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
- GSDP per Worker = $\frac{\text{Labor's share of GDP * GSDP}}{\text{Number of workers in state}}$
- Multiply GSDP per Worker by probability that a person of age j is working = $\text{Workers}_j/\text{Population}_j$
- 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

$$W_{ij}^{2017} = \text{Output Produced by person of age } j \text{ in state } i$$

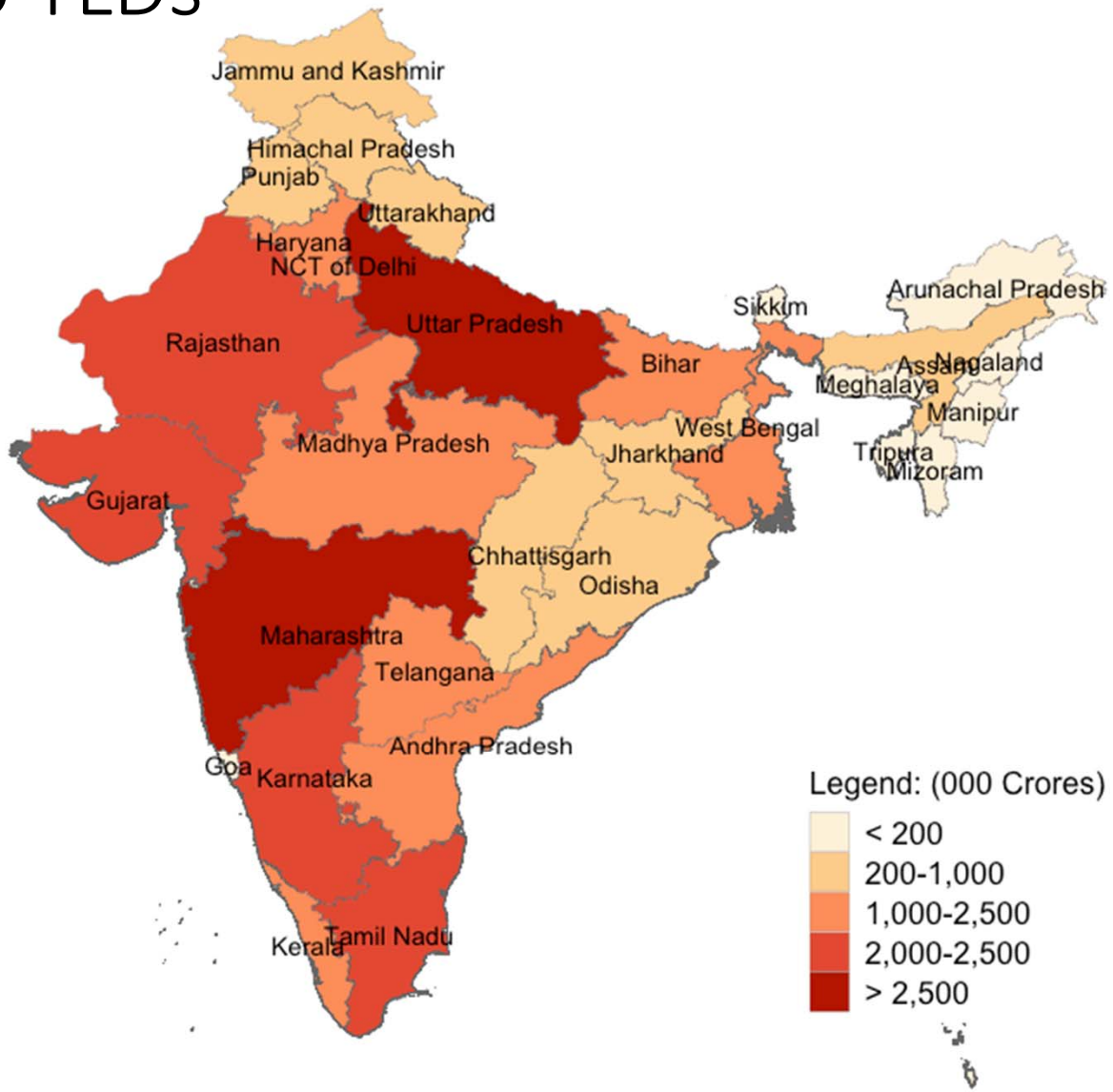
$$W_{ij}^{2017} = \underbrace{\begin{pmatrix}\text{Output}\\ \text{per worker}\end{pmatrix}_i}_{\frac{\alpha GSDP_i}{\text{workers}_i}} \times \underbrace{\begin{pmatrix}\text{Probability person}\\ \text{age } j \text{ is working}\end{pmatrix}_i}_{\frac{\text{workers}_{ij}}{\text{population}_{ij}}}$$

$$\text{Output lost due to illness} = \sum_j W_{ij}^{2017} YLD_{ij}^{2017}$$

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

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

$$PV_{ij} = \sum_{t=j}^{84} \begin{pmatrix} \text{Output} \\ \text{per worker}_i \end{pmatrix} (1+g)^{t-j} A_{it} (1+r)^{j-t}$$

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

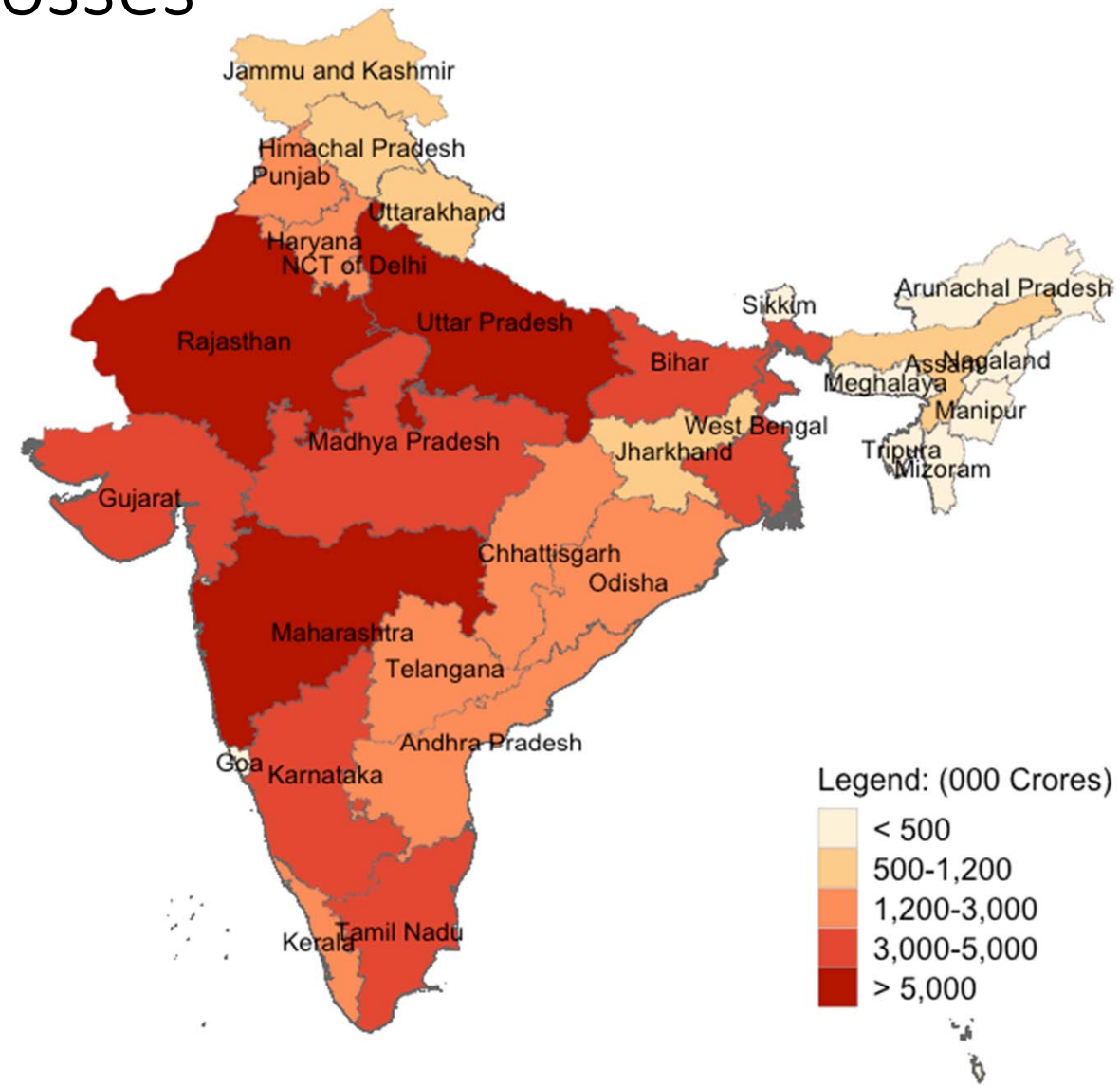
$r = \text{discount rate}$

$A_{it} = P(\text{work at age } t)_i \times P(\text{survive to age } t)_i$

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

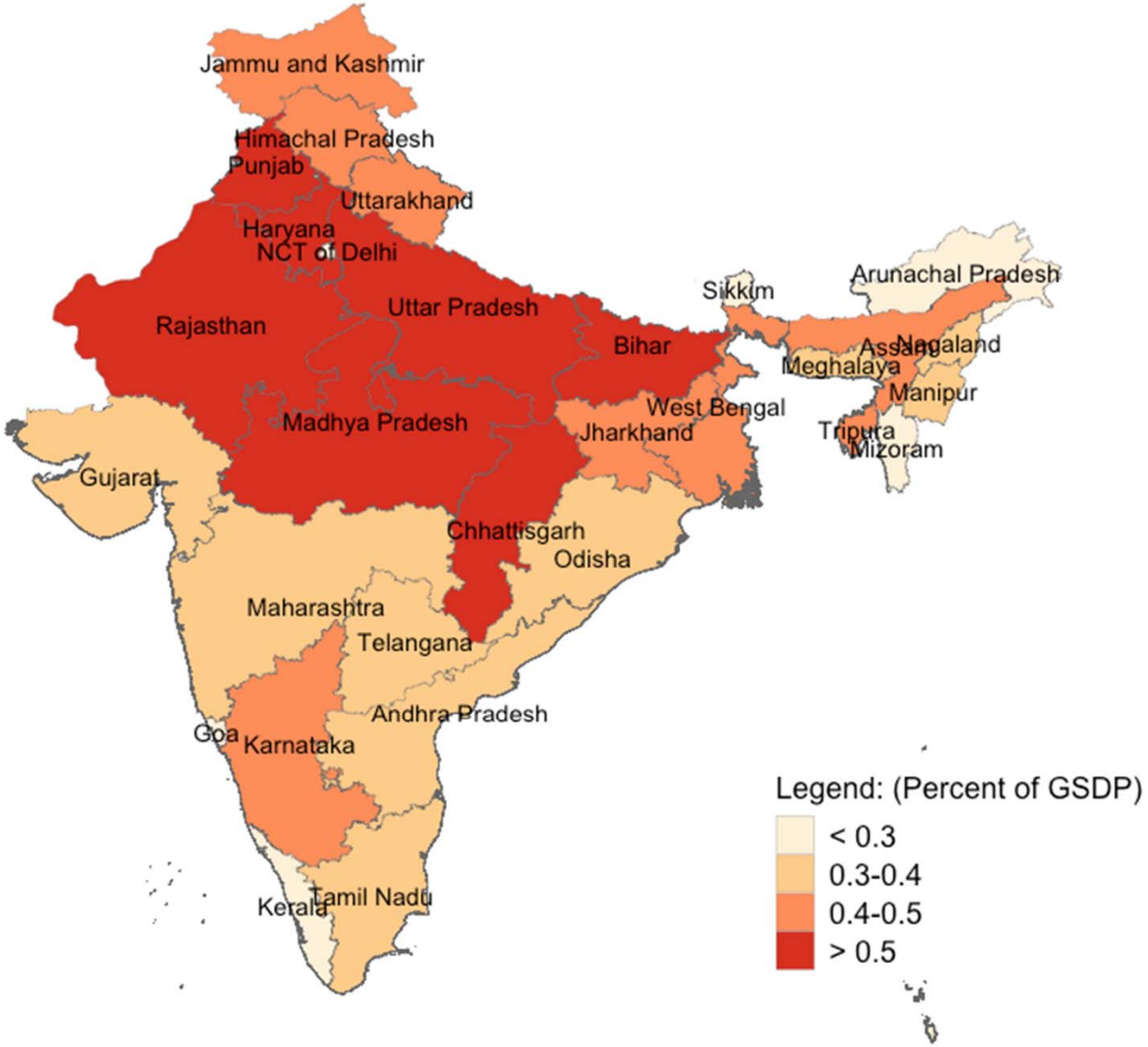
Mortality Losses



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*

$$\begin{pmatrix}\text{Health expenditure}\\ \text{due to air pollution}\end{pmatrix} = \sum_d \begin{pmatrix}\text{Expenditure}\\ \text{per DALY}\end{pmatrix}_d \times \begin{pmatrix}\text{DALYs due to}\\ \text{air pollution}\end{pmatrix}_d$$

DALYs Attributable to Air Pollution, by Disease

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

Health Expenditures Attributable to Air Pollution

	Yearly expenditures per DALY (2014 Rs)	Yearly expenditures attributable to air pollution (2014 Crores)	Yearly expenditures attributable to air pollution (2016 Crores - inflated using the CPI)
LRIs	13,420	15,215	15,898
COPD	13,420	15,145	15,825
IHD	13,435	12,372	12,928
Stroke	14,464	4,203	4,392
Lung Cancer	9,024	615	642
Total		47,550	49,686

Health Expenditures Associated with Air Pollution

- Expenditures associated with air pollution are approximately 10.5% of total heath 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 mature 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