}+\mu_{kci})}. \tag{5}$$

Write

$$\xi_{jc} = \delta_{jc} - (\beta_0 x_{jc} + \alpha_0 p_{jc} + \eta_j + \lambda_c) \equiv \omega_{jc},$$

**Identification condition:** the IV should be uncorrelated with $\omega_{jc}$. Denote the vector of the parameters by $\theta$ and a set of instruments by $Z_{jc}$.
$\Rightarrow$ Nonlinear GMM estimate is

$$\hat{\theta} = \arg\min \omega_{jc}(\theta)'(Z_{jc})\Phi^{-1}(Z_{jc}')\omega_{jc}(\theta), \tag{6}$$

where $\Phi^{-1}$ is the optimal weight matrix.

# C. Interpretation of the Parameter Estimates

Our estimate of $-\beta/\alpha$ is likely to provide a lower bound estimate of MWTP for air quality.

- First, households in China may have limited information on the level of air pollution as well as the negative health effects of air pollution.
- Second, our approach assumes that indoor air pollution levels in the absence of air purifiers are equal to ambient pollution levels.
- Third, our model assumes that the reduction in indoor air pollution is zero if households do not purchase a HEPA purifier, but there can be other avoidance methods that households can take to reduce indoor air pollution.
- Fourth, our model and empirical analysis incorporate running costs incurred by filter replacement but ignore electricity costs.

# A. Empirical Strategy

The primary challenge is that **air pollution** and **air purifier prices** in the demand estimation are likely to be endogenous in nonexperimental data.

- Air pollution is generated by observed and unobserved economic factors; can correlate with omitted variables in the demand equation.
- Solution: RD
- If firms have the ability to set prices due to imperfect competition, they may set prices in response to the unobserved demand factors, which creates correlation between the price and error term in the demand estimation.
- Solution: fixed effects; IV (variation at city-by-product level)

# A. Empirical Strategy

## Air pollution

**First stage on air pollution:**

$$x_c = \gamma N_c + \phi_1 d_c + \phi_2 d_c N_c + \nu_l + \epsilon_c \tag{7}$$

where $x_c$ represents $PM_{10}$ in city $c$, $N_c$ is the dummy variable for the north, $d_c$ represents the distance between city $c$ and the Huai River. Balance Test

**Reduced-form of the RD design:**

$$\ln s_{jc} = \rho N_c H_j + \alpha p_{jc} + (\psi_1 d_c + \psi_2 d_c N_c + \nu_l) H_j + \eta_j + \lambda_c + \epsilon_{jc} \tag{8}$$

We allow the control function for the running variable $(\psi_1 d_c + \psi_2 d_c N_c)$ and the longitude-quartile fixed effects $(\nu_l)$ to differ between HEPA and non-HEPA purifiers by including $(\psi_1 d_c + \psi_2 d_c N_c) H_j$.

# A. Empirical Strategy
## Air pollution

**Second stage on air pollution:**
We estimate the MWTP for clean air by regressing

$$\ln s_{jc} = \beta x_c H_j + \alpha p_{jc} + (\phi_1 d_c + \phi_2 d_c N_c + \nu_l) H_j + \eta_j + \lambda_c + \epsilon_{jc}, \qquad (9)$$

using $N_c H_j$ as the instrument for $x_c H_j$.
The parameter of interest is $-\beta/\alpha$.

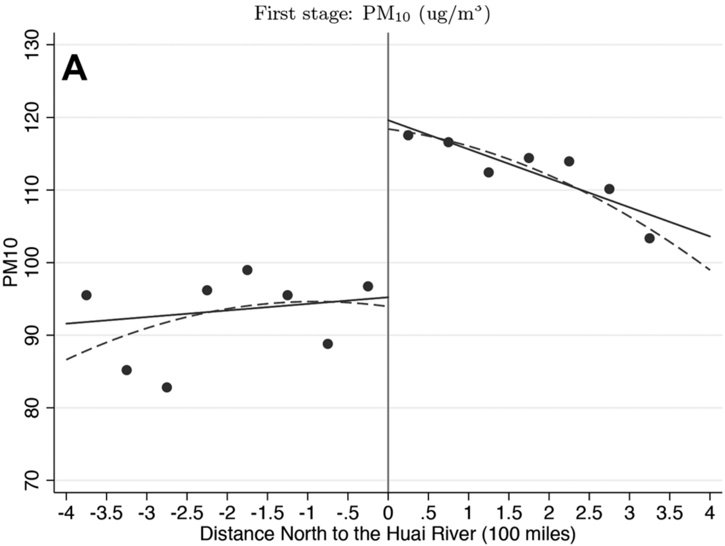
# A. Empirical Strategy

## Instruments for air purifier price

- Many of the omitted variables are controlled by product and city fixed effects. The remaining concern is **product-by-city-level unobserved demand factors** correlated with product-by-city-specific price variation.
- An ideal instrument is a **supply-side cost shifter** at the product-by-city level that does not directly affect demand.
- $\Rightarrow$ 2 IV: road distance from a product's manufacturing location to its market (city) & its interaction with manufacturer dummy variables.

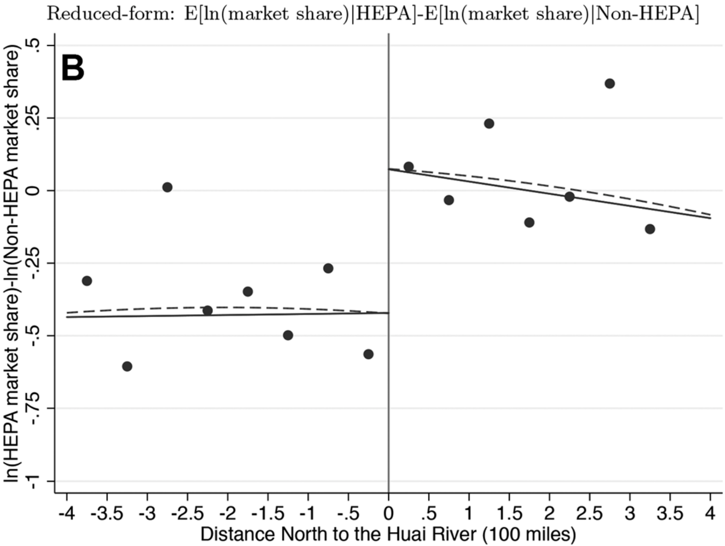
# B. Graphical Analysis of the RD Design

## RD at the Huai River boundary



# B. Graphical Analysis of the RD Design

## RD at the Huai River boundary



# C. Baseline Results: Standard Logit Model

First-Stage Estimation for $PM_{10}$ and Air Purifier Price

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Dependent Variable: $PM_{10}$ ($\mu g/m^3$) | | | |
| A. First-stage estimation for $PM_{10}$: | | | | |
| North | 24.54*** | 24.55*** | 24.38*** | 24.19*** |
| | (6.97) | (6.98) | (8.71) | (8.86) |
| Observations | 49 | 49 | 49 | 49 |
| $R^2$ | .36 | .36 | .56 | .57 |
| Control function for running variable | Linear × north | Quadratic | Linear × north | Quadratic |
| Demographic controls | | | Yes | Yes |
| Longitude-quartile fixed effects | | | Yes | Yes |
| | Dependent Variable: Price ($) | | | |
| B. First-stage estimation for air purifier price: | | | | |
| Distance to factory (hundreds of miles) | 18.43*** | 18.39*** | 12.70** | 12.67** |
| | (4.97) | (4.98) | (4.94) | (4.93) |
| Distance to factory$^2$ (hundreds of miles) | −2.32*** | −2.33*** | −1.49* | −1.49* |
| | (.72) | (.72) | (.77) | (.77) |
| Distance to factory$^3$ (hundreds of miles) | .10*** | .10*** | .06 | .06 |
| | (.03) | (.03) | (.04) | (.04) |
| Observations | 7,359 | 7,359 | 7,359 | 7,359 |
| $R^2$ | .96 | .96 | .96 | .96 |
| Control function for running variable | Linear × north | Quadratic | Linear × north | Quadratic |
| Product fixed effects | Yes | Yes | Yes | Yes |
| City fixed effects | | | Yes | Yes |
| Longitude-quartile fixed effects × HEPA | Yes | Yes | Yes | Yes |
| Predicted effect of 500 miles on price | 46.46*** | 46.30*** | 33.22*** | 33.16*** |
| | (12.07) | (12.15) | (11.43) | (11.42) |
| Predicted effect as % of mean price | 10.2 | 10.2 | 7.3 | 7.3 |

# C. Baseline Results: Standard Logit Model

Standard Logit: Reduced-Form and Second-Stage Estimation Results

| | Dependent Variable: ln(Market Share) | |
|---|---|---|
| | (1) | (2) |
| A. Reduced form of the RD design: | | |
| North × HEPA ($\rho$) | .4275*** | .4216*** |
| | (.0329) | (.0320) |
| Price ($\alpha$) | −.0052*** | −.0052*** |
| | (.0001) | (.0001) |
| Observations | 7,359 | 7,359 |
| First-stage *F*-statistic | 870.29 | 1,115.94 |
| Control function for running variable | Linear × north | Quadratic |
| B. Second stage of the RD design: | | |
| $PM_{10}$ × HEPA ($\beta$) | .0299*** | .0302*** |
| | (.0030) | (.0032) |
| Price ($\alpha$) | −.0048*** | −.0048*** |
| | (.0001) | (.0001) |
| Observations | 7,359 | 7,359 |
| First-stage *F*-statistic | 285.16 | 292.01 |
| Control function for running variable | Linear × north | Quadratic |
| MWTP for 5 years ($-\beta/\alpha$) | 6.2077*** | 6.3100*** |
| | (.6649) | (.7130) |
| MWTP per year | 1.2415*** | 1.2620*** |
| | (.1330) | (.1426) |

# C. Baseline Results: Standard Logit Model

Robustness Checks

| | Dependent Variable: ln(Market Share) | | | |
|---|---|---|---|---|
| | 250 Miles (1) | 300 Miles (2) | 350 Miles (3) | 400 Miles (4) |
| A. Control function for the running variable—linear × north: | | | | |
| $PM_{10}$ × HEPA ($\beta$) | .0296*** | .0322*** | .0268*** | .0299*** |
| | (.0029) | (.0047) | (.0010) | (.0030) |
| Price ($\alpha$) | −.0036*** | −.0038*** | −.0042*** | −.0048*** |
| | (.0002) | (.0002) | (.0001) | (.0001) |
| Observations | 5,619 | 5,878 | 7,107 | 7,359 |
| First-stage *F*-statistic | 1,921.77 | 526.20 | 1,348.93 | 285.16 |
| MWTP for 5 years ($-\beta/\alpha$) | 8.2840*** | 8.4562*** | 6.3748*** | 6.2077*** |
| | (1.0665) | (1.4798) | (.2764) | (.6649) |
| MWTP per year | 1.6568*** | 1.6912*** | 1.2750*** | 1.2415*** |
| | (.2133) | (.2960) | (.0553) | (.1330) |
| B. Control function for the running variable—quadratic: | | | | |
| $PM_{10}$ × HEPA ($\beta$) | .0298*** | .0327*** | .0265*** | .0302*** |
| | (.0028) | (.0046) | (.0010) | (.0032) |
| Price ($\alpha$) | −.0035*** | −.0037*** | −.0042*** | −.0048*** |
| | (.0002) | (.0002) | (.0001) | (.0001) |
| Observations | 5,619 | 5,878 | 7,107 | 7,359 |
| First-stage *F*-statistic | 2,122.08 | 467.03 | 1,399.44 | 292.01 |
| MWTP for 5 years ($-\beta/\alpha$) | 8.4464*** | 8.7436*** | 6.3470*** | 6.3100*** |
| | (1.0758) | (1.5087) | (.3034) | (.7130) |
| MWTP per year | 1.6893*** | 1.7487*** | 1.2694*** | 1.2620*** |
| | (.2152) | (.3017) | (.0607) | (.1426) |

# D. Role of Information in WTP for Clean Air

Role of Information in WTP for Clean Air

| | Dependent Variable: ln(Market Share) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| $PM_{10}$ × HEPA | .0192*** | .0174*** | .0193*** |
| | (.0018) | (.0027) | (.0025) |
| $PM_{10}$ × HEPA × post-2013 | .0329*** | .0307*** | .0280*** |
| | (.0076) | (.0079) | (.0090) |
| Price | −.0072*** | −.0072*** | −.0064*** |
| | (.0001) | (.0002) | (.0002) |
| Observations | 10,780 | 10,780 | 10,780 |
| First-stage *F*-statistic | 113.39 | 112.01 | 189.15 |
| Control function for running variable | Linear × north | Linear × north | Linear × north |
| Product fixed effects × post-2013 | Yes | Yes | Yes |
| City fixed effects × post-2013 | Yes | Yes | Yes |
| Longitude-quartile fixed effects × HEPA × post-2013 | Yes | Yes | Yes |
| Salary × HEPA | | Yes | Yes |
| Salary × price | | | Yes |
| MWTP per year before 2013 | .5313*** | .4867*** | .6001*** |
| | (.0595) | (.0874) | (.0918) |
| MWTP per year after 2013 | 1.4438*** | 1.3458*** | 1.4707*** |
| | (.1475) | (.1376) | (.2009) |
| Difference in MWTP per year | .9124*** | .8591*** | .8706*** |
| | (.1961) | (.2040) | (.2647) |

# E. Heterogeneity in WTP for Clean Air

Heterogeneity in WTP for Clean Air: Random-Coefficient Logit Estimation Results

| | Dependent Variable: ln(Market Share) | |
|---|---|---|
| | (1) | (2) |
| $PM_{10}$ × HEPA: | | |
| Mean coefficient ($\beta_0$) | .0459*** | .0498*** |
| | (.0084) | (.0092) |
| Interaction household income ($\beta_1$) | .0924*** | .0891*** |
| | (.0224) | (.0253) |
| Standard deviation ($\sigma_\beta$) | .0056*** | .0102*** |
| | (.0020) | (.0021) |
| Price: | | |
| Mean coefficient ($\alpha_0$) | −.0069*** | −.0071*** |
| | (.0007) | (.0007) |
| Interaction with household income ($\alpha_1$) | .0028** | .0028** |
| | (.0011) | (.0011) |
| Standard deviation ($\sigma_\alpha$) | .0026 | .0024 |
| | (.0030) | (.0030) |
| Observations | 7,359 | 7,359 |
| Control function for running variable | Linear × north | Quadratic |
| GMM objective function value | 375.05 | 378.93 |
| MWTP per year: 5th percentile | .38 | .07 |
| MWTP per year: 10th percentile | .49 | .20 |
| MWTP per year: 25th percentile | .75 | .53 |
| MWTP per year: 50th percentile | 1.19 | 1.10 |
| MWTP per year: mean | 1.34 | 1.41 |
| MWTP per year: 75th percentile | 1.90 | 2.04 |
| MWTP per year: 90th percentile | 2.92 | 3.45 |
| MWTP per year: 95th percentile | 3.86 | 4.69 |

# E. Heterogeneity in WTP for Clean Air

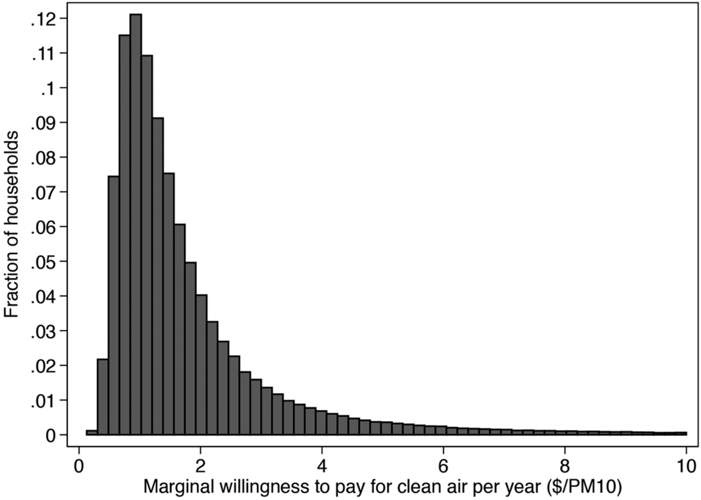



FIG. 3.—Distribution of marginal WTP for clean air. This histogram is based on the random-coefficient logit estimation results in column 1 of table 7 and household-level annual income from the 2005 census microdata. A color version of this figure is available online.

# E. Heterogeneity in WTP for Clean Air

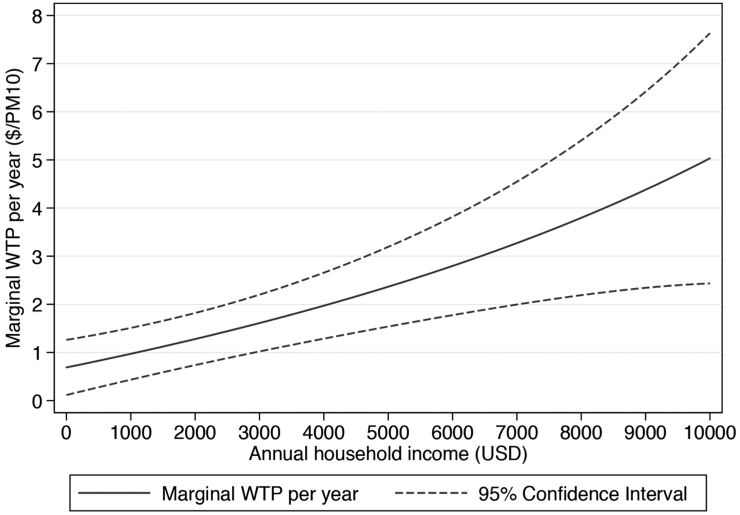



FIG. 4.—Marginal WTP for clean air and household income. This figure shows the relationship between the estimated marginal WTP for clean air and household-level income.

# E. Heterogeneity in WTP for Clean Air

POLICY IMPLICATIONS

| | Household Level ($) | Aggregate ($) |
|---|---|---|
| A. Policy-relevant MWTP measures ($ per 1 $\mu$g/m$^3$ annual reduction in PM$_{10}$): | | |
| In-sample estimate (from table 7) | 1.34 | |
| Seven northern cities | 1.62 | 10.13 million |
| Nationwide | 1.26 | .45 billion |
| B. Cost-benefit analysis—heating reform in seven northern cities: | | |
| Abatement cost ($) | 2.25 million | |
| Estimated PM$_{10}$ reduction ($\mu$g/m$^3$) | 11.91 | |
| Total WTP ($) | 105.07 million | |
| Benefit-cost ratio | 46.70 | |
| | Wind | Natural Gas |
| C. Cost-benefit analysis—replacement of coal power plants by wind or natural gas: | | |
| Estimated PM$_{10}$ reduction ($\mu$g/m$^3$) | .56 | .46 |
| Total WTP ($) | .26 billion | .21 billion |
| MWTP for replacing coal-based electricity ($/MWh) | 17.9 | 14.5 |

NOTE.—This table shows policy-relevant MWTP measures and the cost-benefit analysis of two policies discussed in sec. VI.

# E. Heterogeneity in WTP for Clean Air

Comparison of Implied VSL

| Study | Country (1) | Implied VSL ($/Year) (2) | Income ($/Year) (3) | Income Elasticity of VSL (4) |
|---|---|---|---|---|
| Kremer et al. 2011 | Kenya | 24 | 480 | |
| This study | China | 455 | 8,332 | 1.010 |
| León and Miguel 2017 | Sierra Leone (Africans) | 13,500 | 62,360 | 1.012 |
| León and Miguel 2017 | Sierra Leone (Non-Africans) | 23,232 | 99,000 | 1.008 |

# Limitations & Further Work

- First, a limitation of our data set is that we do not observe individual-level transactions.
  - It needs to be assumed that a household can purchase at most one air purifier and uses it for 5 years on average.
  - The data set does not include online sales.
- Second, there is no information on indoor avoidance behavior besides air purifier purchases.
- Third, this paper focuses on a static demand model without exploiting time series variation in the data because the exogenous variation in air pollution comes from cross section.
- Fourth, there needs to be more research on how market failures affect revealed-preference estimates of MWTP for environmental quality as emphasized by Greenstone and Jack (2013).

*The End*