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I Z A
World of Labor
Evidence-based policy making

Environmental regulations and business decisions

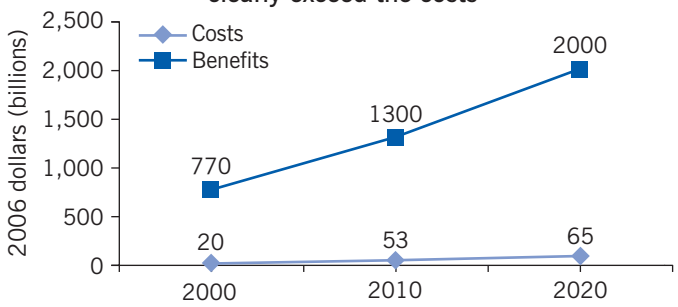
Environmental regulations impose costs on firms, affecting productivity and location but providing significant health benefits

Keywords: regulation, productivity, plant location, pollution abatement costs

ELEVATOR PITCH

Environmental regulations raise production costs at regulated firms, though in most cases the costs are only a small fraction of a firm's total costs. Productivity tends to fall, and firms may shift new investment and production to locations with less stringent regulation. However, environmental regulations have had enormous benefits in terms of lives saved and illnesses averted, especially through reductions in airborne particulates. The potential health gains may be even greater in developing countries, where pollution levels are high. The benefits to society from environmental regulation hence appear to be much larger than the costs of compliance.

The benefits of the 1990 US Clean Air Act Amendments clearly exceed the costs



Note: Benefits arise primarily from reduced mortality due to air quality improvements. Costs represent the impact on the economy of air pollution abatement costs.

Source: [1].

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KEY FINDINGS

Pros

- Environmental regulations have greatly improved air and water quality, especially in areas that were dirtiest before regulation.
- Reducing airborne particulates is especially beneficial, saving thousands of lives and preventing millions of illnesses each year.
- The potential health benefits may be even greater in developing countries, where pollution levels are high.
- Proposed reductions in greenhouse gas emissions have potentially large benefits from slowing climate change and preventing some of its adverse impacts.

Cons

- Environmental regulations raise production costs and lower productivity by requiring firms to install pollution control equipment and change production processes.
- Regulatory costs can influence firms' decisions about locating new plants and shifting production among existing plants.
- Stricter regulations on new plants can discourage new investment and keep dirtier plants operating longer than originally expected.
- Stricter regulations in dirty locations can lead to increasing pollution in once-clean areas.

AUTHOR'S MAIN MESSAGE

Environmental regulations, intended to protect human health and the environment, generally result in higher production costs and lower productivity in firms, which can lead them to shift investment and production to less stringent locations. Research on the effects of environmental regulation has focused mainly on air pollution regulations in the US. Overall, regulatory benefits clearly outweigh the costs, but most benefits come from reductions in fine particulates; some other regulations have costs that exceed the benefits. Society gains only from environmental regulations whose benefits (e.g. reduced mortality) exceed their costs.

MOTIVATION

Beginning in the 1970s, environmental regulation in developed countries became substantially more stringent as part of a wave of new social regulation reflecting greater government willingness to intervene in business decisions. Many countries established national-level environmental agencies (France's Ministry of Environment in 1971, Japan's Environmental Agency in 1971, and Germany's Federal Environmental Agency in 1974); environmental agreements were also adopted at the regional and international level (the UN Environment Programme in 1972 and the European Economic Community's first Environmental Action Programme in 1973). In the US, this expanded interest in environmental regulation was expressed in the creation of the Environmental Protection Agency in 1970 and the passage of the Clean Air Act in 1970 and the Clean Water Act in 1972. Both acts have been amended and additional regulations have targeted toxic waste, requiring firms to report toxic releases and assigning liability for cleaning up toxic waste sites. Opponents argue that these regulations impose huge costs on business, lowering productivity and prodding firms to move elsewhere. Proponents argue that regulation can spur innovation, thus providing economic benefits as well as reducing pollution. A better understanding of the costs and benefits of environmental regulation is needed to help design optimal policies.

Environmental regulations: how clean is clean enough?

Laws relating to environmental regulation tend to focus on benefits and ignore costs. The Clean Air Act of 1970 seeks "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." The Clean Water Act of 1972 seeks "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" and calls for the complete elimination of water pollution discharges by 1985. Most environmental regulations in the US are defined by the Environmental Protection Agency at the federal level, while enforcement is carried out primarily by state environmental agencies.

With respect to air pollution, the Environmental Protection Agency is required to define national ambient air quality standards to protect human health. Over time, these standards have been revised as new scientific evidence emerges. The discovery that particulate-related mortality came mostly from small particles prompted a shift in the particulate standard from total suspended particles in 1971 to particulate matter of less than 2.5 microns (PM2.5) in 1997, with further tightening in 2006 and 2012. Stricter standards can also be driven by lawsuits brought by environmental groups seeking to force agencies to tighten their standards.

A common characteristic of environmental protection laws is a focus on eliminating pollution or reducing it to a level at which there are no observable health effects, in contrast to the economist's view of balancing the incremental benefits and costs of pollution reduction. Over the years, a series of executive orders have required federal agencies to prepare a benefit–cost analysis before issuing a major regulation. While this may make it more difficult to issue costly regulations, the underlying legal justification for the regulation is not tied to benefits exceeding costs.

DISCUSSION OF PROS AND CONS

Regulatory differences and looking under the lamppost

One under-appreciated aspect of environmental regulation in developed countries is that regulatory approaches vary considerably for different pollution media. In the US,

air pollution follows a top-down approach, with the Environmental Protection Agency setting overall national ambient air quality standards for each pollutant that must be met in every county in every state. State agencies must then develop state implementation plans that impose stricter regulations in "non-attainment" counties—counties whose pollution levels exceed the air quality standards. A similar approach is taken in the EU, where the European Commission sets air quality standards and countries must develop plans to reduce pollution in any region that fails to meet the standards.

In contrast, water pollution regulation follows a bottom-up approach in the US but a top-down approach in the EU. In the US, each plant that discharges into navigable waters requires a permit for those discharges. State regulators write most water permits, which require monthly reporting of discharges. The permits tend to follow the Environmental Protection Agency's industry-specific guidelines but can be stricter when water conditions warrant. EU water regulation is more like air regulation, with countries required to develop a management plan for each river basin district. Concern about toxic materials in the US led to a requirement that manufacturing plants provide annual public reports in the Toxic Release Inventory.

Market-based regulatory approaches such as tradable permits have long been favored by economists for providing an efficient allocation of pollution reduction by equalizing the marginal cost of reductions across polluters. Market-based approaches also provide a measure of regulatory intensity, since permit prices reflect the marginal cost of abating pollution. In the US, sulfur allowance trading under the 1990 Clean Air Act Amendments was associated with lower than expected compliance costs and widely considered a success. In recent years, tradable permits have been proposed for reducing greenhouse gas emissions, most notably in the EU Emissions Trading System.

Empirical research on the economic impact of environmental regulation has followed the tradition of "looking under the lamppost"—focusing on the most readily available data. Data on US environmental regulation far exceed what are available for other countries, helping explain why so much of this research has focused on the US, despite several limitations.

County location is easily connected to economic data, and the non-attainment ("dirty air") counties that should face stricter regulation are easily identified. Thus, there are many studies on US air regulations at the county level. Regulatory stringency for water pollution is set on a plant-by-plant basis, which makes data collection and analysis much more difficult, so there are far fewer studies on water pollution. The Toxic Release Inventory provides easily accessible annual data for tens of thousands of manufacturing plants—but there is often no clear connection between the reported releases and any particular regulatory program.

This paper focuses on environmental regulations that affect firms' production processes. Regulations that mandate changes in product characteristics, such as increased fuel economy requirements for motor vehicles, reduced volatility in paints, or bans on specific pesticides, certainly affect firms' decisions, but they are not addressed here.

Pollution abatement costs and productivity impacts

Three basic approaches are used to measure the costs of environmental regulation: surveys, engineering studies, and econometric analyses. For the US manufacturing sector,

the Pollution Abatement Costs and Expenditures (PACE) survey, conducted annually by the Census Bureau between 1973 and 1994 and only sporadically after 1994 (in 1999 and 2005), provides detailed information on air, water, and solid waste pollution abatement spending for capital investment and operating costs. Engineering studies forecast the cost of new environmental standards based on the cost of purchasing and operating the equipment needed for compliance. Econometric analysis can measure the costs of existing environmental regulation, given data on production costs and (crucially) measures of the differences across observations or over time in the extent of regulation faced by the plants, firms, industries, or economies being studied. Each approach has its disadvantages. Surveys rely on respondents to allocate some costs between abatement and production (for example, in the case of investment in new capital that is both cleaner and more productive). Engineering analyses rely on predictive methods and do not allow for improvements in abatement technology. And econometric analyses are subject to biases if there are errors in measurement or omitted key variables. This review focuses on econometric approaches, but it can be important to benchmark those results against the other approaches where possible.

Many of the earliest analyses of the impact of environmental regulations on business focused on their impact on productivity, defined as output per unit of input. Many different productivity measures are available, varying in the definition of inputs. Total factor productivity measures include all of a plant's inputs (labor, capital, and materials); other measures such as labor productivity (output per worker hour) use a single input. Productivity growth happens when output increases faster than inputs. Spending money on pollution abatement increases measured inputs, but the resulting improvement in environmental quality is not counted as an output. Thus, a plant's measured productivity declines. The reduction in productivity should be roughly equivalent to the share of pollution abatement costs in total costs. A firm whose pollution abatement costs are 2% of its total costs should have a 2% lower level of measured productivity, all else being equal. Econometric analyses can test whether the relationship between abatement costs and productivity is larger or smaller than this, implicitly testing whether reported abatement costs overstate or understate the true abatement costs.

The expansion of government regulation in the 1970s coincided with a slowdown in productivity growth in US manufacturing industries, raising speculation that regulation had contributed to the productivity slowdown. This apparent relationship prompted a series of research projects examining the impact of environmental regulation on productivity, many of them using the US Pollution Abatement and Control Expenditures (PACE) survey.

Early studies using economy-wide data found that pollution abatement costs explained a small part (perhaps one-fifth) of the productivity slowdown. Using industry-level data, one study found a greater productivity slowdown in the 1970s in industries with higher pollution abatement costs [2]. Using plant-level data, another study found large impacts on productivity (suggesting under-reported costs) for paper mills and steel mills but not for oil refineries, though these impacts were substantially smaller when plant-specific fixed-effects were included [3]. One study found less significant impacts of abatement costs on productivity using a different fixed-effects model [4]. Another study of paper mills found large impacts on productivity but with significant variability across plants—paper mills incorporating a pulping process were significantly more sensitive to abatement costs, while mills that had recently been renovated were significantly less sensitive [5]. More recently, a study created a county-year index of abatement costs from the PACE survey

data and found no statistically significant impact of higher pollution abatement costs on productivity for the average manufacturing plant [6].

Studies of the impact of pollution abatement costs on productivity in other countries seem to find smaller impacts than in the US. An analysis of ten German industries found significant differences in productivity impacts across industries, but the estimated reductions in productivity growth were relatively small [7].

Productivity analyses using measures of regulation other than reported pollution abatement costs have found varying results. An examination of oil refineries in the Los Angeles area, which face extremely stringent air pollution regulations, found no evidence of falling productivity as a result of increased regulation [8]. (Recall that the oil industry also seemed less sensitive to abatement costs in [3].) A study focusing on US counties with changes in their pollution attainment status found that polluting plants had significantly lower productivity in years when their county was in non-attainment and was thus facing stricter regulations [9].

Location and investment decisions

In addition to examining the direct costs of environmental regulation on productivity, economists have studied how firms respond to regulatory-driven cost differences. Much of this research has examined the decision on where to locate a plant. When locating a new plant, a profit-maximizing firm should consider many factors besides factor prices and availability, such as regulatory compliance costs. If more stringent environmental regulations discourage firms from locating in a particular jurisdiction, politicians might weaken regulations to attract new plants. This possibility of a "race to the bottom" in environmental stringency is especially likely when the damages from a pollutant are widely dispersed (or can be directed to a neighboring jurisdiction by locating plants near the border). If a pollutant's damages are more locally concentrated than the benefits from the new plant, the opposite effect could occur, with politicians showing a "race to the top" or "not in my back yard" bias by imposing increasingly stricter regulations.

One of the initial justifications in the US for establishing federal environmental standards was to avoid having individual states relax their environmental standards for competitive reasons. Amendments to the Clean Air Act, such as New Source Performance Standards and Prevention of Significant Deterioration, increased the regulatory stringency for new plants in areas with clean air (attainment counties), to avoid incentives for plants to move there from dirtier locations with stricter regulations (non-attainment counties). Studies show that Congressional voting on those programs was driven less by politicians' environmental stance and more by the economic interests of their constituents: the principal beneficiaries of the new regulations were Eastern industrial firms and coal-mining firms that would otherwise have been at a competitive disadvantage compared with new plants in attainment counties.

Considerations of both data availability and the federal nature of US regulation, which allow for measurable differences in stringency across states and counties, account for the fact that most studies on the location decisions of plants have worked with US manufacturing sector data. The magnitude of regulatory cost differences within the US may be small compared with differences across countries, but potentially confounding differences in factor prices and availability are also likely to be smaller within the US.

One study looked at the number of new plants in ozone-generating manufacturing industries that were opened in each county and found large and statistically significant declines (26–45%) in counties that had failed to meet ozone standards [10]. Large multi-plant firms responded sooner than single-plant firms, suggesting that large firms managed the regulatory process better. Existing plants survived longer in non-attainment counties, while new plants were larger initially but grew more slowly, consistent with facing stricter regulations on plant expansions. The overall impact of the regulation was to spread ozone pollution geographically from initially high-ozone counties to initially low-ozone counties. Reducing peak ozone exposures in high-population areas may be beneficial, but increasing ozone elsewhere is clearly an unintended consequence of the regulation.

A similar outcome was found for a comparison across European countries of industry location in the early 1990s [11]. The share of each industry's production that occurred in each country was related to that country's stringency of environmental regulation and the industry's pollution intensity, controlling for other factors that might affect location. As expected, less stringent countries were more attractive for dirtier industries, although the effect was significant only for the dirtiest industry studied, industrial chemicals.

Environmental regulation could also affect investment decisions by firms. Plants facing greater regulatory stringency may be less profitable, leading multi-plant firms to shift production (and investment) to their other plants and possibly to close the plant facing high regulation if compliance costs are especially high or if the industry is in decline and some plants need to close anyway. Regulations may also require substantial capital investments in abatement equipment, reducing the financing available for investments in production capital if the firm follows a rule-of-thumb for allocating capital expenditures across plants, such as a pre-set capital budget for each plant. Investment in production capital at paper mills was crowded out by capital investments in abatement equipment, with plants in a multi-plant company that had high abatement capital costs receiving significantly less in production capital investments [12].

Environmental regulation can also affect the choice of production technology. If different technologies have different environmental consequences, firms should choose cleaner (and presumably more expensive) technologies at plants facing more stringent regulation. Multiple production techniques are available for making paper, so plants can tailor their production technology decisions to the regulatory environment. New paper mills in states with stricter regulations tend to choose a low-pollution technology, while mills in states with a different mix of air and water pollution respond to the relative regulatory stringencies on air and water pollution in their choice of technology [12]. The mere existence of a regulation may change the set of production techniques available, providing incentives to develop cleaner methods. In some cases, "technology-forcing" regulations impose impossibly strict pollution reductions (which existing techniques cannot meet), anticipating that research will produce technologies that can accomplish those reductions before the standard takes effect.

Benefits from pollution reductions

While the costs associated with environmental regulation have been substantial, the best available information indicates that the overall benefits have far exceeded the costs. Benefits come in the form of reduced illness and death, as well as ecosystem services, such

as improved visibility and better recreational water quality. Expressing these benefits in monetary terms requires a variety of assumptions. For example, the "value of a statistical life" calculation comes from workers' choices between risky and safe jobs. The value of a statistical life is the increase in wages that a group of workers would require to accept a risky job with the probability of one death on average per year. If the probability of death on the job is one in 1,000, the value of a statistical life would be the extra pay to 1,000 workers. If each worker requires, say, $5,000 to accept the higher risk, the overall cost is $5 million ($5,000 × 1,000)—the value of a statistical life. If workers require only $500 each to accept that risk, then the value of a statistical life would be only $500,000. Calculating this value allows us to express lives saved (benefits) in monetary terms for comparison with costs. It seems clear that reductions in air pollution account for the vast bulk of these benefits, with most of the benefits coming from reductions in mortality as a result of lower ambient concentrations of fine particulates.

A systematic examination of the benefits and costs of US environmental regulation of both air and water pollution finds that the largest benefits came from reducing particulate emissions from industrial point sources, with benefits many times the costs [13]. A series of epidemiological studies over time have confirmed large impacts of particulates on mortality. The US Environmental Protection Agency's most recent (2011) assessment of the benefits and costs associated with the Clean Air Act Amendments of 1990 estimates that by 2020 the reductions in particulate emissions will result in 230,000 fewer deaths annually, providing 85% of the predicted $2 trillion in annual benefits, far exceeding the predicted $65 billion in annual costs [1]. The gap between benefits and costs is so large in this case that it is unlikely to be reversed by any plausible adjustment in the measurement methodology, although the averted deaths tend to occur among older people with other health issues, while the value of a statistical life used to calculate the benefits comes from decisions by much younger people choosing between safe and risky jobs.

While most people in developed countries have relatively low exposure to air and water pollution, people in many developing countries face much higher levels, implying that the health benefits of pollution reductions are likely to be greater. The World Health Organization estimates that air pollution exposure leads to 3.7 million premature deaths, mostly in developing countries. Estimates of annual premature deaths from air pollution in China alone range from 350,000 to 1.2 million. Similarly, the health benefits from reducing water pollution are limited in developed countries, which already have high drinking water quality and adequate sanitation, but could be much larger in developing countries, where access to clean drinking water and sanitation is poor.

While the evidence is strong that overall environmental regulations have benefits that exceed costs, this conclusion does not necessarily apply to individual regulations. As noted, the vast majority of pollution abatement benefits in the US are associated with reductions in fine particulates. A systematic examination of the benefits and costs of US environmental regulation concluded that air pollution controls on mobile sources (which generate little particulate pollution) probably have costs that exceed benefits, as do most water pollution controls, except in the case of a few highly polluted bodies of water [13]. Even a new regulation to reduce particulate pollution would not necessarily pass a benefit–cost test. The benefits must be evaluated on the margin, considering only the incremental reductions in particulates attributable to the new regulation, not the large benefits that have been achieved by earlier regulations.

Air pollution and the Beijing Olympics

High levels of air pollution in Beijing raised concerns among athletes and others before the 2008 Summer Olympic Games. The government took extraordinary measures to reduce pollution during the games, closing hundreds of factories and power plants, halting major construction works, and imposing driving bans on trucks and automobiles. Pollution levels fell dramatically (sulfur dioxide down by 60%, carbon monoxide down by 48%, and nitrogen dioxide down by 43%). Medical researchers tracked a set of biological markers in 125 healthy Beijing residents and found that the markers followed the pollution levels—improving during the games and rebounding to near pre-Olympic levels after the pollution controls were relaxed.

Source: University of Rochester Medical Center. "Beijing Olympics provides rare window into air pollution's effect on health." May 15, 2012. Online at: http://www.urmc.rochester.edu/news/story/index.cfm?id=3501

LIMITATIONS AND GAPS

Our understanding of the economic impacts of environmental regulation is shaped by the data that are available for analysis. Most research has focused on US regulation, because US data have historically been the best organized and most easily available. The best-known of the US studies examine air pollution regulation, specifically differences between non-attainment counties with dirty air that face stricter regulation than attainment counties with cleaner air. These differences could reflect a shifting of economic activity among counties rather than a reduction in overall activity, overstating the total effect. In any case, knowing the impact of this particular regulation may have little or no relevance for estimating the impact of some other regulation—for another country or another pollution medium—or even for US air pollution regulation in the future, since existing estimates are based on past levels of regulatory stringency associated with past standards for air pollutants.

Better information on pollution abatement costs is needed. Resuming regular collection of US PACE survey data and initiating similar surveys in other countries would greatly assist researchers and policymakers in developing more efficient regulations. These surveys could also gather data on specific abatement equipment being installed to meet new regulations, providing a more complete context for plant-level analysis. Those who are developing new regulations should provide more information on the range of control techniques expected to be used to achieve compliance. That information could be used for later comparisons with actual compliance outcomes, enabling more accurate retrospective cost analyses and eventually improving the quality of cost estimate prediction.

An important area of current research is evaluating the benefits and costs of proposed regulations on greenhouse gas emissions to reduce the risk of future climate change, but this topic is especially challenging. Reports from the Intergovernmental Panel on Climate Change leave little doubt that human-generated emissions of greenhouse gases are having substantial impacts on the earth's climate and could lead to serious problems in the future. However, the global nature of the problem makes it impossible to compare outcomes between affected and unaffected areas, and the long time lags involved make it potentially risky to wait until all the data are in before conducting econometric analyses of the benefits and costs of the regulations.

Most of this evidence comes from command-and-control regulation, which relies on detailed regulations specifying what is permitted and not permitted, combined with ongoing inspection. In theory, market-based regulation based on economic incentives, such as tradable permits, could provide greater flexibility and lower compliance costs, but the evidence is not yet in.

SUMMARY AND POLICY ADVICE

Environmental regulations and their implementation have varied widely across countries, across pollution media, and over time. Policymakers using studies of past regulation as a guide for future decisions should carefully examine the regulatory context to ensure comparability.

The evidence demonstrates that environmental regulations impose costs on manufacturing plants. These costs can be observed in lower productivity, and the size of the productivity reductions helps in measuring the costs of regulation for plants, even without survey information on specific abatement costs. The costs of regulation can also be observed in the ways that firms respond to those costs—being more likely to open new plants in jurisdictions with less stringent regulations, investing less in plants where regulations are stricter, and choosing production technologies based on local regulatory stringency.

While environmental regulations impose costs, it seems clear that their overall benefits greatly exceed their costs. However, the distribution of costs and benefits across specific regulations varies widely. The vast majority of the overall benefits come from reductions in emissions of fine particulates from industrial sources. Regulations targeting air emissions from motor vehicles and water pollution discharges from point sources generate much smaller benefits, probably less than their costs [13]. Evaluating a new regulation must be done "on the margin" by considering only the incremental benefits and costs from the regulation, not those attributable to prior regulations. Society gains only from environmental regulations whose benefits (such as reduced mortality from cleaner air) exceed their costs.

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Competing interests

The IZA World of Labor project is committed to the *IZA Guiding Principles of Research Integrity*. The author declares to have observed these principles.

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