Estimating the Economic Costs of Air Pollution

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Economic Costs Due to Air Pollution

• Loss in output associated with morbidity and mortality
• Loss in leisure time and utility/enjoyment
• Health expenditures associated with pollution-related disease
• Impacts of air pollution on worker productivity
• Impacts on agriculture and ecosystems
• Damages to buildings and materials
• Aesthetic impacts
• Impacts on child brain development, IQ
What Has Been Valued?

- Loss in output associated with morbidity
  - Output = contribution to state GDP
  - Morbidity measure by Years Lost Due to Disability

- Loss in output associated with premature mortality
  - Compute present value of lost output due to premature deaths due to air pollution

- Health expenditures associated with air pollution
Measuring Morbidity Due to Air Pollution

• Years Lost Due to Disability (YLDs)
  • Measured by disease
  • Reflect prevalence of disease and disability weight
  • Percent of YLDs due to pollution calculated

• In 2017 5.4 million YLDs associated with air pollution due to
  • COPD  IHD  Diabetes  Cataracts
  • LRI  Stroke  Lung cancer

• 55% due to COPD
Output Lost Due to YLDs

- Measure only contribution to GDP, by state

- \( \text{GSDP per Worker} = \frac{\text{Labor’s share of GDP} \times \text{GSDP}}{\text{Number of workers in state}} \)

- Multiply GSDP per Worker by probability that a person of age \( j \) is working = \( \frac{\text{Workers}_j}{\text{Population}_j} \)

- Output lost is product of adjusted output lost at each age \( j \) times YLD\(_j\) summed over all ages
Output Lost Due to Illness in 2017

\[ W_{ij}^{2017} = \frac{\alpha GSDP_i}{\text{workers}_i} \times \frac{\text{workers}_{ij}}{\text{population}_{ij}} \]

Output lost due to illness = \( \sum_{j} W_{ij}^{2017} YLD_{ij}^{2017} \)
Lost Output Due to YLDs - I

• Total loss for India, based on 2016-17 GDP, is INR 37,000 Crore—about 0.24% of GDP

• States with highest monetary losses are:
  • Maharashtra (INR 4,500 Crore)
  • Uttar Pradesh (INR 4,300 Crore)
  • Tamil Nadu (INR 2,400 Crore)
  • Karnataka (INR 2,200 Crore)
  • Rajasthan (INR 2,100 Crore)

• This reflects both number of YLDs and GSDP
Loss Due to YLDs
Lost Output Due to YLDs - II

• Ranking is different when expressed as a percent of GSDP

• States with highest losses as a percent of GSDP are:
  • Uttar Pradesh (0.35%)
  • Bihar (0.30%)
  • Rajasthan (0.29%)
  • Haryana (0.26%)
  • Himachal Pradesh (0.26%)
  • Uttarakhand (0.26%)
Output Lost Due to Premature Mortality

• Compute present value of output lost over remainder of a person’s lifetime
• GSDP per worker in 2017 assumed to grow at rate $g$
• Earnings at each future age weighted by
  • Probability person survives to that age
  • Probability a person of that age works
• Adjusted earnings at each future age are discounted to the present at rate $r$
• Initial estimates assume $g = 4.53\%$ and $r = 6\%$
Present Value of Future Output

\[ PV_{ij} = \text{Present value of future output for person of age } j \text{ in state } i \]

\[ PV_{ij} = \sum_{t=j}^{84} \left( \frac{\text{Output per worker}_i}{(1 + g)^{t-j} A_{it} (1 + r)^{j-t}} \right) \]

where \[ g = \text{rate of growth in output per worker} \]

\[ r = \text{discount rate} \]

\[ A_{it} = P(\text{work at age } t)_i \times P(\text{survive to age } t)_i \]
Lost Output Due to Mortality - I

• Total loss for India, based on 2016-17 GDP, is INR 79,000 Crore—about 0.50% of GDP

• States with highest monetary losses are:
  • Uttar Pradesh (INR 10,700 Crore)
  • Maharashtra (INR 7,800 Crore)
  • Rajasthan (INR 5,600 Crore)
  • Karnataka (INR 4,800 Crore)
  • Tamil Nadu (INR 4,600 Crore)

• This reflects both number of deaths, GSDP
Mortality Losses
Lost Output Due to Mortality - II

• Ranking is different when expressed as a percent of GSDP

• States with highest losses as a percent of GSDP are:
  • Uttar Pradesh (0.85%)
  • Rajasthan (0.76%)
  • Bihar (0.74%)
  • Madhya Pradesh (0.62%)
  • Chhattisgarh (0.59%)
Losses as a Percent of GSDP
Issues in Computing Lost Output

• Computations ignore value of household production, production in the informal sector
  • Could adjust for output of non-workers
• Results are sensitive to the values of $g$ and $r$; specifically to $(1+g)/(1+r)$
• Our ratio is consistent with $g = .06$ $r = .075$
• Other members of the team have built an optimal growth model of the Indian economy that can inform this choice
Would Like to Go Beyond Lost Output

- What people would pay to reduce their risk of dying exceeds the value of lost output
  - Reflects lost enjoyment of being alive
  - Reflects risk aversion

- Willingness to pay for mortality risk reductions used to evaluate environmental policies in India
  - CSTEP Benefit-Cost Analysis of Emissions Standards for Coal-Based Thermal Power Plants in India (2018)
  - Somanathan (ISI Delhi) and Chakravorty (ATREE) Social Costs of Power from Coal and Renewables in India (2018)

- Should these estimates be included?
Health Expenditures Associated with Air Pollution

• How much of expenditures on the following diseases are associated with air pollution:
  • COPD   IHD   Diabetes   Cataracts
  • LRI   Stroke   Lung cancer

• Determine total health expenditures by disease using 71st round of NSS
• Calculate expenditure per DALY for each disease
• Determine fraction of DALYs attributable to air pollution
Health Expenditures Associated with Air Pollution

- Calculate expenditure per DALY for each disease associated with air pollution
- Determine DALYs attributable to air pollution for each disease $d$

\[
\left( \text{Health expenditure due to air pollution} \right) = \sum_d \left( \text{Expenditure per DALY} \right)_d \times \left( \text{DALYs due to air pollution} \right)_d
\]
# DALYs Attributable to Air Pollution, by Disease

<table>
<thead>
<tr>
<th>Disease</th>
<th>Total DALY (thousands)</th>
<th>Cause-specific DALYs attributable to air pollution (thousands)</th>
<th>AP DALYs as a Percent of total DALYs</th>
<th>Percent of AP DALYS Attributable to Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRIs</td>
<td>23,624</td>
<td>11,338</td>
<td>48%</td>
<td>29%</td>
</tr>
<tr>
<td>COPD</td>
<td>24,699</td>
<td>11,286</td>
<td>46%</td>
<td>29%</td>
</tr>
<tr>
<td>IHD</td>
<td>36,988</td>
<td>9,209</td>
<td>25%</td>
<td>24%</td>
</tr>
<tr>
<td>Stroke</td>
<td>17,611</td>
<td>2,906</td>
<td>17%</td>
<td>8%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>11,163</td>
<td>2,674</td>
<td>24%</td>
<td>7%</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>2,060</td>
<td>681</td>
<td>33%</td>
<td>2%</td>
</tr>
<tr>
<td>Cataracts</td>
<td>2,525</td>
<td>597</td>
<td>23%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>118,669</strong></td>
<td><strong>38,684</strong></td>
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</tr>
</tbody>
</table>
## Health Expenditures Attributable to Air Pollution

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yearly expenditures per DALY (2014 Rs)</th>
<th>Yearly expenditures attributable to air pollution (2014 Crores)</th>
<th>Yearly expenditures attributable to air pollution (2016 Crores - inflated using the CPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRIs</td>
<td>13,420</td>
<td>15,215</td>
<td>15,898</td>
</tr>
<tr>
<td>COPD</td>
<td>13,420</td>
<td>15,145</td>
<td>15,825</td>
</tr>
<tr>
<td>IHD</td>
<td>13,435</td>
<td>12,372</td>
<td>12,928</td>
</tr>
<tr>
<td>Stroke</td>
<td>14,464</td>
<td>4,203</td>
<td>4,392</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>9,024</td>
<td>615</td>
<td>642</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>47,550</strong></td>
<td><strong>49,686</strong></td>
<td></td>
</tr>
</tbody>
</table>
Health Expenditures Associated with Air Pollution

- Expenditures associated with air pollution are approximately 10.5% of total health expenditures

- Approximately 0.33% of GDP is associated with health expenditures related to air pollution

- These are significant costs:
  - Given the high percent of health expenditures that are out-of-pocket (~ 70%)
  - Given the often impoverishing nature of cancer and heart disease
Conclusions

• Output losses from YLDs and premature mortality associated with air pollution are substantial:
  • Morbidity losses are, in the aggregate, about 0.24% of India’s GDP; mortality losses about 0.5% of GDP
  • In Uttar Pradesh, Bihar and Rajasthan, the sum of these losses exceeds 1% of GDP
  • Health expenditures associated with air pollution are over 10% of total health expenditures
  • Economic losses far exceed what we have quantified