“Market-Based Pollution Control Regulation: Implementing Economic Theory in the Real World”

96-11-01

Roger Raufer

National Affairs, IOS Press, 1996
Market-Based Pollution Control Regulation: Implementing Economic Theory in the Real World*

by Roger K. Raufer**

Introduction

The development of economic-oriented environmental regulatory mechanisms has been one of the noteworthy advances in environmental management in recent years. A 1987 survey conducted by OECD found that more than 150 economic instruments were being used for environmental protection in the 14 countries studied; six years later, the overall numbers of instruments had increased by about 50 per cent.1

The United States has been very active in this field, and in particular has taken the lead in the use of quantity-based (as opposed to price-based) approaches. It began to apply these in the 1970s towards air pollutants such as particulates, sulfur dioxide, volatile organic compounds, and other emissions regulated to achieve National Ambient Air Quality Standards (NAAQS). In 1990, a market-based approach to acid rain control was adopted, and regulatory agencies are currently developing new market-based control programmes to deal with high ambient levels of ozone.

The world of governmental regulators differs considerably from that of theoretical economists, however, and regulations adopted to date have been strongly influenced by the difficulties and problems arising from previously-adopted pollution control programmes. These real-world considerations have affected not only the design of the new regulatory approaches; in many cases, they constitute their very raison d'etre.

This paper outlines the experience that the United States has had adopting such market-based approaches, and the on-going transition from command/control regulation towards economic-based programmes. This regulatory experience is likely to prove critical in the future development of international markets in carbon dioxide and greenhouse gases. The U.N. Conference on Trade and Development (UNCTAD) has already proposed such a market-based system,2 and some consider such an approach to be the only feasible method of tackling this ambitious environmental goal in the future.3

The engineering view

Environmental mandates are not a new phenomenon, of course. One historian has noted that legal prohibitions designed to minimize environmental degradation have been found in the more than twenty civilisations, many

---


** Dr. Phil., University of Pennsylvania, USA.
no longer in existence, that have appeared on the face of the planet. For example, a Londoner was supposedly hanged in 1308 for violating an air pollution proclamation issued by the King. The King found the sulfurous smell of coal smoke offensive, and determined to put a stop to it. Hanging would today be considered a rather severe punishment for such an environmental infraction, but the underlying approach is still very relevant for pollution control.

Society, through some legitimately recognized authority (i.e., the king, parliament, pollution agency, etc.) issues orders to protect or improve environmental conditions, and then ensures that these orders are carried out. This is often referred to as "command/control" environmental regulation. Prohibition as the command, and execution as the means of control, are both extreme forms of the approach.

Prohibitions are attractive, of course, because they completely eliminate the pollution problem. But such absolutist measures are usually only realistic when alternative technologies or options are available, or if the environmental damage is particularly severe. Command/control regulations usually operate at some level less than complete prohibition, and governments have developed a whole arsenal of such requirements. Some common air pollution examples are outlined in Figure 1.

Figure 1: Engineering Approach to Pollution Control

A. A Generic "Black Box"

B. Pollution Control of "Black Box" Process

Emission standards limit the amount of pollution coming out of a stack. These are often stated in terms of emission rates (i.e., tons/year, pounds per day, or pounds per hour) of pollution.

Performance standards limit the amount of pollution coming out of a stack based on the amount of material being processed. For example, in certain cases, New Source Performance Standards for electric generating stations in the U.S. allow the unit to emit 1.2 pounds of sulfur dioxide for every million Btu's of heat input from the coal.

Product standards limit the quality of fuels which can be used. For example, the City of Philadelphia currently limits the sulfur content of distillate and fuel oils being sold or burned within the City.

Design standards tell the polluter how the process must be designed. For example: a degassing tank at the corner gas station must be 3d or it... minimize evaporation of the solvent.

It is not difficult to understand how these regulations came about. If one thinks like an engineer, then any pollution generating process can be considered a generic "black box" with inputs and outputs. Regulatory limits on inputs, outputs or the black box itself are explicit, and compliance can be readily determined. The "black box" model of pollution control regulation seems appropriate to engineers, but it does not say much about what is going on in the environment. For many years the British required use of "Best Practical Means" (BPM) for pollution control. When BPM technology was installed and operated on a pollution source, then whatever happened to the environment simply happened. After all, the emission sources using BPM were already doing the best that they could, and nothing more could reasonably be expected of them.

Such reasoning had its proponents in the U.S., but a different regulatory method prevailed. This alternative suggested that the goals of the pollution control program should be based not on what technology could deliver, but rather on what was happening in the environment. The goals of the pollution control program should be specific levels of environmental quality, allowing limited levels of pollutants in the air or water. Such an approach could take into account a wide range of factors, such as public health, damage to ecosystems, visibility, etc., when these environmental quality goals were set.

Technology-based approaches like BPM became the means to achieve these higher environmental goals. It was necessary to link the source-specific technology requirements with the ambient environmental goals in some manner, but this could be done through physical modeling (such as estimating the atmospheric dispersion of emissions from a stack). The command/control regulatory scheme in Figure 2 thus became the norm in the U.S. in the early 1970s.

Figure 2: Command/Control Regulation

Goals
- Environmental Quality Standards

Regulatory Measures:
1. Prohibitions
2. Technology-Based Standards
   - Emission Standards
   - Performance Standards
   - Product Standards
   - Design Standards

The economic View

Engineers usually based decisions about the "best" level of pollution control by looking for the "kink" in the marginal cost curve (i.e., the control level where marginal costs began to rise steeply). Economists, however, suggested that the focus on marginal costs
alone was not enough; a good decision also required information about marginal benefits.

When the economist had constructed such marginal cost and marginal benefit curves, the pollution control decision became readily apparent. Optimal pollution control occurred where the two curves crossed at the point where marginal costs and benefits were equal. From the economists’ viewpoint, this — not ambient standards — was the appropriate environmental goal. Note in Figure 3 that if the emission source controls less than the level where the curves cross (such as at level $A$), then it is not spending enough, since every extra dollar of pollution control results in more than one dollar of environmental benefits. On the other hand, if there is pollution control beyond the crossover point (such as at level $B$), then every additional dollar the emission source spends on pollution control results in less than one dollar of environmental benefits.

![Figure 3: Optimal Pollution Levels](image)

Unlike supply and demand, however, there is no "invisible hand" that will guide society to that singular point. So economists have had to address not only the determination of the environmental goal, but also the regulatory means to achieve it. They offered two approaches: one based on prices, and the other based on quantities. The price mechanism was developed by the English economist Arthur Pigou in his classic text *The Economics of Welfare* in 1920, and pollution taxes are therefore referred to as Pigouvian taxation. The quantity approach was outlined by Professor John Dales of the University of Toronto in 1968, in his book entitled *Pollution, Property and Prices*. These price and quantity mechanisms in Figure 4 are really different sides of the same coin, since the same firms apply the same pollution control at the same cost, and reach the same end result (*i.e.*, reaching the goal where $MC = MB$). There are, however, important differences in their application, particularly in the political arena.

While much of the world has tended to focus on the price-based Pigouvian tax approach, the political characteristics of property rights, markets, and minimizing wealth transfers to the public sector has led the U.S. increasingly towards the quantity-based approaches.

![Figure 4: Economic Approaches](image)

### Theory meets the real world

1. **Emissions Trading**

   The introduction of economic mechanisms in the U.S. was not a result of their theoretical elegance or efficiency characteristics, but rather the result of problems associated with the command/control approach. Because new facilities could not be built in areas exceeding the ambient standards, the U.S. Environmental Protection Agency (EPA) decided that new facilities would be required to "offset" their emissions (*i.e.*, reduce emissions in the area before being allowed to introduce new emissions). This unintentionally gave existing sources a new property right (their pollution emissions), and someone who might be willing to pay for them (a new source moving into the area). Eventually, EPA expanded this approach to existing sources, allowing them to treat their plants as though they were under an invisible "bubble"; sources could trade as long as the pollution leaving the bubble was less than required under command/control regulations. Another provision allowed the establishment of emission banks to hold Emission Reduction Credits (ERCs), the pollution credits bought and sold in the programme.

   The resulting emissions trading programme, shown in Figure 5, was thus not really a true economics-oriented programme. Rather, it was an adjunct pro-

![Figure 5: Emissions Trading Programme](image)
programme grafted on to the command/control regulatory approach, designed to make it more efficient. It kept the same goals as under command/control (i.e., the NAAQS), and also kept the same technology-based standards. These types of constraints strongly limited the effectiveness of this programme, and the market in ERCs has been relatively small.

2. The Acid Rain Market

Sulfur dioxide was regulated under the command/control programme, and control measures were taken to ensure that the localised air quality near emissions sources met the NAAQS. It became clear, however, that these localised efforts were not sufficient to address another environmental problem — the total loading of this pollutant, which was causing acid rain.

Initial attempts to address this problem began by examining the same types of command/control solutions (e.g., setting ambient sulfate standards, targeting specific pollution sources, etc.). These attempts were not successful, and attempts to employ the efficiency characteristics of emissions trading were shown to be problematical. The debate changed dramatically, however, when economists at the Environmental Defense Fund framed the solution in terms of the quantity-based regulatory approach. The existing controls on sulfur dioxide under command/control were retained to protect localised health and welfare concerns, but the total pollution loading was addressed through an additional control programme which allowed the purchase and sale of Emission Allowances (EAs). The resulting programme, shown in Figure 6, was adopted in 1990.

Figure 6: Acid Rain Control Programmes

<table>
<thead>
<tr>
<th>Goals</th>
<th>Total SO₂ Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localised SO₂ Levels</td>
<td>Pollution Markets (Q-based)</td>
</tr>
<tr>
<td>Emission Trading Programme</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regulatory Measures</th>
<th>Total SO₂ Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prohibitions</td>
<td>Pollution Markets (Q-based)</td>
</tr>
<tr>
<td>2. Technology-based Standards</td>
<td>Nation-wide Market (Allowance Tracking System)</td>
</tr>
</tbody>
</table>

While the U.S. acid rain market is the one closest to the economists’ theoretical programme outlined in Figure 4, it is important to recognise that even this programme did not adopt the economists’ goal of MC=MB. Instead, it set a value for Q (8.95 million tons of SO₂) based essentially on political compromise. The political calculus took into account a wide range of information (scientific, technological, economic, social, distributonal, etc.) in achieving this compromise; it did not rely on the economic valuation of environmental benefits through contingent valuation, hedonic pricing, or other analytical techniques to set the target. It did, however, make full use of the economic approach (the quantity-based programme) to accomplish this goal.

The first phase of emissions reductions began in 1995, and the second phase of reductions will be required in the year 2000. Every year, the Chicago Board of Trade holds auctions for emissions allowances, and brokers regularly arrange transactions. It has been estimated that the programme has reduced costs by at least $1 billion/year over a comparable command/control programme.

3. Regional and Local Ozone Markets

Having moved beyond command/control and into quantity-based economic regulatory systems, regulatory agencies began to apply this new approach towards another problem which continued to vex them: ozone. The original command/control programme was supposed to have solved this problem back in the mid-1970s, but it was unsuccessful. Initial control efforts focused on volatile organic compounds (VOCs) emitted from large industrial sources, and then targeted smaller and smaller point sources as the deadlines were passed. Nitrogen oxides (NOx) and VOC emissions from mobile sources were also controlled, although these emissions reductions were offset by the increased numbers of vehicles and the vehicle-miles-travelled (VMT).

As it became clear that the command/control efforts would not achieve the environmental goal, a number of cities and regions in the U.S. began to look to the quantity-based approaches to supplement (or replace) the command/control requirements for ozone control in federal legislation. Los Angeles, for example, developed the Regional Clean Air Incentives Market (RECLAIM) to address NOx, and Chicago developed the Illinois Clean Air market addressing VOCs over a six county area in north-eastern Illinois. In the Northeastern U.S., the Ozone Transport Commission is currently developing a quantity-based programme for NOx emissions from electric utilities and major industrial sources over an eleven state region.

Like the acid rain market, these regional/local markets have followed the general framework of the quantity-based approach, with a number of notable exceptions. First, they have not adopted the economists’ goal of MC=MB either, but have instead retained the original goal from the command/control programme — attaining the NAAQS for ozone. Second, the regulators have selected values of Q in these markets which do not represent the quantity of emissions (or reductions) necessary to achieve the environmental goal; instead, the markets address only some portion of the total Q required. Finally, the nature of the pollutants — NOx and
4. The Open Trading Paradigm

At the same time that these local and regional markets for ozone control are under development, a whole new market-based regulatory approach has been proposed, and is being considered by the EPA to deal with the ozone problem. Known as "open trading," this approach gets its name because it is presented as an alternative to the "closed" (or fixed limit) quantity-based system outlined above. In many respects, open trading is a return to the precepts of the original emissions trading approach (see Figure 7). It similarly relies on command/control to achieve the same environmental goal (the ozone NAAQS). It, too, gives emission credits for reductions beyond the command/control levels. But unlike the ERCs under emissions trading, which represent a continuous stream of reduced emissions into the foreseeable future, the reductions under open trading are discrete and one-time actions. These "discrete emission reductions" (DERs) are also credited after they have already taken place, while ERCs are pre-approved by the government.

Figure 7: Ozone Control Programmes

<table>
<thead>
<tr>
<th>Goals</th>
<th>Environmental Quality Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory Means</td>
<td></td>
</tr>
<tr>
<td>1. Prohibitions</td>
<td>City/Regional Markets</td>
</tr>
<tr>
<td>2. Technology-based Standards</td>
<td></td>
</tr>
<tr>
<td>Emission Stds.</td>
<td>Examples:</td>
</tr>
<tr>
<td>Performance Stds.</td>
<td>Northeast U.S. &quot;NOx Budget&quot;</td>
</tr>
<tr>
<td>Product Stds.</td>
<td>Los Angeles &quot;RE-CLAIM&quot; Programme</td>
</tr>
<tr>
<td>Design Stds.</td>
<td>Illinois &quot;Clean Air Market&quot;</td>
</tr>
<tr>
<td>Brokerage Opportunities</td>
<td>ERCs &amp; Discrete Emissions Reductions (DERs)</td>
</tr>
<tr>
<td></td>
<td>NOx/VOC Emission Allowances</td>
</tr>
</tbody>
</table>

The debate about open trading has split the proponents of economics-based regulatory programmes into "open" and "closed" factions. Proponents of the closed, Q-based approaches, like the Environmental Defense Fund, argue that DERs should have an extremely limited role; they are, in effect, like ERCs — but not as good. This faction, more commonly called the "cap-and-traders," see relatively little value — but lots of potential harm — coming from open trading provisions. The cap is the sacrosanct link to the environmental goal in their view, and DERs provide little help in achieving this goal.

Open trading proponents, on the other hand, focus more on the power of economics to achieve cost-effective emissions reductions. Caps might be useful, but they currently address only a small portion of the emissions actually contributing to the problem. Successive waves of ozone control measures have been implemented, and costs have risen accordingly. Those subject to regulatory pressures (i.e., industry) have been bearing the weight of these costs, despite the fact that their contribution is becoming less and less relevant in quantity terms. There may be many cost-effective means of reducing emissions outside of the cap, and open trading offers a potentially useful approach for tapping into them. It seems disingenuous to open trading proponents that regulators would block economic relief by making quantity the principal criteria for evaluating market-based systems, yet seemingly ignore its importance in drawing up the command/control requirements.

The Problems of Ozone Control Markets

As suggested above, the regional and local quantity-based programmes for ozone control face some difficult implementation issues — even without adding open trading provisions. Like the acid rain markets, there was no attempt to set the goal for ozone control at the point where MC=MB, primarily because of the inherent problems associated with quantifying benefits. The ozone NAAQS thus became the environmental goal. There have now been a number of studies which suggest that the costs of achieving this goal will far exceed the benefits; these studies are subject to most of the same methodological concerns in quantifying benefits, however.

Meeting the ozone NAAQS goal does not depend upon long term pollution loading, like the acid rain control programme. Instead, it is a short-term, episodic standard, measuring ozone levels on an hourly basis. If an area exceeds the 0.12 ppm standard more than four times in a three year period, then the standard is violated. Linking this environmental goal with specific emissions levels is a difficult task for several reasons. Ozone is a secondary pollutant, and is not emitted directly. Instead, it is formed when VOC and NOx emissions react together in the presence of sunlight. The straightforward physical modeling assumed in Figure 2 to link emissions and air quality is thus complicated by very difficult spatial and reaction kinetics. Modeling for ozone tends to be the purview of research laboratories, rather than the standardised regulatory tool (i.e., Gaussian models) employed for most other pollutants. The short term, episodic nature of the target goal makes its attainment highly susceptible to meteorological conditions, in particular during the Summer season. Sunlight and high temperatures favour its formation, but these very factors also tend to increase precursor emissions (i.e., increased volatilisation of organic compounds, increased NOx emissions as peaking turbine units are brought on to meet air conditioning loads, etc.) Thus, regulators are attempting to develop a market to achieve a goal which
would be difficult to achieve under even an idealised regulatory programme.

Another obstacle is that the regulators are dealing with only a small subset of the emissions causing the ozone problem. In many cities like Philadelphia, point sources are responsible for 25 per cent or less of the anthropogenic VOC and NOx precursors; the remainder come from cars, trucks and other mobile sources, and from area sources (e.g., outdoor grills, lawnmowers, consumer products, etc.). In the case of VOCs, it is becoming increasingly clear that biogenic emissions also make a substantial contribution to Summer ozone levels. U.S. citizens have strongly resisted recent command/control efforts to reduce mobile source emissions through such measures as employee trip reduction and enhanced inspection/maintenance programmes, and regulators have continued to place the reduction onus on a more politically viable target: utility and industrial point sources.

Ozone control markets like Los Angeles' RECLAIM programme and the proposed OTC "NOx budget" in the Northeast U.S. target these sources with market-based programmes, but the Q in this case does not result in MC=MB, or even necessarily achieving the NAAQS goal. Rather, Q is set as a function of how much reduction the regulators hope to accomplish from these point sources (e.g., up to 75 per cent of post-RACT-controlled emissions in the OTC's NOx budget). Picking the appropriate target in this manner it is not necessarily a straightforward task for the regulator. In dealing with a subset of emissions, regulators in Los Angeles apparently "overallocated" in the initial years of the RECLAIM programme, and credits flooded the marketplace.

Regulatory agencies must also worry about whether emissions are fungible under market-based approaches. This issue is related to the physical characteristics of the pollutants, and thus to the modeling efforts described above. The ERC market for VOCs was considerably more robust under the initial emissions trading programme than that for particulates, because restrictions on their spatial fungibility were less onerous. Some regulatory agencies have now introduced directional (i.e., upwind/downwind) constraints on VOC transactions. Not all hydrocarbons are equally likely to produce ozone, so it has also been argued that they should be traded with a system that weights the emissions for chemical reactivity. The RECLAIM market in Los Angeles originally intended to include VOCs, but the reactivity issue was not resolved in initial discussions, so it only addressed NOx and SO2. Still another concern about fungible emissions in the ozone control market is the toxicity of the VOCs. Should markets allow trading if there are potential health effects from these pollutants not addressed by their contribution to ozone alone? Should facilities be allowed to trade a VOC if that pollutant might cause cancer?

Finally, one of the most contentious battles has been over the "banking" of EAs, and their subsequent use in a later period – perhaps at a time when the ozone is spik-

Now Add Open Trading

While there are many problems associated with quantity-based ozone markets, open trading provisions introduce even more. EPA views open trading as complementary to the closed, Q-based systems. It also views open trading as potentially a transitional step leading to the more formal closed systems in areas which have not yet developed them.

In terms of developing a complementary open trading market, the key question is: What can one actually do with a DER? Is it clear that they can be generated, but how will the government allow them to be used? Open trading proponents, not surprisingly, suggest a wide-open marketplace, where DERs could be used to meet requirements for virtually all command/control requirements (including some technology provisions that even ERCs are not allowed to meet); to help meet thresholds minimizing new source review requirements; to help sources avoid non-compliance conditions; as an alternative to mobile-source provisions; and even as a means of meeting emissions cap provisions in the closed markets. Closed market proponents, on the other hand, see very limited applications: perhaps in a few cases where technology-based standards were not initially met, or in experimental cases such as international trading in border cities.

This debate has not yet been resolved. The EPA has proposed an approach that lies between these two levels, although its position seems to lie closer to the "closed" market position. It would only allow DERs to be used to meet certain types of emission and new source requirements (with rather tight restrictions); they could not be used to meet mobile source requirements; nor to avoid penalties or non-compliance enforcement actions. The EPA has not finalised this position, however, and it seems unlikely that such guidance will be available for the upcoming 1996 ozone season.

Open trading has been termed an "environmentally superior approach to pollution control" by proponents, and a "fatally flawed" approach that "tramples ... air quality objectives" by opponents. It is neither of these, however, and as a prospective regulatory programme, one must examine it in the context of characteristics normally sought in any such programme involving collective choice. Efficiency. Open trading could certainly act as a relief valve for sources subject to very high marginal costs under retrofit command/control provisions, and its potential role is likely to be helpful to some number of individual sources in this manner. Given the uncertain
efficiency of the target NAAQS standard, and the even more uncertain physical link between source emissions and air quality episode exceedance levels, the focus on highly disparate marginal costs in open trading would appear helpful in efficiency terms.

Equity. Since regulatory agencies tend to focus on one rather narrow group of emission sources that are politically vulnerable to stringent controls, any mechanism which allows them to find more cost effective reductions outside that narrow range would also seem to have favourable equity (of control) characteristics as well. The equity (ambient) impacts on the general public should be minimal, given the regional nature of the pollutant being addressed (although this issue is contentious in the debate about the toxic equivalence of VOCs).

Simplicity. Any regulatory programme should be relatively simple to administer, and open trading is anything but simple. By introducing a third type of pollution credit now available for sale and use (i.e., ERCS, EAs, and now DERs), quantity-based systems are now approaching the point where even air pollution specialists no longer understand the distinction between credit types, and their specific applicability and characteristics.

Transparency. Regulation depends upon public support, and a lack of public understanding has made it difficult to garner public support for quantity-based systems. If even pollution control specialists do not understand open trading, there is little opportunity for public input (or trust) in such a complex regulatory undertaking.

Effectiveness. Ultimately a regulatory programme should work, and accomplish its goals. Given the complexity and constraints discussed above, it seems likely that open trading would have a few transactions and achieve some efficiency, in a few selected instances. It seems highly unlikely that the market would be very robust, and, in fact, it seems likely to face many of the same developmental problems that hobbled the original emissions trading programme.

Open trading in a sense is a return to the reliance on command/control, instead of a new push towards Q-based economic solutions. It hopes to loosen the constraints with a liberal dose of freedom for the polluting sources – to the point that it scares some Q-based proponents. But the likely thin markets under currently proposed restrictions suggest that it would have a minimal effect – on either economic efficiency or the physical attainment of the NAAQs. These problems also raise the fundamental question of whether price-based (rather than quantity-based) regulation may better fit the physical realities of ozone control.

The Future of Quantity-Based Systems

The ultimate quantity-based system is, of course, a market in greenhouse gas emissions (probably beginning with a market in carbon dioxide). Global warming seems to be especially appropriate for such a market based solution, since it does not matter much if CO₂ is emitted in China, Poland or the U.S. – within approximately three weeks, it is fully mixed within the atmosphere. It therefore does not matter much where the reductions occur, either. The early ERC markets showed clearly that the bigger the trading range, the more robust the market. And a control programme to address global warming would appear to offer the biggest environmental market of all.

Given the potential economic impacts of global warming mitigation, it is probably not surprising that the whole framework for control is being discussed in terms of the price-and-quantity-based economic mechanisms. Each has advantages. Environmentalists tend to like one feature of quantity-based systems – they limit the quantity of pollution, and then allow prices to respond accordingly. Price-based systems, on the other hand, set the price (a Pigouvian tax) and then allow the quantity of emissions to respond to that price signal. In global warming, there is not much agreement about the science, and it would thus be very difficult to set an appropriate quantity-based target. A price-based programme like an emissions tax on carbon dioxide (or more likely on oil itself) has the advantage that it could be easily collected whenever fuels are sold. Another advantage is that societies may have an idea about the level of reserves that they are willing to devote to the global warming problem. A tax-based approach could target this level of spending, and then apply those resources efficiently. It would also generate a large amount of revenue, which could be used to address global warming concerns in poorer, undeveloped areas.

But taxes have their problems as well. The rich, developed countries are unlikely to hand over control of their energy sector to some international tax-setting authority. Nor will they allow a large "slush" fund controlled by international bureaucrats to handle distributional effects, regardless of how well intentioned these programme administrators may be.

The distributional characteristics of the quantity-based approaches are much more suitable to the complex, politically-charged problem of global warming. Indeed the only major analysis concluded that this is the only practical approach. Such a permit trading approach could be introduced slowly through bilateral agreements, and built up over time as it becomes more and more successful. In fact, this is essentially what is happening today, under various "joint implementation" programmes. In a number of cases, firms in developing countries have already agreed to offset carbon dioxide emissions in other countries. For example, Applied Energy Services (AES), a U.S. firm that builds non-utility power plants, decided to plant 2-3 million trees in Guatemala to offset the CO₂ from a new power plant it was building in Connecticut. 20

Another innovative market transaction tied together the U.S. acid rain market and global warming reductions. In that deal, Arizona Public Service Company agreed to trade 25,000 SO₂ emission allowances for 1.75 million tons of CO₂ reductions from Niagara Falls' Shaw Power Corporation. 21 The CO₂ reductions, although not legally
required, were paid for with approximately $1 million in tax benefits from the allowance transaction. The Environmental Defense Fund has agreed to work with the utilities in identifying appropriate global warming reductions.

Conclusions

U.S. experience with implementing quantity-based pollution control programmes has evolved over the past twenty years, and such economic mechanisms are playing an increasingly important role in dealing with complex environmental problems like acid rain and ozone control. Although well grounded in economic theory, the market-based systems have relied heavily upon the command/control framework already in place. Since the implementation of economic programmes can be a complex and difficult task, the existence of such a framework has no doubt aided pollution control efforts.

Just as one must learn to walk before running, the underlying command/control programme afforded the necessary infrastructure for data gathering and initial control efforts. As costs have risen, however, and as the polluters subject to such regulations have become increasingly smaller and more diverse, the limits of such regulation have become readily apparent.

It seems unlikely that the U.S. will abandon its historical commitment to command/control regulation, and an uneasy alliance between market-based and command/control programmes will have to be hammered out on a virtually pollutant-by-pollutant basis. The ozone-control programmes appear to be amongst the most difficult, and the discussions above have highlighted these difficulties. It would appear that the physical science aspects of CO2 global warming will be simple in comparison. But perhaps that is only fair, given the uncharted heights of distributional terrain which still lie ahead.

References
10. The acid rain provisions constitute Title IV of the Clean Air Act Amendments of 1990.
14. The Ozone Transport Region (OTR) was established under Section 184 of the 1990 Amendments to the Clean Air Act. It includes Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, Pennsylvania, the District of Columbia, and that portion of Virginia included in the Consolidated Metropolitan Statistical Area of Washington, D.C. The "NOx budget" is part of a Memorandum of Understanding (MOU) signed by members of the Ozone Transport Commission (OTC), which contains the Governor (or designated representative) of each OTR state, as air pollution control officials representing each state, and EPA regional representatives from the affected regions.