Valuing Health Risk Reductions from Air Quality Improvement: Evidence from a New Discrete Choice Experiment (DCE) in China

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Toulouse School of Economics

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Ambient PM$_{2.5}$ ranks 4$^{th}$ mortality risk factor in China

- Ambient particulate matter pollution
- Household air pollution from solid fuels
- High fasting plasma glucose
- Alcohol use

Other risk factors include:
- Dietary risks
- High blood pressure
- Tobacco smoking
- Alcohol use
- Occupational risks
- Physical inactivity and low physical activity
- High total cholesterol

Credit: Dalhousie University, Aaron van Donkelaar

NASA Global satellite-derived map of PM2.5 averaged over 2001-2006
A unique and important regulatory context motivates for a new Discrete Choice Experiment study in China

- Increased public awareness: haze crisis
  - PM$_{2.5}$ became nationwide major concern since 2013

- Increased political will
  - “Clear rivers and green mountains are as valuable as mountains of gold and silver.” by President Jinping Xi
  - Reflected in the newly amended Constitution in March, 2018

- BCA urgently needed: demand for monetizing health risks
  - Ongoing discussion but not used in practice
  - Value of a Statistical Life (VSL) lack of research support
Motivations, continued

- Few China VSL studies conducted to date
  - See, e.g., Hammit: session A7 Mar 16 Friday 2:00-3:30PM Room A: VSL in China from 1996 to 2016
  - CVM most commonly used, data collected 1990s~2000s
  - Risk reduction scenarios were set too big or too small

- Even fewer studies for willingness to pay (WTP) based morbidity risk valuation
  - “Value of a statistical illness” (VSI)
  - Globally needed

- Aim is to elicit individual WTP for public provision of mortality AND morbidity risk reductions from air quality improvement in China (Beijing)
Graphical illustration of VSL and VSI

The value of a statistical case (VSC) is the:
- value of a statistical life (VSL) when $p$ is mortality risk
- value of a statistical illness (VSI) when $p$ is the risk of illness

How to set this $\Delta p$
Risks and risk reductions in our setting are very different from those in cleaner places

- **US**: PM$_{2.5}$ low, baseline risk already very low, the slope C-R big, risk reduction often set around “1 per 100k people per year”
- **China**: PM$_{2.5}$ high, baseline risk high, C-R is small, risk reduction big or small ??? Depend on policy scenarios and actual calculations
- Prior Chinese air pollution VSL studies not helpful: 1~200 per 100k!

![Integrated Exposure Response (IER) model](Burnett et al, 2014)
Global Burden of Disease Study online archive, data for Beijing

Provincial data (now disappeared)

Per 10k people per year

<table>
<thead>
<tr>
<th>Cause</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient particulate matter</td>
<td></td>
</tr>
</tbody>
</table>

Deaths | YLDs | DALYs

Beijing

For every 10,000 people over a 1 year period:

- **Deaths**
- **% of all cause mortality**
- **Risk factor attribution**
- **Deaths attributable to PM2.5**
- **Risk factor attribution to O₃**
- **Deaths attributable to O₃**

Health risks of interest = max policy space

1 small square = 1 person
10,000 people in total

Red: stroke deaths
Yellow: non-fatal stroke cases
Black box: proportion from air pollution

<table>
<thead>
<tr>
<th>Lung cancer</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31.4</td>
</tr>
<tr>
<td></td>
<td>5.2%</td>
</tr>
<tr>
<td></td>
<td>11.3%</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>NA</td>
<td>6.80%</td>
</tr>
<tr>
<td>NA</td>
<td>2.1</td>
</tr>
</tbody>
</table>

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## Attributes and their levels

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Description used in choice sets</th>
<th>Attribute levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>morbidity</td>
<td>non-fatal cases prevented per year per 100K people</td>
<td>50, 100, 150</td>
</tr>
<tr>
<td>mortality</td>
<td>Deaths prevented per year per 100k people</td>
<td>5, 10, 20</td>
</tr>
<tr>
<td>delay</td>
<td>Years before effective</td>
<td>0 (no delay), 2, 5, 10</td>
</tr>
<tr>
<td>cost</td>
<td>Your cost from now on (CNY/year)</td>
<td>200,500,1000,2000</td>
</tr>
</tbody>
</table>

Note: illness type (IHD, Stroke and COPD) is addressed by split sample design
8 tasks randomly drawn from a 48 D-efficiency designed choice sets

Which one do you prefer? Status-quo, program 1-1 or 1-2?

○ Status quo
  you have no additional cost

Risk remains current situation

○ Program 1-1
  in 100,000 people per year
  number of prevented non-fatal cases: 150
  number of prevented deaths: 5
  years before effect illustration: 5
  your costs: 500 yuan/year

Risk remains current situation

○ Program 1-2
  in 100,000 people per year
  number of prevented non-fatal cases: 50
  number of prevented deaths: 20
  years before effect illustration: 10
  your costs: 2000 yuan/year

Risk remains current situation

Note: red cases are death cases, yellow cases are non-fatal cases. The parts in frame are cases caused by air pollution. Blue cases are reduced by the program.
Online survey during 2016 fall

- 1060 respondents from the 0.3 million internet panel of Beijing citizens
- Widely used, sojump company
- Randomly stratified by age, gender, education, income
- Sample well representing the Beijing internet enabled population
Empirical models following discrete choice literature

- Utility that respondent n derives from choosing alternative j in choice set t

\[ U_{njt} = sq + \beta_{n1} morbidity_{njt} + \beta_{n2} mortality_{njt} + \beta_{n3} delay_{njt} + \beta_{n4} cost_{njt} + \varepsilon_{njt} \]

  - WTP-morbidity = \(-\frac{\beta_{n1}}{\beta_{n4}}\)
  - WTP-mortality = \(-\frac{\beta_{n2}}{\beta_{n4}}\)

- multinomial logit model (MNL)
  - \( \beta_{nk} = \beta_k \)

- mixed logit model (MXL)
  - \( \beta_{nk} = \beta_k + \sigma_{nk} \)

- latent class model
  - \( \beta_{nk} = \beta_{ck} \)

- WTP space model
  - \( V_{njt} = \beta_{n4} (sq^* + wtp_{n1} morbidity_{njt} + wtp_{n2} mortality_{njt} + wtp_{n3} delay_{njt} + cost_{njt}) \)
### Model estimates for MNL, MXL and WTP space model

<table>
<thead>
<tr>
<th></th>
<th>Model (1)</th>
<th>Model (2)</th>
<th>Model (3)</th>
<th>Model (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MNL</td>
<td>MXL (β&lt;sub&gt;cost&lt;/sub&gt; fixed)</td>
<td>MXL (β&lt;sub&gt;cost&lt;/sub&gt; random)</td>
<td>WTP space model</td>
</tr>
<tr>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>morbidity</td>
<td>0.00291***</td>
<td>-0.000967</td>
<td>0.00414***</td>
<td>0.62***</td>
</tr>
<tr>
<td></td>
<td>(0.000365)</td>
<td>(0.000814)</td>
<td>(0.000612)</td>
<td>(0.373)</td>
</tr>
<tr>
<td>mortality</td>
<td>0.0211***</td>
<td>0.0209***</td>
<td>0.0311***</td>
<td>19.71***</td>
</tr>
<tr>
<td></td>
<td>(0.00243)</td>
<td>(0.00444)</td>
<td>(0.0035)</td>
<td>(2.186)</td>
</tr>
<tr>
<td>delay</td>
<td>-0.0627***</td>
<td>-0.109***</td>
<td>-0.0923***</td>
<td>-66.01***</td>
</tr>
<tr>
<td></td>
<td>(0.00417)</td>
<td>(0.00702)</td>
<td>(0.00661)</td>
<td>(5.966)</td>
</tr>
<tr>
<td>cost</td>
<td>-0.000849***</td>
<td>-0.00120***</td>
<td>-0.0187***</td>
<td>-0.00407***</td>
</tr>
<tr>
<td></td>
<td>(0.0000257)</td>
<td>(0.0000351)</td>
<td>(0.00316)</td>
<td>(0.000521)</td>
</tr>
<tr>
<td>sq</td>
<td>-0.459***</td>
<td>-1.495***</td>
<td>-2.317***</td>
<td>-894.0***</td>
</tr>
<tr>
<td></td>
<td>(0.0533)</td>
<td>(0.071)</td>
<td>(0.0827)</td>
<td>(45.27)</td>
</tr>
<tr>
<td>Observations</td>
<td>25440</td>
<td>25440</td>
<td>25440</td>
<td>25440</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-8658</td>
<td>-7183</td>
<td>-6430</td>
<td>-7011</td>
</tr>
<tr>
<td>AIC</td>
<td>17326</td>
<td>14382</td>
<td>12877</td>
<td>14040</td>
</tr>
<tr>
<td>BIC</td>
<td>17367</td>
<td>14447</td>
<td>12950</td>
<td>14114</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; ***, **, * Statistical significance at 1, 5, 10% level, respectively; MNL = Multinomial Logit; MXL = Mixed Logit; WTP = willingness to pay; italics are estimates for WTPs.
# Model estimates for Latent Class model with 3 classes

<table>
<thead>
<tr>
<th>Model (5)</th>
<th>Latent Class</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>morbidity</td>
<td></td>
<td>0.00400 ***</td>
<td>0.00272 **</td>
<td>0.0029</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.000474)</td>
<td>(0.00103)</td>
<td>(0.00194)</td>
</tr>
<tr>
<td>mortality</td>
<td></td>
<td>0.0255 ***</td>
<td>0.0199 **</td>
<td>0.00671</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00336)</td>
<td>(0.00641)</td>
<td>(0.0132)</td>
</tr>
<tr>
<td>delay</td>
<td></td>
<td>-0.0721 ***</td>
<td>-0.0929 ***</td>
<td>-0.00451</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.00578)</td>
<td>(0.0114)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>cost</td>
<td></td>
<td>-0.000517 ***</td>
<td>-0.00433 ***</td>
<td>-0.000292 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0000433)</td>
<td>(0.00029)</td>
<td>(0.000138)</td>
</tr>
<tr>
<td>sq</td>
<td></td>
<td>-2.339 ***</td>
<td>-2.332 ***</td>
<td>2.977 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.11)</td>
<td>(0.174)</td>
<td>(0.317)</td>
</tr>
<tr>
<td>Class share</td>
<td></td>
<td>0.473</td>
<td>0.304</td>
<td>0.223</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td>25440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td></td>
<td>-6577</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td></td>
<td>13189</td>
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</tr>
<tr>
<td>BIC</td>
<td></td>
<td>13327</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Standard errors in parentheses; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; ***, **, *Statistical significance at 1, 5, 10% level, respectively.
Willingness to pay for mortality risk reduction

WTP mortality (2016 CNY)

- Model (3) MXL \|_\text{cost random}
- Model (4) MXL WTP space
- Model (5) Latent Class

0.4
0.3
0.2
0.1
0
-20 0 20 40 60
WTP

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Willingness to pay for morbidity risk reduction

WTP morbidity (2016 CNY)

- Model (3) MXL |Â_cost random
- Model (4) MXL WTP space
- Model (5) Latent Class

0.05 0.1 0.15 0.2
-10 0 10 20 30
WTP morbidity (2016 CNY)
No significant difference among IHD, COPD and Stroke

WTP mortality in CNY, by illness type, Model (4)
### WTP estimates across models

<table>
<thead>
<tr>
<th></th>
<th>Model (1)</th>
<th>Model (2)</th>
<th>Model (3)</th>
<th>Model (4)</th>
<th>Model (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MNL</td>
<td>MXL $\beta_{cost}$ fixed</td>
<td>MXL $\beta_{cost}$ random</td>
<td>WTP space</td>
<td>Class1</td>
</tr>
<tr>
<td><strong>WTP-mortality:</strong> WTP for preventing one premature death from air pollution per year per 100,000 people</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>24.90</td>
<td>17.09</td>
<td>36.55</td>
<td>19.71</td>
<td>43.51</td>
</tr>
<tr>
<td>95% CI</td>
<td>[19.40/30.39]</td>
<td>[14.07/20.10]</td>
<td>[32.43/40.66]</td>
<td>[19.00/20.41]</td>
<td>[42.49/44.54]</td>
</tr>
<tr>
<td>Median</td>
<td>18.73</td>
<td>11.28</td>
<td>19.83</td>
<td>49.37</td>
<td>4.65</td>
</tr>
<tr>
<td>SD</td>
<td>50.07</td>
<td>68.27</td>
<td>11.71</td>
<td>11.71</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>WTP-morbidity:</strong> WTP for preventing one non-fatal illness from air pollution per year per 100,000 people</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>3.43</td>
<td>-0.82</td>
<td>5.64</td>
<td>0.62</td>
<td>6.80</td>
</tr>
<tr>
<td>95% CI</td>
<td>[2.59/4.27]</td>
<td>[-1.63/-0.01]</td>
<td>[4.68/6.59]</td>
<td>[-0.07/1.31]</td>
<td>[6.64/6.97]</td>
</tr>
<tr>
<td>Median</td>
<td>0.56</td>
<td>1.02</td>
<td>1.72</td>
<td>7.73</td>
<td>0.64</td>
</tr>
<tr>
<td>SD</td>
<td>13.44</td>
<td>15.89</td>
<td>11.44</td>
<td>1.86</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**VSL:** 0.5 to 4.3 million CNY (0.03 to 0.7 million USD)

**VSI:** 10k to 700k CNYs (1.5k to 104k USD)

1 USD ≈ 6.64 CNY at 2016 average
Application: Per capita benefit of 10μg/m³ PM$_{2.5}$ reduction for rich versus poor, clean versus dirty Chinese cities

1 USD ≈ 6.64 CNY at 2016 average
Application: Per capita benefit of $10\mu g/m^3$ PM$_{2.5}$ reduction for China cities, New York City, Seoul and Monrovia

1 USD $\approx$ 6.64 CNY at 2016 average
Conclusions

- DCE in a unique and important regulatory context with newest information of health risks in high pollution level
- VSL 0.4 million USD in 2016
  - 0.5 to 4.3 million CNY (0.03 to 0.7 million USD) across models
  - Risk context: current Beijing, air pollution major adult illnesses
- VSI 60k USD in 2016
  - 10k to 700k CNYs (1.5k to 104k USD) across models
- No statistical illness type effect on WTP
  - Consistent with majority literature (except Cameron et al 2008)
- “Unit” health benefit of air pollution control
  - Dirty and poor cities much lower than clean and rich cities
  - Pollution control need to be very cost effective to pass B>C criteria in dirty and poor places