The Cost of Air Pollution

Strengthening the Economic Case for Action

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Strengthening the Economic Case for Action

The World Bank and Institute for Health Metrics and Evaluation
University of Washington, Seattle

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Foreword

The science is clear: breathing polluted air increases the risk of debilitating and deadly diseases such as lung cancer, stroke, heart disease, and chronic bronchitis. Air pollution is now the world's fourth-leading fatal health risk, causing one in ten deaths in 2013.

At the same time, air pollution from industries, construction sites, agricultural practices, vehicles, and the combustion of dirty energy sources continues to grow. About 87 percent of the world's population now live in countries in which ambient pollution levels exceed air quality guidelines set by the World Health Organization. In low- and middle-income countries, the danger is even more pronounced: 90 percent of the population in these countries was exposed to dangerous levels of ambient air pollution in 2013.

To reduce the number of people gradually being contaminated by the air they breathe, pollution control would need to be at the top of the agenda for most governments. However, in most countries, such expenditure competes with other budgetary priorities and policy objectives. Demonstrating the economic burden of pollution can help tilt the balance of decisions in favor of investments in clean air.

This study is the result of a collaboration between the World Bank and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, Seattle. It represents an effort to merge cutting edge science and rigorous economic analysis for the good of public health.

The study has found that premature deaths due to air pollution in 2013 cost the global economy about $225 billion in lost labor income, or about $5.11 trillion in welfare losses worldwide. That is about the size of the gross domestic product of India, Canada, and Mexico combined—and a sobering wake-up call.

However impressive and abstract these large numbers are, it is our hope that the cost of premature deaths for countries' economies will leave the pages of this study and inform public debate and policy decisions at the national level. In country after country, the cost of pollution in human lives and on the quality of life is too high. We must work together to reduce it.

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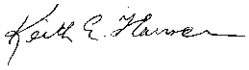

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Abbreviations

AAP	ambient air pollution
ALRI	acute lower respiratory infection
ANS	adjusted net savings
AOD	aerosol optical depth
APM	ambient $PM_{2.5}$
ASDR	age-standardized death rate
COPD	chronic obstructive pulmonary disease
DALYs	disability-adjusted life years
EPA	Environmental Protection Agency (U.S.)
GBD	Global Burden of Disease
GDP	gross domestic product
GPR	Gaussian process regression
HAP	household air pollution
IARC	International Agency for Research on Cancer
IER	integrated exposure-response
IHD	ischemic heart disease
IHME	Institute for Health Metrics and Evaluation
ILO	International Labour Organization
LFPR	labor force participation rate
LRI	lower respiratory infection
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget (U.S.)
PAF	population attributable fraction
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
PMEH	Pollution Management and Environmental Health (World Bank)
PPP	purchasing power parity
RR	relative risk
RFF	Resources for the Future
SAR	Special Administrative Region
TM5-FASST	FAst Scenario Screening Tool
UI	uncertainty interval
VSL	value of statistical life
VSLY	value per statistical life year
WHO	World Health Organization
WTP	willingness to pay
YLDs	years lived with disability
YLLs	years of life lost

All dollar amounts are U.S. dollars unless otherwise indicated.

Executive Summary

Introduction

Air pollution is recognized today as a major health risk. Exposure to air pollution, both ambient and household, increases a person's risk of contracting a disease such as lung cancer, stroke, heart disease, and chronic bronchitis. According to the latest available estimates, in 2013, 5.5 million premature deaths worldwide, or 1 in every 10 total deaths, were attributable to air pollution. Air pollution has posed a significant health risk since the early 1990s, the earliest period for which global estimates of exposure and health effects are available. In 1990, as in 2013, air pollution was the fourth leading fatal health risk worldwide, resulting in 4.8 million premature deaths.

Air pollution is especially severe in some of the world's fastest-growing urban regions, where greater economic activity is contributing to higher levels of pollution and to greater exposure. But air pollution is also a problem outside cities. Billions of people around the world continue to depend on burning solid fuels such as wood, charcoal, coal, and dung in their homes for cooking and heating. Consequently, the health risk posed by air pollution is the greatest in developing countries. In 2013 about 93 percent of deaths and nonfatal illnesses attributed to air pollution worldwide occurred in these countries, where 90 percent of the population was exposed to dangerous levels of air pollution. Children under age 5 in lower-income countries are more than 60 times as likely to die from exposure to air pollution as children in high-income countries.

Air pollution is not just a health risk but also a drag on development. By causing illness and premature death, air pollution reduces the quality of life. By causing a loss of productive labor, it also reduces incomes in these countries. Air pollution can have a lasting effect on productivity in other ways as well—for example, by stunting plant growth and reducing the productivity of agriculture, and by making cities less attractive to talented workers, thereby reducing cities' competitiveness.

Motivation for This Study

This study sets out to calculate the economic costs of premature mortality from air pollution to strengthen the business case for governments to act ambitiously in reducing pollution. The costs of pollution to society are many, but a full accounting is beyond the scope of this report. Instead, it will focus on what many studies have shown to be the largest and most damaging cost of pollution: premature mortality.

The number of deaths each year attributable to air pollution makes a compelling case for reducing pollution. Valuing the costs of premature deaths associated with pollution helps to further highlight the severity of the problem. Governments face a wide array of competing development challenges, and monetizing the costs of pollution can help them decide how to allocate scarce resources to better the lives of their citizens. Monetary values can also help

them measure the benefits of policies to tackle pollution and, when compared with costs of implementation, to devise cost-effective air quality management plans.

This study also presents the results of 2013 Global Burden of Disease Study (GBD 2013 Collaborators 2015). The GBD measures illnesses and premature deaths from a multitude of causes and risk factors around the world, including air pollution. It offers the most extensive estimates of exposure and trends in air pollution levels and their associated burden of disease. The GBD effort dates to the early 1990s when the World Bank commissioned the original GBD study for feature in its *World Development Report 1993: Investing in Health*. Since 2010, the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, Seattle, has steered the GBD study, with the latest set of estimates for 2013.

Methodology

The disease burden attributable to air pollution is estimated by first measuring the severity of air pollution and the extent to which people are exposed to it (Brauer et al. 2016; Cohen et al. n.d.). The GBD evaluates exposure to outdoor (ambient) air pollution as well as indoor air pollution in households cooking with solid fuels. The GBD approach to estimating ambient air pollution aims to make the greatest use of information from different sources in the most reasonable way possible, combining data from ground monitoring with satellite observations and chemical transport models. Exposure to household air pollution is estimated from a combination of data on the proportion of households using solid fuels, estimates of indoor pollution concentrations associated with fuel use, and the ratio of personal to area exposure.

The GBD then evaluates how personal exposure raises people's relative risk of contracting illnesses such as ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, acute lower respiratory infections, and pneumonia. Elevated risk among the exposed population translates into a higher portion of deaths from these conditions each year, which are attributed to air pollution.

Using the GBD estimates of premature mortality attributable to pollution, this study values the economic costs in dollar terms following two different approaches: (1) a welfare-based approach that monetizes the increased fatality risk from air pollution according to individuals' willingness to pay (WTP); and (2) an income-based approach that equates the financial cost of premature mortality with the present value of forgone lifetime earnings. Each of these approaches is given equal weight in this report, although they are tailored to different purposes.

The welfare-based approach is intended to measure the economic costs of fatal health risks to the individuals that make up a society. By increasing people's risk of contracting a deadly illness, air pollution represents a threat to the many things they value, including consumption, leisure, good health, and simply being alive. This value is reflected in the WTP, which captures the trade-offs that individuals are willing to make to reduce their chances of dying. The value of statistical life (VSL) represents the sum of many individuals' WTP for marginal changes in

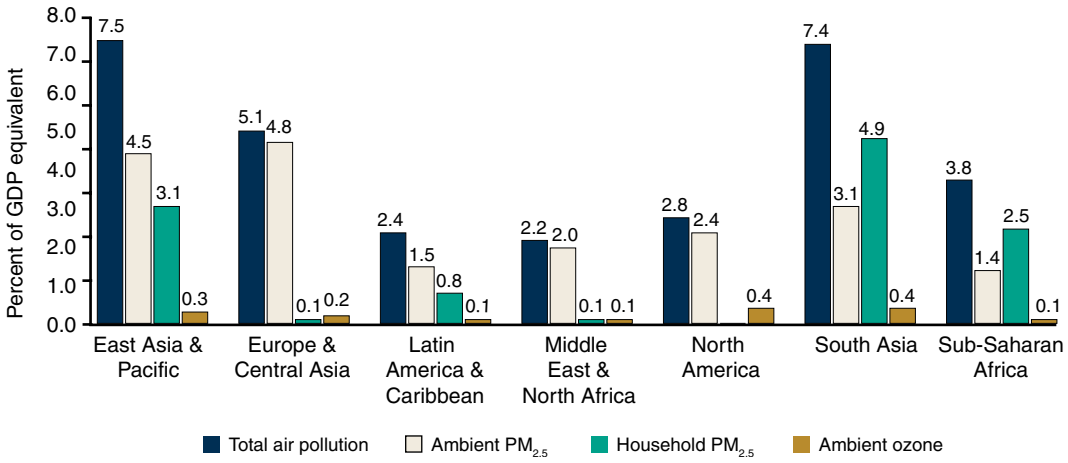
their risk of death. It is *not* the value of any single person's life or death, nor does it represent a society's judgment as to what that value should be. The VSL is also not meant for cross-country comparisons as to the value of life and death in different countries. The WTP-based approach is best suited for analyses of economic welfare, and it has become the standard approach in high-income countries for valuing the mortality risks associated with pollution (see Viscusi 1993; Cropper 2000; OECD 2012).

The income-based approach is more suited to financial analysis and measuring pollution costs within the extended boundaries of the national accounts—for example, as a component of the World Bank's adjusted net savings (ANS) measure. ANS, or "genuine savings," is a measure of the change in the value of a nation's assets, including manufactured capital as well as natural and human capital (see Hamilton and Clemens 1999; World Bank 2005, 2011). Positive savings represents an investment in future well-being as a nation accumulates the assets needed to drive economic growth and at least sustain current levels of consumption. Within the ANS framework, premature mortality due to pollution represents a disinvestment in a nation's human capital stock. As with the degradation of other forms of capital, this disinvestment is valued according to the expected loss of income over the lifetime of the asset. The Ministry of Social Development in Chile, for example, has adopted this approach for valuing premature mortality (Chile MDS 2014).

Key Findings

In 2013 exposure to ambient and household air pollution cost the world's economy some $5.11 trillion in welfare losses. In terms of magnitude, welfare losses in South Asia and East Asia and the Pacific were the equivalent of 7.4 percent and 7.5 percent of the regional gross domestic product (GDP), respectively (figure ES.1).[1] At the low end, losses were still equal to 2.2 percent of GDP in the Middle East and North Africa. Household air pollution from

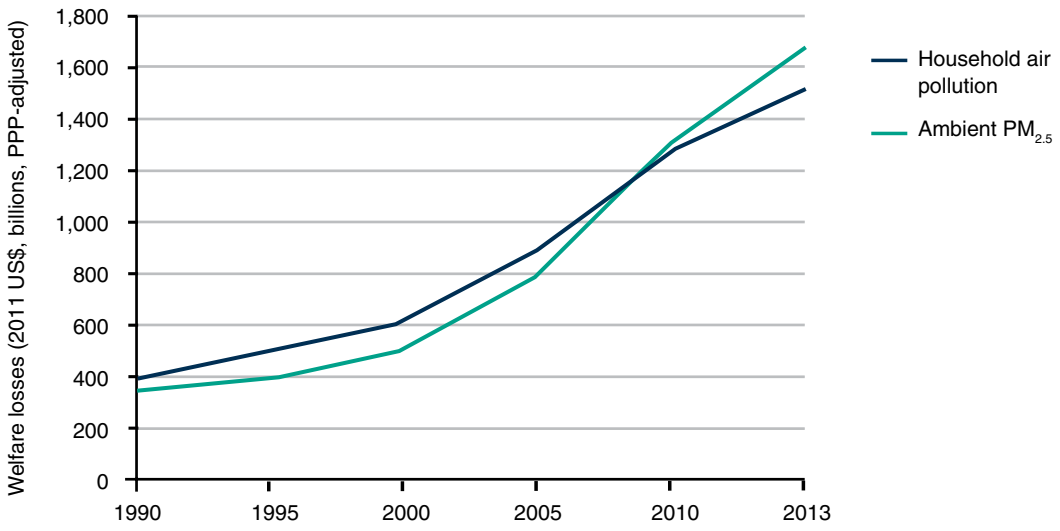
FIGURE ES.1 Welfare Losses Due to Air Pollution by Region, 2013



Sources: World Bank and IHME.

Note: Total air pollution damages include ambient $PM_{2.5}$, household $PM_{2.5}$, and ozone. GDP = gross domestic product.

FIGURE ES.2 Welfare Losses from Ambient $PM_{2.5}$ and Household Air Pollution in Low- and Middle-Income Countries, 1990–2013



Sources: World Bank and IHME.

cooking with solid fuels was the biggest cause of losses in South Asia and Sub-Saharan Africa. In all other regions, losses were largely caused by ambient air pollution from fine particulate matter ($PM_{2.5}$). Labor income losses, while expectedly lower than welfare losses, were nonetheless substantial in regions with younger populations. Lost income for countries in South Asia totaled more than $66 billion in 2013, the equivalent of nearly 1 percent of GDP. Globally, the labor income losses totaled $225 billion in 2013.

Moreover, air pollution costs have grown since 1990. From 1990 to 2013, welfare losses nearly doubled and labor income losses increased by 40 percent, despite countries having made great gains in economic development and health outcomes (figure ES.2). In low-income countries, declines in death rates were more than offset by population growth and greater total exposure to polluted air. In middle-income countries, total exposure and health impacts also increased. However, most of the estimated increase in welfare losses stemmed from people placing a greater value on reducing fatality risks. Similarly, from 1990 to 2013 average wages increased in real terms in all but the high-income countries that are not members of the Organisation for Economic Co-operation and Development (OECD), causing forgone labor income losses per premature death to be higher. Across countries in all income groups, the age profile of people affected by pollution shifted, so that a higher proportion of deaths occurred among people later in their working life, having a countervailing, but not equal or greater, effect on income losses.

Ambient air pollution is becoming a greater challenge, and household air pollution remains a persistent challenge despite some gains. Since the 1990s, exposure to ambient air pollution has grown in most countries (other than high-income), with some of the greatest increases in the heavily populated, fastest-growing regions, including South Asia and East Asia and the Pacific. By 2013 about 87 percent of the world's population was living in areas that exceeded the Air

Quality Guideline of the World Health Organization (WHO), which is an annual average of 10 micrograms per cubic meter ($\mu g/m^3$) $PM_{2.5}$. Although the age-standardized death rate due to ambient $PM_{2.5}$ exposure has decreased in most countries since 1990 because of overall improvements in health, population growth and increased exposure have nonetheless increased the number of premature deaths. From 1990 to 2013, premature mortality attributable to ambient $PM_{2.5}$ increased by 30 percent, from 2.2 million deaths to 2.9 million deaths per year. Global welfare losses from exposure to ambient $PM_{2.5}$ rose 63 percent over the same period, reaching $3.55 trillion—a reflection of worsening exposure in many fast-growing countries as well as the higher marginal costs for fatality risks associated with rising incomes. Labor income losses due to ambient $PM_{2.5}$ climbed from $103 billion to $144 billion per year.

Although two-fifths of the world's population was exposed to household air pollution from cooking with solid fuels in 2013, exposure has declined in most countries since 1990. Declines in exposure ranged from nearly 100 percent in many higher-income countries to under 10 percent across much of Sub-Saharan Africa. The age-standardized death rate from household air pollution decreased from 75 deaths per 100,000 persons in 1990 to 47 per 100,000 in 2013, a 38 percent drop. And yet, despite the reductions in exposure and death rates, the total number of deaths associated with indoor air pollution has mostly remained constant at about 2.9 million per year. Welfare losses due to household air pollution in low- and middle-income countries in 2013 were on the order of $1.52 trillion, while labor income losses reached $94 billion.

The very young and older adults remain particularly vulnerable: in 2013 about 5 percent of deaths of children under 5 and 10 percent of deaths among adults over 50 were attributed to air pollution, compared with less than 1 percent among young adults. This age pattern of mortality has remained unchanged since 1990. Among all ages and over time, a larger share of men than women have died prematurely from air pollution–based illnesses.

Recommendations and Way Forward

The fact that global welfare losses from fatal illness attributable to air pollution are in the trillions of dollars, is a call to action. The additional costs of pollution not captured by this report make reducing exposure all the more urgent for achieving the goals of shared, inclusive, and sustainable prosperity. Furthermore, the growing challenge of ambient air pollution and persistence of household air pollution impacts despite improvements in health services suggest that incremental progress to improve air quality will not be sufficient and that achieving real reductions in the cost of pollution will require more ambitious action.

Meanwhile, by placing air pollution–related health risks in the context of other health risks that, unlike air pollution, are typically within the purview of health agencies, the Global Burden of Disease approach is emphasizing the need for health agencies to consider this important health burden and calling for ministries of environment and health to work together to deal with this challenge.

Notes

1. Here, welfare losses are expressed as a percentage of GDP equivalent only to provide a convenient sense of relative scale and not to suggest that welfare is a share of GDP or that the two are a measure of the same thing.

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