Lecture on air pollution impacts and damage

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Literature:
Parry, Heine, Lis and Li (2014), ch 4 (on Measuring pollution damage from fuel use)
Overall impacts of ambient emissions to air

• Impacts highly dependent on population concentrations
• Important types of emissions:
• Transport, the burning of gasoline and diesel
• Power plants, most problematic from burning of coal, natural gas to a smaller degree
• Local heating: burning of wood, coal
• Industrial pollution, with burning of all fossil fuels, including diesel generators
• Also other industrial emissions that may be dangerous or harmful
Types/sources of air pollution

• CO2: Causes global warming.
• SO2: Causes damage to human health, other life, buildings.
• NOx: Causes inflammation of the airways, potentially serious lung damage. Negative impacts on plant growth.
• PM10: Course air particles, cause lung disease.
• PM2.5: Fine particles, causes damage to human health (pulmonary disease, heart disease, lung cancer).
• O3 (ozone): Causes damage to human health, agriculture.
• CO (carbon monoxide): Highly toxic and can be lethal. But usually in too low concentrations to cause problems (except in some highly polluted urban areas).
Types of impacts of air pollution

• Mortality impacts, but most for persons who are already sick or weak.
• Morbidity impacts, increases in the incidence of pulmonary disease, lung cancer and other cancers, heart disease, and stroke, lower life quality.
• Impacts on materials, in particular from SO2 on buildings and constructions (corrosion and deterioration).
• Impacts for agriculture (ozone).
• Impacts on visibility (smog and smoke).
• Note that increased CO2 concentrations can have beneficial impacts for some agricultural products («carbon fertilization»).
Valuing damages from local air pollution emissions through impacts on human health and well-being

• Involves the following steps:
  • Determining how emissions affect the amount of harmful substances inhaled
  • Assessing how such pollution exposure affects mortality and morbidity rates
  • Attaching monetary values to given health impacts (mortality impacts: the value of statistical life, VSL; morbidity impacts: assessments of costs associated with ill health)
  • Translating these monetary impacts into costs per unit of emission
  • Adding possible other «nuisance effects» of air pollution
Assessing population exposures to emissions

• Intake fraction (iF) for primary pollutant defined by

\[ iF \equiv \frac{\sum_{i=1}^{N} P_i \times \Delta C_i \times BR}{Q} \]

• P = population, delta C = change in ambient pollution concentration, BR = average breathing rate. Q = emissions of primary pollutant.

• Overall intake then defined as iF times Q.

• Can be the case that iF falls in Q (there is a «saturation effect» of pollution for humans). Then, theoretically (and paradoxically), the emissions tax could be lower for higher pollution concentrations.

• But: This is not much of an issue if environmental taxes are actually imposed, as pollution will be reduced (to levels below saturation) in response.
Average pollution concentrations (PM 2.5) in selected countries, 2010
Mortality and morbidity effects of air pollution

• Four adult diseases are mainly involved: Chronic pulmonary disease, lung cancer, heart disease, and stroke.

• The most important and significant air pollutant for human health is PM2.5. These are tiny particles in the air which permeate the lungs and may even reach the bloodstream.

• Note that, in some main cities in China (such as Shanghai), pulmonary disease is the leading cause of death. This is highly related to the high air pollution level in China.
Baseline Mortality Rates per Year for Illnesses Potentially Aggravated by Pollution, Selected Regions, 2010

[Bar chart showing annual mortality rate per 1,000 population for various regions, with categories including Global, Andean Latin America, Australasia, and others, with color-coded bars for causes of death like lung cancer, heart disease, pulmonary disease, and stroke.]
Mortality due to different classes of pollution in developing countries

• An estimated 8.4 million persons globally die from pollution every year. About 90% of these live in developing countries.
• This makes pollution a leading cause of death in lower-income countries, alongside with cancer and heart disease (much of which is also related to pollution).
• The leading causes of pollution deaths are:
  1. Household air pollution, 3.7 million
  2. Ambient air pollution, 3.1 million
  3. Soil and food pollution and poisoning, 0.9 million
  4. Water pollution, 0.8 million.
Among these, 1-3 mainly affect older persons, while 4 mainly affect infants and small children (90%).
Valuing pollution damage to human health

• Valuing increased mortality: Use estimates of the value of statistical life (VSL).
• Alternative: Use values based on quality adjusted life years (QALYs)
• Main difference between the two:
  • The former ignores/diminishes the value of a longer expected future life span for a given individual.
  • The latter focuses only on expected future life span.
• We will come back to these issues in more detail in the seminar next week.
Standard way to measure VSL across countries

• *Income adjustment.* We obtain a value for mortality risk reduction (per life saved) for individual countries (denoted $V_{\text{country}}$) from that for the OECD as a whole (denoted $V_{\text{OECD}}$), using the formula below.

• In the formula, $\eta$ is an elasticity parameter, showing to what degree VSL depends on national income per capita (PPP adjusted).

\[ V_{\text{country}} = V_{\text{OECD}} \left( \frac{I_{\text{country}}}{I_{\text{OECD}}} \right)^\eta \]
Valuing mortality risk, selected countries, assuming $\eta = 0.8$
Air pollution deaths, selected countries, 2010

Annual deaths attributed to ambient air pollution

- Andean Latin America
- Australasia
- Caribbean
- Central Asia
- Central Europe
- Central Latin America
- Central sub-Saharan Africa
- East Asia
- Eastern Europe
- Eastern sub-Saharan Africa
- High-income Asia Pacific
- High-income North America
- North Africa and Middle East
- Oceania
- South Asia
- Southeast Asia
- Southern Latin America
- Southern sub-Saharan Africa
- Tropical Latin America
- Western Europe
- Western sub-Saharan Africa
Damages from coal plant per ton of SO2 emissions, selected countries (2010)
Average SO$_2$ Emission Rates at Coal Plants with and without Control Technologies, 2010

![SO$_2$ Emission Rates Chart]

- **Australia**
- **Brazil**
- **Chile**
- **China**
- **Germany**
- **India**
- **Indonesia**
- **Israel**
- **Japan**
- **Kazakhstan**
- **Mexico**
- **Poland**
- **South Africa**
- **South Korea**
- **Thailand**
- **Turkey**
- **United Kingdom**
- **United States**
- **Zimbabwe**

**SO$_2$ emissions rate, kilotons/PJ**

- **uncontrolled emissions rate**
- **difference between controlled and uncontrolled emissions rate**
Damages from ground-level NOx emissions per ton, selected countries (2010)
Corrective coal tax estimates, selected countries, 2010 (in total, and by main source)
Breakdown of air pollution damages from coal by types of emissions, selected countries, 2010

The bar chart shows the share of emissions in total air pollution damages for various countries, categorized by types of emissions (SO2, NOx, (direct) PM2.5). The chart visually represents the proportion each type of emission contributes to the total air pollution damages in each country.
Optimal corrective taxes on natural gas for power plants. Selected countries, 2010
Optimal corrective taxes on natural gas for home heating.
Selected countries, 2010
## Impacts of corrective coal taxes by country

<table>
<thead>
<tr>
<th>Impacts of policy reform</th>
<th>Brazil</th>
<th>Egypt</th>
<th>Germany</th>
<th>Indonesia</th>
<th>South Africa</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective tax (no emissions controls), $/GJ</td>
<td>6.4</td>
<td>na</td>
<td>89.2</td>
<td>8.9</td>
<td>5.0</td>
<td>31.7</td>
</tr>
<tr>
<td>corrective tax (net of rebate for emissions controls), $/GJ</td>
<td>4.4</td>
<td>na</td>
<td>9.3</td>
<td>5.7</td>
<td>4.6</td>
<td>8.7</td>
</tr>
<tr>
<td>current tax/subsidy, $/GJ</td>
<td>0</td>
<td>na</td>
<td>-1.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fuel prices: percent increase in coal price to generators</td>
<td>88.7</td>
<td>na</td>
<td>449.0</td>
<td>126.4</td>
<td>127.1</td>
<td>664.1</td>
</tr>
<tr>
<td>current generators’ price, $/GJ</td>
<td>5.5</td>
<td>na</td>
<td>5.9</td>
<td>5.0</td>
<td>3.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Fuel use: percent reduction in fuel use</td>
<td>17.3</td>
<td>na</td>
<td>40.0</td>
<td>21.7</td>
<td>21.8</td>
<td>45.7</td>
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<tr>
<td>current coal use, petajoules</td>
<td>570</td>
<td>na</td>
<td>4,323</td>
<td>1,531</td>
<td>5,800</td>
<td>24,601</td>
</tr>
<tr>
<td>Fiscal: revenue gain, percent of GDP</td>
<td>0.1</td>
<td>na</td>
<td>2.1</td>
<td>1.1</td>
<td>5.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Emissions: percent reduction in nationwide CO2 emissions</td>
<td>2.1</td>
<td>na</td>
<td>21.5</td>
<td>7.6</td>
<td>18.1</td>
<td>18.8</td>
</tr>
<tr>
<td>share of current emissions from coal</td>
<td>12.1</td>
<td>na</td>
<td>53.7</td>
<td>34.8</td>
<td>83.1</td>
<td>41.3</td>
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<tr>
<td>Health: premature pollution-deaths avoided</td>
<td>72</td>
<td>na</td>
<td>2,581</td>
<td>1,114</td>
<td>1,109</td>
<td>12,546</td>
</tr>
<tr>
<td>lives saved per petajoule reduction in coal</td>
<td>0.7</td>
<td>na</td>
<td>1.5</td>
<td>3.3</td>
<td>0.9</td>
<td>1.1</td>
</tr>
</tbody>
</table>
## Impacts of corrective natural gas taxes by country

<table>
<thead>
<tr>
<th>Impacts of policy reform</th>
<th>Brazil</th>
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<th>Indonesia</th>
<th>South Africa</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective tax (no emissions controls), $/GJ</td>
<td>2.0</td>
<td>2.1</td>
<td>4.5</td>
<td>2.4</td>
<td>2.0</td>
<td>3.1</td>
</tr>
<tr>
<td>corrective tax (net of rebate for emissions controls), $/GJ</td>
<td>2.0</td>
<td>2.1</td>
<td>3.1</td>
<td>2.3</td>
<td>2.0</td>
<td>3.1</td>
</tr>
<tr>
<td>current tax/subsidy, $/GJ</td>
<td>0</td>
<td>na</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fuel prices: percent increase in gas price</td>
<td>9.7</td>
<td>7.0</td>
<td>21.6</td>
<td>11.4</td>
<td>9.4</td>
<td>14.3</td>
</tr>
<tr>
<td>current generators' price, $/GJ</td>
<td>4.8</td>
<td>3.3</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Fuel use: percent reduction in fuel use</td>
<td>4.5</td>
<td>3.3</td>
<td>9.3</td>
<td>5.2</td>
<td>4.4</td>
<td>6.5</td>
</tr>
<tr>
<td>current natural gas use, petajoules</td>
<td>993</td>
<td>1,755</td>
<td>3,450</td>
<td>1,607</td>
<td>152</td>
<td>25,926</td>
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<tr>
<td>Fiscal: revenue gain, percent of GDP</td>
<td>0.1</td>
<td>1.6</td>
<td>0.4</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Emissions: percent reduction in nationwide CO2 emissions</td>
<td>0.6</td>
<td>1.7</td>
<td>2.3</td>
<td>1.1</td>
<td>0.1</td>
<td>1.7</td>
</tr>
<tr>
<td>share of current emissions from natural gas</td>
<td>0.12</td>
<td>0.51</td>
<td>0.24</td>
<td>0.22</td>
<td>0.02</td>
<td>0.26</td>
</tr>
<tr>
<td>Health: premature pollution-deaths avoided</td>
<td>4</td>
<td>13</td>
<td>209</td>
<td>55</td>
<td>0</td>
<td>403</td>
</tr>
<tr>
<td>lives saved per petajoule reduction in natural gas</td>
<td>0.1</td>
<td>0.2</td>
<td>0.6</td>
<td>0.7</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Air and water pollution policy and child mortality in India (Greenstone and Hanna, AER 2014)

• The accident at the chemical plant belonging to Union Carbide (a US multinational corporation), in Bhopal, India in 1984, with massive release of poisonous pesticide gas, likely caused more than 8,000 deaths and perhaps 500,000 injuries. It is today widely considered the world’s greatest environmental disaster caused by industry.

• This accident led to the start of certain environmental reforms in India, which have been studied by G&H. They study in particular how air and water pollution control reforms were carried out.

• These authors find that the pace of regulatory improvement was much faster for air pollution than for water pollution.
Air and water pollution policy and child mortality in India (Greenstone and Hanna, AER 2014) (cont.)

• Why was there more progress for air than for water?
• Political economy here likely played a role.
• For the middle and higher economic classes in India, which have (by far) most influence on policy, it is relatively easy to guard against poor water quality by buying bottled water (at reasonable prices), and as virtually everyone has good sanitation facilities.
• For air pollution, it is much more difficult for even the rich to guard against poor ambient air quality. The only way to guard against this is by cleaning the air.
• This has led to greater political pressure to do something about air quality, than to water quality, in India.
• Poor people in India (most of the population) have been suffering from this, as their water quality and infrastructure facilities are poor.
• Still today, about 2/3 of all households in India do not have in-house sanitation. (In China and throughout Latin America, virtually everyone has.)
• (Did you see the movie «Slumdog Millionaire?»)