Confessions of a Team that did *Interdisciplinary Research*

Warren Sanderson, Erich Striessnig
Wolfgang Schöpp, Markus Amann

Why Confessions?

- Interdisciplinary research is something that many people say they want to do, but few actually admit doing it.

Interdisciplinary Research

"I'M ON THE VERGE OF A MAJOR BREAKTHROUGH, BUT I'M ALSO AT THAT POINT WHERE CHEMISTRY LEAVES OFF AND PHYSICS BEGINS, SO I'LL HAVE TO DROP THE WHOLE THING."

The GrandPrograms Involved

- Mitigation of Air Pollution (MAG)

- World Population (POP)

Our offspring

[Effects on Well-Being of Investing in Cleaner Air in India]

Take Home Messages

- Interdisciplinary Research can be done.

- It can be fun.

- It can be productive.

What’s in a name?

- Effects on Well-Being of Investing in Cleaner Air in India

- *Well-Being*

- *Cleaner Air*

The Model Parents

- ***GAINS MODEL***
- Greenhouse Gas and Air Pollution Interactions and Synergies Model

- ***SEDIM***
- Simple Economic and Demographic Interaction Model

Disciplines

- Energy Systems
- Atmospheric Chemistry
- Epidemiology
- Economics
- Demography

The Offspring's Accomplishments

- "In India, air pollution abatement investments clearly improve well-being."

Organization

- 1. This Introduction
- 2. The GAINS Model – Markus Amann
- 3. The SEDIM Model – Warren Sanderson
- 4. Putting it all together in a coherent and publishable package – Erich Striessnig
- 5. YSSP research – Haochen Wang
- 6. Panel Discussion of Future Interdisciplinary Research

Economic Growth in a World of Environmental Constraints

The SEDIM Model

Constraints

- The 20th century was the century of growth.
- The 21st century is going to be the century of constraints.

- How can we think about integrating these constraints into an economic model?

Environmental Constraints

- Challenges posed by global climate change
- economic costs of necessary abatement policies modeling the impact of environmental degradation on human health and productivity
- Challenges posed by energy and natural resource scarcity
- substitution technologies transition to renewable energies

Demographic Constraints

- Challenges posed by unprecedented societal aging in
- some parts of the world
- include realistic demography
- think about how aging societies are different from "stable populations"
- Opportunities generated by favorable age-structure dynamics in others
- How to make the most out of a potential "demographic dividend"?
- How to model the ongoing educational transitions?

Challenges for the Economic Growth Modeler

- Any realistic model of economic growth has to take environmental challenges into account.
  - The constraints will be different in different parts of the world
  - There is enormous uncertainty

Are We Really in Equilibrium

- Many economic growth models assume that we are:
- 1. in equilibrium
- 2. have perfect foresight (or rational expectations)
- 3 and therefore there are no surprises.
- (we know all our environmental problems with certainty today)

Do We Believe This?

- In a world of unanticipated environmental change and unanticipated costs, the assumption of perfect foresight makes no sense.

Out of Equilibrium

- We need a model capable of studying out-of-equilibrium dynamics.

Enter SEDIM

- SEDIM does not assume perfect foresight
- agents are characterized by adaptive, forward looking behavior
- they make use of limited common information on how the economy evolved in the past. . .
- . . . using this information they “plan ahead” and react to surprises.

One type of output, Y_t, is generated, using a Cobb-Douglas production function

$$Y_t = A_t * L^{\alpha} * K^{1-\alpha}$$

Anything that causes economic growth, has to do so by affecting one of these sources:

L_t . . . Effective Labor

K_t . . . Capital Stock

A_t . . . Total Factor Productivity

(α. . . Output Elasticity of Labor)

The workforce in SEDIM includes the full information on the population's age- and educational attainment structure

$$L_t = \sum_{a=alfe(t)}^{alfx(t)} POP_{a,t} EU_{a,t}$$

$alfe(t)$ . . . age of labor market entry in year t

$alfx(t)$ . . . age of labor market exit in year t

$POP_{a,t}$ . . . population at age a in year t

$EU_{a,t}$ number of efficiency units embodied by worker of age a in year t

Capital

- There are two types of capital holders
  - Consumers
  - Corporations and wealthy individuals

Capital

- Consumers have income from labor and from capital assets. They save for life-cycle purposes
- Their goal is to smooth consumption over their lifetime.
- BUT consumers have imperfect foresight.

Corporations

- Corporations and wealthy individuals receive income from capital investments.
- Their income depends on the rate of return to capital.
- They do not save for life-cycle consumption smoothing.

Total Factor Productivity

SEDIM is a model of conditional convergence/divergence characterized by two gaps

a country's "technological gap" with respect to the global technological leader

a country's gap to its own "potential" level of A_t

Determining factors of a country's "potential", its "backwardness", and the speed of catching-up include

rate of capital formation

educational attainment level of the workforce

population age-structure

the interaction of education and age-structure

an economy's level of "openness"

the quality of political institutions, i.e., corruption, rule of law

Measuring Well-Being

- In our paper in ES&T, we measured well-being using a version of the UN's Human Development Index.

- Erich Striessnig will say more about this in a moment.

Challenge

- Reproducing India's pattern of economic growth as it happened in the past and as it is expected to happen in the future.

- We did this by altering the rate of total factor productivity in a way that was consistent with the policy changes actually observed in India.

Interdisciplinarity

- SEDIM initially contained ideas from two disciplines:
  - Economics
  - Demography

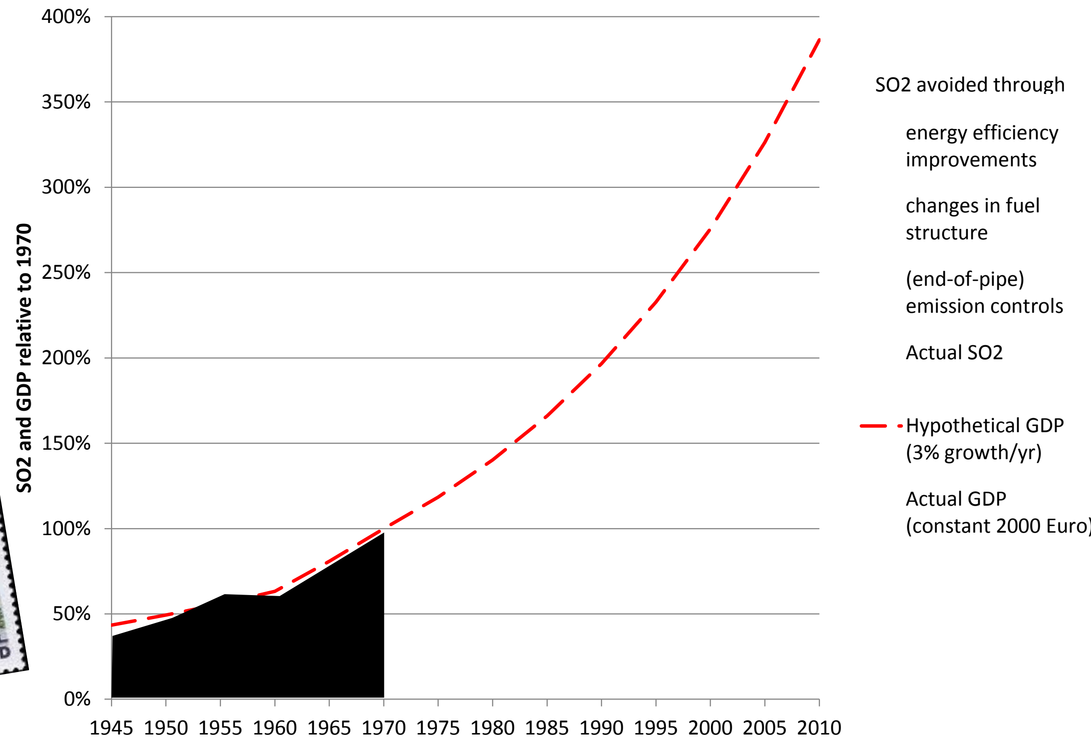
- To do the research on India, we added a third discipline:
  - Epidemiology

The GAINS (Greenhouse Gases - Air Pollutants Interactions and Strategies) model - Applications in Europe and Asia

Markus Amann
Program Director
Mitigation of Air Pollution and Greenhouse Gases

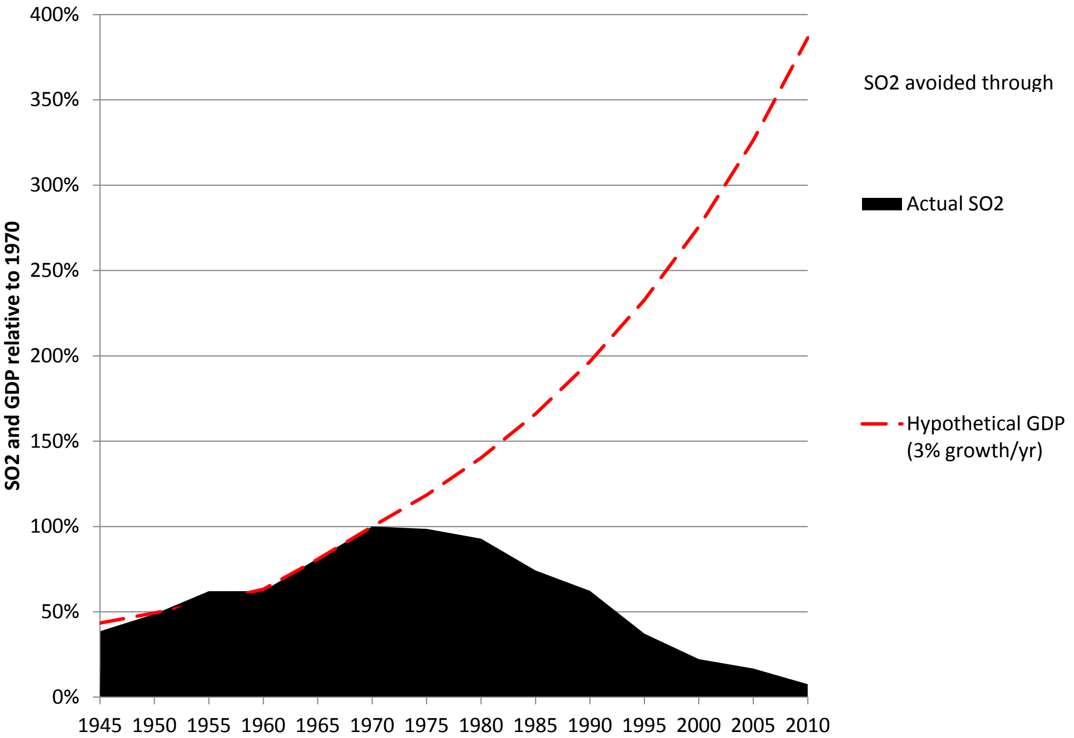
How has pollution been reduced in Europe?

SO_2 emissions in Western Europe:
A 1970's perspective



How has pollution been reduced in Europe?

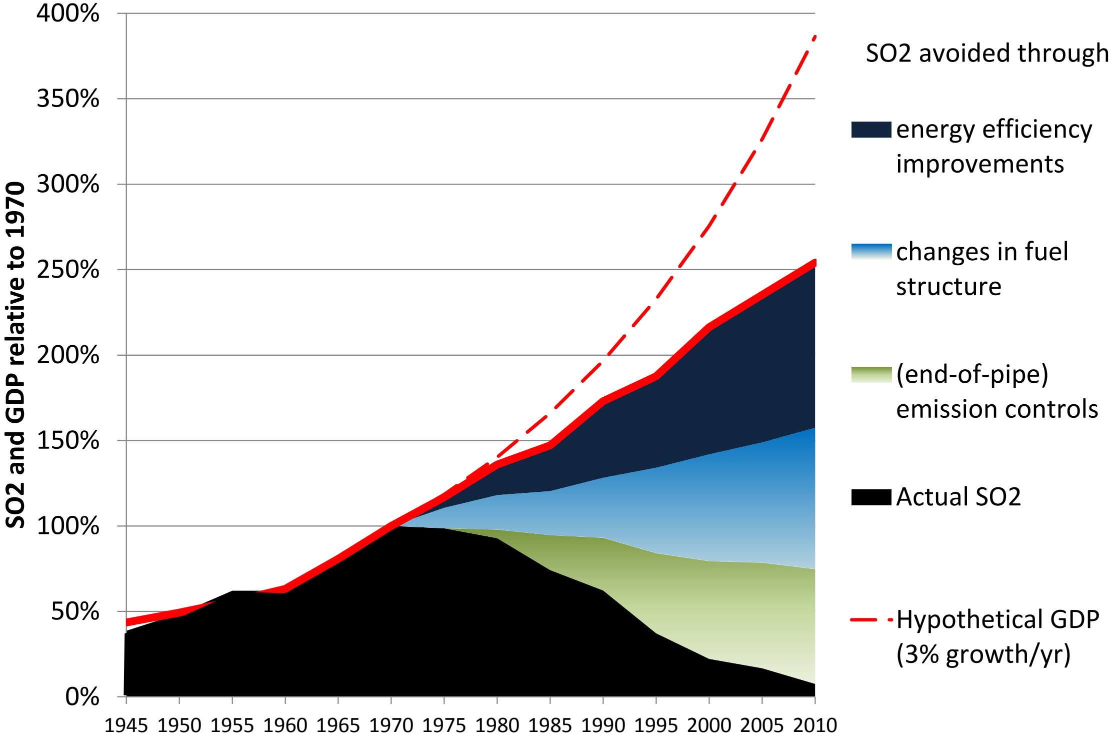
SO_2 emissions in Western Europe: 1945-2010



Source: IIASA
http://gains.iiasa.ac.at

How has pollution been reduced in Europe?

Decoupling between GDP and SO_2 emissions in Western Europe

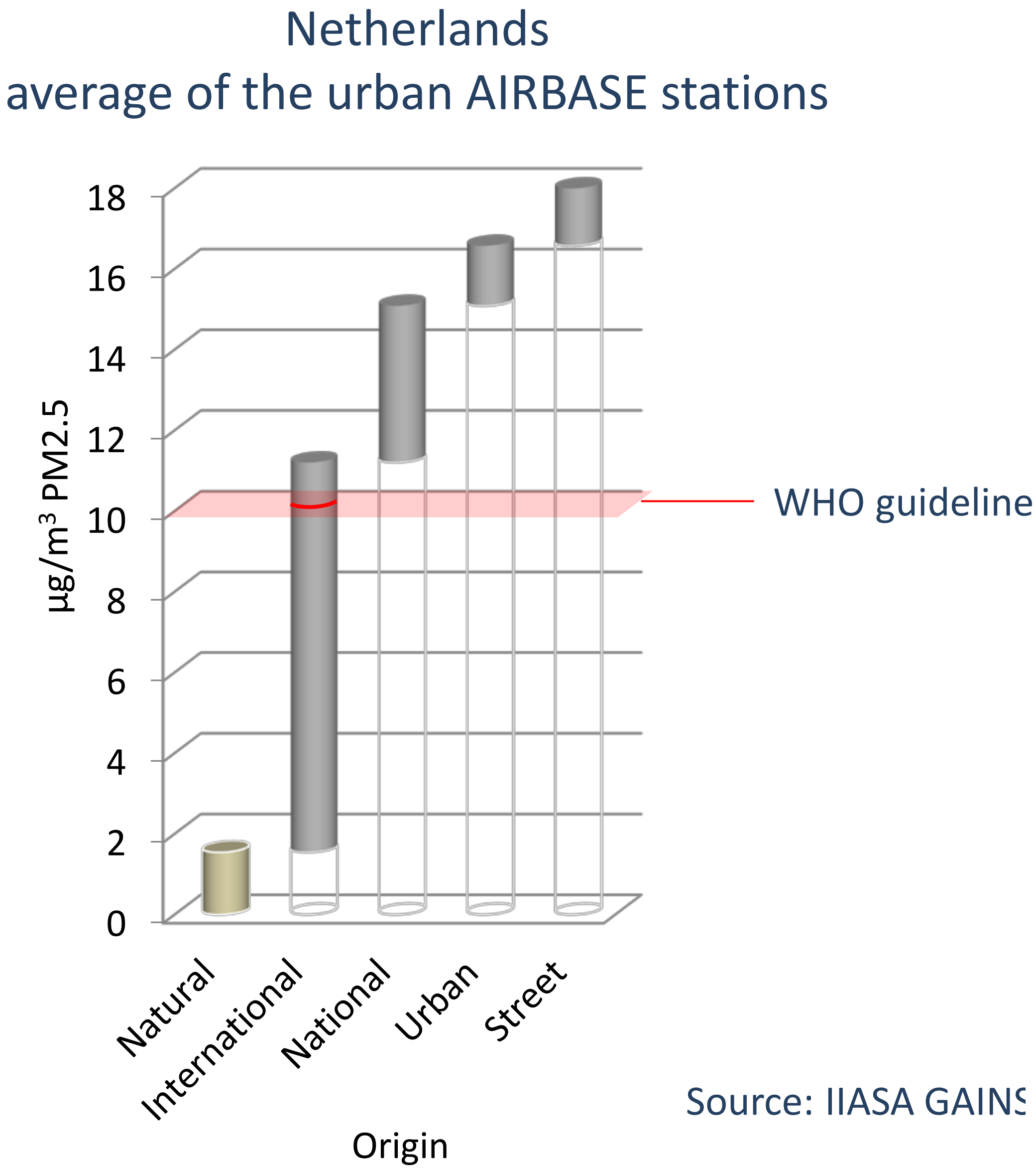


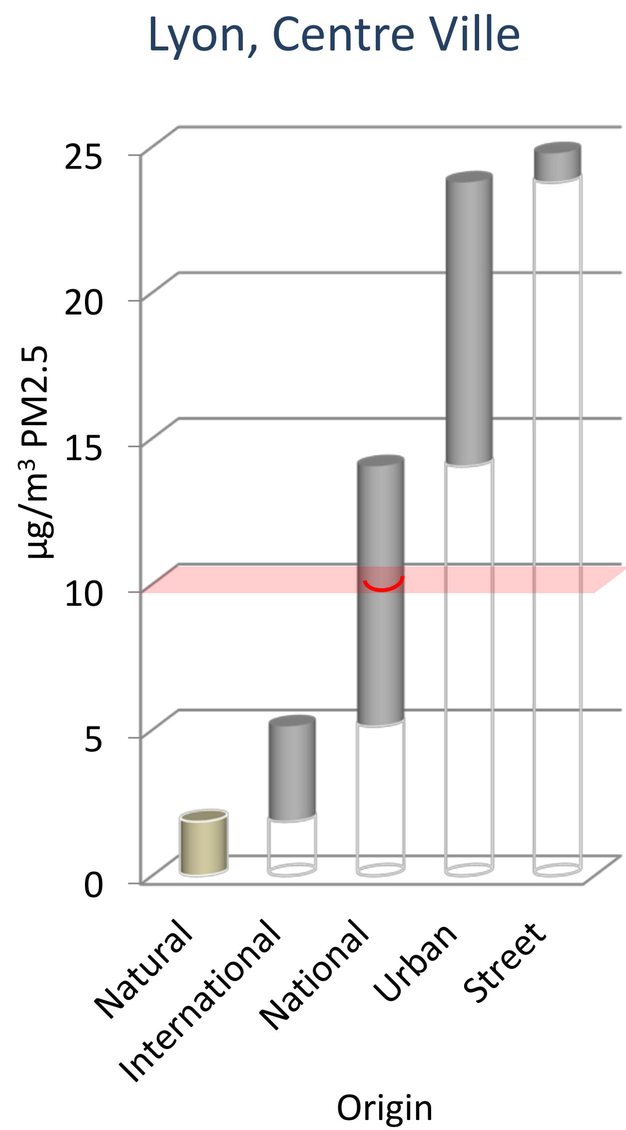
Source: IIASA
http://gains.iiasa.ac.at

GAINS: A multi-pollutant/multi-effect systems perspective

	PM (BC, OC)	SO_2	NO_x	VOC	NH_3	CO	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM (Loss in life expectancy)	√	√	√	√	√					
O_3 (Premature mortality)			√	√		√		√		
Vegetation damage: O_3 (AOT40/fluxes)			√	√		√		√		
Acidification (Excess of critical loads)		√	√		√					
Eutrophication (Excess of critical loads)			√		√					
Climate impacts: Long-term (GWP100)	(√)	(√)	(√)	(√)	(√)	(√)	√	√	√	√
Near-term forcing	√	√	√	√	√	√	(√)	√	(√)	(√)
Carbon deposition to the Arctic and glaciers	√									

Origin of PM2.5 - 2009



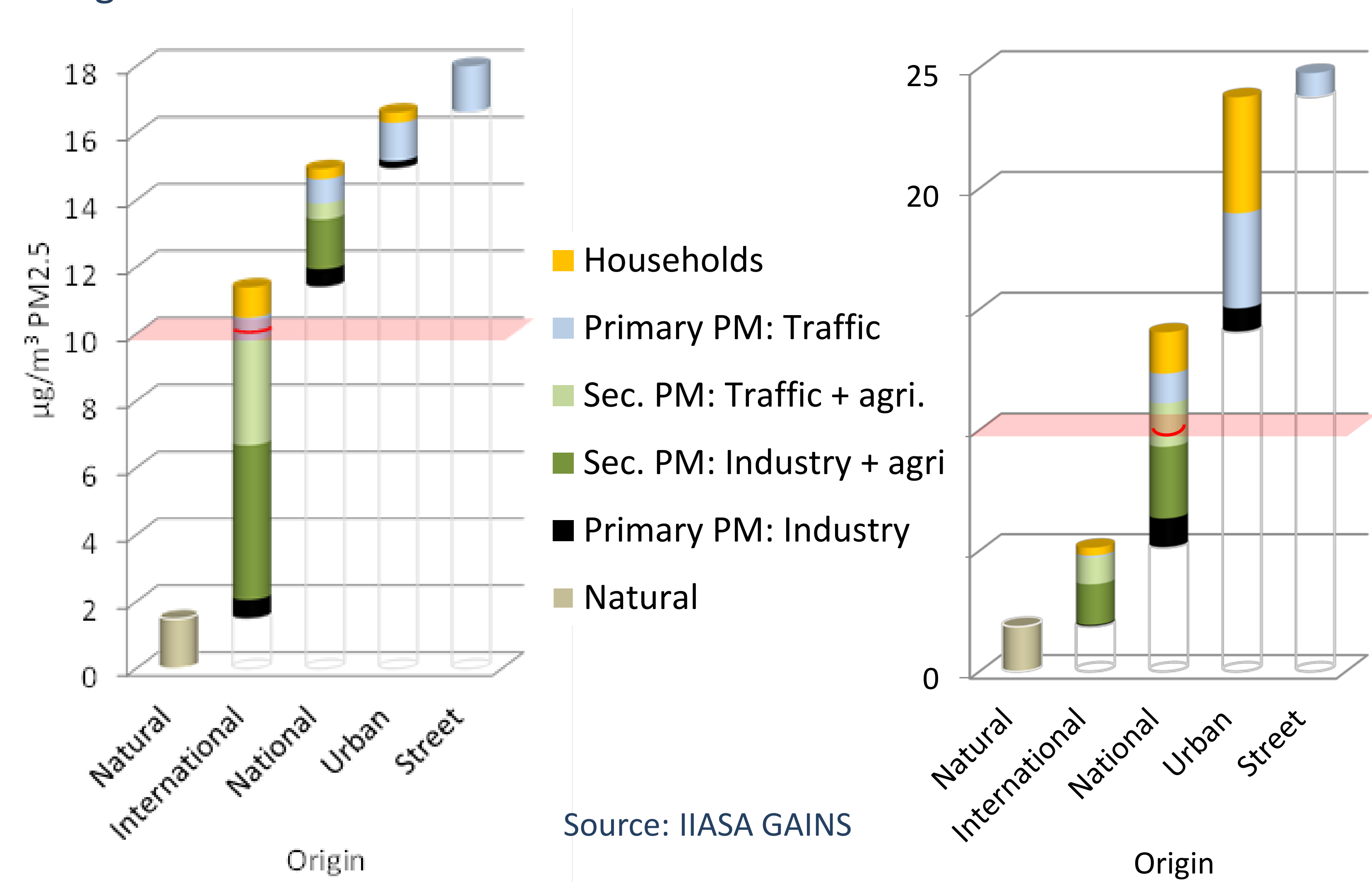


Source: IIASA GAINS

Origin of PM2.5 - 2009

Netherlands
average of the urban AIRBASE stations

Lyon, Centre Ville

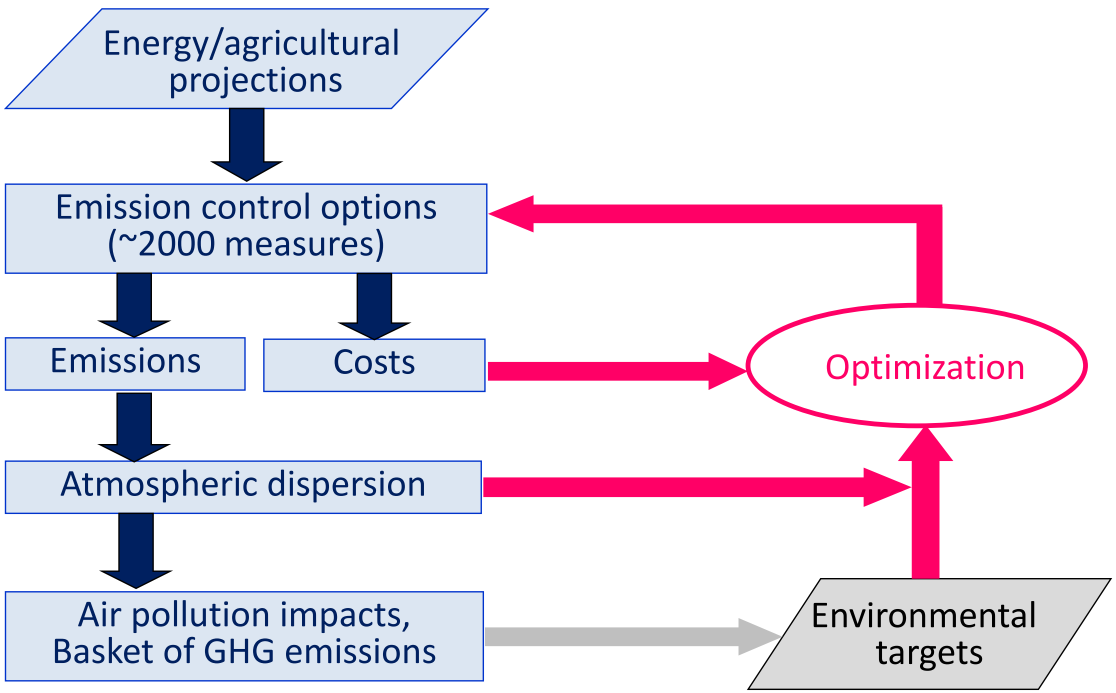


Source: IIASA GAINS

IIASA's GAINS systems approach for cost-effective emission reduction strategies

There are large international differences in

- emission densities,
- potentials and costs of further measures,
- sensitivities of ecosystems,
- meteorological and climatic conditions, etc.

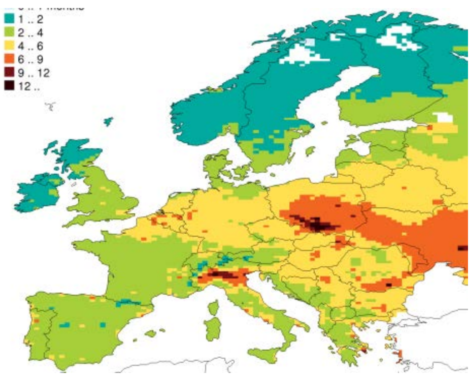


Policy applications of GAINS

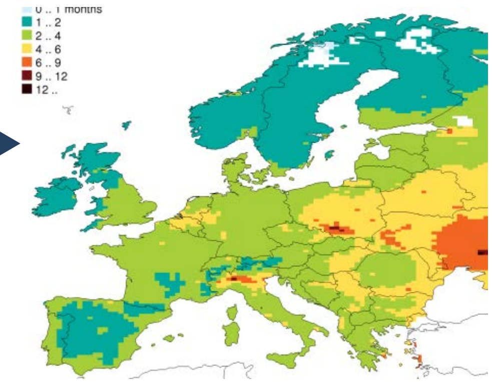
GAINS has been the key scientific tool for

- international environmental agreements, e.g.
  - UN-ECE LRTAP
  - EU air quality and climate policies
- international assessments
  - UNEP
  - IPCC
  - AMAP

The target of the Thematic Strategy on Air Pollution for 2030



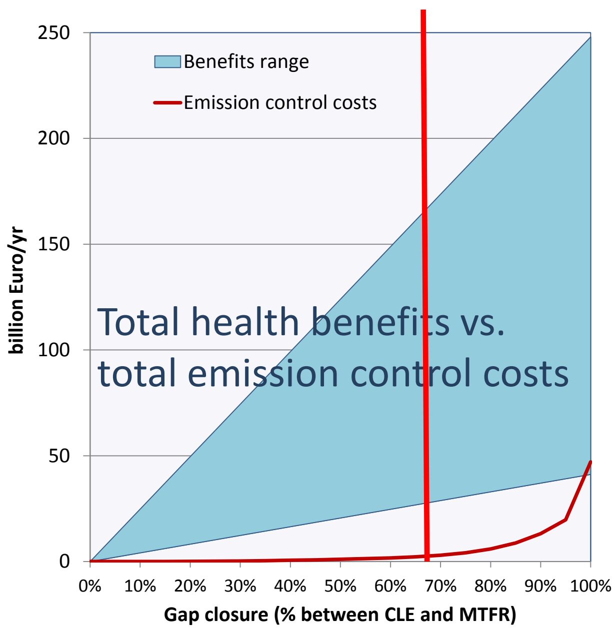
Loss in statistical life expectancy

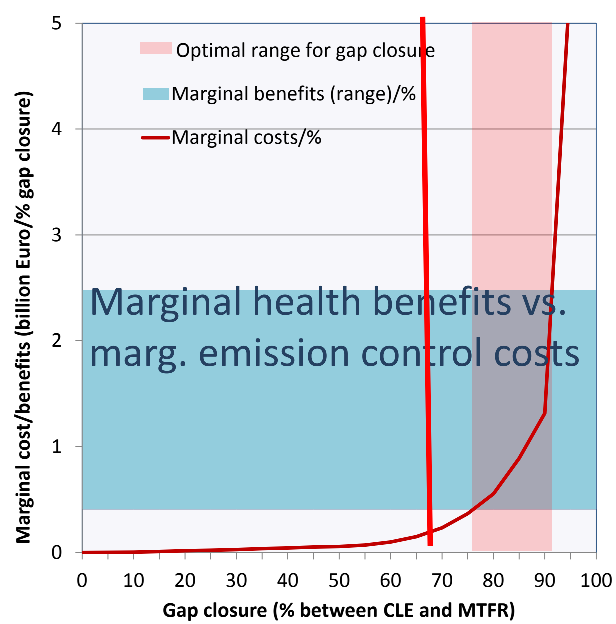


Current legislation 2030:
5 months life shortening

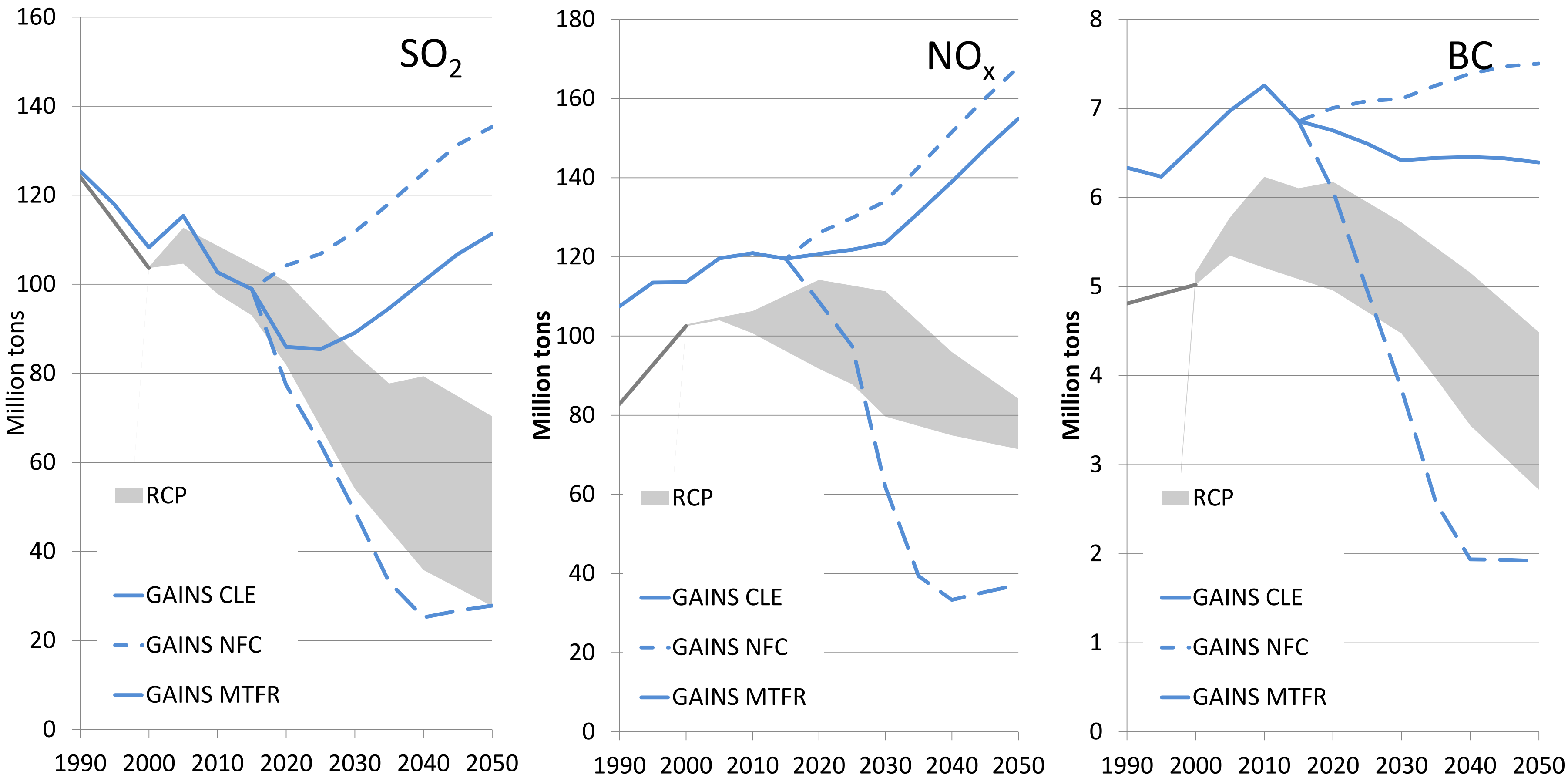
Commission proposal:
67% ‘gap closure’ in 2030:
-50% health impacts
compared to 2005

Maximum additional controls:
3.6 months life shortening





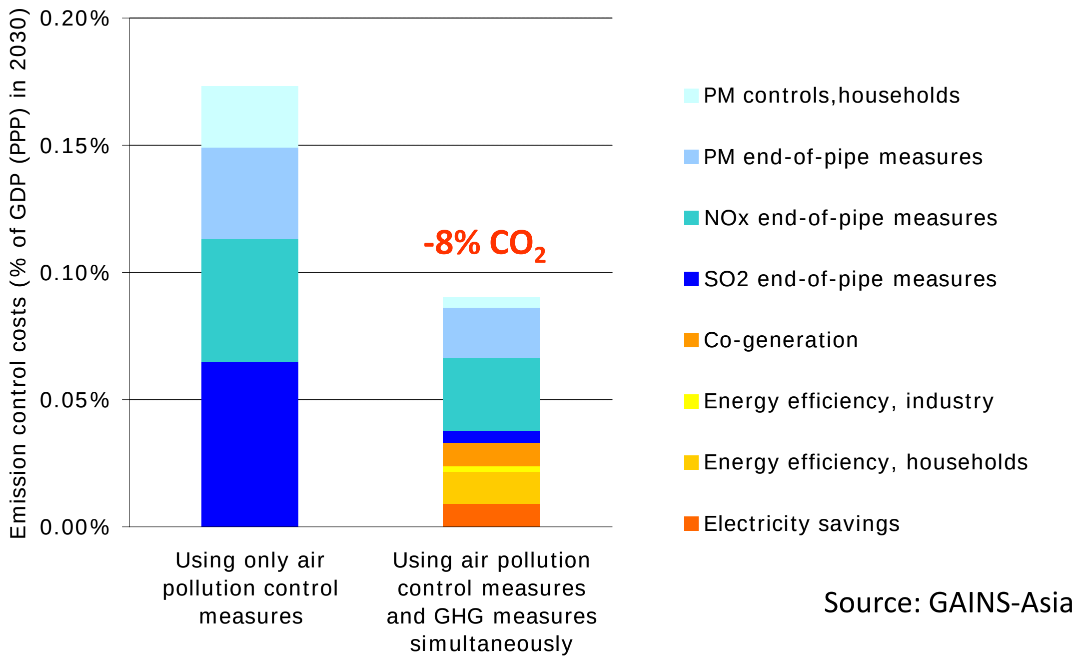
Range of future global emissions
HTAP/GAINS policy scenarios vs RCP



Source: GAINS model; ECLIPSE V5 scenario

Co-benefits from an air quality perspective

Costs for reducing PM2.5 population exposure in China by 50%



Source: GAINS-Asia

Cost-effective portfolios to improve air quality include measures that also reduce long-lived GHGs

Conclusions

- GAINS provides an integrated management approach for air pollution and greenhouse gases:
  multi-pollutant/multi-effect, multiple scale, cost-effectiveness
- GAINS shapes air quality and climate policies in Europe and Asia,
  provides focus on co-benefits
- GAINS has a long history of policy applications in Europe

Well-being and the Macro-economic Effects of Investing in Cleaner Air in India

Warren Sanderson[1,2], Erich Striessnig[1,3], Wolfgang Schöpp[1], Markus Amann[1]

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[2]Stony Brook University (SUNY)

[3]Vienna University of Economics and Business (WU)

Population Association of America 2013 Annual Meeting
New Orleans, April 12

Outline

The Future of Economic Growth Modeling

1. **Environmental Constraints**
2. **Demographic Constraints**

Environmental Constraints

- Challenges posed by global climate change
  - economic costs of necessary abatement policies
  - modeling the impact of environmental degradation on human health and productivity
- Challenges posed by energy and natural resource scarcity
  - substitution technologies
  - transition to renewable energies

Demographic Constraints

- Challenges posed by unprecedented societal aging
  - Think about how aging societies are different from “stable populations”
- Opportunities generated by favorable age-structure dynamics
  - How to make the most out of a potential “demographic dividend”?
- Include **realistic demography**!
- How to model the ongoing educational transitions?

The SEDIM Model

SEDIM

Simple Economic Demographic Interaction Model

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SEDIM

Simple Economic Demographic Interaction Model

- Agents' are characterized by adaptive, forward looking behavior.
- They make use of limited common information on how the economy evolved in the past...
- ...using this information, they "plan ahead"
- They are able to react to "surprises"!
- SEDIM does not assume perfect foresight

Case Study

Well-being and the Macro-economic Effects of Investing in Cleaner Air in India

$PM_{2.5}$ in India

Main Research Question:

What effect do environmental regulations have on well-being?

- Economic growth in India accompanied by tremendous increases in emission concentration levels.
- Policies aimed at implementing stringent emission standards likely to result in huge health benefits.
- We need a model which can balance the health benefits on the one hand and the economic costs on the other.

What is $PM_{2.5}$?

Definition

$PM_{2.5}$ is particulate matter with a diameter of 2.5 microns or less

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- **This stuff kills people!**

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Definition

$PM_{2.5}$ is particulate matter with a diameter of 2.5 microns or less

- **This stuff kills people!**
- Well documented
  - Pope et. al. (New England Journal of Medicine, 2009)
    "[a] decrease of 10 μg per cubic meter in the concentration of fine particulate matter was associated with an estimated increase in mean ($\pm SE$) life expectancy of 0.61 $\pm$ 0.20 year (P = 0.004)."
  - Brook et. al. (Journal of the American Heart Association, 2010)
    "overall evidence is consistent with a causal relationship between $PM_{2.5}$ exposure and cardiovascular morbidity and mortality."

Why India?

	Delhi	Mumbai	Kolkata
$PM_{2.5}$	99	52	73

Table 1 : Ambient concentrations of $PM_{2.5}$ for various cities in 2005 in $\mu g/m^3$. Source: GAINS

Why India?

	Delhi	Mumbai	Kolkata
$PM_{2.5}$	99	52	73

Table 1 : Ambient concentrations of $PM_{2.5}$ for various cities in 2005 in $\mu g/m^3$. Source: GAINS

The WHO-standard for $PM_{2.5}$ is $10\mu g/m^3$!

$PM_{2.5}$ abatement strategies

Indian Current Legislation (ICL)

- Controls on dust emissions from the power sector and industry accounting for national emissions limit values
- Low sulfur liquid fuels for the residential, commercial and transport sectors
- Slow penetration of improved cooking stoves using biomass
- CNG for buses and three wheelers in urban areas
- Emission limit values for road transport sources up to Euro 4/IV
- Emissions of sulfur from the power sector and industry remain uncontrolled

European Current Legislation (ECL)

- EU-legislation
  - stationary sources in the power sector and industry (Proposal for the Industrial Emissions Directive)
  - transport sources: phasing-in EU legislation up to EURO 6/IV for road transport and up to stage IV for non-road sources
- National legislation on industrial and small combustion sources (if stricter than the EU-wide legislation)

These two policy interventions will be compared to a **no additional-control** (NOC) scenario.

Reform Schedule

1. Phasing-in (2010-2019)
   - gradual implementation of the emission regulations set by the reform
   - modeled as the building up of the total necessary abatement capital stock
2. Maintenance Phase (2020-2030)
   - abatement capital in place has to be maintained and operated
   - additional costs from new facilities that also have to comply with the new standard

Note: We do not maintain a certain **level** of $PM_{2.5}$ concentration, but a certain **standard** of emissions

Costs and Benefits

	Cost as fraction of GDP			$PM_{2.5}$ concentration		
Year	NOC	ICL	ECL	NOC	ICL	ECL
2010	0.00%	0.15%	0.54%	46	46	46
2015	0.00%	0.15%	0.55%	60	52	38
2020	0.00%	0.15%	0.43%	74	57	30
2030	0.00%	0.12%	0.29%	116	72	31

Table 2 : Cost as a fraction of GDP and $PM_{2.5}$ concentrations (in $\mu g/m^3$) in three scenarios, India, 2010, 2015, 2020, 2030. Source: GAINS

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- In 2005 India spent around 3.8% of GDP on health and 3.23% on education (Source: WDI)

Effects of $PM_{2.5}$ in SEDIM

1. Effect of mortality
2. Effect of morbidity

Effects of $PM_{2.5}$ in SEDIM

1. Effect of mortality
    - Each additional $10\mu g/m^3$ of $PM_{2.5}$ increases the relative risk of dying at adult ages (>30) by 4%.
        - changes the age- and education structure of the population
        - people adapt their savings behavior
        - changes in the rate of capital formation as well as changes in the population age- and education structure affect the rate of technological change
2. Effect of morbidity

Effects of $PM_{2.5}$ in SEDIM

1. Effect of mortality
2. Effect of morbidity
   - Each additional $10 \mu g/m^3$ of $PM_{2.5}$ increases the number of work-loss days by 0.046 (Source: Hurley et. al. 2005)
     - affects the effective labor force

Results: GDP

	YEAR	NOC	ICL	ECL
Total GDP (in Billions)	2010	4.96	1.000	1.000
	2015	7.16	1.000	1.001
	2020	9.90	1.000	1.003
	2030	16.79	1.001	1.007

Table 3 : Total GDP, GDP per capita, and GDP per worker in three scenarios, India, 2010, 2015, 2020, 2030. Notes: NOC in 2000 international US$. Numbers in ICL and ECL relative to NOC.

Results: GDP

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	2015	7.16	1.000	1.001
	2020	9.90	1.000	1.003
	2030	16.79	1.001	1.007
GDP per Capita	2010	4073	1.000	1.000
	2015	5514	1.000	1.001
	2020	7200	0.999	1.000
	2030	11135	0.996	0.995

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	2015	5514	1.000	1.001
	2020	7200	0.999	1.000
	2030	11135	0.996	0.995
GDP per Worker	2010	6713	1.000	1.000
	2015	8849	1.000	1.001
	2020	11392	0.999	1.001
	2030	17308	0.999	1.002

Table 3 : Total GDP, GDP per capita, and GDP per worker in three scenarios, India, 2010, 2015, 2020, 2030. Notes: NOC in 2000 international US$. Numbers in ICL and ECL relative to NOC.

Results: Consumption

	YEAR	NOC	ICL	ECL
Consumption per Capita	2010	3065	1.000	1.000
	2015	4291	0.998	0.993
	2020	5702	0.997	0.993
	2030	9213	0.995	0.992

Table 4 : Forecasted consumption per capita and $PM_{2.5}$ concentration in three scenarios, India, 2010, 2015, 2020, 2030. Notes: Consumption per capita in NOC in 2000 international US$. Consumption in ICL and ECL relative to NOC.

Results: Consumption

	YEAR	NOC	ICL	ECL
Consumption per Capita	2010	3065	1.000	1.000
	2015	4291	0.998	0.993
	2020	5702	0.997	0.993
	2030	9213	0.995	0.992
$PM_{2.5}$	2010	46	46	46
	2015	60	52	38
	2020	74	57	30
	2030	116	72	31

Table 4 : Forecasted consumption per capita and $PM_{2.5}$ concentration in three scenarios, India, 2010, 2015, 2020, 2030. Notes: Consumption per capita in NOC in 2000 international US$. Consumption in ICL and ECL relative to NOC.

Results: Longevity

	YEAR	NOC	ICL	ECL
Life Expectancy at Birth	2010	70.5	70.5	70.5
	2015	71.8	72.0	72.5
	2020	72.9	73.5	74.4
	2030	74.9	76.2	77.7

Table 5 : Life expectancy at birth and lives saved for three different scenarios, India, 2010, 2015, 2020, 2030. Notes: "Lives saved" refers to the difference in the number of people dying in that year in the respective scenario and NOC

Results: Longevity

	YEAR	NOC	ICL	ECL
Life Expectancy at Birth	2010	70.5	70.5	70.5
	2015	71.8	72.0	72.5
	2020	72.9	73.5	74.4
	2030	74.9	76.2	77.7
Annual Averted Deaths in 1000s	2010	0	0	0
	2015	0	179	462
	2020	0	423	1106
	2030	0	1212	2527

Table 5 : Life expectancy at birth and lives saved for three different scenarios, India, 2010, 2015, 2020, 2030. Notes: "Lives saved" refers to the difference in the number of people dying in that year in the respective scenario and NOC

Political implications

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- Well-being is higher than in the NOC in both the ICL and the ECL scenario

Political implications

- In India investments in reducing $PM_{2.5}$ will have no discernible effect on GDP growth
- The large increase in longevity outweighs the small decreases in the mean level of educational attainment and GDP per capita
- Well-being is higher than in the NOC in both the ICL and the ECL scenario
- **Policies aiming at reducing $PM_{2.5}$ in India increase well-being and almost pay for themselves**

THANK YOU!

Contact
erich.striessnig@wu.ac.at

How does economic growth take place in SEDIM?

- One type of output, Y_t, is generated, using a Cobb-Douglas production function

$$Y_t = A_t * L_t^{\alpha} * K_t^{1-\alpha} \quad (1)$$

$\Rightarrow$ Anything that causes economic growth, has to do so by affecting one of these sources:

$L_t \ldots$ Effective Labor

$K_t \ldots$ Capital Stock

$A_t \ldots$ Total Factor Productivity

($\alpha \ldots$ Output Elasticity of Labor)

Effective Labor, L_t

The workforce in SEDIM includes the full information on the population's age- and educational attainment structure

$$L_t = \sum_{a=alfe(t)}^{alfx(t)} POP_{a,t} * EU_{a,t} \tag{2}$$

$alfe(t)$ ... age of labor market entry in year t

$alfx(t)$ ... age of labor market exit in year t

$POP_{a,t}$ ... population at age a in year t

$EU_{a,t}$ ... number of efficiency units embodied by worker of age a in year t

Capital, K_t

Two types of capital holders

1. Consumers
2. Corporations or "wealthy individuals"

Capital, K_t

Two types of capital holders

1. Consumers
   - Income from labor and from capital assets
   - Save for life-cycle purposes
     - goal is to smooth consumption over their entire lifetime
     - **BUT:** suffer from imperfect foresight
2. Corporations or "wealthy individuals"

Capital, K_t

Two types of capital holders

1. Consumers
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Capital, K_t

Two types of capital holders

1. Consumers
2. Corporations or "wealthy individuals"
   - Receive income from capital investments
   - Non-life-cycle savers
     - investment rate depends on rate of return to capital

Capital, K_t

Two types of capital holders

1. Consumers
2. Corporations or “wealthy individuals”

The savings/investments of consumers and corporations interact to “buffer” the effect of aging.

Total Factor Productivity, A_t

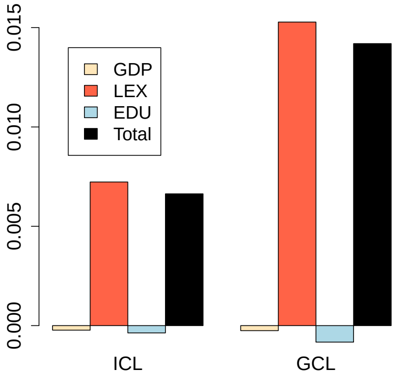
SEDIM is a model of conditional convergence/divergence characterized by two gaps

1. a country's "technological gap" with respect to the global technological leader
2. a country's gap to its own "potential" level of A_t

Determining factors of a country's "potential", its "backwardness", and the speed of catching-up include

- rate of capital formation
- educational attainment level of the workforce
- population age-structure
- the interaction of education and age-structure
- an economy's level of "openness"
- the quality of political institutions, i.e., corruption, rule of law

Results: HDI



HDI by component relative to NOC, India, 2030