KEY TAKEAWAYS

1. The benefits that came with using a cap-and-trade market to reduce ground-level ozone pollution were at least twice the cost to polluters.

2. The researchers discovered the NOx Budget Program, a cap-and-trade market for nitrogen oxides (NOx), significantly decreased emissions of NOx air pollution, and consequently high-ozone days, by 40 percent.

3. The cap-and-trade market decreased the use of medications, saving people $800 million per year, and reduced premature mortality, valued at about $1.3 billion a year. The elderly disproportionately benefitted.

4. Overall, the study found that the benefits from reducing 1 million tons of NOx are about $2.6 billion. The research additionally points to substantial benefits from reducing ground-level ozone pollution.

5. More broadly, the study has produced the first large-scale evidence on the relationship between medications or so-called ‘defensive expenditures’ and pollution. This finding opens up a new category of benefits from pollution reductions generally and therefore has important implications for determining the stringency of environmental regulations.
Introduction

Ozone is a harmful gas that forms when emissions of nitrogen oxides (NOx) and volatile organic compounds (VOCs) from power plants, factories, and cars are exposed to heat and sunlight. It is one of the six main pollutants controlled by the Clean Air Act. But, unlike the other pollutants covered by the Act, it has remained persistently high.¹

President Obama tightened the standard for reducing ozone, requiring states and cities to limit ozone concentrations to 70 parts per billion. As of 2015, 126 million Americans or about 40 percent of the population live in areas that violate this new air quality standard for ozone. The rule is set to go into effect in October 2017, though it has been plagued by contentious between environmentalists, industry, states and the courts about the extent of the benefits from ozone reductions.

These ozone standards are contentious at least partly because much of the previous evidence comes from studies where the connection between air pollution and health is not decisive. Further, these studies often measure just the direct costs from poor air quality such as health impacts like respiratory illnesses and mortality, which are the standard way to assess the benefits of air pollution reductions. However, people have long theorized that individuals spend a great deal on air filters, medications, and other products to protect themselves from the health problems caused by air pollution. These defensive investments, however, are often ignored when assessing the benefits of policies to reduce air pollution or in determining the stringency of such policies because there is little empirical evidence about whether they are meaningful.

At the same time, there is a sense that these often ignored defensive investments may be an important part of the overall health costs of air pollution. For instance, the annual cost of prescription medications for asthma is reported to exceed the monetized value of any other component of asthma’s social cost, including mortality, emergency department admissions, or lost productivity. Therefore, the exclusion of these defensive costs underestimates the amount people are willing to pay for clean air.

This study evaluated the NOx Budget Program’s cap-and-trade market to reduce NOx. Specifically, it measures the benefits from efforts to reduce ozone by examining both the impacts on mortality and defensive investments, measured by medication expenses, and compares them to the firms’ compliance costs. Reducing NOx emissions plays a central role in controlling ozone concentrations. This is underscored by the fact that the new ozone standard requires a 65 percent reduction in NOx emissions between 2011 and 2025. Finally, although market-based instruments like the NOx Budget Program are viewed as among the most important contributions of economics to environmental policy, this study represents perhaps the first time any analysis has linked actual health measurements directly to emissions and air quality measures in order to evaluate an emissions market.

Research Design

The researchers evaluated the social benefits of improved air quality through a quasi-experiment that looked at pollution, direct health impacts, and defensive investments in the form of medical expenses.

Specifically, they evaluated the Nitrogen Oxides (NOx) Budget Program, which ran from 2003 to 2008, and covered 19 states and Washington DC, including: Alabama, Connecticut, Delaware, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Michigan, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, and West Virginia.²

Each state received a set of permits and chose how to distribute those permits to affected sources. Once permits were distributed, affected sources – which included more than 2,500 electricity generating units and industrial boilers – could buy and sell permits through open markets. A single emissions cap regulated the entire market region, though firms could bank allowances for any future year. The market operated only during summer months, between May 1 and September 30, because winter ozone levels in the Eastern and Midwestern United States are low, and ozone spikes to high peaks on hot and sunny days. At the end of the summer, each source had to give the EPA one allowance for each ton of NOx emitted.

To conduct the study, the authors collected an unprecedented amount of data. First, they collected total daily emissions of NOx, sulfur dioxide, and carbon dioxide emissions for all states, from the EPA’s Clean Air Markets Division. Because ozone formation is impacted by the weather, the researchers also compiled daily maximum and minimum temperature, total daily precipitation, and dew point temperature data for the same time spans and regions. The researchers then collected confidential data on more than 100 million medication purchases, plus hospital visits and costs, and deaths.

The researchers compared across participating and non-participating NOx Budget Program states, in years before versus after the program began, and in summer—when the program was running—versus the winter. Comparing the differences between these data allowed them to plausibly isolate the causal effects of the emissions market on pollution, direct and indirect investments, and health.

1. Ground-level ozone which affects health when people breathe it, the focus of this study, are unrelated to holes in the atmospheric ozone layer, which affect health through causing skin cancer, and which are not the focus of this study.

2. The NBP also covered a small part of Missouri beginning in 2007; the analysis excludes Missouri.
“Our research shows that efforts to reduce ozone extend lifespans. While previous research had suggested this, the especially novel finding here is that pollution reductions lead to significant reductions in the purchases of medications that protect people from becoming sick or even dying prematurely. We believe this is the first large-scale evidence on the relationship between medications or so-called ‘defensive expenditures’ and pollution and opens up a new category of benefits from pollution reductions generally. The implications for air pollution policy are potentially enormous.”

**MICHAEL GREENSTONE**
**DIRECTOR, ENERGY POLICY INSTITUTE AT THE UNIVERSITY OF CHICAGO**

**Findings**

1. **The NOx Budget Program cap-and-trade market significantly decreased air pollution, and consequently high-ozone days.** Just prior to the start of the cap-and-trade market, NOx emissions were fairly flat, with pollution spiking during summer months. Once the market was in place, NOx emissions dropped by 40 to 50 percent during the summer months.

Since NOx forms ozone, it is unsurprising that the researchers also discovered a 6 percent drop in average ozone concentrations. The number of summer days with high ozone levels (i.e., more than 65 parts per billion) was reduced by about 40 percent, or by about 7 to 10 days each summer.

**Figure 1 · Total Daily NOx Emissions In The NBP-Participating States**

**Figure 2 · NBP Market Impact On NOx Emissions And Ambient Ozone Pollution**

Note: The Cap-and-Trade program the researchers studied capped total pollution from May 1 through September 30 each year, beginning after the year 2003. This graph shows total emissions of nitrogen oxides pollution from regulated industrial sources in the Eastern U.S. The y-axis shows total daily emissions in thousands of tons.
2. The cap-and-trade market led to a drop in the use of medications, saving $800 million a year, and a drop in life years lost valued at about $1.3 billion a year. In the 19 Eastern and Midwestern states covered by the market, medication expenditures decreased by 1.5 percent, translating into a savings of roughly $800 million annually. This is about equal to the annual compliance costs imposed by the cap-and-trade market. Because people can take other indirect steps to reduce the costs of air pollution — like avoiding time spent outside and purchasing air filters — the savings from medication costs are likely just a portion of the benefits that come from reductions in defensive investments.

Further, during the summer months, in the states where the market was in place, the mortality rate declined by 0.4 percent, or a decrease of roughly 2,000 premature deaths per summer. Among people 75 and older, the market prevented about 1,300 deaths each summer (or 65 percent of total prevented deaths), suggesting that the elderly disproportionately benefited from the market. Overall, standard techniques suggest that the reduced mortality is valued at about $1.3 billion annually.

3. Reductions in NOx emissions lead to reductions in respiratory and cardiovascular medication purchases and premature mortality. The study provides the first plausibly causal direct link between the effect of NOx emissions on health and defensive investments such as medication purchases. More broadly, the research points to substantial annual benefits from reducing ground-level ozone pollution.

4. The monetary benefit from reducing 1 million tons of NOx emissions is about $2.6 billion. Using data on medication prices and standard economics techniques, the study found that each 1 million ton decrease in NOx emissions a year saves about $500 million in medication expenditures and roughly 3,100 premature summertime deaths, with an estimated value of $2.1 billion in mortality benefits.

5. When applied to the market, the benefits in the form of reduced medicine costs and life-years saved are more than twice the compliance costs incurred by polluters. Using this generalizable metric, the researchers conducted a transparent cost-benefit evaluation of the NOx Budget Program. They found that the market decreased NOx emissions by 427,000 tons in aggregate per summer on average. The average cost of a NOx permit was $2,500 per ton. NOx permit prices provide an upper bound on the costs firms spend to abate pollution, since firms would only buy permits after exhausting all less costly engineering methods of reducing pollution. This means that the market caused firms to spend at most $1.1 billion annually to abate NOx. Over the life of the market, this upper bound on cost amounts to $4.8 billion.

On the benefits side, the market led to a decrease in medication expenditures of $820 million per year, or $3.7 billion over the life of the market. Adding to this the value of the reduced rates of mortality, and the benefits of the market are nearly twice the costs (i.e., $9.6 billion in benefits and $4.8 billion in costs).

Policy Implications

President Obama required every city to decrease ground-level ozone below 70 ppb, a regulation due to begin implementation in October 2017, in part by requiring decreased NOx emissions. This research finds that when a cap-and-trade market is used, the benefits from NOx regulations are substantial and greatly exceed costs. This conclusion is highly relevant to debates over this change in ozone air quality standards, though rigid air quality standards are a different type of policy than cap-and-trade markets.

More broadly while much research has accounted for the direct costs of pollution, such as asthma and other illnesses, this study breaks new ground by examining defensive investments, such as medication costs, to defend against these illnesses. The results demonstrate that reductions in defensive investments are an important benefit from reducing pollution. In the case of the NOx pollution, the results suggest that they are roughly 60 percent of the benefits from reductions in mortality. To date, defensive investments are almost never counted when devising air pollution policies, which suggests that these policies’ benefits are currently being underestimated, potentially substantially so. This study has opened up a new category of benefits from pollution reductions that has the potential to fundamentally alter the regular updating of cost-benefit analyses that determine the stringency of regulations that flow from the Clean Air Act and other environmental policies.

About EPIC

The Energy Policy Institute at the University of Chicago (EPIC) is confronting the global energy challenge by working to ensure that energy markets provide access to reliable, affordable energy, while limiting environmental and social damages. We do this using a unique interdisciplinary approach that translates robust, data-driven research into real-world impacts through strategic outreach and training for the next generation of global energy leaders.