The Evolution of Emissions Trading

by
Tom Tietenberg
Mitchell Family Professor of Economics
Colby College
Waterville, ME 04901-8852

Introduction

Over the last thirty plus years the use of transferable permits to control pollution has evolved from little more than an academic curiosity to the centerpiece of the US program to control acid rain and international programs to control greenhouse gases. What explains this rather remarkable transition? How was the approach shaped by economic theory and empirical research?

EARLY HISTORY

By the late 1950s both economists and policy makers had formed quite well developed and deeply entrenched visions of how pollution control policy should be conducted. Unfortunately these two visions were worlds apart.

Economists viewed the world through the eyes of Pigou (1920). Professor A. C. Pigou had argued that in the face of an externality, such as pollution, the appropriate remedy involved imposing a per-unit tax on the emissions from a polluting activity. The tax rate would be set equal to the marginal external social damage caused by the last unit of pollution at the efficient allocation. Faced with this tax rate on emissions, firms would internalize the externality. By minimizing their own costs firms would simultaneously minimize the costs to society as a whole. According to this view rational pollution control policy involved putting a price on pollution.

Policy makers, on the other hand, preferred controlling pollution through a series of legal regulations ranging from controlling the location of polluting activities to the specification of emissions ceilings.

The result was a standoff in which policy-makers focused on quantity-based policies (Kelman 1981), while economists promoted price-based remedies (Kneese and Schultze 1975). During the standoff, the legal regimes prevailed. Taxes made little headway.

In 1960 Ronald Coase published a remarkable article in which he sowed the seeds for a rather different mind set. (Coase 1960) Arguing that Pigou's analysis had an excessively narrow focus, Coase argued that by making property rights explicit and transferable, the market could play a substantial role not only in valuing these rights, but also in assuring that they gravitated to their best use. To his fellow economists Coase pointed out that a property rights approach allowed the market to value the property rights (as opposed to the government in the Pigouvian approach.) To policy-makers Coase pointed out that the then existing legal regimes provided no incentives for the rights to flow to their highest valued use.

It remained for this key insight to become imbedded in a practical program for controlling pollution. John Dales (1968) pointed out its applicability for water and Tom Crocker (1966) for air.

THEORETICAL FOUNDATIONS

The appeal of emissions trading comes from its ability to achieve a prespecified target at minimum cost even in the absence of any regulator information on control costs. Under this system permits are either auctioned off or distributed among emitters on the basis of some criterion such as historical use. As long as marginal abatement costs differ, incentives for trade exist. High marginal abatement cost firms buy permits from low marginal cost firms until the market clears and the demand for permits equals the fixed supply.

While the general properties of the system had been correctly anticipated by Dales and Crocker, it remained for Baumol and Oates (1971) to demonstrate them formally. Interestingly enough their original paper is not about a marketable permits system, but rather about a charge system designed to meet a predetermined environmental target. Nonetheless because the mathematics is perfectly equivalent for the two cases, the result derived for a charge system immediately was recognized as relevant for emissions trading.

Baumol and Oates proved that a uniform charge would result in meeting the predetermined environmental target cost-effectively. This was important because it implied that the control authority had to impose only a single tax rate on all polluters for the allocation of control responsibility to be achieved at minimum cost. Since all profit-maximizing firms would equate their marginal control costs to this uniform charge, marginal control costs would necessarily be equalized across emitters, precisely the condition required for a cost-effective allocation.

The main practical difference between the two approaches, however, was how the "correct" price would be determined. While any price would result in equal marginal costs, only one price would be consistent with meeting the prespecified standard. In a tax and standards system, this price would be found iteratively, through trial and error. In the marketable permits system the price would be established by the interaction of the demand for and supply of permits in the market. Not only would the control authority have no role in setting the price, but prices would be determined immediately, avoiding a long iterative procedure.

The Baumol and Oates results only apply in a special case--when all emissions from all emitters have the same impact on the environmental target. (Tietenberg, 1973) When the target involves meeting an ambient concentration standard, this case has become known as the "uniformly mixed" case. One prominent example involves climate change gases, since all emissions have the same impact on the environmental target regardless of the location from where they are emitted. The Baumol-Oates theorem is also valid when the environmental target is defined in terms of aggregate emissions rather than pollutant concentrations..

In many other cases, however, the location of the emissions does matter. In these cases the contribution of any unit of emissions to the environmental target (say an ambient standard that sets a concentration limit at a particular location in the air or water) will depend on its location. All other things being equal, sources closer to the receptor are likely to have a larger impact than those further away. For these cases neither a single tax rate nor permit price will suffice. Differentiation of rates among sources is necessary.

Montgomery (1972) proved the existence of a cost-effective permit market equilibrium in this more complicated case. In general, those sources having higher marginal impacts on the environmental target need to pay higher prices per unit of emissions, which can be implemented by having separate permits for each receptor location. (Tietenberg 1973) When the environmental target is defined in terms of pollutant concentrations in the ambient air (as it is in most countries), the permits can be defined in terms of allowable concentrations units. Although he emissions allowed by each permit would degrade the concentration at the associated receptor location by the same amount, each permit would allow differing amounts of emissions depending on the location of the emitter vis a vis the receptor. Each permit would authorize fewer emissions for those emitters having a greater impact on the receptor location for each unit of emissions.

THE POLICY CONTEXT

Stripped to its essentials, the U. S. approach to pollution control prior to the adoption of emissions trading, which remains partially in tact today, relied upon a **command-and-control** approach to controlling pollution. Ambient standards, which establish the highest allowable concentration of the pollutant in the ambient air or water for each conventional pollutant, represent the targets of this approach. To reach these targets emission or effluent standards (legal discharge ceilings) are imposed on a large number of specific discharge points such as stacks, vents, outfalls or storage tanks.

The political acceptability of a cost/effectiveness, quantity-based approach grew as the difficulties with the command-and-control approach became more apparent. Both cost/effectiveness and a quantity-based approach seemed more consistent with, and a less radical departure from, traditional environmental policy. Existing pollution targets could be retained.

THE PUSH FOR REFORM

A pivotal point in the reform movement occurred when empirical cost/effectiveness studies showed that it was possible to reach the predetermined standards at a much lower cost than was the case with the traditional command-and-control regime. This rather consistent finding, produced for a number of different pollutants and geographic settings, offered the politically salable prospect of either achieving the existing environmental objectives at a much lower cost or of obtaining a much higher level of environmental quality for the same expenditure. While theory showed that command-and-control regulation typically was not cost-effective, empirical work demonstrated that the degree of inefficiency was very large indeed. This work suggested that the gains from reform would be large enough outweigh the transition costs.

THE EVOLUTION OF EMISSIONS TRADING[1]

---

[1] Due to limitations of space only a small sampling of the operating programs can be mentioned here. Emissions trading has been used in many other contexts including the RECLAIM program in the greater Los Angles area, [Hall and Walton, 1996] the program to phase out lead in gasoline, [Nussbaum, 1992] the NOx Budget program in the Northeast, [Farrell, 2001], reducing or eliminating ozone depleting chemicals, [Stavins, 1993] emissions averaging of industrial toxics, [Anderson, 2001] and controlling particulates in Santiago, Chile [O'Ryan, 1996; Montero et.al., 2002].

THE OFFSET POLICY: THE PROBLEM BECOMES THE SOLUTION

The political opportunity to capitalize on these economic insights came in 1976. By then it had become clear that a number of regions, designated "nonattainment" regions by the Clean Air Act, would fail to attain required ambient air quality standards by the deadlines mandated in the Act. Since further economic growth appeared to make the air worse, contrary to the intent of the statute, EPA was faced with the unpleasant prospect of prohibiting many new businesses (those which would emit any of the pollutants responsible for nonattainment in that region) from entering these regions until the air quality met the ambient standards.

Prohibiting economic growth as the means of resolving air quality problems was politically unpopular among governors, mayors, and many members of Congress. EPA was facing a potential revolution. At this point, of necessity, EPA considered its options. Was it possible to address the air quality problem while facilitating further economic growth?

It was possible, as it turns out, and the means for achieving these apparently incompatible objectives involved the creation of an early form of emissions trading. Existing sources of pollution in the nonattainment area were encouraged to voluntarily reduce their emission levels below the current legal requirements. Once the EPA certified these excess reductions as "emission reduction credits", they became transferable to new sources that wished to enter the area.

New sources were allowed to enter nonattainment regions providing they acquired sufficient emission reduction credits from other facilities in the region so that total regional emissions were lower (not just the same!) after entry than before. (This was accomplished by requiring new sources to secure credits for 120% of the emissions they would add; the additional 20% would be "retired" as an improvement in air quality.) Known as the "offset policy," this approach not only allowed economic growth while improving air quality, the original objective, it made economic growth the vehicle for improving the air. It turned the problem on its head and made the problem part of the solution.

It wasn't long before the federal government began to expand the scope of the program by allowing credits to be banked and permitting existing sources to trade with other existing sources. In this program the government not only was required to certify each reduction before it qualified for credit, but credit trades were generally approved by the control authority on a case-by-case basis. Not surprisingly the huge transactions costs associated with this level of government involvement limited the effectiveness of the program, leading one pair of commentators to subtitle an article about this program "Why is this Thoroughbred Hobbled?"(Dudek and Palmisano 1988)

TACKLING ACID RAIN: THE SULFUR ALLOWANCE PROGRAM

The most successful version of emissions trading to date has been its use in the U. S. for controlling electric utility emissions contributing to acid rain. Under this innovative approach, allowances to emit sulfur oxides were allocated to individual plants with the number of authorized emissions being reduced in two phases so as to assure a reduction of 10 million tons in emissions from 1980 levels by the year 2010.

Perhaps the most interesting political aspect of this program was the role of trading in the passage of the acid rain bill. Though reductions of acid rain precursors had been sought with a succession of bills over the first two decades of Clean Air Act legislation, none passed into law. With the inclusion of an emissions trading program for sulfur in the bill, the compliance cost was reduced sufficiently to make passage politically possible.

Sulfur allowances form the heart of the tradable permit program. The allowances are allocated to specified utilities on the basis of an allocation formula. Each allowance, which provides a limited authorization to emit one ton of sulfur, is defined for a specific calendar year, but unused allowances can be carried forward into future years. They are fully transferable not only among the affected sources, but even to individuals who may wish to "retire" the allowances, thereby denying their use to permit emissions.

Emissions in this controlled sector cannot legally exceed the levels permitted by the allowances (allocated plus acquired). An annual year-end audit balances emissions with allowances. Utilities that emit more than is authorized by their holdings of allowances face a substantial per ton penalty and must forfeit allowances worth an equivalent number of tons in the following year.

This program has several innovative features that were influenced by analysis, but in the interest of brevity I will mention only one -- assuring the availability of allowances by instituting an auction market. Although allowances can either be transferred by private sale or in the annual auction, historically the problem with the private sale route was that prices were confidential so transactors operated in the dark. Due to an absence of knowledge not only about potential buyers and sellers, but also about prices, transactions costs were high; the lack of price transparency inhibited effective emissions trading.

EPA facilitated this market by instituting an auction market run by the Chicago Board of Trade. During the negotiations, utilities fought the idea of an auction because they knew it would raise their costs significantly. Whereas under the traditional means of distributing allowances utilities would be given the allowances free of charge, under an auction they would have had to buy these allowances at the full market price, a potentially significant additional financial burden.

To gain the advantages an auction offers for improving the efficiency of the market, while not imposing a large financial burden on utilities, EPA established what has become known as a *zero revenue* auction.(Hahn and Noll 1982) Each year the EPA withholds from its allocation to utilities somewhat less than 3% of the allocations, and auctions these off. In the auction these allowances are allocated to the highest bidders with successful buyers paying their actual bid price (not a common market-clearing price). The proceeds from the sale of these allowances are refunded to the utilities from which the allowances were withheld on a proportional basis. Although this auction design is not efficient, because it provides incentives for inefficient strategic behavior (Hausker 1992; Cason 1993), the degree of inefficiency is apparently small. (Ellerman, Joskow et al. 2000)

EMISSIONS TRADING IN THE KYOTO PROTOCOL ON CLIMATE CHANGE

In December 1997, industrial countries and countries with economies in transition (primarily the former Soviet Republics) agreed to legally binding emission targets for greenhouse gases at the Kyoto Conference. The Kyoto Protocol became effective in February 2005.

The Kyoto Protocol authorizes three cooperative implementation mechanisms that involve tradable permits--Emission Trading, Joint Implementation and the Clean Development Mechanism.

- "Emissions Trading" (ET) allows trading of "assigned amounts" (the national quotas established by the Kyoto Protocol) among countries listed in Annex B of the Protocol, primarily the industrialized nations and the economies in transition.

- Under "Joint Implementation" (JI) Annex B Parties can receive emissions reduction credit when they help to finance specific projects that reduce net emissions in another Annex B Party country. This "project-based" program is designed to exploit opportunities in Annex B countries that have not yet become fully eligible to engage in the ET program described above.

- The "Clean Development Mechanism" (CDM) enables Annex B Parties to finance emission-reduction projects in non-Annex B Parties (primarily developing countries) and to receive certified emission reductions (CERs) for doing so. These CERs could then be used along with in-country reductions to fulfill "assigned amount" obligations.

These programs have, in turn, spawned others. Even individual companies are involved. BP, an energy company, has established company-wide goals and an intra-company trading program to help individual units within the firm meet those goals. Despite the fact that the United States has not signed the Kyoto Protocol, even American companies, states and municipalities have accepted caps (some voluntary and some mandatory) on CO_2 and methane emissions and are using emissions trading to help meet those goals. The Chicago Climate Exchange has been set up to facilitate these trades.

THE EUROPEAN EMISSIONS TRADING SYSTEM (EU ETS)

The largest emission trading program for climate change has been developed by the European Union to facilitate implementation of the Kyoto Protocol. (Kruger and Pizer 2004) The EU program covers 25 countries, including the 10 "accession" countries, most of which are former members of the Soviet bloc. Its first three years, from 2005 through 2007, constitutes a trial phase. The second phase coincides with the first Kyoto commitment period, beginning in 2008 and continuing through 2012. Subsequent negotiations will specify future details.

Initially, the program covers only carbon dioxide (CO_2) emissions from four broad sectors: iron and steel, minerals, energy, and pulp and paper. All European installations in these sectors larger than established thresholds, some 12,000 in all, are included in the program.

LESSONS ABOUT PROGRAM EFFECTIVENESS

Economic principles have been used to design the programs and economic analysis has helped to shape the evolution of these programs and to assess their success. Two types of studies have been used to evaluate cost savings and air quality impacts: *ex ante* analyses that depend on computer simulations and *ex post* analyses that examine the actual implementation experience.

The vast majority, though not all, of the large number of *ex ante* studies have found command-and-control outcomes to be significantly more costly than the least cost alternative. (Tietenberg, 2006)

Although detailed *ex post* analyses are relatively rare, two detailed evaluations of the sulfur allowance program have been conducted. (Carlson, Burtraw et al. 2000; Ellerman, Joskow et al. 2000) While both found considerable cost savings had been achieved in meeting the air quality goals following the implementation of the program, their interpretation of the sources of these savings differs. While Ellerman et al. found substantial savings due to the structure of the sulfur allowance program, Carlson et.al. attributed a larger share of the lower costs to factors they saw as exogenous to the trading program (declines in the price of low-sulfur coal and improvements in technology that lowered the cost of fuel switching).

Whereas conventional wisdom holds that emissions trading lowers costs, but has no affect on air quality, that seems to be an oversimplification. In retrospect we now know that the feasibility, level, and enforcement of the emissions cap can all be positively affected by the introduction of emissions trading. In addition emissions trading may trigger environmental effects from pollutants that are not covered by the limit. While most of these external effects are desirable, some are detrimental. (Tietenberg 2006)

In general, air quality has improved substantially under emissions trading. For some programs the degree to which credit for these improvements can be attributed solely to emissions trading (as opposed to exogenous factors or complementary policies) is not completely clear.

For credit programs, such as the US Emissions Trading Program, the magnitude of the positive air quality increases and cost savings have been smaller and the achievements have come more slowly than anticipated by the original proponents. Constraints imposed on early credit programs by an excessively cautious bureaucracy took their toll. Fortunately the number and intensity of these constraints have tended to diminish over time as familiarity with this approach increases bureaucratic comfort with it.

LESSONS FOR PROGRAM DESIGN

BASELINE PLUS CREDITS VS. CAP AND TRADE.

Emissions trading programs fit into one of two general categories: credit programs or cap-and-trade programs.

- Credit trading, the approach taken in the US Emissions Trading Program (the earliest program), allows emission reductions above and beyond baseline legal requirements to be certified as tradable credits.

- In a cap-and-trade program a total aggregate emission limit (the cap) is defined and then allocated among users. Compliance is established by simply comparing actual use with the assigned firm-specific cap as adjusted by any acquired or sold permits.

Establishing the baseline for credit programs in the absence of an existing permit system can be challenging. For example, the basic requirement in the Clean Development Mechanism component of the Kyoto Protocol is “additionality”. Deciding whether reductions are "additional" (as opposed to reductions that would have occurred anyway) requires establishing a baseline against which the reductions can be measured.

Defining procedures that assure that the baselines don’t allow unjustified credits is no small task. A pilot program for Activities Implemented Jointly, which was established at the first Conference of the Parties in 1995, demonstrated the difficulties of assuring "additionality". Requiring proof of additionality was found to impose very high transaction costs as well as introduce considerable *ex ante* uncertainty about the actual reductions that could be achieved. (Schwarze 2000) By imposing a cap that can be directly compared with actual emissions, cap-and-trade programs avoid this complication and reduce transaction costs significantly.

PRICE VOLATILITY, CAPS AND SAFETY VALVES

In contrast to an alternative policy such as environmental taxation, which provides some assurance of stable prices, in the face of "shocks" a cap can lead to politically unacceptable permit price increases. For example, participants in an emissions trading program in the greater Los Angeles area (known as RECLAIM-The **Re**gional **C**lear **A**ir **I**ncentives **M**arket) experienced a very large unanticipated demand for power that could only be accommodated by increasing the output from older, more polluting plants. Supplies from the normal sources of power, including imported hydropower from the Pacific Northwest, were severely diminished by a variety of circumstances. The large increase in demand for emission permits resulting from the need to bring these “dirty” plants on line, coupled with the fixed supply of permits, caused permit prices to soar in a way that was never anticipated.

To gain the political support needed for implementation, modern emissions trading programs have had to deal with participant concern over volatile prices. The general prescription is to allow a “safety valve” in the form of a predefined penalty that would be imposed on all emissions over the cap once prices exceeded predefined threshold. (Jacoby and Ellerman 2004) This per unit penalty would typically be lower than the sanction imposed for noncompliance during normal situations (when compliance would be much easier). In effect this penalty would set the maximum price that would be incurred in pursuit of environmental goals in unusually trying times.

In the case of RECLAIM when permit prices went over a predefined threshold, the program was suspended until they figured out what to do and an alternative (substantial) fee per ton was imposed in the interim. The revenue was used to subsidize additional alternative emission reductions, typically from sources not covered by the cap. (Harrison 2002)

INITIAL ALLOCATION METHOD

Most operating systems either exclusively or mainly allocate permits free-of-charge to the program participants on the basis of some criterion (historic authorized emissions, for example). Free distribution has advantages and disadvantages. Recent work examining how the presence of pre-existing distortions in the tax system affects the efficiency of the chosen policy instrument demonstrates that the ability to use revenue from the sale of permits to reduce these distortions (rather than giving them to users) can enhance the efficiency of the system by a large amount.[2] That conclusion, of course, supports the use of revenue-raising instruments such as taxes or auctioned permits rather than free distribution. (Goulder, Parry et al. 1999; Parry, Williams et al. 1999)

How revenues are distributed, however, also affects the relative attractiveness of alternative approaches to environmental protection from the point of view of various stakeholders. To the extent that stakeholders can influence policy choice, using free distribution in general and prior use in particular as allocation criteria has increased the implementation feasibility of emissions trading. (Svendsen 1999) This historical experience, however, need not be decisive for the future, since the empirical evidence suggests that the amount of the revenue needed to hold users harmless during the change is only a fraction of the total revenue available from auctioning. (Bovenberg and Goulder 2000) Allocating all permits free of charge is therefore not inevitable in principle, even when political feasibility considerations affect the design.

---

[2] One example is the use of these revenues to allow income tax rates to be reduced, thus reducing the distortions associated with taxing income.

Basing the initial allocation on prior use can also promote inefficient strategic behavior. An initial allocation based upon historic use creates an incentive to intensify emissions prior to th implementation date (to qualify for a larger initial allocation). In emissions trading this effect has generally been minimized by basing initial allocations on a combination of activity levels, which are historically based, and emission rates per unit of activity based on standard norms.

Recent economic research (Parry, Sigman et al. 2006) has also demonstrated that auctioned allowances can have more desirable distributional properties than freely distributed allowances. In response to this new evidence on both the efficiency and distributional advantages of auctioned permits the several states in a new emissions trading program to control carbon emissions in the Northeast (The Regional Greenhouse Gas Intitiatve) are currently planning to auction off the allowances.

SPATIAL ASPECTS

Traditional theory presumes that the commodity being traded is homogeneous. In practice, without homogeneity, transfers can confer external benefits or costs on third parties, resulting in allocations that do not maximize net benefits.

On example of an external effect involves pollutants where the location of the emission, not only the amount of emission, matters. Spatial issues arise whenever the transfer could alter the point of emission. Although, as noted above, theoretically optimal permit systems can be defined to address spatial issues, in practice they have not been used because of their inherent complexity. Practical solutions for incorporating source location into an emissions trading program so as to deal with these spatial issues is a difficult, but manageable, proposition. (Tietenberg 1995)

One possibility involves dividing the control region into zones. Zonal permit systems that can be initiated with plausible amounts of information are typically not very effective.(Tietenberg 2006, Chapter 4) When permits cannot be traded across zonal boundaries, the cost penalty can be very sensitive to the initial allocation of zonal caps. Studies suggest that no conventional rule of thumb for allocating the required emission reduction among zones comes close to the cost-effective allocation.

An alternative strategy, now also common, involves the creation of trading rules, which govern individual transactions. One trading rule strategy, known locally as "regulatory tiering," applies more than one regulatory regime at a time. In the sulfur allowance program sulfur emissions are controlled both by the regulations designed to achieve local ambient air quality standards as well as by the sulfur allowance trading rules. All transactions have to satisfy both programs. Thus trading is not restricted by spatial considerations (national one-for-one trades are possible), but the use of acquired allowances is subject to local regulations protecting the ambient standards. Unlike programs that restrict all transactions or employ a much more strict cap to prevent spatial concentration peaks (known as "hot spots"), this approach prohibits only the few transactions that would result in a hot spot. *Ex ante* empirical analysis of this approach suggests that regulatory tiering may well be an effective compromise. (Atkinson and Tietenberg 1982)

THE TEMPORAL DIMENSION

Ex post evaluations have revealed that the temporal aspects of emissions trading provisions have been quite important in terms of both saving costs and promoting quicker reductions. Emissions trading systems can incorporate temporal flexibility by allowing banking, borrowing or both. *Banking* means holding a permit beyond its designated date for later use or sale. *Borrowing* means using a permit before its designated date.

The economic case for this flexibility is that it allows sources to optimally time their abatement investments. Flexibility in timing is important not only for reasons that are unique to each firm, but also for reasons that relate to the market as a whole. When everyone makes control investments at the same time, it strains the supply capacity of the system, driving input prices up.

When only the aggregate stock of emissions over some time period matters, the price of permits would normally rise at the rate of interest and the holders would automatically choose to use them in the manner that minimizes the present value of abatement costs. Decentralized decision-making in this case would be compatible with social objectives. Special temporal controls would be counterproductive.

When a single aggregate emissions cap is not sufficient to protect against damage from concentration peaks, timing become a separate control variable. Situations where the damaging effects of peak concentrations are important open the door to a potentially important market failure. (Kling and Rubin 1997) While firms have an incentive to minimize the present value of abatement cost, they do not have an efficient incentive to minimize the present value of all costs including the damage caused by hot spots. In general the resulting incentive is to delay abatement (abating too little during the early periods and concentrating too much abatement later).

Delaying abatement, however, is not always the optimal choice for the firm, even in an unrestricted permit market. When over time marginal abatement costs rise, marginal production costs fall, aggregate emission targets decline, or output prices rise, firms have an incentive to bank, rather than borrow, permits. In the sulfur allowance program due to the ability to bank emissions firms reduced emissions early (when concentrations were high) and increased them later (when concentrations were lower). In this case banking clearly reduced concentrations and reduced costs. (Ellerman, Joskow et al. 2000)

Concluding Comments

Emissions trading provides a good example of the "pendulum" theory of public policy. In the early 1970s, emissions trading was considered an academically intriguing, but ultimately impractical, idea. It had trouble getting on the national agenda. Reformers had few successes.

However, that changed once the expectations created by the economic analysis had been confirmed on the ground by the sulfur allowance program. It demonstrated not only the feasibility of the approach, but also its effectiveness. Emboldened by success, expectations and enthusiasm started to outrun reality.

In the final stage, the one I believe we are now in, reality once again is beginning to reassert itself. My sense is that both policy makers and academics are beginning to realize not only that emissions trading has achieved a considerable measure of success, but it also that it has specific weaknesses. It has also been interesting to observe the growing prominence of auctioned permits, moving the whole enterprise much closer to the economic point of view that prevailed at the outset.

Economic analysis has helped us to understand that not all emissions trading programs are equal. Some designs are better than others. Furthermore, one size does not fit all. Emissions trading programs can (and should) be tailored to each specific application.

The evidence suggests that while emissions trading is no panacea, well-designed programs, which are targeted at pollution problems appropriate for this form of control, are beginning to occupy an important and durable niche in the evolving menu of environmental policies. This economic idea has come of age.

References

Anderson, R. C. (2001). The United States Experience with Economic incentives for Pollution Control. Washington, DC, National Center for Environmental Economics.

Atkinson, S. E. and T. H. Tietenberg (1982). "The Empirical Properties of Two Classes of Designs for Transferable Discharge Permit Markets." Journal of Environmental Economics and Management **9**(2): 101-121.

Baumol, W. J. and W. E. Oates (1971). "The Use of Standards and Prices for Protection of the Environment." Swedish Journal of Economics **73**: 42-54.

Bovenberg, A. L. and L. H. Goulder (2000). Neutralizing Adverse Impacts of CO2 Abatement Policies: What Does it Cost? Behavorial & Distributional Effects of Environmental Policy. C. E. Carraro and G. E. Metcalf. Chicago, University of Chicago Press.

Carlson, C., Dallas Burtraw, et al. (2000). "Sulfur Dioxide Control By Electric Utilities: What Are The Gains From Trade?" Journal of Political Economy **108**(6): 1292–1326.

Cason, T. N. (1993). "Seller Incentive Properties of EPA's Emission Trading Auction." J. Environ. Econ. Manag. **25**(2): 177-95.

Coase, R. (1960). "The Problem of Social Cost." The Journal of Law and Economics **3**(October): 1-44.

Crocker, T. D. (1966). The Structuring of Atmospheric Pollution Control Systems. The Economics of Air Pollution. H. Wolozin. New York, W. W.Norton & Co.**:** 61-86.

Dales, J. H. (1968). Pollution, Property and Prices. Toronto, University of Toronto Press.

Dudek, D. J. and J. Palmisano (1988). "Emissions Trading: Why is this Thoroughbred Hobbled?" **13**(2): 217-56.

Ellerman, A. D., P. Joskow, et al. (1997). "1996 Update on the Compliance and Emissions Trading Under the US Acid Rain Program." MIT Center for Energy and Environmental Policy Research, Cambridge.

Ellerman, A. D., P. L. Joskow, et al. (2000). Markets for Clean Air: The U. S. Acid Rain Program. Cambridge, UK, Cambridge University Press.

Farrell, A. (2001). "Multi-lateral emission trading: lessons from inter-state NOx control in the United States." Energ Policy **29**(13): 1061-1072.

Goulder, L. H., I. W. H. Parry, et al. (1999). "The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting." J. PUBLIC ECONOMICS **72**(3): 329-360.

Hahn, R. W. and G. L. Hester (1989). "Where Did All the Markets Go? An Analysis of EPA's Emission Trading Program." **6**(1): 109-153.

Hahn, R. W. and R. G. Noll (1982). Designing a Market for Tradeable Emission Permits. Reform of Environmental Regulation. W. A. Magat. Cambridge, Mass, Ballinger**:** 119-146.

Hall, J. V. and A. L. Walton (1996). "A Case Study in Pollution Markets: Dismal Science vs. Dismal Reality." **XIV**(2): 67-78.

Harrison, D., Jr. (2002). Tradable Permits for Air Quality and Climate Change. The International Yearbook of Environmental and Resource Economics: 2002/2003. T. Tietenberg and H. Folmer. Cheltenham, UK, Edward Elgar**:** 311-372.

Hausker, K. (1992). "The Politics and Economics of Auction Design in the Market for Sulfur Dioxide Pollution." Journal of Policy Analysis and Management. **11**(4): 553-72.

Jacoby, H. D. and A. D. Ellerman (2004). "The Safety Valve and Climate Policy." Energy Policy **32**(4): 481-491.

Kling, C. and J. Rubin (1997). "Bankable Permits for the Control of Environmental Pollution." Journal of Public Economics **64**(1): 99-113.

Kneese, A. V. and C. L. Schultze (1975). Pollution, Prices, and Public Policy. Washington, DC, The Brookings Institution.

Kruger, J. A. and W. A. Pizer (2004). "Greenhouse Gas Trading in Europe - The New Grand Policy Experiment." Environment **46**(8): 8-+.

Montero, J. P., J. M. Sanchez, et al. (2002). "A Market-Based Environmental Policy Experiment in Chile." Journal of Law and Economics **45**(1, Part 1): 267-287.

Montgomery, W. D. (1972). "Markets in Licenses and Efficient Pollution Control Programs." Journal of Economic Theory **5**(3): 395-418.

Nussbaum, B. D. (1992). Phasing Down Lead in Gasoline in the U.S.: Mandates, Incentives, Trading and Banking. Climate Change: Designing a Tradeable Permit System. T. Jones and J. Corfee-Morlot. Paris, Organization for Economic Co-operation and Development Publication**:** 21-34.

O'Ryan, R. (1996). "Cost-Effective Policies to Improve Urban Air Quality in Santiago, Chile." Journal of Environmental Economics and Management **31**(3): 302-313.

Parry, I. W. H., H. Sigman, et al. (2006). The Incidence of Pollution Control Policies. The International Yearbook of Environmental and Resource Economics 2006/2007. T. Tietenberg and. H. Folmer. eds. Cheltenham, UK, Edward Elgar**:** 1-42.

Parry, I. W. H., R. C. Williams, et al. (1999). "When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets." Journal of Environmental Economics and Management. **37**(1): 52-84.

Pigou, A. C. (1920). The Economics of Welfare. London, Macmillan.

Schwarze, R. (2000). "Activities Implemented Jointly: Another Look at the Facts." Ecological Economics **32**(2): 255-67.

Seskin, E. P., R. J. Anderson, Jr., et al. (1983). "An Empirical Analysis of Economic Strategies for Controlling Air Pollution." Journal of Environmental Economics and Management **10**(2): 112-124.

Stavins, R. and R. Hahn (1993). Trading in Greenhouse Permits: A Critical Examination of Design and Implementation Issues. Cambridge, MA, John F. Kennedy School of Government, Harvard University.

Svendsen, G. T. (1999). "U. S. Interest Groups Prefer Emission Trading: A New Perspective." Public Choice **101**(1-2): 109-28.

Tietenberg, T. H. (1973). "Controlling Pollution by Price and Standard Systems: A General Equilibrium Analysis"." Swedish Journal of Economics **75**: 193-203.

Tietenberg, T. H. (1995). "Tradable Permits for Pollution Control When Emission Location Matters: What Have We Learned?" Environmental and Resource Economics **5**(2): 95-113.

Tietenberg, T. H. (2006). Emissions Trading: Principles and Practice. 2nd ed. Washington, DC, Resources for the Future.