

Economic Strategies to Reduce Acid Deposition: A Review of Current Policy Initiatives

Externalities were first recognized in Pigou's (1920) *Economics of Welfare* as costs that society incurs, which are not reflected in market transactions. For the most part externalities were considered an abnormal market failure until Ayres and Kneese (1969) presented evidence to the fact that environmental externalities – “those associated with the disposal of residuals resulting from the consumption and production process” – were an inevitable part of resource use. The laws of thermodynamics tell us that processes that use stocks of raw materials and convert them to other forms must result in waste. No conversion of energy is 100% efficient; therefore, when natural resources are taken from the environment and employed to make consumer goods, waste results from the material transformations. This waste or pollution is returned to the environment. Most consumer products do not reflect the costs associated with this waste disposal and society bears the cost in terms of health effects and degraded ecosystems.

This paper outlines one of the many externalities associated with fossil fuel consumption – acid deposition – and the issues involved with developing policies to control it. Acid deposition is an excellent example of an environmental externality because it has attributes characteristic of many pollution problems in that it is a non-localized problem that crosses political boundaries; has effects that can reach well into the future; and has multiple point and non-point, natural and anthropogenic sources. Because of these and other issues, policymakers struggle to find effective ways to regulate such externalities. Using the example of fossil fuel consumption and acid deposition, this paper reviews the three main economic strategies that seek to internalize the cost of environmental externalities: command and control strategies, environmental taxes, and tradable permit systems.

EXTERNALITIES OF FOSSIL FUEL CONSUMPTION

Electricity production and transportation are two areas where environmental externalities abound. In our consumption of fossil fuels, humans produce emissions that

affect public goods and the cost of these effects are not borne by the person receiving the benefits of the fossil fuel use. Fossil fuel consumption has environmental externalities associated with every phase of use from extraction and refining to transportation and distribution. This paper will focus on the post-distribution externalities associated with the conversion of fossil fuels to useable energy. Emissions from fossil fuel burning include several greenhouse gases (carbon dioxide, methane, carbon monoxide, other hydrocarbons), particulate matter, trace metals, and gases that produce acid rain (sulfur dioxide (SO_2) and nitrogen oxides (NO_x)). These pollutants have detrimental effects on human health, ecological systems, and built capital that are not reflected in the consumers' price for fossil fuels.

SO_2 and NO_x (including nitrous oxide, nitrogen dioxide, and nitric oxide) emitted from fossil fuel burning are released into the atmosphere where they react with water to form sulfuric and nitric acids. This anthropogenic acidification process leads to effects on human health, built capital, and ecosystems. Human health effects include increased respiratory problems due to inhalation of dry particles and increased formation of tropospheric ozone via NO_x compounds (U.S. EPA, 2003). Acid rain also has an effect on buildings and construction materials exposed to low pH precipitation over time. Paint, brick, and stone are degraded at faster rates when exposed to acids, thereby accelerating their natural deterioration processes. This can lead to the loss of historic buildings and sculptures and increased economic costs associated with the shorter lifespan of construction materials and restoration efforts (McGee, 2003). Aquatic ecosystems feel the effects of acid deposition through decreased pH of their waters. As these systems become more acidic, many organisms cannot survive, thus leading to habitat loss for pH sensitive species. Also increased nitrogen inputs from NO_x emissions enhance eutrophication of aquatic systems. In terrestrial environments, acid deposition depletes calcium (Ca) in soils and directly leaches physiologically important pools of Ca from foliage. In forested ecosystems, this loss of Ca leads to an increased vulnerability to environmental stressors like cold temperatures, disease, and drought, which can ultimately lead to forest decline (Schaberg *et al.* 2001).

ISSUES AFFECTING POLICY FORMATION

Like many environmental problems, acid deposition has many attributes that make policy implementation difficult. It is a non-localized problem that crosses political borders. In the United States Midwestern states are major producers of SO_2 and NO_x emissions from large coal-fired power plants. Air currents transport the pollutants outside of state and regional borders until they are released over Northeastern states. Northeastern states are receiving detrimental effects of the pollution without receiving the benefits of purchasing power from these plants. Regulating a non-localized externality such as acid deposition means forging a relationship between the environmental regulator (in this case, the U.S. Environmental Protection Agency) and the public utilities. These two groups have conflicting interests. The EPA is responsible for achieving an acceptable balance between abatement technologies and environmental damage while the public utilities are responsible for pricing their product based on production costs (including abatement) (Baron 1985). In some cases in Europe and Asia, acid deposition is an international problem. Emissions from Chinese coal-fired power plants reach Japan; and European nations trade pollution problems in the same manner as U.S. states (Wetstone and Rosencrantz, 1983).

The components of acid deposition have many sources including natural and anthropogenic, point and non-point sources, adding another difficulty to policy formation. Natural sources of NO_x include bacterial activity, wildfires and lightening, while SO_2 is emitted from wetlands, oceans and volcanoes. Policymakers must adjust their emissions standards based on these natural background levels of these compounds. Many policies that attempt to mitigate the externalities of fossil fuel burning focus on point source emitters, like power plants, because it is much easier to monitor and regulate a stationary source. Mobile sources, like automobiles, are more difficult to control, thus creating an equity problem – how can the government tell power plants to control emissions or pay a fine, when people are driving more cars that are increasingly larger and less fuel-efficient without paying any fines for their pollution?

Another issue involved with creating policies to address acid deposition is uncertainty. What is the acceptable level of pollution in terms of human and ecosystem

health effects? How much is pollution “costing” society in terms of human health problems and loss of ecosystem services? Can these values be quantified in monetary terms? These are the difficult questions policymakers address when faced with regulating pollutants. Several studies have been conducted to quantify these externalities in terms of a monetary value. The cost of environmental damage ranges from \$0.13-\$9.15 per pound of SO₂ and \$0.02-\$12.25 per pound of NO_x in terms of 1989 U.S. dollars (Koomey and Krause, 1997). As evident from the large range of values, there is much uncertainty in determining monetary values for ecosystem services damaged by human actions. Ecosystems are dynamic systems with several feedback loops making it difficult to accurately predict outcomes of events. In economic terms the best-case scenario for policymakers would be to find the point where the marginal cost of emitting one more pound of pollution would equal the marginal benefit of services gained from the impacted ecosystems. Any ecologist will tell you that determining this point is impossible, yet when policymakers contact ecologists for their expert advice that is precisely what they are looking for – that “magic” level of pollution that is acceptable to both economic and environmental health. Despite the problems associated with formulating policies to address acid deposition, three major economic strategies have been developed and utilized throughout the world: command and control techniques, environmental taxes, and tradable permit systems.

COMMAND AND CONTROL STRATEGIES

One method employed to manage pollution is a command-and-control (CAC) strategy where regulatory agencies set emissions standards or abatement levels and enforce monetary fines on those who do not comply with the standards. Ideally the fines are used to pay for damages associated with the pollution. As stated earlier, problems arise with uncertainties about appropriate levels at which to set standards. How much pollution is acceptable to humans and sustainable for ecosystems? Once an appropriate limit is determined, regulation is reasonable – monitor the polluters for compliance and fine those sources which exceed the defined emissions standard or abatement level.

Japan has the strictest CAC policies aimed at a reduction in SO₂ and NO_x emissions. In 1968 Japanese authorities set limits for acceptable concentrations of NO_x and SO₂. The daily average of hourly values is the lowest in the world – pollutant levels cannot exceed 0.02 ppm for NO_x and 0.04 ppm for SO₂ (Wetstone and Rosencrantz, 1983). To meet these strict standards, Japan became the first nation to require power plants and factories to use both SO₂ and NO_x abatement technologies. They also invoked the CAC strategy of setting limits for SO₂ emissions at the largest pollution sources and collecting fees from those that do not comply. The main impetus for setting these standards was to reduce human health effects so the fees collected were used to fund the medical care of patients suffering from the effects of air pollution (Morishima, 1999). In addition to CAC strategies, Japan also imposes a tax on vehicles related to the amount of pollution they release and a lower sales tax on vehicles powered by electricity or methanol.

Kochi *et al.* (1999) conducted cost-benefit analyses on the Japanese SO₂ fee policy using values of human health effects as the benefits gained from pollution reduction. They found that since its induction in 1968, the ratio of benefits to costs has been on the decline. During the first five years this ratio was 3.32, from 1974-1983 it dropped significantly to 0.80; and from 1983-1993 it again fell to 0.28. In terms of human health benefits, it appears that CAC strategies are only cost-effective in their early stages. This may be due to a lack of incentives to reduce pollution below the mandated limits. Once the limits are reached, no further reductions are necessary so pollution remains at the set levels. The early stages of regulation prompted the private sector to develop abatement technologies that were less expensive than the steep fines imposed by the government and an insurgence of new technologies came into the market, including fuel desulfurization processes, fuel conversion to liquefied natural gas, and sulfur scrubbers to remove SO₂ from emissions. Eventually marginal costs of incrementally reducing pollution (via technological advancements for abatement) exceed the marginal benefits gained from human health protection. The CAC strategy of SO₂ fees was responsible for producing new technologies and cleaning up the most populated areas of Japan, however it appears that now other strategies may be necessary if Japan is to further reduce their impacts.

In contrast to Japan, China's CAC strategies have proven to be only marginally successful in cleaning up their acid deposition problem. Similar to Japan, the Chinese Environmental Protection Bureau (EPB) set ambient air quality standards, conducted dispersion models to estimate impacts from their largest sources, and set individual levels for specific polluters (Raufer, 1999). Fees collected from polluters exceeding their pollution allowance were supposed to be used to for additional pollution abatement at sources. However, funds collected from SO₂ fees have never exceeded administrative costs of implementing the program.

There are several reasons why China's policies failed and Japan's succeeded. Limits and fees set by the Chinese authorities are not severe enough to elicit change. Ambient air standards for SO₂ are set at 0.06 ppm for residential areas and 0.10 ppm for industrialized sectors. Monitoring efforts in 1999 (Wu et al. 2000) showed that 33% of all suburbanized areas exceeded the 0.06 ppm standard. This points out one of the failures of the system: if fees are not high enough, it may be more cost-effective to industries to pay the fine rather than reduce their emissions. China followed Japan's lead and based their fee structure on human health effects. However, the value placed on a human life in China was a nominal 270 US\$, resulting in very low fees for non-compliance (Wu et al. 2000). Another criticism of China's CAC strategy is poor regulatory systems. Studies have often shown that China's EPB is more concerned with pursuing production goals and economic growth rather than environmental protection (Raufer, 1999). In 2000 China agreed to accept Japanese aid in developing air pollution control strategies. Currently the government is working on a cap-and trade system similar to the one in the U.S. discussed in a later section of this paper. This is good news for Japan and other Asian nations since China is the largest source of acid deposition precursors and these pollutants travel outside of national boundaries to be deposited in other countries.

ENVIRONMENTAL TAXES

Based on Pigou's solution to externalities of imposing a tax equal to the externality costs (Pigou, 1920), environmental or "green taxes" are used worldwide to control pollution. In contrast to the regulatory nature of CAC strategies, environmental

taxes use economic theory and the market system to protect public goods. Although the degree of environmental protection is not as absolute as with CAC strategies, environmental taxes often lead to more long-term behavioral changes (Milne, 2003). Often environmental taxes are complimented with government subsidies for abatement technologies, making it more cost effective to use abatement strategies instead of paying the tax, thus providing further incentive for reducing emissions. In countries employing environmental taxes, income tax is generally reduced and the tax base shifts to environmental taxes. Businesses receive compensation for paying environmental taxes through reductions in their contributions to employees' social security funds (EEA, 2000).

Environmental taxes have been the key policy initiative for European countries looking to internalize the costs of pollution. European environmental taxes include all taxes on energy, transportation, pollution, and resources, which accounted for 6.71% of the European tax base in 1997 (EEA, 2000). Worldwide, environmental taxes account for less than 3% of tax revenue (Fischlowitz-Roberts, 2002). All European countries have a tax on motor fuels and most have a tax on motor vehicle registration and use. In recent years, an increasing number of European countries have imposed taxes on energy use and industrial emissions. At the same time, income taxes are reduced to offset the cost of environmental taxes (EEA, 2000). Sweden, Denmark, and The Netherlands have been leaders in this tax-base shift from income taxes to environmental taxes.

Sweden was one of the first countries to start a tax-base shift, beginning in 1991 with taxes on sulfur and carbon emissions that were offset by reductions in income tax. At this time they also imposed a tax on fuels based on the amount of sulfur (4.40 US\$/kg S). Only those fuels with less than 0.1% S content were exempt. Because of these taxes, the average content of S in fuels has steadily decreased. In just the first year, the average amount of S in diesel fuel dropped from 0.15% to 0.10%. As a result, Swedish authorities continued to lower the S level at which taxes were incurred. By 2000, only fuels with less than 0.005% S were exempt from taxes (EEA, 2000). Swedish taxes on electricity have also proven to be successful. As of 2000, energy taxes have reduced emissions by 4% below 1990 levels in Sweden, while the economy and population continued to grow (Fischlowitz-Roberts, 2002). By reducing income taxes and shifting the tax base to

energy, citizens gain more control in determining how their money is spent and feel empowered to make energy-conserving choices, thus reducing the amount of pollution from these sources.

Denmark's tax shift from income to environmental taxes is the highest in Europe. As of 2000, 9.5% of Denmark's tax base came from environmental taxes (EEA, 2000). Their energy taxes are among the highest in the world, with the largest income resulting from an aggressive tax on SO₂ emissions that was implemented in 1996. Their car registration tax, which is based on vehicle fuel efficiency, is the highest in Europe. As a result of effectively incorporating the externalities of fossil fuel consumption into its price, consumer and producer behavior has undeniably changed. Denmark has consequently become a world leader in wind turbine and energy-efficient appliance industries (Fischlowitz-Roberts, 2002). The demand for renewable energy technologies and efficient products spiked due to high taxes on fossil fuel consumption and firms answered that demand.

The Netherlands is another fine example of a tax base shift resulting in new technologies and a cleaner environment. Second only to Denmark, 9.4% of Dutch tax base is generated from environmental taxes (EEA, 2000). Their Green Tax Commission implemented a broad Regulatory Energy Tax (RET) on natural gas, fuel oil, electricity, and heating oil. The goal of RET was to change consumer behavior, rather than generate revenue. Most of the tax is borne by the consumer, effectively increasing the cost of household energy use. In exchange for this increase in energy costs, income taxes were reduced. The RET has resulted in a 15% decrease in household energy use and 10% decrease in fuel use since its inception in 1998 (Fischlowitz-Roberts, 2002). Like Denmark, The Netherlands is a world leader in renewable energy technologies, particularly wind turbines and solar power (EEA, 2000).

TRADABLE PERMITS

In a tradable permit system, authorities set a maximum level of total emissions nationwide and distribute limits to individual pollution sources, much like CAC strategies. Instead of collecting fees for non-compliance, however, tradable permits take

pollution control into the economic market. Polluters who reduce emissions below their limit receive pollution “credits” equal to the extra pollution kept from the atmosphere. These credits or permits are tradable in that polluting companies can use the permits to offset pollution at other sources that they own, sell the permits to other firms, or bank them for future use. If a firm must exceed pollution limits, they must purchase permits to do so. The major benefit of this system is its focus on total pollutant levels, which is better correlated to environmental damage than setting maximum emission rates at individual sources (Schmalensee et al, 1998).

Lately trends in environmental externality policy have been leaning toward adoption of a tradable permit system to replace CAC strategies. The U.S. has been a leader in the development of such policies. Originally the Clean Air Act Amendments of 1970 and 1977 imposed CAC strategies similar to those discussed earlier. In 1990 the U.S. Environmental Protection Agency amended the Clean Air Act once again, including the establishment of an SO₂ and NO_x permit trading program. The program capped total SO₂ emissions from point sources nationwide at 11.2 million tons, decreasing annually to reach 4.5 million tons in 2010 and 3 million tons in 2018. NO_x emissions are capped at 5.1 million tons, decreasing to 2.1 million tons in 2010 and 1.7 million tons in 2018 (EPA, 2003). Total reductions in emissions by 2018 amount to a 73% reduction in SO₂ and a 67% reduction in NO_x emissions from 2000 levels.

Early effects on emissions due to the implementation of the tradable permit system showed a significant decrease in SO₂ emissions. For example, in 1995 SO₂ emissions were 5.2 tons – 39% below the set cap for that year (Schmalensee et al, 1998). One reason for this over-compliance is that many of the pollutant permits are being banked for future use because the cost of a permit is expected to increase significantly as cap levels decline. Because the tradable permit system acts within the economic market system, as fewer permits are allowed (based on lower emissions caps), demand for the permits increases, resulting in higher costs. Although this system has resulted in decreased SO₂ emissions, the fact that many companies have banked permits does not bode well for future reductions. Another reason for the over-compliance involves influence from other market factors. In the mid-1990s rail rates declined, allowing inexpensive access to low-S fuels in Wyoming (Schmalensee et al, 1998). By extracting,

refining, transporting, and burning low S coal, many power plants are able to meet point-source emissions standards from their plants. Because the transportation sector does not participate in the tradable permit program, emissions have essentially been transferred from point source to mobile source emissions.

The U.S. EPA has declared the tradable permit system a success – SO₂ rates have, in fact, declined. However, this decline has not prompted a reduction in acid deposition. This is likely due to the fact that although SO₂ emissions are declining, total NO_x emissions are not. More NO_x is emitted from the transportation sector than from the point sources regulated in the cap-and-trade program. Unlike Europe's environmental taxes that are more equally distributed between transportation and energy sectors, the U.S. cap-and-trade program does not address the mobile sources of acid-causing pollutants.

CONCLUSIONS

The general trend in pollution control policies is to move from CAC strategies to those that work within the market framework – environmental taxes or tradable permit programs. These alternatives have proven successful in reducing emissions in a cost-effective manner, but they must address issues of scale and equity in order to be effective over the long term. European countries have been successful in reducing pollution and providing incentives for renewable energy technologies because the scale of the tax is appropriate to elicit such changes. If the tax were set too low, consumers would have chosen to simply pay the tax rather than reduce their emissions. Since consumers pay a tax on each unit of pollution, there is always an incentive to reduce emissions through new technologies or efficient behaviors. Environmental taxes, therefore, provide incentives both for firms to develop more efficient technologies and for consumers to change their behaviors.

In terms of the three main principles of ecological economic theory - sustainable scale, equitable distribution, and efficient allocation - tradable permit policies fall short of being the panacea for pollution control. As is the case with most policies based around efficient allocation, tradable permits are a success. They present a cost-effective way of

reducing emissions, based on our existing market system. The question of sustainable scale is much more difficult to answer. As discussed earlier, uncertainties abound in terms of appropriate levels at which to set caps. The lack of correlation between reduced SO₂ emissions from the U.S. cap-and-trade program and a reduction in acid deposition indicates that this policy is not the ultimate solution to the problem. The tradable permit system does not address mobile sources because it works at a different scale. Imagine a policy where automobile drivers had a set level of pollutants they could emit during the course of a year. If you wanted to take a cross-country road trip and you might have to bank permits or purchase them on the market in order to do it. This policy would not be very cost-effective and enforcement would be difficult, if not impossible.

Perhaps the greatest failure of the cap-and-trade program is its lack of regard to issues of equitable distribution across time and space. In temporal terms, the strong over-compliance of today could lead to more pollution in the future as firms cash in on their banked permits. This creates an equity problem across generations. The cap-and-trade program also does little to address the fact that acid deposition is a non-localized problem. Midwestern coal-fired power plants can purchase permits to maximize production while Northeastern states pay in terms of increased acid deposition. A third equity failure can occur if one firm owns several pollutant sources. That firm could opt to clean up one source to well below cap limits and give their earned pollution credits to the other sources.

The best policies for reducing pollution must consider ecological and human health effects when determining a sustainable scale for pollution levels. In absence of hard data indicating safe pollutant levels for ecosystem and human health, policies to address pollution should focus on reductions in general, coupled with monitoring to track effects. Policies should also focus on adaptive management principles and be flexible when monitoring data indicates a need for change. In the case of acid deposition policymakers might make more headway if ecosystem vulnerability is used as a guideline for equitable distribution. More vulnerable systems, like those in the Northeastern U.S. that have received relatively more acid deposition, could be protected by stricter standards in areas that are source regions for the Northeast.

On a final note, one must address the issue of enforcement. In recent months, the Bush administration has implemented several exemptions for firms to disregard the Clean Air Act provisions by relaxing regulations. This ironically named Clear Skies Act undermines the Clean Air Act's New Source Review laws (NRDC, 2003). The New Source Review requires old plants to install modern abatement technologies before expanding and increasing emissions. Under the new legislation, these provisions would be weakened, allowing 20,000 older facilities to increase emissions in order to expand and increase profits. The first step towards effective pollution prevention policy is to enforce its regulations. With exemptions like ones proposed in the Clear Skies Act, the U.S. cap-and-trade program has little hope of success in reducing acid deposition.

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