Ancillary benefit of reducing GHG emissions

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GLOBAL IQ
IMPACT QUANTIFICATION OF GLOBAL CHANGES

Benefits of reducing Greenhouse Gases (GHG)

Climate change target
> reducing CO_2 emissions

Primary benefits: reduce global warming – less extreme weather events, rise in sea levels, glacier melting.

<u>Uncertain and far in the future</u>

Secondary (ancillary) benefits: health benefits from lower pollution.

<u>More immediate</u>

Source: adapted from Wang and Smith (1999) WHO

Theoretical framework

- **INTERNATIONAL MODELS** (Rübbelke 2009). Impure public good model of climate change.
  - Game theoretical framework that looks at free-riding incentives with ancillary benefits.
- **Karen Pittel** *(Ifo Institute and University of Munich)*

- **DOMESTIC MODELS** (Krupnick et al. 2000).
  - Consider ancillary benefits as choice of any other domestic pollutant.
  - Theory of environmental regulation of pollution

» command-and-control vs. economic incentives.

Empirical Research steps

Bottom-up approaches

Consider specific causal linkages, usually with micro-level data.

1. **Epidemiological studies** - estimating dose response functions
2. **Willingness to pay studies** - estimating the value of reduced mortality/morbidity
3. **Industrial change studies** - estimating the impact of various policy options

Bottom Up Studies – DRF

AUTHORS	LOCATION	MODEL & CONTROLS	RESULTS
Aunan and Xiao-Chuan (2004)	China	Use previous studies for health-response functions. Meta analysis presented below.	A 10mg/m3 rise in pollution increases by 0.3 to 1% mortality from various health related illnesses.
El Fadel and Massoud (2000)	Lebanon	Hospital data in various parts of Beirut: COPD hospital admissions, Pneumonia hospital admissions, Respiratory and cardiac hospital admissions	Measures in terms of COI, WTP and human capital approaches.
Wang and Smith (1999)-WHO	China	Bottom-up methodology for Two sectors-energy and household. 10% below business-as-usual (BAU) by 2010 and 15% below by 2020.	Annual avoided death of some scenarios could reduce total mortality by as much as 4%. but variation by sector: conservative estimates show, for example, that the health benefits of one ton reduction in particulates emissions from household stoves are at least 40 times larger than those from coal-fired power plants.
Andrew Foster, Naresh Kumar (2011)	Delhi	Air pollution data, collected at 113 sites from July-December 2003, compute exposure at the place of residence of 3989 subjects. A socio-economic and respiratory health survey was administered in 1576 households. This survey collected time-use, residence histories, demographic information, and direct measurements of lung function with subjects.	Strongest results for those spending lots of time outdoors.
Haidong Kan, Bingheng Chen (2003)	Shanghai	Conditional logistic function, controlling for weather conditions, 48h MA of an index of pollutants.	A 10mg/m3 increases by 1% mortality.

1. Epidemiological studies

Dose response functions

Table 1
Summary ranges of worldwide health impacts DRFs for PM_{10}, $PM_{2.5}$, BS, and TSP (Vedal, 1997)[a]

Change in PM concentration	Percent increase in mortality (%)	Percent increase in morbidity (%)[b]	Morbidity type
Increase of 10 $\mu g/m^3$ in PM_{10}	0.1–4.6	0.2–2.9	Pneumonia hospital admissions
		0.8–11.5	COPD hospital admissions
		0.2–6.4	Respiratory hospital admissions
		0.6–1.2	Cardiac hospital admissions
		0.4–6.0	Emergency cases of asthma
		0.3–0.4	Bronchitis hospital admissions
		1.1–24.9	LRI symptoms
		0.4–13.0	URI symptoms
		1.6–17.6	Cough symptoms
Increase of 10 $\mu g/m^3$ in $PM_{2.5}$	0.4–3.7	0.41–24.6	Respiratory hospital admissions
		3.7–20.9	Asthma hospital admissions
Increase of 10 $\mu g/m^3$ in BS	NR	0.07–18.2	Respiratory hospital admissions
		0.3–5.3	Asthma hospital admissions
		1.2–16.5	COPD hospital admissions
Increase of 100 $\mu g/m^3$ in TSP	3.3–8.3	NR	NR

[a] *Abbreviations:* COPD, chronic obstructive pulmonary disease; LRI, lower respiratory illness; URI, upper respiratory illness; NR, not reported.
[b] Morbidity — the incidence of respiratory and/or cardiovascular symptoms and diseases.

End-point (pollutant)	Coefficient (%)	S.E.	Reference (particle measure in original study)
All-cause mortality			
PM_{10}	0.046	0.017	Jin et al., 1999 (TSP)
	0.028	0.009	Xu et al., 2000 (TSP)
	0.038	0.017	Cropper et al., 1997 (TSP)[a]
	0.030	0.010	Kan and Chen, 2003 (PM_{10})
SO_2	0.191	0.060	Xu et al., 1994
	0.161	0.059	Wong et al., 2001
	0.024	0.009	Xu et al., 2000
	0.039	0.024	Venners et al., 2003
	0.159	0.025	Kan and Chen, 2003
Mortality due to cardiovascular diseases			
PM_{10}	0.128	0.053	Jin et al., 1999 (TSP)
	0.040	0.015	Kan and Chen, 2003 (PM_{10})
	0.036	0.013	Xu et al., 2000 (TSP)
	0.072	0.055	Cropper et al., 1997 (TSP)[a]
SO_2	0.169	0.045	Kan and Chen, 2003
	0.182	0.041	Venners et al., 2003
	0.018	0.012	Xu et al., 2000
Mortality due to respiratory diseases			
PM_{10}	0.359	0.127	Jin et al., 1999 (TSP)
	0.052	0.143	Cropper et al., 1997 (TSP)
	0.094	0.053	Wong et al., 2001 (PM_{10})
	0.060	0.035	Kan and Chen, 2003 (PM_{10})
	0.302	0.199	Xu et al., 1994 (TSP)
	0.043	0.027	Xu et al., 2000 (TSP)
SO_2	0.104	0.048	Venners et al., 2003
	0.325	0.078	Kan and Chen, 2003
	0.736	0.744	Xu et al., 1994
	0.074	0.025	Xu et al., 2000
Hospital admissions for respiratory diseases			
PM_{10}	0.159	0.030	Wong et al., 1999 (PM_{10})
	0.100	0.025	Wong et al., 2002 (PM_{10})
SO_2	0.129	0.040	Wong et al., 1999
	0.178	0.040	Wong et al., 2002
Hospital admissions for cardiovascular diseases			
PM_{10}	0.060	0.025	Wong et al., 1999 (PM_{10})
	0.070	0.020	Wong et al., 2002 (PM_{10})
SO_2	0.159	0.050	Wong et al., 1999
	0.208	0.035	Wong et al., 2002
Chronic respiratory illness in adults			
PM_{10}	0.299	0.014	Zhang et al., 1999 (TSP)
	0.648	0.129	Xu and Wang, 1993 (TSP)
	0.461	0.050	Jin et al., 2000 (TSP)
	0.725	0.370	Xiao et al., 1990 (TSP)
Chronic respiratory illness in children			
PM_{10}	0.362	0.017	Qian et al., 2000 (TSP)
	0.969	0.045	Qian et al., 2004 (PM_{10})
	4.756	0.815	Yu et al., 2001 (PM_{10})
	0.447	0.054	Zhang et al., 2002 (PM_{10} and TSP)

For mortality and hospital admissions the coefficients refer to percentage change in number of cases per person per μg/m^3 change in daily ambient concentration. For chronic respiratory illness they refer to percentage change in prevalence rates per μg/m^3 change in long-term concentration. S.E.: Standard Error.

a Carried out in Delhi and thus not included in the meta-analysis. Shown here because TSP levels in Delhi are similar to, e.g. Beijing and use of coal is widespread.

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Source: Anunan and Xiao-Chuan (2004)

How to estimate a DRF

- Lagged moving averages of air-pollution levels, e.g. the mean of air-pollution levels of the current and 3 preceding days. Or some other time-stratified method.
- Include other controls such as temperature, humidity, day of week, a time variable or season, age, individual fixed effects.
- Regress to see if they correlate significantly with mortality for a specific lung disease.
- Need data on daily mortality/morbidity, air pollution and weather data. Yanjun et. Al (2011) use from August 1, 2006 to December 31, 2008 in Shenyang.

Source: Zhaoyi et al. (2000), Yanjun et al. (2011)

Baseline

Always compare to a situation of no change.

- Know the «typical» number of deaths/illnesses by age and sex groups
- Estimate improvements by a reduction in pollutants.

Table 4
Percent distribution of death in Lebanese households

Sex[a]	Age group[b]							
	0–9	10–19	20–39	40–59	60–69	> 70	Unknown	Total
Male (51)	5.54	2.67	9.60	18.31	21.35	37.48	5.07	100.00
Female (49)	6.50	2.91	4.00	13.30	17.18	51.13	5.00	100.00
Total (100)	5.93	2.77	7.31	16.27	19.66	43.03	5.03	100.00
Total number of deaths	808	375	921	2131	2593	5935	677	13 440

[a] US Bureau of the Census (1999).
[b] MSA (1996).

Distribution of predicted lives saved per year due to 10 $\mu g/m^3$ reduction in PM_{10}

Sex	Age group							
	0–9	10–19	20–39	40–59	60–69	> 70	Unknown	Total
Male (51)	0–17	0–8	1–30	1–58	1–67	3–118	0–16	6–314
Female (49)	0–20	0–9	0–12	1–40	1–52	3–155	0–15	5–303
Total (100)	0–37	0–17	1–42	2–98	2–119	6–273	0–31	11–617

Environmental Burden of Disease (EBD) in a population

Ostro (2004), WHO

$$AF = \frac{\Sigma\, P_i\, RR_i - 1}{\Sigma\, P_i\, RR_i}$$

Pi are various subgroups of population, minus the control one;

RR is the relative risk function for sub-population i, e.g. Children, or elderly people

EDB: Relative Risk

Outcome and exposure metric	Source	Relative risk function[a]	Suggested ß coefficient (95% CI)	Subgroup
All-cause mortality and short-term exposure to PM10[b]	Meta-analysis and expert judgment (see text)	RR = exp[ß (X -Xo)]	0.0008 (0.0006 - 0.0010)[c]	All ages
Respiratory mortality and short-term exposure to PM10 (all-cause mortality for upper bound where applicable)	Meta-analysis (Table 2)	RR = exp[ß (X-Xo)]	0.00166 (0.00034, 0.0030)	Age <5 years
Cardiopulmonary mortality and long-term exposure to PM2.5	Pope et al. (2002); R Burnett[d]	$RR = [(X+1)/(Xo+1)]^{ß}$	0.15515 (0.0562, 0.2541)	Age >30 years
Lung cancer and long-term exposure to PM2.5	Pope et al. (2002); R Burnett[d]	$RR = [(X+1)/(Xo+1)]^{ß}$	0.23218 (0.08563, 0.37873)	Age >30 years

Source: Ostro (2004)

2. Valuation Studies: different methods

	Valuation Method	Description
Mortality	Human Capital	Based on present value of productivity of an individual, lost in case of premature death.
	WTP	Ask people directly what they are willing to pay for reduced risk of mortality. Captures intangibles.
Morbidity	COI	Consider 1) medical expenses and 2) lost wage and restricted activities while in bed
	WTP	1) Averting method behaviour: time and money spent by an individual to avoid air pollution is the lowest bound value of health 2) Contingent valuation method: willingness to pay to avoid symptoms and lost days of work.

Source: adapted from El-Fadel and Massoud 2000

Bottom Up Studies - Valuation methods

AUTHORS	LOCATION	MODEL & CONTROLS	RESULTS
El Fadel and Massoud (2000)	Lebanon	Hospital data, Beirut: COPD, Pneumonia, Respiratory and cardiac hospital admissions	Measures in terms of COI, WTP and human capital approaches.
Cifuentes, Prieto, and Escobari (2001)	Chile	WTP survey	Get WTP also old people (70-80 years)
Alberini et al. (1997)	Taiwan	WTP survey	WTP
Alberini et al. (2007)	Delhi	Survey of commuters, WTP on mortality	Value of a Statistical Life for most exposed groups.
Alberini et al. (2006)	Canada	WTP with latency values	The farther away in time, the higher the reduction in WTP
Alberini, Kohlova and Scasny (2005)	Czech Republic	VSLthrogh contingent valuation survey	Mortality benefits of environmental policy
Scasny and Melichar	CR, Poland, Hungary	Meta analysis of valuation approaches	Taxonomy of methodologies

3. Other studies: industrial change

- Look at different policy tools used
  - The nature of ancillary benefits varies with the structure of the implemented climate policy.
  - Compare different scenarios: coal washing, briqueting, change indoor heating, traffic policies, energy efficiency vs susbtitution in sources of energy, etc
  - Lutter and Shogren (2001)

Further issues

- Thresholds and interactions between pollutants
- Latency and cumulative effects
- Ancillary *costs*, such as unemployment, externalities from fuels different from coal…
- Indoor pollution
- Uncertainty
- Equity (O'Neill et. al 2003)

Distributional Impacts

Poorer people may suffer more from air pollution because

1. They are more exposed
   - Proximity to roadways > more exposed since prices are depressed
   - Co-exposure to indoor pollution
   - "Dirtier" jobs

2. They have worse health

But little literature in LDC, usually match to ZIP code

Reference	Population	Study design	Place/years	Main effect pollutant(s)	Health outcome	Socioeconomic variable	Level[a]/resolution	Key findings
HEI 2000	American Cancer Society (ACS) cohort (*n* = ~500,000); Harvard Six Cities Study (*n* = 8,111)	Prospective cohort	USA, 1982–1989 (ACS) 1975–1991 (6 cities)	$PM_{2.5}$	Mortality	Educational attainment (< high school, high school, > high school)	Individual/person	Greatest effects among least educated; monotonic dose response for all-cause mortality
Pope et al. 2002	ACS (*n* = 500,000)	Prospective cohort	USA, 1982–1998	$PM_{2.5}$	Mortality	Educational attainment (< high school, high school, > high school)	Individual/person	Greatest effects among least educated; monotonic dose response for all-cause mortality
Ito and Thurston 1996	Residents of Cook County, Illinois	Time series	Chicago, IL, USA 1985–1990	PM_{10}	Daily mortality	Race (black/white), sex	Individual/person	Greatest effects among black women, then white women, black men, and white men
Gouveia and Fletcher 2000	Residents of São Paulo, Brazil	Time series	Brazil, 1991–1993	PM_{10}	Daily mortality	Composite index of socioeconomic conditions (from 1991 Census)	Group/district (58 in a city of 9.5 million)	Air pollution effects larger in districts of higher socioeconomic level
Samet et al. 2000	Residents of 20 U.S. cities	Time series pooled data	USA, 1987–1994	PM_{10} (O_3, CO, SO_2, NO_2)	Daily mortality	Educational attainment, income, (percent poverty, percent nonwhite, and transportation habits; the last three only in HEI NMMAPS)	Group/county	No effect modification by any of the variables considered
Zanobetti and Schwartz 2000	Residents of Chicago, Detroit, Minneapolis–St. Paul, Pittsburgh	Time series pooled data	USA, 1986–1993	PM_{10}	Daily mortality	Race, sex, educational attainment	Individual/person	Higher effect in women; race and educational attainment were weak modifiers
Cifuentes et al. 1999	Residents of Santiago, Chile	Time series	Chile, 1988–1996	$PM_{2.5}$	Daily mortality	Educational attainment (elementary, high school, university)	Individual/person	Greatest effects among least educated; monotonic dose response for all-cause mortality
Wojtyniak et al. 2001	Residents of four Polish cities: Cracow, Lodz, Poznan, Wroclaw	Time series	Poland, 1990–1996	Black smoke, NO_2, SO_2	Daily mortality	Educational attainment (elementary or less, secondary, above secondary or university)	Individual/person	Greatest effects among least educated; monotonic dose response for all-cause mortality for black smoke, SO_2
Gwynn and	Hospital admissions in	Time series	New York,	PM_{10}, acidity	Respiratory-	Non-Hispanic whites,	Individual/person	Higher effects among races

Gwynn and Thurston 2001	Hospital admissions in New York, New York	Time series	New York, 1988–1990	PM_{10}, acidity (H^+), O_3, sulfate	Respiratory-cause hospital admissions	Non-Hispanic whites, all other races/ethnicities, insured and uninsured	Individual/person	Higher effects among races other than white and uninsured for O_3; less marked differences for other pollutants
Zanobetti et al. 2000a	Hospital admissions in 10 U.S. cities	Time series meta-regression	U.S. cities, 1985–1994; time interval varies by city	PM_{10}	Hospital admissions, respiratory and cardiovascular	Percent population living in poverty; percent nonwhite population	Group/person	No multiplicative-scale effect modification observed by socioeconomic factors
Zanobetti et al. 2000b	Medicare recipients in Cook County, Illinois	Time series	Cook County, IL, 1985–1994	PM_{10}	Hospital admissions, respiratory and cardiovascular	Primary: race and sex; secondary: concurrent diagnosis/previous admission	Individual/person	No significant effect modification by sex or race; higher effects among those with respiratory infections/asthma, previous admissions
Norris et al. 2000	Residents of Seattle, Washington < 18 years of age	Time series	Seattle, WA, 1995–1996	PM_{10} (CO, NO_2, SO_2)	Asthma ED visits	High vs. low ED-use regions	Group/zip code	No effect modification by ED use rates; significant difference in absolute visits
Linn et al. 2000	Residents of South Coast Air Basin (California)	Time series	Los Angeles, Riverside,San Bernadino, Orange Counties,1992–1995	PM_{10}, CO, NO_2, O_3	Hospital admissions, respiratory and cardiovascular	Sex, ethnicity (white, black, Hispanic, other)	Individual/person	Increased cardiovascular effects in blacks and whites relative to Hispanics and other
Tolbert et al. 2000	Children in Atlanta, Georgia (< 16 years)	Time series	Atlanta, GA, 1993–1995	PM_{10}, NO_2, O_3	Asthma ED visits	Race, Medicaid status, sex	Individual/person	No effect modification due to race or Medicaid status
Zanobetti and Schwartz 2001	Medicare recipients in Cook County, Illinois	Time series	Cook County, IL, 1988–1994	PM_{10}	Hospital admissions, respiratory and cardiovascular	Secondary: diabetic status	Individual/person	Higher cardiovascular hospital admission rates among diabetics vs. nondiabetics

Abbreviations: ED, emergency department; HEI, Health Effects Institute; NMMAPS, National Morbidity, Mortality, and Air Pollution Study; $PM_{2.5}$, particulate matter < 2.5 μm in aerodynamic diameter; PM_{10}, particulate matter < 10 μm in aerodynamic diameter.

[a]Group vs. individual.

Problems with measuring environmental equity

- Socio-economic conditions change, income at a single point in time is not capturing the cumulative effects on health.

- Child socio-economic circumstances have an impact for the entire lifetime's health.

(Integrated Assessment Models)

- Multi-sector economy with energy sector(s), input-output matrices of fuels and pollutants, dose response functions and health costs.
- Solve for the dynamic recursive growth process.
- Disadvantages
  - lack of technological detail
  - sensitivity of results to variation of key parameters (elasticity of substitution between fuels, etc.).

Integrated Assessment Models

AUTHORS	LOCATION	MODEL & CONTROLS	RESULTS
Dessus and O'Connor (2001)- 1st in LDCs	Santiago del Chile	GE model, elasticity of substitution between different types of energy sources and between energy and other inputs.	Including benefits, no welfare loss from 10% emission reduction by 2010 or carbon tax of $75/tC, even with conservetive controls.
Bussolo and O'Connor (2001)	India	CGE	On conservative assumptions emissions could be reduced by somewhat more than 10 per cent from their 2010 baseline level without incurring net costs.
Complainville and Martins (1994)	Many developing countries	CO_2, SOX and NOX multicountry, multi-sector, dynamic general equilibrium model (OECD GREEN)	
Aunan et al. (2003)	China	Three different approaches: •Bottom-up study in the capital of Shanxi province (Taiyuan), •a semi-bottom-up study in Shanxi province as a whole, •and a top-down study using a computable general equilibrium model (CGE) for China	Starts from a specific policy, Cleaner Production project.
Aunan et al. (2007)	China	CGE model, Nox ancillary benefits. Also models impact on agricultural yields	China may reduce its CO_2-emissions by 17.5 per cent without suffering a welfare loss. Half of the benefit originates in the agricultural model.
Garbaccio and Jorgenson (2000)	China	Multi-sector Solow growth (dynamic recursive) – good description.	A policy which reduces carbon emissions by 5% every year from base case will reduce premature deaths by some 3.5 to 4.5%. With commonly used valuation methods, the health damage caused by air pollution in the first year is about 5% of GDP. A policy to modestly reduce carbon emissions would therefore reduce local health losses by some 0.2% of GDP annually.
Gielen, and Changhong (2001)	China, Shanghai	Linear programming MARKAL model for the Shanghai energy system. optimal set of policies for reduction of SO_2, NOx and CO_2 in Shanghai for the period of 2000–2020	The results show that no-regret options are not so advantageous because Shanghai has improved its energy efficiency significantly in recent years.
Van Vuuren et al. (2003)	China	Simulation model IMAGE/TIMER, it does not optimise scenario results on the basis of perfect foresight, but instead, simulates year-to-year investments decisions based on a combination of bottom-up engineering information and specific rules about investment behaviour, fuel substitution and technology. SO_2	Combining all options considered, it appears to be possible to reduce emissions compared to the baseline scenarios by 50%.

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Thank you!