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POLLUTION MANAGEMENT In Focus

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Environmental Challenges of Fuel Use

Among the potential effects of fossil fuel combustion are urban air pollution, acid rain, and changes in global climate. A study of six cities in developing countries and of an industrial area in Poland examined how various fuels and sources contribute to health and other environmental damages and analyzed abatement strategies for reducing these damages. Substantial differences were found between cost-effective strategies for mitigating local and global environmental effects. The study illustrates the difficulty of devising efficient policies, given the complex relationships among pollution sources, control options, and environmental impacts. This real-world complexity calls for a skillful mix of policy instruments built on rigorous analysis.

Kseniya Lvovsky and Gordon Hughes

Worldwide, exposure to the high levels of particulates in urban air causes hundreds of thousands of cases of premature death and respiratory illness. The levels of exposure and the associated health burdens are much higher in low- and middle-income countries than in rich countries. These country-specific problems interact with a growing concern about global climate change, which has no boundaries. Designing policies and measures to combat the adverse environmental effects of fossil fuels is becoming an urgent challenge.

In addressing this challenge, it is essential to take account of the magnitude of the damages attributable to different fuels, sectors, and pollutants. This note draws on studies of six large cities around the world that suffer from high levels of air pollution (see Box 1). The cities differ in geographic and climate conditions, demographic characteristics, fuel mix and use patterns, the sectoral composition of the economy, and income level. Together, they have a total population of nearly 50 million and represent a span of variables that affect the environmental costs of fuel use. The evidence emerging from this exercise is likely to be representative of the typical situation in many urban areas in developing countries.

Damages, Fuels, and Sources

In the six urban areas, the social costs of all environmental impacts totaled US$3.8 billion, of which *health impacts accounted for 68 percent.*[1] Climate change impacts amounted to 21 percent (using a shadow price of US$20 per ton of carbon emissions), and local nonhealth effects contributed 11 percent.

The key factors that influence the magnitude of environmental damages and the relative shares of local and global impacts are the fuel mix and the sectoral composition of fuel use. Figures 1 and 2 illustrate three important findings.

1. By far the greatest part of the *local damages, which are dominated by health impacts*, comes from small household, commercial, and industrial boilers and stoves and from vehicles, rather than from large industries and power plants. Local

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Box 1. Coverage and Methodology of the Six-City Study

Environmental damages of fuel use considered

- Adverse *health effects* of exposure to air pollution (for example, increased respiratory illness and premature death in the exposed population)
- *Local nonhealth effects* (reduced visibility, soiling, and material damage)
- Contribution to *global climate change*

Pollutants

- *Local effects:* particulate matter (PM_{10}—particles less than 10 microns in aerodynamic diameter), sulfur dioxide (SO_2), and nitrogen oxides (NO_x)
- *Global effects:* carbon dioxide (CO_2)

Fuels

- Major fossil fuels (coal, fuel oil, diesel fuel, and gasoline) and wood

Sources of pollution

Power plants, district heating plants, large industrial and commercial boilers, small industrial and commercial boilers, household stoves and boilers, and vehicles

Cities

Bangkok (Thailand), Krakow (Poland), Manila (Philippines), Mumbai (India), Santiago (Chile), and Shanghai (China)

Major steps in damage assessment

- *Fuel use inventory* in various sectors: amount of a particular fuel consumed in each sector and the quality of the fuel (ash and sulfur content of coal; sulfur content of petroleum products)
- *Emissions estimates* for all fuel uses, based on the fuel use inventory and the abatement technologies (if any) adopted in each sector
- *Source apportionment* that relates source-specific emissions to the impact on ambient conditions and exposure levels using dispersion modeling (including simulation of secondary particles from SO_2 and NO_x emissions)
- *Assessment of health impacts* using dose-response relationships between ambient levels of certain pollutants and health effects, as established in a large number of studies
- *Valuation* of mortality, morbidity, and nonhealth effects using a coherent set of estimates based on the willingness-to-pay approach, which provides a basis for comparison across different effects and countries

pollutants emitted by small (low-stack) sources are responsible for much higher marginal damage costs per ton because the emissions are dispersed over a small area and very close to the exposed populations.

2. By contrast, large sources, which are the main contributors to CO_2 emissions, have a greater effect on *global damages* than do small sources.
3. The sectoral differentiation in fuel use is at least as significant for the environmental costs of fuel combustion as the differences in the type of fossil fuel used. (See the data for various uses of coal and for other fuels in Figure 2.)

These results imply that policies have to target different sectors and fuel uses—*and thus need to be designed differently*—according to whether the primary objective is to mitigate local or global impacts.

As Figures 3 and 4 show, diesel-powered vehicles and small stoves and boilers that burn coal or other "dirty" fuels impose the highest social costs per ton of fuel.[2] The environmental costs of these fuel uses are so high that the marginal damages exceed both producer and retail fuel prices. The greatest disparities between local and global damages are also found for these fuel uses.

Mitigation Strategies

Simply calculating damages is not an adequate foundation for policy. The next step is to compare the environmental damages with the costs of the available control options. An analysis of this kind was conducted for the metropolitan area of Katowice in southern Poland. The Katowice area has historically relied on coal mining and heavy industry, and today it represents a major obstacle to Poland's compliance with current and proposed European Union (EU) directives for ambient air quality.

A wide range of control options across various pollution sources was examined. The options included installation or upgrading of filters and dust controls; improved combustion techniques; a switch from coal to alternative sources of heat such as gas, smokeless coal, or district heating; and fuel-saving measures that could be adopted in response to projected changes in the structure and level of energy prices, assuming transition to the EU pattern.

The analysis focused on three least-cost strategies:

Figure 1 — Sectoral contribution to local and global damages: Average for the six cities

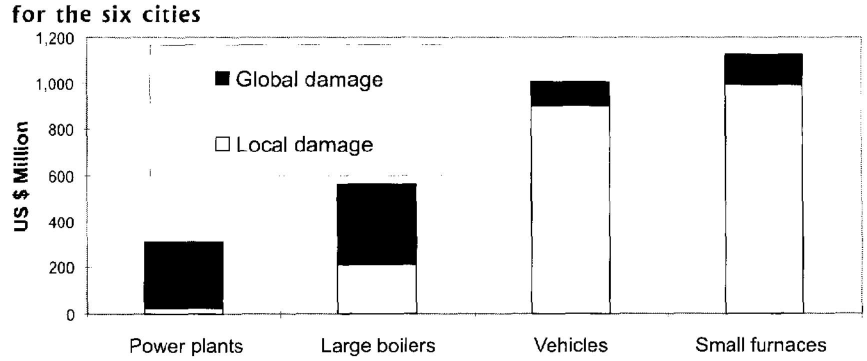


Figure 2 — Fuel composition of local and global damages: Average for the six cities

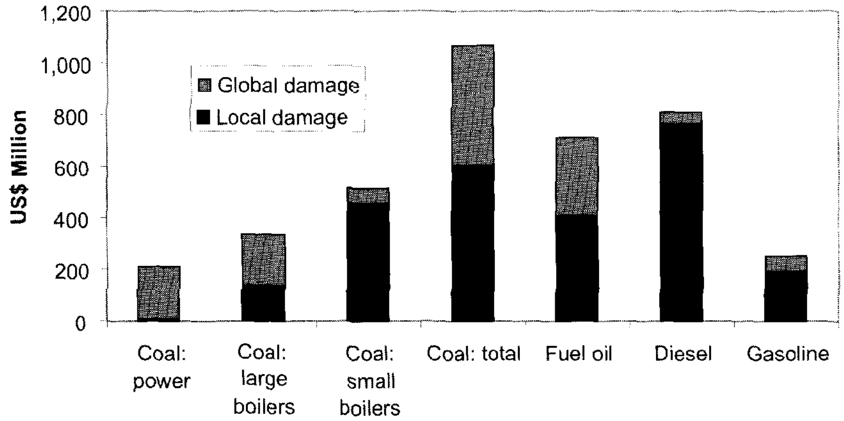


Figure 3 — Marginal environmental costs of fuels: Average usage in the six cities

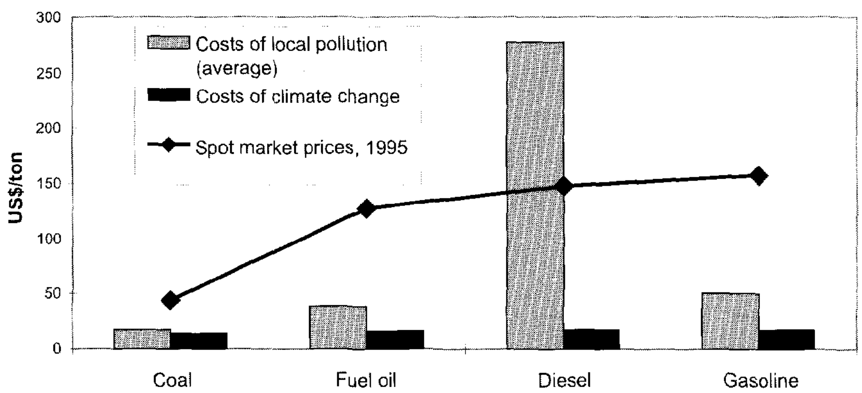
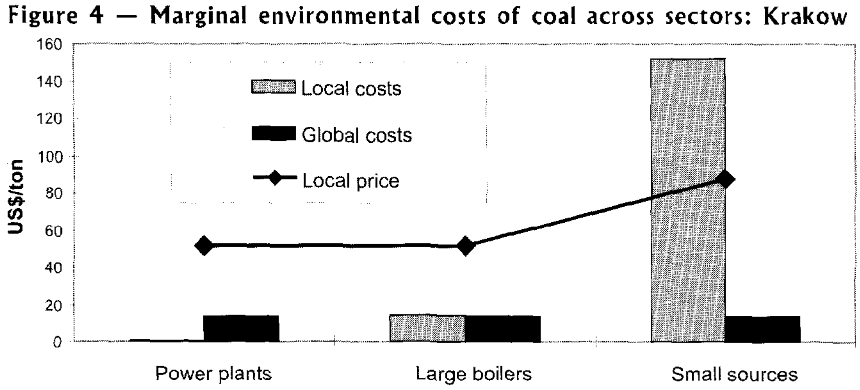


Figure 4 — Marginal environmental costs of coal across sectors: Krakow



- A *PM_{10} strategy* for reducing average exposure to PM_{10} and the associated health damage, without regard to any other benefits
- A *CO_2 strategy* for reducing CO_2 emissions, without regard to any local benefits
- An *"optimal"* strategy, defined as the most efficient combination of measures for reducing the total social damage (local, regional, and global) caused by all four pollutants—PM_{10}, SO_2, NO_x, and CO_2.

The damages (or benefits) per unit of pollution (or pollution reduction) were valued using the following weights and pollution units:

- Ambient PM_{10} resulting from PM_{10} emissions and from the conversion of some SO_2 and NO_x to secondary particulates in the atmosphere—US$11 million per $\mu g/m^3$ (microgram per cubic meter) change in annual average exposure, based on health damage to 2.5 million people in the area
- SO_2 and NO_x emissions—US$800 per ton and US$2,500 per ton, respectively, based on estimates by the European Commission's ExterneE project of damage to crops and forests caused by acid deposition and ozone[3]
- CO_2 emissions—US$20 per ton of carbon.

Regardless of its objective, each strategy yields a host of complementary benefits from reducing local, regional, and global pollution. Figure 5 shows the total social benefits that would be generated by incurring different costs under these three strategies.

For a particular cost level, the benefits of the optimal strategy are, by definition, equal to or greater than the benefits of any strategy that focuses on one or two pollutants only. An interesting result is that the PM_{10} strategy is very close to the Optimal strategy (and even identical at the lower part of the curves). This indicates that there is no practical difference between the two strategies until local pollution is substantially reduced. There are, however, considerable differences between the PM_{10} strategy (or the Optimal strategy) and the CO_2 strategy. At the beginning of the curves, there is a small overlap area because switching certain industrial boilers from coal to gas is the most effective measure under both strategies. The ranking of measures under the strategies then distinctly diverges until the upper ends of the curves. The use of smokeless coal or gas for residential heating and of some dust controls for district heating plants and other industrial boilers are most cost-effective for combating PM_{10} exposure. Under the CO_2 strategy, fuel efficiency measures at power and central heating plants, and a switch from coal to gas at district heating plants, are preferred.

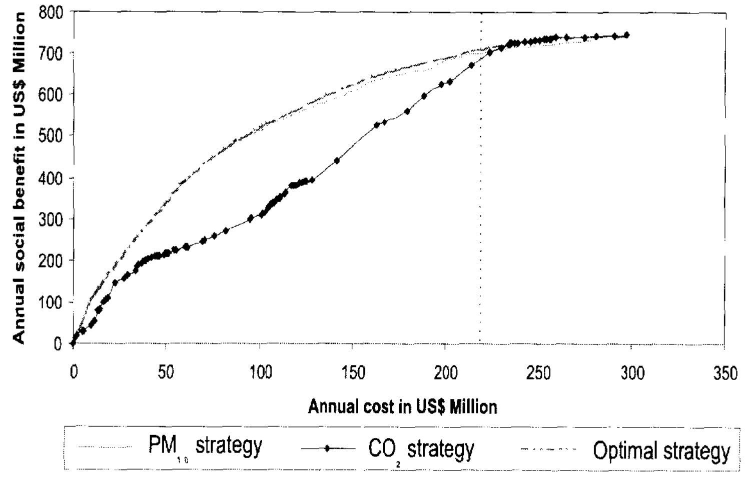
The cost implications of this difference are significant. Efficient programs of measures to meet the proposed EU air quality standards for 2005 and 2010—30 and 20 $\mu g/m^3$ of PM_{10}, respectively— would cost less than US$40 million and US$65 million per year under the PM_{10} strategy. The costs of meeting the same targets would be much greater—US$120 million and US$165 million, respectively—if a strategy focusing on CO_2 emissions were adopted. For annual costs between US$40 million and US$170 million, social benefits generated under the CO_2 strategy are more then US$100 million lower each year. This loss in social welfare represents the costs of missed opportunities associated with the choice of the CO_2 strategy, even when the total social benefits of CO_2 reduction measures exceed the costs.

Balancing Local and Global Objectives

There is almost no difference between the PM_{10} and CO_2 strategies at the point at which the marginal benefit is equal to the marginal cost for the optimal strategy (shown by the vertical dotted line in Figure 5). At this point, all three strategies are very close and yield largely comparable local, regional, and global benefits. The most cost-effective way to reach that point is to follow the optimal strategy, which is in large part identical to the PM_{10} strategy. Thus, by focusing first on controlling local pollution—which is responsible for by far the largest damage in developing country cities—and gradually introducing stricter regulations and more expensive abatement measures, it would be possible to meet, over the longer term, local, regional, and global environmental objectives in a manner that maximizes the overall social benefit.

Additional financial resources from the international community for reduction of carbon emissions can accelerate the reconciliation of local and global objectives. But the costs of ensuring a *substantial* reduction will be large. For example, the incremental cost of meeting EU targets for improving local air quality in a manner that maximizes the reduction in CO_2 implies a value of carbon of about US$80 per ton.

Figure 5 — Costs and total benefits of alternative strategies



Note: The total benefit includes the benefits of reducing average exposure to PM_{10} and emissions of SO_2, NO_x, and CO_2.

From Strategies to Policies

In low- and middle-income countries with high levels of urban air pollution, the most efficient strategy for reducing overall environmental damages would be to focus on mitigating local health impacts, at least in the short to medium term. The implementation of such a strategy, however, remains a difficult challenge.

The large range of environmental damages for different combinations of fuels and sources, as well as the large disparity between the Optimal and CO_2 abatement strategies, shows that simple pricing measures, such as a carbon tax, will be neither sufficient nor cost-effective. An efficient strategy for addressing local pollution problems implies a high degree of differentiation in signals across sources and locations that cannot feasibly be achieved by fuel taxes or emissions charges alone. Emissions and fuel standards, land-use regulations, and other command- and-control interventions, which are easier to design in a differentiated manner, will continue to play a major role in air quality management. When the greatest part of (health) damages comes from small, dispersed sources that burn coal or other dirty fuels, provision of viable incentives for cleaner fuels and cleaner combustion technologies through innovative financing schemes also seems a promising approach. The specific mix of policy instruments will ultimately depend on the prevalence of particular fuels and sources in a given city, on distortions in fuel markets, and on the maturity of institutions. Serious analytical work is as important as ever in formulating policy advice for developing country cities that are choking in smoky air while becoming involved in the global agenda.

Notes

1. The assessment of damages is based on 1993 data.
2. Diesel is treated as a motor fuel only. Other uses of diesel are included in the fuel oil category.
3. European Commission, Directorate-General XII. 1995. *ExternE Externalities of Energy*. Brussels.