001-046 copy 1/14/00 2:50 PM Page 1

PART ONE

Incentive-Based Environmental Quality Control

1

Emissions Trading Emerges from the Shadows

Richard F. Kosobud

Under emissions trading regulation, business and government share the commanding heights of environmental policy. Each makes key decisions. The former is free to trade emission rights or to choose, and to develop, air pollution control measures with the incentive in mind of minimizing control costs. The latter reserves the right to set emission rates or aggregate levels of pollution under which tradable rights can be generated, to establish trading rules, and to monitor and enforce compliance with the incentive in mind of increasing public welfare. Public interest groups also appear on these heights by exerting their influence on trading policies and government and business decisions.

On these heights, it is clear that the regulated and regulating communities have new roles to play compared with their responsibilities under traditional regulation. Emissions trading is both a simplification of regulation in that decisions are assigned to those who can carry them out best and a complication in that new rules and procedures must be established, tested, and refined. These rules and procedures have been undergoing continuing development as existing trading programs to control air pollution mature, such as those to limit sulfur dioxide (SO_2) emissions, and new implementation plans get underway, such as those to reduce the emissions of nitrogen oxides (NO_x), volatile organic compounds (VOCs), and carbon dioxide (CO_2). A first objective of this book is to bring together a group of leading researchers to present their latest and most authoritative studies on these matters for the benefit of business and government.

Emissions trading as a new environmental regulatory tool is moving out of the shadows and into the arena of public scrutiny, thus attracting attention not only from the immediately affected communities, but also from a widening circle of public officials, public interest groups, academics, and the informed public itself. It is still controversial in some quarters. Emissions trading is undergoing a rapid development process, introducing unfamiliar terms and concepts into the discussion of environmental policy. We are all in school to obtain a clearer understanding of this recent arrival on the regulatory scene. Consequently, a second objective of this book is to provide authoritative studies that are clear and readable guides to the numerous and changing definitions and concepts that have come to be embodied in this regulatory mechanism.

Not all of the ever-growing audience has greeted the new arrival with enthusiasm or approval. Doubts about the market's transparency and concerns about compliance with and enforcement of trading rules, among other problems, are raised in many quarters. A third objective is to present a wide range of views about emissions trading including the commentary of public interest groups, government administrators, and academics, with the intention of reaching readers who want more information before making up their minds about the net benefits of this policy instrument and its applicability to other pollutant problems. Our aim is to help develop a more informed appraisal and discussion of this new tool.

Emissions trading has long been studied from the theoretical point of view and advocated by mainstream economists in technical journals, read only by a relative few. Its recent implementation has generated a growing body of evidence that suggests that market incentives can work in the right circumstances and that some measure of success can be claimed in the first trials. The importance of this empirical evidence is hard to overemphasize for our purposes, as there are few deductive truths on matters of regulatory policy. Therefore, a final objective is to include qualified observers to review that evidence and to appraise that claim of success in an effort to help answer the basic question: Can this new regulatory balancing act between government and the private sectors be constructed so as to provide for the public a cleaner environment in a more cost-effective, more flexible, and less confrontational way?

Fitting Emissions Trading into the Environmental Policy Context

It is easy to lose sight of the ultimate goals of environmental policy when engaged in a discussion of the merits of regulatory reform. The question of the choice of regulatory measure typically occurs well along in the logical sequence of issues that arise in the recognition and consideration of an environmental problem. Yet, resolution of issues at earlier stages can have a bearing on regulatory decisions; for example, the determination of the negative impact of a pollutant can have a bearing on the setting of a limitation on the aggregate of tradable emission allowances allocated—the cap in a cap-and-trade market. A useful device is to envision the sequence of these issues and decisions as occurring along an environmental policy decision tree and to locate the branch where this book begins.

The First Policy Decision

The rooted trunk of the decision tree represents the recognition of an environmental problem. Has some failure of the market system or government activity or some information gap given rise to a negative externality affecting air quality that merits attention? That is, are there harms to human health, especially to people suffering from heart disease, asthma, or emphysema, damages to trees and crops, and impairment of materials caused by the emission of substances into the atmosphere whose social costs are not reflected in the accounting sheets of private transactions or in the budgets of government? If so, the prices of commodities or stated costs of government activities do not accurately measure what society must give up to have these goods and services. Society suffers both damages and an inefficient allocation of resources because there is too much of the activity or commodity that gives rise to the harmful emissions. Put another way, there are inadequately defined property rights for disposal in the atmosphere and therefore no appropriate charge is being levied.

Private or Public Resolution?

The first branching of the decision tree represents the choice of mitigating the harms either by private negotiation, government intervention, or doing nothing at all if the costs of mitigation are too high. Private negotiation between affecting and affected parties, including defensive or averting maneuvers by those who suffer, represents movement along one branch. For the problems dealt with in this volume, ranging from urban smog through acid rain to global warming, it puts too much of a strain on the imagination to conceive of a site big enough, time interval long enough, and transaction negotiations simple enough that would enable all concerned parties to get together in one forum or another to resolve the matter privately. Private defensive actions by individuals to counteract air pollution would appear to fall far short of an optimal solution.

Degree of Public Intervention

Proceeding, then, along the government intervention branch, which in effect assigns air rights to the public, brings us to the next fork where the question of the appropriate extent or efficient degree of such intervention is to be answered. In principle, a full benefit-cost analysis could be very helpful at this point in providing a means of finding where the balance of the reduction in harms and increase in control costs occur. In practice, the methodology is not yet adequate to the task for these complex air quality problems nor can the estimates currently available secure agreement among contending parties (Portney, 1995). A striking lesson is available in the legislative mandate to reduce SO_2 emissions as found in Title IV of the Clean Air Act Amendments of 1990 (CAAA).

The National Acid Precipitation Assessment Program (NAPAP) was funded in the 1980s to provide Congress with evidence on acid rain harms initially with a focus on vegetation and water quality. This information was to be used in the reconsideration of clean air legislation. The massive NAPAP research effort produced, and is still producing, much useful information. As the debate began leading to the 1990 legislation, two problems with this effort became apparent. First, an important part of the research effort was not finished in time to be of use. Second, the available findings indicated that the acid rain harms or monetized damages uncovered at that time were below what some observers expected. The benefits of reducing SO_2 emissions, a major precursor of acid rain, were thus shrouded in uncertainty. The control costs, on the other hand, were perceived to be rising, particularly those of traditional regulation that required flue gas desulfurization (scrubbers).

Congress appears to have cut the SO_2 Gordian knot in the 1990 Act by reducing historical aggregate emissions in successive stages by about one-half, and by specifying a national emissions trading mechanism that hopefully could reduce the control costs of achieving this target. One has to be politically tone-deaf to fault these judgments on the grounds that a thorough benefit-cost analysis was not on hand. Equipped as we are with hindsight, the legislative decision to set this target looks to be not only defensible but also prescient. In his study, Dallas Burtraw (Chapter 7) reports that new research on the health impacts of acid rain aerosols reveals more serious damages than previously estimated. Both Burtraw and A. Denny Ellerman (Chapter 8) provide interesting new data on the cost savings achieved by the SO_2 allowance-trading program.

The voices that once argued that the extent of the 1990 reduction of SO_2 emissions was too steep, with costs exceeding benefits, have been muted, and voices are now heard that further reductions may be desirable. Similarly, the early criticisms of the mandate to establish a SO_2 allowance cap-and-trade market, if not muted, have been sounded less frequently, replaced by reports of market successes. Studies in this volume cast much light on the events underlying these changing views and perceptions and can contribute to our understanding of like developments that may occur in the implementation of emissions trading for other pollutants.

This is not to deny the usefulness of the benefit-cost approach in framing regulatory questions and obtaining partial answers of value in policy making. William Nordhaus in his work on global warming, summarized in Chapter 3, provides a leading example of the value of modeling benefits and costs. In the case of global warming, he finds that while some cuts in greenhouse gas emissions are justified, the extent and timing of those proposed in the Kyoto Protocol will result in marginal control costs exceeding marginal benefits, as estimated in his model.

In the case of establishing regional aggregate caps on SO_2 and NO_x emissions, precursors of urban smog in Los Angeles, James Lents (Chapter 10) reports on the political judgments made by the local authority, under permissive state legislation, that cut allowable emissions by well over half in a series of year-by-year reductions. Political establishment of reduction targets, or setting the optimum amount of pollution reduction based upon a benefit-cost analysis implies a willingness to accept a certain amount of air pollution and an abandonment of zero-air pollution or zero-risk goals. Issuance of a quantity of tradable emission allowances brings out this point dramatically in comparison with traditional regulation. The quantity of allowances issued makes it clear to all that some pollution will occur. Traditional regulations, for example, a requirement that the best available control technology be used, tend to obscure the reality that some pollution also will occur in this instance. Robert Stavins (Chapter 2) discusses the ethical basis of this difference between the two types of regulation.

Centralized versus Decentralized Control?

Assuming agreement on government intervention and on the degree of reductions of pollutant emissions or concentrations does not imply agreement about the regulatory measure best able to attain these limitations. Should it be centralized direction that specifies the exact technology for control of emission rates, or establishes performance standards for these rates that are, in fact, based on specific technologies? Or should it be decentralized incentive-based management that relies on pollutant taxes or the autonomy and anonymity of tradable emission rights? Or some combination? Here in our branching process, we have come closer to the topics of this book.

While economists and market advocates had long urged the use of decentralized incentive regulation, their advice was largely unheeded in environmental legislation prior to 1990. Centralized rate-based direction that specified devices such as sulfur scrubbers on smokestacks and catalytic converters on cars dominated the regulatory roost. The reasons for this well-known domination were many and undoubtedly complex. Much environmental legislation was passed in response to public alarm over pressing environmental problems and therefore was designed to show that the alarm was being answered with centralized control that appeared to effectively eliminate the problem once and for all. This was largely true of many features of the 1970 Clean Air Act. The regulating community could argue they needed the centralized tools to make sure the job was done—after all, weren't market failures the cause in many instances? As for the regulated community, one can be suspicious that many emitters, once regulated, discovered they could live with the details of centralized regulation because it would earn them economic rents unavailable to enterprises trying to make a start. The public interest community, in large part, appeared to harbor a distrust of impersonal market forces and a suspicion that effective monitoring and enforcement of trading rules would be difficult if not impossible to implement. Besides, zero pollution still was a goal of some segments of the green community.

There also seemed to be technical or physical reasons for preferring centralized control for some pollutants. For example, urban ozone is a local and seasonally transitory pollutant that has many sources of precursor emissions. In addition, one precursor, the hydrocarbons, contains toxic elements like benzene. Can market incentives provide protection of the public's health in these instances?

In sum, there would appear to be formidable interests in support of traditional regulation. However, the winds of change are blowing through the branches. Robert Stavins (Chapter 2) provides a perspective on the reasons for a growing interest in decentralized instruments. Perhaps foremost among them was the stubborn resistance of certain atmospheric pollutants to command-and-control measures that regulate the rate but not the volume of pollution. Added to this problem was the related increase in the (marginal) costs of further required reductions. For many of the pollutants considered in this volume, control costs vary, sometimes dramatically, among emitters. Consequently, centralized direction requiring the same measure or rule across all sources sacrifices the gains to be obtained from having those who could reduce cheaply do more of the emission reduction task.

Recently, serious efforts have been made to bring low-level ozone and its precursors under the sway of incentive-based regulation. One explanation is the accumulation of knowledge about the pollutant and the spatial transport of its precursors. Another explanation is the increase in our understanding of how emissions trading can be combined with traditional control measures. Mary Gade and Roger Kanerva (Chapter 5) bring us up to date on the advanced modeling and design progress in this area as achieved by the Ozone Transport Assessment Group.

That emissions trading can result in significant savings goes a long way in explaining the heightened interest in this incentive regulation. Both static and dynamic cost-effectiveness of control can be realized. In the former case, it can be shown by a demonstration, which is an achievement of economics (Montgomery, 1972), that allowing emitters to make current control decisions on the basis of decentralized taxes or tradable emission prices can lead to a cost-effective allocation of reductions across emitters—no other allocation can do the job more cheaply. This would not mean equal reductions, but reductions in which marginal control costs were equated to tax rates or tradable emission right prices by cost minimizing emitters, some reducing more, others reducing less. In the latter case of dynamic cost-effectiveness, meaning an efficient intertemporal allocation of control efforts, it can be shown that emitters in the decentralized case can make future decisions that lead to a least-cost time path.

These results have many and powerful implications that our contributors make use of in their discussion of trading applications. Certain conditions must prevail for these results to hold, such as competitive markets and reasonable transactions costs.

Delegating flexibility to the emitters to make relevant choices in light of their detailed knowledge of their production and control possibilities opens up another avenue for cost savings. Both tax and market incentives can lead the emitter to search for and develop control innovations that could bring down associated costs even further than those achievable by existing measures. Command-and-control regimes have been criticized because they can act to stifle this innovative incentive. Should an emitter be creative in these circumstances and thus risk having lower emission rates imposed? The hypothesis that traditional regulation and innovation do not go hand-in-hand is certainly not refuted by some of the history of SO_2 command and control from 1970 through 1990. Initially, higher smokestacks were required of coal-burning utilities; then later, costly scrubber technology was imposed. The first reduced interest in other more effective measures and succeeded mainly in spreading the precursors of acid rain over a wider region. The second slowed the introduction of low-sulfur coal.

Another telling criticism of relying solely on centralized control is that it leads to undue confrontation between regulated and regulating communities that can result in behavior on both sides that detracts from the goal of achieving a cleaner environment cost-effectively. The regulated community may well feel that it knows best the details of operations bearing on emissions and that the other side would need to duplicate the entire emitter's staff to carry out detailed supervision. The regulating community may well feel that the other side is derailing the regulatory process to avoid the detailed supervision that would appear necessary to assure compliance. If confrontation does not develop under traditional regulation, then suspicions grow among observers that something shady is going on.

These criticisms of traditional regulation are often heard and frequently appealed to in discussions of regulatory policy, but they should not be pushed too far. Some designs of trading schemes require the emitter to earn tradable credits by reducing emissions below the rate required under continuing command-and-control measures. The idea is to prevent excess local pollution. That is, we have a combination of the two regulatory measures at work in a complementary fashion. In the most comprehensive market design, the SO_2 cap-and-trade allowance market, state-by-state standards for emission rate control remain in effect as a floor to local performance. Another recent and important example is found in the new U.S. EPA rules on NO_x emission reductions. Here, emissions trading is a promising option for control of stationary sources of pollution, but traditional regulation will continue as a major tool for control of emissions from mobile and area sources (U.S. EPA, 1998).

In fact, as environmental policy has evolved in the United States, all levels of government including special districts have been active in pollution control and are unlikely to willingly abdicate their roles. The issue then emerges: Will there be conflicts between the continuing layers of command and control and the incentive-based efforts impairing the effectiveness of both, or will there be a workable combination enhancing the effectiveness of each? Will the varying levels of regulating authority be able to coordinate their efforts to manage incentive-based instruments? These issues, being far from resolved, are important topics considered in this volume. They highlight the fact that part of the business before us is the question: Can increasing the role of decentralized control mesh well with the remaining layers of traditional regulation?

What Form of Decentralized Control? Emissions Trading versus Pollution Taxes

There are a variety of decentralized or incentive-based measures that range from exhortation for a cleaner environment, to government purchase and thus subsidy of control equipment, to stimulation of pollution prevention agreements, and finally to emissions trading and pollution taxes. We shall concentrate on the last two measures at the next fork in the branches of our decision tree. In principle, they would appear to lead to the same effects in reducing pollution and therefore would appear to be a matter of indifference as to choice. In practice, they differ significantly.

Both emissions taxes and trading, when introduced, put a price on pollution, thus internalizing the social costs of the offending substance and altering the choices of control options at the emitter's level. If emission allowance price and tax rate are equal, having been so set by the market or by environmental policy, then cost-minimizing emitters can be expected to equate marginal control costs to that price or rate. The general observer would note, in a world of certainty and full information, that emitters were making their individual reductions in the same way under either tax or trading regulation. If a tax rate were in effect, the individual emitter's least-cost decisions would lead to a minimum of taxes paid plus control expenditures on remaining emissions. If emissions trading were in effect, the sum of the prices of marketable allowances turned over to the government to cover emissions plus remaining control expenditures would be at the same minimum.

Therefore, it doesn't really matter whether we choose tax or trading regulation, we obtain the benefits of decentralized incentive-based implementation in either case. Unfortunately, it is not that simple; there are political, economic, and even moral reasons given for preferring one regulatory instrument over the other.

The above arguments about equivalence assumed a world of perfect certainty of knowledge about the relationships between the monetary values of harms and control measures and the extent of pollution reduction. If uncertainty prevails about these relationships, the government may justifiably worry about the importance of errors in choosing one instrument or the other. Potential errors depend upon the government's knowledge of how control costs and harms vary with emissions. If uncertain costs vary little with emissions, but harms vary significantly, the choice of emissions trading will lead to less serious error. That is, issuance of a limited number of allowances provides more control over harms than does the setting of a tax rate. Emitters equating the tax rate with marginal control costs could be far off the optimum extent of reduction due to the incorrect rate set under uncertainty. Continually changing the rate to reach the correct one could be unsettling, and unpopular. In contrast, the amount of tradable allowances issued could be more closely aligned with the reduction in harms desired. Control costs were not well estimated in the case of SO_2 emissions as Burtraw and Ellerman explain in detail. In the other case, where the relationship of harms to the degree of regulation is uncertain but control costs are better known and rising sharply, the reverse situation prevails (Weitzman, 1974).

There are other departures or slippages from the ideal that could lead to problems with taxes or emissions trading. The presence of large costs in searching for and negotiating with trading partners can reduce the savings achievable under tradable property right schemes. Other slippages include the presence of monopoly power, difficulties of acquisition of market knowledge, problems of managing the portfolio of tradable allowances, and uncertainties about the bearing of other forms of regulation upon emissions trading. These potential difficulties have led some observers to recommend the use of pollution taxes (Tolley and Edwards, 1997). Pollution taxes, however, have economic problems of their own including the unfavorable impact of resetting rates when circumstances change. Choosing the tax instrument raises questions of monitoring and collection expenses. Based on experience to date, emissions trading has become the preferred alternative. It is worth noting some of the reasons for this preference.

Economic factors appear to have been less important in the final determination of which decentralized instrument to use than their relative political acceptability. The economic aspects are less visible and more difficult to document; the political aspects are sitting partridges on a leafless twig. Taxes on pollutants have not been favored, to say the least, by emitters who have argued that imposing a tax rate makes them pay twice; once for the rate on emissions and once for the control of reducing emissions. The countervailing argument is that the tax paid on emissions measures the harms imposed by the remaining emissions. The method of allocating tradable emission rights to emitters can finesse these arguments.

The attraction to emitters of emissions trading over pollution taxes is due in large part, as our contributors explain, to the free allocation of tradable credits to individual sources. This free allocation has characterized applications of all emissions trading efforts to date. If these tradable entitlements were to be auctioned off rather than freely allocated, so that emitters would have to pay for their initial allocation, the difference between the financial impact of taxes and trading would diminish, as would the political support for emissions trading. There is a social cost to this free allocation, however, because it denies revenue to the government which could be used to reduce other tax rates that distort prices and lessen welfare. This may not be too high a price to pay for a cost-effective policy instrument.

We are now ready to move along the final branch of environmental policy decisions where emissions trading regulation is to be designed and implemented. New issues and choices concerning different trading schemes require clarification, new concepts and definitions of market activities and commodities require attention, and new data and other evidence on market performance require appraisal. As our authors assume some familiarity with these subjects in order to move quickly to their tasks, it is appropriate to provide a brief guide and summary to these key ideas and terminologies in this introduction. We invite the reader desiring such background to join a growing audience and us in this educational undertaking.

THE EMISSIONS TRADING LITTLE RED SCHOOLHOUSE

In an advanced capitalistic society, designing and establishing a new environmental market would seem a routine project. There are examples of functioning markets all around and our extended experience with them would seem sufficient for us to comport ourselves as buyers or sellers as if it were now part of our genetic makeup. It is also clear what we want of green markets. We want efficient mechanisms that grind out equilibrium prices that reveal marginal control costs without bias at just the right level to equate the marginal benefits of reducing pollutant harms. Or, if not that, then we want prices that reveal marginal control costs that minimize the use of society's resources for control of pollution at the targeted level. Those outcomes imply a thick market with sufficient transactions to assure that all possible savings have been realized by emitter control decisions. A few simple rules for such markets would seem to suffice to have trading activity off and running quickly.

It is not that easy. As we mentioned, not everyone is enthused about using the market mechanism for environmental policy. Resistors have included, besides those one might expect, segments of the business community, in particular segments of the electric utility industry (Rosenberg, 1997). Old vested interests are not always easily overcome. The time required to get these markets underway, the extensive efforts needed to design market features, and the complexities of securing agreements from all affected and concerned parties suggest that something even more complex is going on. In creating new-fashioned environmental markets, every design feature is a candidate for critical examination and every batch of transactions the subject of intensive scrutiny. The public and private interests are more intertwined than in most other markets and therefore green markets are likely to be more intricate in their evolution than other types.

It is no wonder, then, that a number of different market patterns or models have emerged in the implementation stage with important variations ranging from coverage of sources to the caps in the cap-and-trade markets. Some differences reflect characteristics of the pollutant, but many others reflect contrasting views about efficient or acceptable market features. As we have said in another context, there are few deductive truths in the design and implementation of environmental markets. Our contributors clarify and appraise particular model designs based on accumulating evidence. Their studies can contribute to a better understanding of the workings of these varied regulatory tools. To the extent that the results indicate that one tool can serve our environmental ends better than others, a wider understanding and acceptance of market approaches is secured. That is one of the important assignments for our contributors.

The assignment that remains for us in this part of the introduction is to describe a simple but unifying framework within which emissions trading key terms can be defined and particular market designs compared. That is, we present the first course in the political economy of trading systems preparatory to tackling the advanced material.

At one end of the framework, or spectrum, we place the cap-based or closed-system markets and at the other end, the rate-based or open system. Several features stand out for us in making this basic distinction. The former, the most comprehensive in design, is based on the fundamental rule that the emitters are required to participate and deliver to the government a tradable credit or allowance for each unit of emission during the relevant time period. The government secures control, if all goes well, of the aggregate volume of the emissions from covered sources by determining the aggregate cap or emissions budget and by making allocations to individual sources during the relevant time period. In the latter design, the open system, emitters may elect to participate, and if they do, they may earn a tradable credit by reducing emissions below the required rate set by traditional regulation. The fundamental rule is that any emissions above the regulated rate require a tradable credit be turned over to the government, such emissions creating a demand for tradable credits. The government maintains control of the rate but not the aggregate volume of emissions because the hours of operation that the rate is in effect are not controlled. The hours of operation will depend upon firm, industry, or economywide factors.

Even without intimate knowledge of trading, the reader will sense other features that distinguish the two types. The quantities of credits traded in the open system can be uncertain and the prices hard to predict. The closed system enables the government to take a more hands-off position with respect to the quality of the tradable credit maintaining only a benign monitoring and enforcement position. The open or rate-based system raises a long series of questions about the quality of the tradable credit. Was the reduction from the legal rate generated properly? Is the reduction measurable? Can the procedure once specified be enforced? To assure the reductions do in fact clear the air, the government is drawn into a detailed hands-on involvement with the transactions. We shall see from the Belanger study that this involvement can be burdensome both to the regulated and regulating communities.

Cap-and-Trade or Closed-System Emissions Trading

The major cap-based variant in use has the government assign (or auction) dated tradable allowances to emitting sources within an aggregate limit of or cap on emissions. Emission reductions can be measured from a historical benchmark or projected future period. Sources then may control their individual emissions or emit and turn over appropriately dated allowances from their portfolio or some cost-effective combination. The portfolio of allowances can be managed by trading or by banking if permitted. A less well-known and less used variant is the cap-and-credit market that is based on a performance standard set by dividing the aggregate emissions budget or cap by total heat input or capital stock utilization; those sources with individual ratios below the overall standard get marketable credits, those above must acquire them. The interesting property of this market is that the performance standard can be reset as environmental circumstances change. This resetting aspect may be one reason this variant has not been tried often as it introduces an additional element of uncertainty into emission trading plans.

We have already suggested that cap-and-trade markets have been the most widely praised and strongly advocated incentive approach to pollution reduction. They also have been among the most intently discussed and, on occasion, hotly debated instruments to be implemented. The reader will find reasons for both views as well as an introduction to the details of their design by working through their features as depicted in Table 1.1. The table describes four of the most important current applications in effect or scheduled for implementation in the near future.

Table 1.1 provides at a glance definitions of and a guide to major market characteristics. However, the entries are very simplified and omit important details and modifications. All simplifications can be dangerous if these limitations are overlooked. The general comments that follow the table are intended to minimize the dangers by adding information to the entries of the table.

The Four Markets

Of the four markets described in Table 1.1, the SO_2 allowance plan is perhaps best known, most closely watched, and most fully in operation of all. It is the only market with a nationally

Table 1.1 Features of Cap-and-Trade Closed Systems Emissions Trading

Features	Four Selected Markets				
	Title IV CAAA '90	No_x Rule U.S. EPA (OTC)	RECLAIM SCAQMD		ERMS IEPA
1. Pollutant	SO_2	NO_x	NO_x	SO_2	VOC
2. Market coverage					
2.1 Geographical	Nation	23 states + D.C. (States to determine) OTC = 12 states + D.C.	L.A. region		Chicago region
2.2 Number and kind of covered enterprises	Phase I = 110 Phase II = All large electric utilities	Larger stationary sources in various industries	313 Larger stationary sources in various industries	65	283 Larger stationary sources in various industries
2.3 Market coverage of total emissions (%)	69	33	33	75	26
3. Who may trade?	Any registered party	States to determine (OTC: any registered party)	Any registered party		Any registered party
4. Characteristics of tradable credit					
4.1 Name and denomination	Allowance (1 ton of SO_2)	Allowance (1 ton of NO_x)	RECLAIM trading credit (lbs. NO_x) (lbs. SO_2)		Allotment trading unit (200 lbs. VOC)
4.2 When usable?	Year issued and thereafter	Year and season issued and thereafter	Year issued and next annual cycle		Year and season issued and one year thereafter
4.3 Private property?	De facto rights, subject to policy change	De facto rights, subject to policy change	De facto rights, subject to policy change		De facto rights, subject to policy change
5. Cap arithmetic					
5.1 Market start date	1995	2003 (OTC = 1998)	1994	1994	2000
5.2 Baseline date for aggregate cap	1980	2007 projection (OTC = 1990)	2003 projection		Two year average (1994–1996)
5.3 Aggregate cap reduction (%)	50 by 2007	69 Electric utilities, others 12 to 15. (OTC = 75 by 2003)	75 by 2003 (in equal annual steps)	63 by 2003	12 by 2000 (further cuts possible)

(continued)

Table 1.1 *(Continued)*

Features	Four Selected Markets Title IV CAAA '90	No_x Rule U.S. EPA (OTC)	RECLAIM SCAQMD		ERMS IEPA
(Pollutant)	SO_2	NO_x	NO_x	SO_2	VOC
5.4 Individual baseline allocation	Average emissions 1985–1987	To be determined by states	Highest emissions from 1989 to 1992		Average of two years 1994–1996
5.5 Allocations free or auctioned?	Free (2.8% withhheld for annual auction)	To be determined by states	Free	Free	Free (1% withheld for sale)
6. Price and transactions data	Price data from brokers and public auction. EPA allowance tracking	To be determined by states. EPA allowance tracking	Price and transactions data recorded by RECLAIM		Price and transactions data recorded by Illinois EPA
7. Emissions monitoring and program enforcement	EPA emissions monitoring. Fine of $2000 per ton for overages plus make-up	EPA emissions monitoring. Penalties to be determined by states	Emissions monitoring by RECLAIM. Exceedances subtracted from next allocation		Emissions monitoring by Illinois EPA. Exceedances plus penalty subtracted from next allocation
8. Continuing issues and future choices					
8.1 The "hot spot" problem	No locational constraint	Dependent on state decisions	Trading prohibited inland to coastal zone		No locational constraint
8.2 Intersource trading? (stationary, mobil, and area)	Not applicable	Possible where feasible	Possible where feasible		Possible where feasible
8.3 Integrated assessment modeling?	SO_2 modeling	NO_x transport modeling	Regional NO_x and SO_2 modeling		Regional NO_x and VOC modeling

Notes: Column headings: Title IV of the Clean Air Act Amendments of 1990 provides for SO_2 emissions trading. NO_x Rule refers to the U.S. EPA NO_x Final Rule of 1998 that contains provisions for an optional emissions trading plan that states can adopt for intra- and interstate use. OTC = Ozone Transport Commission. RECLAIM is the Regional Clean Air Incentive Market administered by the South Coast Air Quality Management District (SCAQMD) for the extreme nonattainment Los Angeles region. ERMS is the Emissions Reduction Market System administered by the Illinois EPA for the severe nonattainment Chicago region.

1. Pollutant: SO_2 = sulfur dioxide. NO_x = nitrogen oxides, especially nitrogen dioxide. VOC = volatile organic compounds. Market approaches apply to anthropogenic sources primarily caused by fossil fuel combustion and use.

Table 1.1 *(Continued)*

2.1 Market coverage, geographical. Nation = Continental U.S.A. The NO_x Final Rule applies to 23 states east of the Mississippi River. OTC coverage includes the twelve northeastern states plus D.C. The L.A. region includes a coastal and inland zone between which trades can flow only from the former to the latter. The Chicago region comprises the six county area plus two townships.

2.2 Number and kind of covered or included enterprises. Enterprises are legal entities to receive and trade credit allocations. Almost all enterprises operate stationary or fixed-point emission sources with one or more emitting or generating units. In the case of Title IV, most of these are electric utilities. In the case of NO_x trading, most of these are larger boilers, turbines, and combined cycle heat-driven systems in various industries. In the case of ERMS VOC trading, emission sources range over a wider variety of industries including chemical, plating, and cleaning establishments emitting over 10 tons of VOC annually.

2.3 Percentages listed are approximate shares of total anthropogenic emissions covered by market rules.

5.2 These are baseline dates for aggregate cap determination. Title IV occurs in two phases with separate caps. Title IV and ERMS programs refer to a historical period. The NO_x Final Rule refers to a projected level of emissions that would occur without a market plan. Reductions are calculated from that level. RECLAIM estimates what reductions would be required to achieve local area attainment of NAAQS by 2003 and uses that level as a cap.

5.3 Allocations to individual enterprises under the aggregate cap are made by a complex process. In the case of Title IV, the allocation is to the electricity generating unit (boiler, turbine, or combined cycle system) of which an enterprise may own more than one. These allocations, which are a series of allowances each with its own date, were based on heat inputs in the interval 1985 to 1987 and adjusted for various reasons by Congress (to encourage scrubbers, reward past control decisions, etc.). The individual allocations under the NO_x Final Rule are to be determined by state implementation plans. The OTC percentage reductions refer to stationary sources.

The RECLAIM allocations were made by the source choosing the highest emission levels from the interval 1989 through 1992, then reduced in equal annual percentage steps to reach the 2003 attainment goal. The ERMS allocation is based on an average of the highest emissions in the years 1994 to 1996; however, in justified cases a substitution of years from 1990 to 1997 could be made. Reductions were then allocated to fit the aggregate cap. A further complication in this case is that the aggregate cap may be altered if the incoming concentrations of NO_x and VOC from other areas are changed by policies such as the NO_x Final Rule. These incoming concentrations, or boundary conditions, were found to exert a significant influence on local ozone concentrations.

7. Emissions monitoring and program enforcement: Continuous emissions electronic monitoring equipment is required of larger generating or emission units wherever possible with materials balance or input data utilized in other cases. Reliable monitoring assures the value of a tradable credit and has worked satisfactorily in the case of Title IV, as Burtraw and Ellerman explain. The RECLAIM program has required discussions between regulated

(continued)

Table 1.1 *(Continued)*

	and regulating community as new monitoring equipment has been installed and put in working order, as Lents reports.
8.1	The hot spot problem arises when emissions from a source at a specific location cause more or less harms at a receptor site than emissions from other locations.
8.2	Intersource trading: An important fact of life for NO_x and VOC emissions trading is that significant emissions occur from mobile and area sources not covered in the market. This motivates attempts to devise ways to give tradable credits to stationary sources that can bring about reductions in vehicle, off-road mobile, or consumer product emissions. Few of these attempts are sufficiently well along to appraise their success. Obvious difficulties are being encountered in monitoring the extent and permanence of the reductions.
8.3	Integrated assessment modeling is discussed in the text.

legislated mandate. The U.S. EPA Final Rule for NO_x reduction issued in 1998 provides for an optional but recommended use of cap-based markets as a choice by 23 affected states. We have folded the Ozone Transport Commission (OTC) cap-and-trade market into this scheme because it is very similar in design, covers the same pollutant, affects a 13 state subset of the affected states of the Final Rule, and could be incorporated into the Final Rule program at a later date. The Final Rule has been challenged in court and its implementation remains to be determined. RECLAIM programs administered by SCAQMD of the Los Angeles region for local NO_x and SO_2 control have the distinction of being first off the mark in initiation. The ERMS program was developed by the Illinois EPA, and will be, if successful, the first cap-and-trade market to control VOC stationary source emissions.

The Pollutant

We have adopted the notational convenience of SO_2 for all the sulfur oxides, NO_x for nitrogen oxides instead of the often-used NO_2, and VOC for volatile organic compounds instead of reactive organic gases (ROG), or volatile organic materials (VOM). In this choice, the frequency of use has been put above creativity. All of these molecules play complex roles in the larger ecosystem acting in some instances as nutrients and in other cases as harmful agents. NO_x also can act as a cleansing agent for urban ozone at one concentration and a precursor at another. Nothing in school should be too easy. From emission, primarily as by-products of the combustion and use of fossil fuels, to final deposition as a harmful agent, these pollutants undergo complex physical, chemical, and meteorological processes.

Air quality models capturing some of these processes preceded initiation of each of these markets. Such modeling efforts, under continuing development, are an essential scientific background to effective control in general, and to effective market design. Market designs have also drawn on clinical and epidemiological studies of the impacts on human health as an approach to the estimation of the benefits of pollution reduction. The results of this scientific activity affect market coverage, caps, and many other features. Extensive accounts of the varying model specifications and results are available or cited elsewhere (U.S. EPA, 1998). Brief reference is made from point to point on significant aspects that bear directly on emissions trading schemes.

Market Coverage

Pollutants have no respect for political boundaries but markets do. For the Title IV market, the coverage is the continental United States, thus including some areas where SO_2 deposition is light and emissions few and excluding some areas, for example, in Canada, where deposition is more serious. The extent of reductions in emissions under the cap and the gains in efficiency through trading are thought to more than offset these spatial incongruities, as we have noted. The 23-state coverage of the EPA NO_x market was guided by information on atmospheric NO_x regional transport based on air quality models built for these purposes. VOC emissions have a more local orientation in large urban areas. Chapter 5 by Mary Gade and Roger Kanerva is informative on the results of modeling these pollutant movements. Special urban airshed models were developed to assist policy decisions about coverage in the RECLAIM and ERMS markets. In the case of RECLAIM, a spatial distinction was made between NO_x and SO_2 emissions sources located along the coast and sources inland. In view of modeling results of the prevailing winds, trading was permitted from coastal sources to inland but not the other way around.

The number and kinds of covered emission sources required to participate in a cap-and-trade market have always presented the unwary observer with seemingly different counts and definitions. Typically only larger emitters with fixed-point or stationary emitting units are included in the core coverage. Biogenic emissions can be important but are beyond the direct incentive approach, although some thought has been given to awarding credits for reductions brought about in this area. Reductions from mobile and area sources by core participants is another avenue for earning credits that has been utilized to a limited extent.

For each market, we have chosen to enter the number of enterprises or legal entities that manage portfolios as of the current date (recalling that mergers and acquisitions occur from time to time). This is typically much smaller than the number of plants and emissions generating units. For example, an investor owned utility might have more than one plant and within each plant there might be more than one electricity-generating unit (boiler or turbine). SO_2 allowances were assigned in Phase I to 263 such larger boilers and turbines. Later almost 200 additional generating units were brought voluntarily under the cap. All these units were owned by 110 separately managed utilities covered by the Phase I area (generally east of the Mississippi River). Similar distinctions are necessary for NO_x and VOC emitting source arithmetic. The entity responsible for making control, trading, and compliance decisions is the legal enterprise, and that is the number we have entered in the table.

With respect to kinds of emission generating enterprises, we distinguish between stationary, mobile, and area sources. Stationary or fixed-location sources tend to be the larger emitters per unit, fewer in total number than the other sources, and the simplest to incorporate into the market. The included stationary sources do not always emit the most significant share of the total from all sources, an area of contention as one might expect. Row 2.3 in the table gives our estimates of the covered stationary source share of total emissions. Mobile and area sources are typically very numerous and small thus posing problems for allocation of tradable credits. Extensions of the market whereby stationary sources can gain tradable credits for devising ways to reduce mobile and area emissions, for example, the cash for clunkers idea, have been proposed and are undergoing testing.

Who May Trade?

Determining who is allowed to participate in the market is not as simple a matter as it seems. In addition to covered sources that receive allocations, there has been a debate about allowing brokers, speculators, and others to join in the trading. The promotion of liquidity and an efficient market would point toward allowing everybody to participate, providing competitive rules are observed. Some regulators expressed concern about the impact of speculative activity on prices and allowance availability in thin markets. The SO_x and RECLAIM markets have been generally opened to brokers, speculators, and others, with the only requirement being that they must register. The same is true of the OTC market, and likely will be true of the NO_x Final Rule dependent upon state determinations. The ERMS market design initially restricted the qualifications of traders, setting forth detailed requirements for the designation and training of account officers acting for the affected source. These restrictions on participation have been relaxed in response to criticisms that they may make the market thin.

Characteristics of the Commodity—the Tradable Right

That the government should issue a tradable permit to pollute creates ethical questions for some, an issue that surfaces from time to time. It provokes the answer that this incentive system gives the government control over the volume of pollution, that the cap is typically a significant reduction in baseline emissions, and that the reduction is achieved at a reduced cost thus freeing society's resources for other desirable purposes. Another problem sometimes mentioned is that the enabling legislation, such as the CAAA'90, or administrative rule defines tradable credits not to be private property. The idea is to allow for government policy changes affecting the quantity, and thus the value, of tradable allowances as new knowledge of harms or costs surfaces. Thus the liability of the government for actions impairing the value of the right would be limited. Despite both these concerns, allowances or credits currently being traded by emitters, brokers, speculators, environmentalists, and school children are increasing in volume as if they were free of all sin and were in fact private property.

The bankability of the tradable right is an important matter that affects the intertemporal performance of the market. For efficient management of a portfolio of allowances, each of which can be used on or after its issuance date, the cost-minimizing emitter would aim to equate future control expenditures to expected future prices of allowances. Banking enables traders to make efficient intertemporal control decisions. When tradable credits of different first-use dates are issued, as is the case for the SO_2 and RECLAIM markets, various kinds of swaps and exchanges can also be executed to achieve this intertemporal requirement. In the case of the SO_2 market, the allowances are bankable permanently after the first-use date. The large bank of allowances being built up implies that emissions will be over the cap at a future date when the bank is drawn down. In the case of the RECLAIM markets, there is the problem of a transient, hot weather pollutant like ozone that could be aggravated by bursts or spikes of use of banked RECLAIM Trading Credits. Thus, banking per se is not allowed, but by introducing overlapping 12-month cycles and allowing the use of credits allocated in one cycle to be used in another, some intertemporal flexibility is introduced and a type of limited banking is granted. In the case of the ERMS program, where the same problem emerges, banking is permitted for one year after the first use date. The NO_x Final Rule suggests that if the bank builds beyond a certain point, then trades from the bank during the ozone season may take place only at a discount.

Cap Arithmetic

Market designers know that whatever contention has taken place over features up to this point is likely to be overshadowed by the disagreements between regulated and regulating communities that occur over the aggregate cap, and individual allocations under that cap. Since the aggregate cap is a reduction, the first sensitive point is reduction from what level or baseline? We have already discussed the issue of setting the cap so that harms are reduced to an acceptable level. However, what is acceptable to one group may not be to another. We have entered in Table 1.1 the present cap reductions as a percent from the baseline. The baseline from which the reduction is calculated raises different concerns. The baseline that has been most often chosen is some historical period on the grounds that the data are (somewhat) accurately in the record. Even if this were true, the matter of which historical period is to be chosen may be debated given business cycles in the economy and changes over time in industry and firm activity. There are winners and losers in this determination.

The NO_x Final Rule attempts an interesting variation in reducing the aggregate cap by making emission projections through the year 2007 assuming no new controls and then calculating the forward-looking cap reduction from that estimated amount. RECLAIM prepared scenarios through 2003 under which attainment of air quality standards (NAAQS) in the LA region would be achieved by tightened traditional regulation, and used that goal for the aggregate cap, which takes the place of the no longer needed, tightened traditional regulation. These forward-looking cap calculations overcome the objection that few historical periods will take all factors into account or satisfy all emitters. They are open to the limitation that unforeseen events may cause the cap to depart from welfare objectives.

Given the aggregate cap, individual source allocations can be based on various considerations. The simplest would be an auction by the government requiring emitters to purchase credits. The auction has attractive aspects in that clear price signals would be obtained and, in addition, the auction revenues could be used to reduce existing taxes that distort in unfavorable ways, like the income tax. However, the regulated community has an easily understood and strong preference for free allocation of credits and that view has held sway in all markets to date. The minor exceptions have been small set-aside percentages for sale to new enterprises, or for an annual auction in the case of the

SO_2 program. Even in the latter case, the net proceeds from the auction are returned to utilities in proportion to the set-aside allowances. Free allocation may well have been a crucial gambit to secure acceptance of a market approach.

Absent an auction, the problem is to establish a reference point for calculating the individual unit's allocation of tradable credits. The reader is invited to try his or her hand at devising an efficient and fair benchmark for this allocation. A historical period suggests itself. However, some emitters may feel they have made efforts to be clean in the past only to be punished by smaller allocations in the future. Other emitters may cite the business cycle, or unusual firm or industry or economywide conditions that necessitate special adjustments. For Phase I of the SO_2 program, the allocation equation for generating units called for multiplying an emissions rate of 2.5 pounds of SO_2 per million Btu's of heat input times the 1985–1987 average heat input. Reductions were then made from this benchmark. Considerable lobbying in congress resulted in a number of modifications of this equation (Joskow and Schmalensee, 1996).

The RECLAIM and ERMS programs have tried to ease this argument in different ways. ERMS allows enterprises to choose the average of the highest two years among the years 1994 to 1996. If justified other years between 1990 and 1997 may be substituted. RECLAIM allows enterprises the choice of the highest year in the interval 1989 to 1992. This latter policy has resulted in a substantial over-the-cap allocation of NO_x credits in the early period of the market. It is instructive to note that the plans for VOC control under a RECLAIM cap-and-trade market ran into major implementation difficulties in part because of disagreement over historical caps and individual allocations, and had to be indefinitely postponed and replaced by continuing command-and-control regulation.

Price and Transactions Data

Emissions trading makes economic sense only if marginal control costs vary among emitters. Those emitters with low costs can sell credits to those with high, both enjoying savings compared with the no-trade solution. If such costs were all the same, then a smart allocation would provide each emitter with enough credits to meet its individual reduction without trading. There is more than scattered evidence that control costs do vary in each of the markets creating the potential for substantial savings in costs from trading. For example, in the SO_2 market, high-sulfur coal scrubbers of various designs, low-sulfur coal, natural gas driven turbines, and other alternatives are available to cost-minimizing utilities. In the NO_x markets, where the pollutant is not in the fuel but arises mostly in the heat chamber, there exist opportunities to modify the temperature and thus NO_x creation, or install low NO_x burners, or introduce various catalytic reduction equipment. In the VOC market, there exist afterburner technologies, substitution among inputs, and product modification options for the consideration of cost-conscious emitters.

Whether this range of control options and technologies available to sources in each of the four markets is sufficient for achieving meaningful savings is, in our view, an empirical question. These savings are not the end of the story. Cost-saving control innovations may be stimulated by market incentives. Our contributors give us valuable insights on these significant matters and alert us to the difficult questions involved in estimating these savings.

If these markets are competitive and functioning well, the resultant prices will yield knowledge about marginal control costs, and the resultant volume of transactions will yield knowledge on the extent of savings being realized. Obtaining this knowledge, and consequently obtaining the basis for an appraisal of emissions trading, will necessitate that full and accurate data on prices and transactions become generally accessible. There are notable differences among the four markets in this regard.

As the U.S. EPA does not record price data on SO_2 allowances, the interested public must resort to the annual springtime auctions managed pro bono by the Chicago Board of Trade or to the voluntary publication of prices by private brokers. While valuable as an indicator, the once-a-year auctions do not provide enough observations for extensive statistical analysis. Burtraw and Ellerman (Chapters 7, 8) rely in large part on broker-provided price data for much of their work. Transactions information for each numbered SO_2 allowance is recorded by the U.S.

EPA Allowance Tracking System that can identify the initial allocation to a source and the final retirement by an emitting source. Intermediate transactions are not recorded. Kruger, McLean, and Chen (Chapter 6) give the reader an indispensable description of the extent and electronic processing of this information that has made accurate transactions data accessible to the public in a prompt manner.

Price and transaction data on the RECLAIM markets are available from the agency itself as it records prices when it records transactions. This information is supplemented by several brokerage houses, one of which offers an electronic bulletin board for posting bids and offers, and another publishes actual price and transactions data. The Illinois EPA plans to maintain an ownership database that will contain identification numbers for each Allotment Trading Unit and a market exchange bulletin board. What kinds of price information will become available on the NO_x markets remains to be seen when state decisions are made on the nature and extent of their participation in emissions trading.

Emissions Monitoring and Program Enforcement

Public and trader confidence in the market depends in an important way upon emissions monitoring and enforcement. The tradable credit can be degraded if monitoring is inaccurate or easy to avoid, and enforcement insufficient. The SO_2 process in these regards sets a good standard. The advanced state of continuous electronic emissions monitoring of what comes out of the smokestacks of electric utilities lends credence to the belief that the emissions record is whole and correct. Our contributors report on details of this feature that yields real-time electronic processing of consequential data at small administrative cost. The financial penalty for exceedances in this instance, $2,000 per ton, is substantially above the market prices of allowances. This deterrent together with a make-up requirement for the next period has greatly diminished concern about exceedances.

The RECLAIM program, as Lents reports, has encountered start-up problems in the installation and management of emissions recording equipment, problems that are currently being addressed through negotiations between the SCAQMD and the regulated community. The NO_x Final Rule follows the SO_2 example in proposing monitoring and enforcement provisions. The U.S. EPA has offered to participate actively in the management of the NO_x cap-and-trade markets if states choose this option. The ERMS program, after initially proposing a financial penalty, accepted the regulated community's counter proposal for a penalty "excursion compensation." For the first offense of not having sufficient tradable credits to cover emissions, the source must turn over in the next period the exceedance plus 20 percent. For the second offense, the penalty is 50 percent.

Continuing Issues and Future Choices

The four markets are efforts to control atmospheric pollution. Applications to obtain cleaner water or land have proved more difficult to develop due, in part, to the locational specificity of pollutants in these instances. Most air pollutants also have locational impacts, which means that emissions from some sources are more harmful to certain receptor areas than emissions from others. A trading scheme that took the details of location into account would require that tradable allowances have weights assigned to them depending on the emitting source and on the damage receptor. In principle this could be done; in practice this introduces much complexity and large transactions costs that could undermine the market's workability (Tietenberg, 1997). The issue becomes one of balancing the aggregate reduction in harms achieved by the cap against the fact that the remaining harms do not fall like the gentle rain evenly on all areas. Only careful quantitative studies can furnish definitive answers on the net effects, although most of the evidence to date suggests that all areas have benefited.

Congress simplified the SO_2 allowance market by making emissions independent of location; that is, emissions could be traded one-for-one no matter where they originated. This has been challenged, but the benefits of a more efficient market have so far outweighed the costs of ignoring the regional transport of this substance, as our contributors demonstrate. The fact that SO_2 emissions were to be reduced by half, and the fact that continuance of an underlying layer of traditional regulation prohibited excess local emissions have both worked to protect against excessive acid rain formation in specific areas.

New pollutant modeling results indicate that NO_x concentrations have a regional movement while VOC concentrations are more local. This information is valuable for designing the geographic coverage of a cap-and-trade market. Furthermore, the depth of reductions prescribed for NO_x, the use of seasonal discounting of trading credits, and the continuance of local restrictions, are believed to provide protection against local adverse health impacts in a cap-and-trade system. The extremely useful simplification of one-for-one trading, independent of the location of the emission, has been generally adopted in other applications such as the VOC market for Chicago. The exception is the RECLAIM two-zone program, as noted. Clearly the local adverse impact or "hot spot" problem will be one for continuing monitoring and research.

The fact that the core sources covered by the cap-and-trade markets emit only a varying fraction of the total is also a matter of concern. It means that the government must rely on traditional regulation for sources not covered. Therefore, some emissions are market controlled and some controlled by traditional regulation. Coordinating these two regulatory mechanisms to achieve cleaner air raises challenging problems. Core sources under the cap are typically larger enterprises with stationary emitting units. It seems plausible that these sources could find it cost-effective to earn credits by devising ways to reduce emissions from mobile and area sources. A number of proposals have been made to stimulate intersource tradable credit creation although the results to date have been limited by difficulties in making arrangements with generally small sources, and in assuring that reductions are quantifiable and permanent. The "open market" concept, discussed in the next section, attempts to create new avenues for tradable credit creation of this type.

Some thought has also been given to interpollutant trading, but the details of such a program have yet to be worked out in view of such complexities as estimating the damage trade-offs among pollutants and hence the weights for the different tradable credits. The idea does suggest the advantages of a more comprehensive modeling of pollutant emission, formation, and transportation that would more fully exploit common origins and interactions. Such modeling could lay the basis for a more coordinated attack on joint control of related pollutants. In the United States, we have yet to develop an integrated assessment model or system that would provide for spatial coverage and the interrelated benefits and costs of atmospheric pollution reduction of the major substances including the pollutants already mentioned plus others like carbon monoxide, ammonia, hazardous air pollutants, and fine particulate matter. We have pieces of that integrated modeling in place. Perhaps at the present stage, given our modeling state of the art, there are advantages to this piecemeal approach; the focus is sharper and the problems of market design simpler. One can envision a future date, however, when an expanded knowledge base would enable the gains of this integrated approach to outweigh the losses of added complexity.

Rate-Based (Often Called Open-System) Emissions Trading

We return to our classification of trading systems that had at one end the cap-and-trade type market. We now turn to the other end where we place rate-based schemes in which participation is voluntary. That is, traditional control regulation without trading remains an option for the emitter. This means that business must calculate whether it is worth the costs of creating, selling or buying a tradable credit, where the costs include not only estimates of marginal control expenditures and the costs of searching for and negotiating with other traders, but also the costs of securing government verification of many details of the specific transaction. This means, for the government, verifying for each proposed emissions reduction credit (ERC) that it is permanent and not due to some transitory event, that it is genuinely surplus and not otherwise required by traditional regulation, that it is quantifiable, a matter often involving complex protocols, and that it is enforceable. The concerned public must try to estimate how much pollution has been reduced and what cost savings have been realized from use of these open-system programs. Managed as they are by the varied states, the available data is not always consistent.

Table 1.2 Features of Rate-Based or Open-System Emissions Trading

	Selected Programs		
		Discrete Emissions Reductions	
Features	Emissions Reductions Credits	Connecticut Program	Open Market Trading Rule
1. Pollutants	NO_x and VOC	NO_x and VOC	NO_x and VOC
2. Market coverage			
2.1 Geographical and other restrictions	Spatial, seasonal, and directional	Spatial, seasonal, and directional	Spatial, seasonal, and directional
2.2 Emitter participation	Voluntary	Voluntary	Voluntary
2.3 Number and kind of enterprise	All sources (stationary, mobile, and area source)	All sources	All sources
3. Who may trade?	Any registered party	Any registered party	Any registered party
4. Characteristics of tradable credit	Denominated in pounds or tons	Pounds or tons	Pounds or tons
4.1 When usable? (bankable?)	Permanent life with restrictions	Discrete amount with restrictions	Discrete amount with restrictions
4.2 Private property?	De facto rights	De facto rights	De facto rights
5. Rate (open system) arithmetic	Tradable credit earned by emissions reduction below legally allowable rate. Calculation based upon netting, offsetting, or bubbling concepts.	Credit earned by discrete reduction below allowable rate	Credit earned by discrete reduction below allowable rate
6. Price and transactions data	Not systematically collected, dependent upon state programs	Collected by state	Dependent upon state programs
7. Government regulation	Detailed verification of seller credit creation, sale, and buyer use.	Detailed verification	Verification of buyer use
7.1 Emissions monitoring and enforcement	State monitoring and enforcement	State monitoring and enforcement	State determination
8. Future issues			
8.1 Intersource trading (stationary, mobile, and area)	Possible where feasible	Possible where feasible	Possible where feasible

Notes: Column headings: Emissions Reduction Credits (ERCs) are described in the text and have a permanent life for the face value of emissions when approved by the government. Discrete Emissions Reductions (DERs) are described in the text and have a variable life dependent on state rules. They may be used only for the finite amount of emissions stated on the face of the credit. The Connecticut program is explained in the Belanger study. The Open Market Trading Rule is described by U.S. EPA in the Federal Register (1998).

Table 1.2 *(Continued)*

2.1	Both ERCs and DERs may have geographic, seasonal, and directional (generally winds from the southwest blow toward the northeast of the United States) restrictions. Note the discussion by Belanger.
2.2	All sources may participate on a voluntary basis, opening up the possibility of earning credit, when approved, by enterprises organizing reductions among mobile and area sources. To date, large enterprises with stationary emitting units have been the most active in these markets.
5.	Tradable credits must be earned by reducing emissions below legally allowable or actual rates or levels as verified by the government. Verification is typically a complex determination on which Belanger's study throws much light.
6.	Price and transaction data vary in their availability from state to state. The advantages of central reporting deserve more consideration.
8.1	In principle, states may propose intersource and interpollutant trading for U.S. EPA approval. States have yet to fulfill their potential role as experimental laboratories in this regard.

Why accept such partial trading schemes when the cap-based model yields control over aggregate pollution and enables a decentralized approach to be monitored efficiently? This is a key question that has been answered by supporters of the rate-based model in the following ways. Obtaining agreements for the design features of the cap-and-trade market, as we have pointed out, have proved time consuming and, on occasion, seemingly impossible. Why not have some cost-effective trading where possible rather than none? Rate-based efforts could be a preparatory step for later cap-based implementation. Moreover, control of urban ozone and its precursors require consideration of the locale, the seasonality of formation, and the directionality of ozone and precursor transport. Cap-based designs, it is argued, could be so complicated in these circumstances as to be not worth the cost whereas the rate-based systems enable individual transactions to be evaluated in terms of these factors. It is better to have varied trading tools in the market-incentive chest that can be adapted to different situations.

To facilitate for the reader a comparison of these approaches, we have entered in Table 1.2 selected features of both the ERC and discrete emissions reductions credits (DERs), two of the major open systems. Having described cap-based systems in detail, we can refer more briefly to the main differences. Three areas deserve close attention as we proceed. The decision to participate by emitters is voluntary and the benefits and costs of participation are likely to be complex and vary by emitter, pollutant, and state characteristics. The regulating community in turn has complex matters about air quality and rules that must be resolved, illustrated in detail by the study of the Connecticut DERs program explained in Chapter 11 by Joseph Belanger. Last, obtaining comprehensive and comparable data for evaluation purposes raises problems that have yet to be resolved.

Emission Reduction Credits (ERCs)

We shall focus on the ERC and DERs designs and experience because they have a more immediate bearing on the concerns of this volume than the trading programs introduced for the removal of leaded gasoline and chlorofluorocarbons in commercial products, both of which affected only a few large enterprises. Stavins comments on these last two programs in his work. First in time of application are the various ERC stratagems whose history can throw light on emissions trading problems and lessons learned.

In 1970, the U.S. Congress amended the Clean Air Act (CAA) to require, in Title I, that EPA issue, periodically review, and if necessary revise National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants, including the three of special interest to us, SO_2, NO_x, and VOC. Criteria pollutants were those acceptable at higher concentrations than toxic pollutants. States were to be the frontline regulators and for that purpose congress required that they submit State Implementation Plans (SIPs) to attain and maintain both primary (health) and secondary standards (visibility, vegetation, and materials protection). Progress toward cleaner air proved much slower than mandated under the prescribed traditional regulation, and in 1977, among other important changes, Congress established the concept of NAAQS nonattainment areas and set stringent deadlines for regions and states to reach attainment with such dramatic, but as yet unused, penalties for the states as loss of highway funds if such were not met.

Concern about penalties together with growing concerns about the increasing marginal costs of cleaning the air, created pressures on many fronts to devise new and hopefully cheaper and quicker ways to comply with the CAA mandates. While control costs were not explicitly to be considered in devising regulation, the EPA introduced over time a series of efforts to introduce emissions trading among acceptable regulatory mechanisms. These included the policies of bubbling, netting, offsetting, and banking, linked together by the tradable ERCs. The bubble policy allowed existing sources to use ERCs to meet SIP requirements in nonattainment areas. Thus, a source within the bubble could earn an ERC by a rate reduction and use that credit elsewhere in its own system or sell to a source, also within the bubble, that could then exceed the allowable rate. In a sense, the SO_2 cap-and-trade market may be viewed as a national bubble for emissions trading.

Netting permits a source to modify or expand one unit within its facility providing the source can reduce emissions at another unit and thus earn compensating ERCs. This simplified the regulatory process. Offsetting enables new sources in a nonattainment area to purchase ERCs, and banking enables sources to store ERCs earned in the above ways for future use. In each instance, the ERC must be certified to be surplus, enforceable, permanent, and quantifiable. The regulatory agency given these assignments, even if disposed favorably toward emissions trading, would find a detailed review and prior approval of the transaction a pressing responsibility. For sources required to have an operating permit under the SIP, this meant a revision of that operating permit. Trading was limited by these regulatory measures. Many trades that did occur were internal to the large firm having more than one emitting facility or unit rather than external or interfirm.

In an effort to increase use of ERCs, the U.S. EPA codified the various rules in the 1986 Emission Trading Policy Statement (ETPS), but the high level of constraints and government supervision inherent in the ERC policies was not fundamentally changed and transaction costs have remained high. The number of trades sanctioned by official state emission trading programs have been relatively small compared with expectations (Dudek, Goffman, and Wade, 1997).

Discrete Emissions Reductions Credits (DERs)

In a clear and forceful statement, the U.S. EPA turned to a new voluntary program that attempted to simplify the ERC regulatory approach and increase emissions trading and its benefits. With its 1995 Open-Market Trading Rule for Ozone Smog Precursors, the agency recommended to the states the establishment of a process whereby sources could voluntarily create discrete emissions reductions for compliance with NO_x and VOC emissions under the 1990 legislation. As with ERCs, sources generate DERs by reducing emissions below permitted levels, but for a discrete amount of emissions and not for a nonending stream. States may decide to allow the DERs to be used at any time in the future.

Furthermore, unlike ERCs, prior approval by governmental authorities is not required to generate DERs. Sellers need not obtain a SIP revision in this case. The burden of securing government approval is shifted mainly to the buyer, a significant change from the ERC policies. Once a source generates these new credits, any person may, at any time, transfer, buy, sell, or trade them to another person in accordance with state laws. They can then be used any time after the state receives notice of their generation. At the time of use, users must retire 10 percent of all DERs dedicated to that particular use as a contribution to cleaner air. Users must provide certification of their authenticity including a statement that due diligence was made to verify that DERs were not previously used and that they were generated in accordance with regulations.

States must prescribe where the DERs can be used. For example, they can be used in the same modeling area in which they were generated or, if generated inside a specified nonattainment area, they can be used outside a nonattainment area. But, if generated outside a nonattainment area, there are restrictions on their use inside the area. Interstate trading of DERs under certain directionality requirements is also covered under the 1995 Open-Market Trading Rule.

The open-market rule was based in part on commentary and trials provided by the Northeast States for Coordinated Air Use Management (NESCAUM) and the Mid-Atlantic Regional Air Management Association (MARAMA) that brought together state and local officials, the business community, and public interest groups to work through the numerous design features. The use of market incentives to achieve environmental goals has strengthened the trend to bring together all interested groups involved in regulation for serious work on changes and reforms. This has helped reduce the confrontations that occurred in some applications of traditional regulation.

This open-market trading design for DERs appears to avoid the contentious issues of cap and allocation, but it presents another set of problems and clouds the relation between trading and aggregate pollution control. One problem that is likely to be encountered is the dependence of the quality of DERs upon the documentation that the seller can provide. Hence, DERs may sell at varying prices. The EPA suggested that intermediaries could help assure quality and ease transaction costs. After a successful trade or two, the emitter may find later regulation moves more quickly. The first indications from this new program is that there are more DERs for sale than buyers' demand, apparently a disequilibrium that price alone at this initial stage cannot solve.

In an effort to bring an early appraisal for the use of DERs to the attention of interested observers, the Workshop asked Joseph Belanger to report on the Connecticut implementation of the new policy. The program has generated a number of transactions for review, primarily for NO_x, and made available price data for analysis.

The Connecticut Department of Environmental Protection has created DERs with some characteristics that differ from those recommended in the model 1995 Rule. One of the distinctions is that an important regulatory simplification has not been utilized. Detailed state regulation continues at both the seller and buyer ends of the transaction. This, as Belanger points out, results in increased administrative burden for sources, as well as for the Department, but in turn has reduced the uncertainty and administrative burden for buyers. Another distinction is that additional usage restrictions are attached to the commodity—they are not generic once created. Each trade, like a trade of ERCs, is viewed as a SIP revision. DERs may be banked for two years only and may be used at a rate per unit time that approximates the rate during which they were created. Thus, they present another distinct trading model for consideration.

The Connecticut program began in 1995 and has generated DERs that cover approximately 6 percent of NO_x emissions from the state's stationary sources. A number of credits have been purchased from sources in New Jersey and Belanger provides interesting data on the transactions. Note that DERs created in Connecticut could not be sold to sources in New Jersey. Prices reported for DERs were in the range of $750 to $850 per ton in late 1998. An instructive note in this study is the thought given to the creation of DERs among sources not ordinarily included in green markets, that is, among mobile and area sources. To the extent this type of credit is more easily adapted to these sources, the DERs credits, or more generally, the open-market can be developed jointly with the closed-market model for stationary sources. To date, these intersource transactions have not been numerous.

Belanger notes in conclusion that consideration is being given in his state to moving from the existing DERs program to the NO_x cap-and-trade policy now being recommended to the affected states, and discussed previously in this introduction. The details brought out in Belanger's account of the program in Connecticut reveal the burden placed on government and business by rate-based regulation. Can the alternative, the cap-and-trade markets, be designed to assure air quality everywhere in the ozone case? One problem is that the precursors of low–level ozone are not uniformly mixed in the atmosphere as are (generally) sulfur dioxide and carbon dioxide. However, the advances in air quality modeling that have increased our knowledge of VOC emissions and its local transport and NO_x emissions and its regional transport have increased the confidence of many that the more comprehensive designs of cap-based markets can control these pollutants. This story is by no means over.

This brings us to the end of our little red schoolhouse. Our aim has been to prepare the way for the graduate studies of our contributors who, in presenting the best answers currently available, bring us to the frontier of emissions trading knowledge, research, and implementation. We turn in this last introductory section to a brief survey of their contributions.

Survey of Contributions

Joseph Belanger's study of the Connecticut voluntary market incentive program gives the reader an insider view of the regulatory procedures in this rate-based case to compare with those of cap-and-trade markets. While the program does not make use of the open market concept that reduces pre-trade approval requirements, it does make use of time-limited discrete emissions reductions (DERs). These differ from ERCs by allowing a finite amount of emissions rather than a never-ending stream. Belanger, as a member of a regulating agency that views market incentives with favor, describes for us the many detailed approvals and considerations that take place prior to and after each transaction to assure that emissions reductions are proper and air quality is not debased. He notes that such procedures lead to large transactions costs and has limited trades to a small percentage of total emissions. His data on specific trades reveals that a few large transactions dominate the scene to date.

Dallas Burtraw has been a close and acute observer of the SO_2 market. He was among the first to recognize that control cost savings were being realized before extensive inter-firm trading occurred as electric utilities reallocated allowances among their own boilers, and as utilities took advantage of the new flexibility afforded by decentralized regulation. His study extends this analysis to a period of increasing transactions. While additional savings are being achieved, he points out that prior events such as the availability of cheaper low-sulfur coal must be given considerable credit. His study includes new research results that reveal the increased health benefits of reducing acid rain precursors that can carry tiny particles deep into the lungs. This finding provides additional support for the legislative cuts in SO_2 emissions by half, and may point toward even deeper reductions. Another finding based on an explicit model is that the congressional mandate of free allocation of allowances to emitters has reduced the potential welfare gains of the market as the government is not able to use revenues received from an auction to reduce other taxes that distort in unfavorable ways.

A. Denny Ellerman is able to draw on the extensive empirical studies his MIT research group has made of the SO_2 cap-and-trade market in his account of the electric utility response to allowance prices. He reports that market information has enabled many utilities to correct early mistakes such as overestimating the prices of allowances and overlooking profitable trades with other emitters. Lower than expected prices for low-sulfur coal and for improved scrubbers have reduced the marginal cost of emissions reductions. Trading and price mistakes were among the reasons for over-compliance that led to an unexpected large bank of unused allowances. Utilities have shown their capacity to learn from these developments in managing their control options both currently and in the post-2000 year phase of tighter restrictions on emissions. They are trading more heavily in the market, and building portfolios of future-dated allowances for cost-effective intertemporal control. Ellerman believes market-based flexibility facilitates the correction of mistakes.

Mary Gade and **Roger Kanerva** share with us the hopes and achievements of the Ozone Transport and Assessment Group where Gade led the overall effort and Kanerva the emissions trading discussion. This remarkable degree of cooperation among the states, the U.S. EPA, the regulated community, and public interest groups left a technical database on NO_x regional transport that has extended our knowledge markedly, and a set of useful recommendations on control measures. Many of these have found their way into the new NO_x control requirements placed on the states by the U.S. EPA and into the recommended cap-and-trade market. These efforts to control regional movement of NO_x need to be followed by local steps to reduce VOC. Here again Gade and Kanerva have been among the pioneers in formulating a cap-and-trade market for limiting stationary source emissions of VOC in Northeastern Illinois. While not all efforts in OTAG were agreed to by all parties, the results achieved in this study are likely to provide lasting guides to environmental policy.

Joseph Kruger, Brian McLean, and **Rayenne Chen** bring out clearly that innovations on the commanding heights of environmental policy can take place in the decisions of the regulating community as well as in those of the regulated community. The electronic processing of allowances in the SO_2 Allowance Tracking System has not only provided assurance, to the public and the market, that the rules for trading and retiring allowances are being followed, but also has provided data to the research community for analysis (as will be seen in the Burtraw and Ellerman studies). This is, of course, only half the story. Electronic monitoring of emissions by means of continuous emissions monitoring devices provides the assurance that emissions are accounted for by allowances. Setting up these systems, managing them, and maintaining contact with the regulated community are the responsibilities of a remarkably small staff at the U.S. EPA Acid Rain Division. Our authors explain what they rightly term is an administrative revolution.

James Lents as executive director of the South Coast Air Quality Management District was at the center of the detailed, sometimes contentious discussions that gave birth to early cap-and-trade markets to achieve cleaner air in the Los Angeles region, that super bowl of smog. His study gives the reader a careful, empirical review of three years of operation of the NO_x and SO_x programs, 1994–1996, plus his analysis of the problems that remain to be resolved. The programs require deep cuts in emissions by the year 2003 but allowed over-allocation of non-bankable trading credits during the first years to ease transition to a market-based approach. Actual emissions have not increased during these early years. The intertemporal price path of tradable credits, which are issued to emitters in advance of their first-use dates, exhibit a plausible rising trajectory. Increased trading of credits also is among the indicators of markets that are beginning to function. Lents notes that problems are being encountered in setting up satisfactory electronic monitoring devices to record emissions, in the slow development of inter-emitter trading, and in the delay of actual reductions of emissions.

Michael Moskow adds a closing note to the volume by highlighting the general applicability of incentive-based regulation to other economic activities outside of environmental concerns. He provides examples in the area of financial regulation, his particular field of expertise. The cost-savings and flexibility potential of this regulatory innovation could be significant in the further development of the Midwest economy, recently the subject of a comprehensive study by the Chicago Federal Reserve Branch. Well-designed public policies, including market-based approaches to regulation, will have a role to play if advances in economic well-being in the region are to continue. The author notes that the Midwest has provided its share of leadership in designing and implementing regulatory innovations for cleaner air. Prominent examples include plans for NO_x control by emissions trading proposed by OTAG, and plans for VOC control by implementation of the Emissions Reduction Market System for the Chicago region.

William Nordhaus has been the developer of sophisticated models of environmental control that have influenced the economics profession and policy-makers alike. These models have boldly included ways of estimating the benefits and costs of alternative control strategies and thus thrown a bright and often critical light on current policy proposals. In his study, he writes for the informed but not technically trained reader, first describing the long history of the evolution of new financial commodities, and then bringing us up to date on the development of the current innovation—tradable emission credits. He finds reasons to rate the U.S. sulfur dioxide allowance program a success to date, but his analysis of the proposals to use tradable credits as a tool to limit greenhouse gas emissions, a global problem, raises important problems. Any realistic analysis of the future contribution of emissions trading to global warming control will do well to heed his cautions.

Richard Sandor is known inside and outside financial circles as a leading creator of new financial products, a skill he now brings to the generation of new environmental financial products. He and his colleague, **Michael Walsh,** have participated in the early stages of work on the sulfur dioxide market, and are now fully engaged in the early stages of the development of the carbon dioxide markets. Their chapter does hit more optimistic notes than that of Nordhaus, but the reader will find that both have a clear understanding of the opportunities and problems that lie ahead in applying market incentives to this, arguably, our most important environmental problem. The differences between their studies may be found mostly in their estimates of the political feasibility of securing agreement among the nations, or subsets of them, on an emissions quota or cap–and–trade plan that could exploit the large differences in control costs among emitters. The issues and choices are squarely met in these studies.

Robert Stavins is well qualified to explain the recent history of market-based approaches, a history that can be puzzling to the newcomer. His work has been in the forefront of our understanding of the potential of market incentives. He applies positive and normative analysis to regulatory innovations that once interested only a few academics but now have become topics of general discussion, and application. Readers will find why traditional regulation had, and still has, an appeal, and why emissions trading has secured additional and influential advocates. Readers will also find a valuable summary of the lessons to be learned from the performance of emissions trading applications to date. He presents guidelines for design features and for implementation in those circumstances where this innovation is likely to work best.

Panelists are vital contributors to the Workshop exchange of ideas, and continue that role in this volume. They provide both commentaries on the studies and original views and information on incentive-based regulation. A few examples among many will suffice in this introduction; all are worth close attention. **Vincent Albanese** shares his extensive knowledge of the various control measures that can reduce NO_x emissions. This information lends support to the idea that marginal control costs vary among emitters, and also provides an inkling of the potential innovations that may be stimulated by incentive-based regulation. **Thomas Klier** brings the tools of economic analysis to bear on the Los Angeles RECLAIM markets and finds that many enterprises are on the rapidly rising portion of the learning curve. **Kenneth Rose** from his vantage point overlooking electric utilities, and having access to comprehensive data, reports on how this twice regulated industry may not yet be taking full advantage of all the profitable trading opportunities in the sulfur dioxide allowance program. **Sarah Wade** explains how one large enterprise has introduced a carbon dioxide emissions-trading program within its own far-flung and diverse activities. It is an internal cap-and-trade type design which takes as its cap a percentage reduction from the firm's historical emissions. This reduction exceeds the average agreed to at the Kyoto conference on this topic. **Thomas Zosel** has had a long experience with all types of regulation and points out the importance of a clear delegation of responsibility between regulated and regulating communities. Mr. Zosel died shortly after completing his study which the editors publish as one of his last contributions to regulatory implementation.

REFERENCES

Dudek, Daniel J., Joseph Goffman, and Sarah M. Wade. 1997. "Emissions Trading in Nonattainment Areas: Potential, Requirements, and Existing Programs." Pp. 15–46 in *Market-Based Approaches to Environmental Policy,* edited by Richard F. Kosobud and Jennifer M. Zimmerman. New York: Van Nostrand Reinhold.

Joskow, Paul L. and Richard Schmalensee. 1996. "The Political Economy of Market-Based Environmental Policy: The U.S. Acid Rain Program." Working paper 96-003, Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology, Cambridge, MA, March.

Montgomery, W. David. 1972. "Markets in Licenses and Efficient Pollution Control Programs." *Journal of Economic Theory* 5: 395–418.

Portney, Paul R. 1993. "EPA and the Evolution of Federal Regulations." Pp. 57–74 in *Economics of the Environment*, edited by Robert Dorfman and Nancy S. Dorfman. Third edition. New York: W.W. Norton Company.

Rosenberg, William G. 1997. "An Insiders View of the SO_2 Allowance Trading Legislation." Pp. 95–100 in *Market-Based Approaches to Environmental Policy*, edited by Richard F. Kosobud and Jennifer M. Zimmerman. New York: Van Nostrand Reinhold.

Tietenberg, Thomas H. 1997. *Environmental and Natural Resources Economics.* New York: HarperCollins College Publishing.

Tolley, George S. and Brian K. Edwards. 1997. "Slippage Factors in Emissions Trading." Pp. 187–197 in *Market-Based Approaches to Environmental Policy,* edited by Richard F. Kosobud and Jennifer M. Zimmerman. New York: Van Nostrand Reinhold.

U.S. Environmental Protection Agency. 1998. "Open Market Trading Rule for Ozone Smog Precursors." *Federal Register* 60 (149) (3 August): 39668–39694.

Weitzman, Martin L. 1974. "Prices and Quantities." *Review of Economic Studies* XLI: 477–491. October.