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Marketable Permits

Managing Local, Regional and Global Commons

Nives Dolšak

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MARKETABLE PERMITS:

MANAGING LOCAL, REGIONAL, AND GLOBAL COMMONS

Nives Dolšak

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ABSTRACT

This dissertation analyzes applicability of marketable permits for managing natural common-pool resources, especially the atmosphere as a sink for carbon dioxide (a global common-pool resource). It focuses on factors affecting "performance" of marketable permits, which is operationalized as: (a) effectiveness to reduce resource overuse, and (b) market liquidity (number of trades, proportion of resource users who trade, and price dispersion). Multiple markets for common-pool resources are examined. These are: sulfur dioxide allowance trading, Wetlands Mitigation Banking, early emission trading programs, Regional Clean Air Incentives Market, Lead Phasedown Program, and production permits for ozone-depleting substances.

Drawing on secondary data, this dissertation employs the Institutional Analysis and Development framework to examine the effects of the following factors on the performance of marketable permits: (1) resource characteristics affecting resource “measurability"; (2) users' characteristics; (3) legal and regulatory environments; and (4) rules regulating users and resource-use.

Three major findings emerge for devising rules to manage the global atmosphere as a sink for carbon dioxide. First, marketable permits perform better when the resource-use is severely limited by an authorized agency and the limits are enforceable at low costs. Given that only countries are parties to the Framework Convention on Climate Change, marketable permits for global atmosphere will have to rely on national limits enforced by national governments. Internationally, compliance with national limits will have to be reviewed periodically and non-compliance at the country level sanctioned. Second, countries should have autonomy to devise their own monitoring and enforcement systems. These systems need to be audited regularly by an accredited third party. Third, within and across countries, differences in the reliability of measuring resource flows attributable to various users will require non-uniform exchange ratios. These ratios should be determined by the scientific advisory board to the Convention, not by market mechanisms. Rather than having as many exchange ratios as resource users, various resource users will be classified into categories. National regulators should have the

autonomy to classify projects into various categories. These categorizations will be reviewed regularly by third-party auditors. Buyer liability will create incentives for correct categorizations.

LIST OF ACRONYMS

AEA	Administration Economic Analysis
ATS	Allowance Tracking System
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFC	chloroflourocarbon
CO	carbon monoxide
CO2	carbon dioxide
CPR	common-pool resource
CWA	Clean Water Act
DOE	The Department of Energy
DU	Dobson unit
EIA	Energy Information Administration
ELI	Environmental Law Institute
EPA	Environmental Protection Agency
ERC	Emission Reduction Credit
FERC	Federal Electricity Regulatory Commission
GAO	Government Accounting Office
GHG	greenhouse gas
gplg	gram per liquid gallon
HCFC	hydrochloroflourocarbon
ITQ	Individual Transferable Quota
mmBtu	million British thermal units
NAAQS	National Ambient Air Quality Standards
NAPAP	National Acid Precipitation Assessment Program
NOx	nitrogen oxides
OBRA	Omnibus Budget Reconciliation Act
ODS	ozone-depleting substances
PUC	Public Utilities Commission
PUHCA	Public Utilities Holding Company Act
RECLAIM	Regional Clean Air Incentive Market
RTC	Reclaim Trading Credit
SO2	sulfur dioxide
SCAQMD	South Coast Air Quality Management District
toe	tons of oil equivalent
UNCTAD	United Nations Commission on Trade and Development
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
WMB	Wetlands Mitigation Banking

CHAPTER 1

INTRODUCTION

The global atmosphere, the shield that protects the Earth from the negative impacts from space, has significantly changed over the last centuries, causing negative effects all over the world. The changes have been linked to overuse of the atmosphere as a sink for pollution of *greenhouse gases* (Climate Change, 1995a,b). One of the reasons for the overuse of the global atmosphere is the nature of this good and its use. Global atmosphere as a sink for air pollution is an example of a common pool resource (CPR). Consumption of these goods is not excludable, but it is rival (Weimer and Vining, 1989). In this case, individuals face incentives to overconsume the resource (Hardin, 1968).

To prevent overconsumption of a CPR, resource users have to craft rules that limit the access to the resource and its use. These rules can either limit the number of users who can use the resource by issuing permits, or alternatively, rules can be devised that prescribe the equipment with which the resource can be used, such as the size of the boat used in fishing or emission filters on stacks. On the other hand, rules can be devised that allow for more flexibility in resource consumption. For example, rights to use the resource can be quantified and allocated among resource users. These rights entitle the holder to withdraw a given flow from the stocks of the resource. The amount of unused rights can be transferred to other resource users.

Transferable rights, used for managing many environmental resources, such as air pollution, water pollution, and fisheries, have also been proposed as a solution to manage the global atmosphere and prevent its overuse. Countries have negotiated an international agreement to limit their use of the atmosphere as a sink for *greenhouse gases*. In general, all parties agree that a system of marketable permits would allow for the maximum flexibility in reducing the emissions. There is, however, no agreement on what system of marketable permits would work.

This dissertation analyzes marketable permit systems that have been used in the United States for over 20 years to draw lessons for designing a system of marketable permits to use the global atmosphere. To be able to compare these markets that differ across multiple dimensions, I first develop an analytical framework that enables a comparative analysis of various CPR markets. This framework is then used to compare the following markets: sulfur dioxide emission allowances, CFC production and consumption permits, local groundwater, lead permits, early EPA emission trading, and wetlands-mitigation banking. Based on the findings from this comparative analysis, I then examine potential designs for an international system of marketable permits for global atmosphere.

In this introductory chapter, I first explain how CPRs differ from other types of goods and how their characteristics affect potential allocation methods. I then critically review various options that have been used in the past to prevent overuse of CPRs, predominantly command-and-control instruments versus market instruments. I then examine two approaches to privatizing CPRs, a Coasian approach and a marketable permit approach. I discuss why the Coasian approach would not work in the case of global atmosphere.

How can we then design a system of marketable permits for using the global atmosphere? Scholars have approached this puzzle in two different ways. I briefly present both approaches and discuss why they offer only a partial answer to the above puzzle. In light of these shortcomings, I then turn to a short discussion of the tasks and contributions of this dissertation. I conclude this chapter with a brief overview of the dissertation.

1.1 Types of Goods and Their Allocation Methods

Individuals consume different goods and services. Some of them, such as food, clothing, and housing are purchased in markets. When a consumer needs a pound of potatoes, he goes to a store or farmers' market and purchases the required quality and quantity. However, when an individual needs a safe environment, she does not go to a police station to purchase two hours of safety. The reason is that the security is provided not only to this individual consumer, but also to all other people in the same area. These two goods, therefore, exhibit two major differences in their consumption, rivalry, and excludability in consumption. Rivalry in consumption means that if a good is consumed by one individual it cannot be consumed by anyone else. Excludability means that an individual can prevent others from consuming this good. By juxtaposing excludability and rivalry in consumption of a good, we get four types of goods, as presented in Table 1.1. For the purpose of simplification, excludability and rivalry are depicted as a dichotomous concept. In reality, they occur over a continuum.

Goods that exhibit rivalry and excludability—private goods—are allocated efficiently in a market. In this case, individual supply/demand is expressed and then aggregated to form a market supply/demand. The clearing market price ensures a Pareto optimum—no individual could be made better off without making somebody else worse off.

Table 1.1: Types of Goods

	Rivalrous Consumption	Nonrivalrous Consumption
Excludable	Private good: Allocation by a market is efficient.	Marketable public goods (club goods): Price can be charged and therefore markets can allocate this good efficiently.
Non-excludable	Common pool resources and externalities: Resource users respond to marginal private costs rather than to marginal social costs. The result is overconsumption, underinvestment, and rent dissipation.	Pure public good: No private supply is likely to occur, because no exclusion is possible. Possible exceptions with privileged and intermediate groups (Olson, 1965).

Source: Adapted from Ostrom and Ostrom (1977:12).

A good that exhibits excludability, but not rivalry in consumption—marketable public good (Weimer and Vining, 1989) or club good (Cornes and Sandler, 1996)—can be provided in a market. As the consumption of the good is excludable, it is possible to charge a fee for provision of this good. In the case of pure public goods, where consumption is non-excludable and non-rival, markets cannot result in a Pareto optimum. Individual consumers have an incentive to misrepresent their willingness to pay and choose instead to free-ride. The pervasiveness of free riding generally leads to no market supply at all.[1] To solve this problem, governmental provision has been suggested. It is, however, not clear how government officials would obtain the relevant information. I defer discussion of the potential failures until later in this chapter.

Common pool resources (CPRs) are goods whose consumption is not excludable, but it is rival. A user of a CPR cannot prevent others from appropriating a unit from the CPR. When a unit is withdrawn, it is used by that user and no one else. In this case, therefore, individuals face an incentive to withdraw from the CPR because if they don't, somebody else will and the unit of the resource will not be available in the future. Individuals, if their behavior is not restrained, will overconsume the resource.

A CPR can be appropriated not only by withdrawing a valuable unit of a resource (gallon of water, a fish, and a barrel of oil) but also by discharging a unit of pollution into a CPR. A discharge of pollution (negative externality) is just a mirror image of the withdrawal from a CPR. In the former case, the consumption of the good is subtractive; in the latter case, the consumption of the good is additive, for example, storage of pollution in a medium. Once a unit of pollution is discharged, a small part of the storage capacity of the medium is used up and it cannot be used by any other polluter. The only difference is that the use of the resource in the former case is embodied in a withdrawn fish, whereas in the latter case, it is embodied in an increased concentration of the pollutant in the medium.

The question then is how to prevent overconsumption of a CPR due to an unrestrained behavior of individuals. Three different approaches have been used: change of appropriation rules by the resource users, governmental intervention, and privatization of the resource. I now turn to a brief review of these solutions.

First, if the resource users have the authority, knowledge, ability, and motivation to change the rules, they can craft rules that prevent deterioration of the CPR (see Ostrom, 1990 for a list of successful institutional arrangements crafted by resource users). They can limit the withdrawn quantity, or, if this is difficult to measure and monitor, they can

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[1] In specific circumstances, such as a privileged or intermediate group where one or a few persons account for a large fraction of demand (Olson, 1965), there may be some, and perhaps even nearly efficient, market supply.

limit inputs that are used in the withdrawal, that is, the access time or the used equipment. Rules restraining the access to the resource can also be created by a government. This distinction is important because in the case of a local resource, resource users have better knowledge and information about the resource itself as well as the behavior of resource users that needs to be changed and monitored. In the case of a global resource, such as the atmosphere, individual users may have the best information on the effects that global warming has on the local environment, but not necessarily on the effects in other local environments or the behavior of other individual resource users.

Intervention by a government has been suggested as the second solution. One solution is that a government taxes the activity imposing negative externality in the amount of marginal social damage (Pigou, 1946). Alternatively, the government may impose technical standards for the equipment used in the CPR withdrawal. The government can also own the resource and manage it in the public interest. In these suggestions, it was implicitly assumed that the government is a benevolent representative of the social interest, capable of aggregating the individual interests that the market failed to aggregate and in possession of complete information of individual valuations of the good. Several scholars have pointed out that governments may not be able to or are not interested in designing policies in the social interest. I review the potential sources of failure in the subsequent paragraphs.

Third, the CPR can be privatized and then allocated in a market. When property rights are well defined, markets efficiently determine what and how much is produced (based on the market prices), how it is most efficiently produced (based on the relationships between marginal productivities of inputs and their prices), how it is distributed (depending on individuals' income and preferences), and how the consumption is allocated over time (based on differences in individuals' discount rates). Price changes provide information to both supply and demand, and adjustments are made.[2] When the rights to exclusive use are incompletely specified or the costs of

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[2] Even though markets work automatically with the "invisible hand," one should not forget that they are social constructs with important social consequences (Burns and Flam, 1987b) and that they are often highly regulated by modern states.

enforcing the rights are high relative to the benefits, markets do not necessarily lead to a Pareto optimum. I discuss these problems in greater detail later in this chapter.

1.2. Government Failures

Weimer and Vining (1989) classify government failures into four groups of problems inherent in general features of a political system: (1) direct democracy, (2) representative government, (3) bureaucratic supply, (4) and decentralized government. In direct democracy, social values can be revealed in referenda. The problem is, however, that no method of voting is both fair and consistent (Arrow, 1963). It is possible that a winning bundle will not represent the will of majority. Demsetz (1964) further points out that decisions based on the majoritarian rule may not maximize welfare if Hicks-Caldorian transfers are not allowed.

Representative government is elected by a constituency. If the representatives come from subnational, geographically defined districts, they will try to represent the interests of these districts at the expense of interests of other units. For example, if a policy has concentrated economic benefits (and diffused economic costs), which often is the case when governments intervene in markets, the representatives will try to adopt a policy that will bring the concentrated benefits to their constituencies (Buchanan, Tollison, and Tullock, 1980). This often leads to policies that do not contribute to aggregate national welfare (Buchanan and Tullock, 1962).

In addition to the policies that bring benefits to the constituency, representative governments tend to pay closer attention to policies with benefits concentrated in the near future and costs dispersed in more distant future (Nordhouse, 1975). Further, representative government has a limited pool of policy options from which it can choose, determined by setting of public agendas by an executive or legislative branch. Sometimes, representatives who prefer a specific policy may need to wait until the "window of opportunity" opens.

Bureaucratic agencies do not need to pass a market test of efficiency. Their contributions to aggregate social welfare therefore depend on diligence and motivation of the representatives who determine their budgets and oversee their operations. Bureaucratic agencies often do not have to pay for the resources they use and may therefore waste them. Monitoring is very difficult and therefore inefficiency is likely to occur. In addition, it is difficult to determine the optimal size of an agency because of the lack of reliable benefits' measures. Distributional goals often further complicate the valuation problem.

Decentralization of government into different branches and different levels of government is beneficial but it usually comes at a price. Decentralization of government into different branches enables a system of checks-and-balances. Decentralization at different levels of government enables that the public policy is closer to the individuals that require and benefit from the policy, it enables a better expression of the local needs, etc. However, decentralized government can also have negative aspects. When local governments provide for local needs, they may impose negative externalities onto other localities. Also, when government is decentralized, a successful implementation of policy depends on multiple units. The lower the level at which benefits and costs of a policy are calculated, the higher the probability that there will be major differences between costs and benefits of this policy in a given unit. In this case, implementation of the policy may require costly compensation.

1.3. Privatization and Market Allocation

Arguments that CPRs are best managed by privatization have evolved in two directions. One direction followed the pioneering work of Coase (1960). According to this school of thought, secure and enforceable property rights allow for private transactions to eliminate the economic inefficiency associated with externalities. Individuals can negotiate among themselves the amount of the activity causing the negative externality and the outcome does not depend on the initial allocation of property rights if transaction costs do not exist (Coase, 1960). This solution assumes that the number of individuals is sufficiently small so that they negotiate a solution. If, however, the number of individuals exposed to a negative externality is sufficiently large, they first have to solve the collective action problem and agree on a solution. The negotiating problems are further complicated if there are multiple sources of an externality (Demsetz, 1967).[3] Modern followers of the Coasian bargaining approach—free market environmentalism—have been critiqued on the basis of high transaction costs. When private property-rights holders have to go to court to enforce their rights, the costs of enforcement can be prohibitively high (Menell, 1991; Blumm, 1992; Brunet, 1992; Funk, 1992; Krier, 1992).

The second school of thought builds on the works of Dales (1968), Crocker (1966), and Montgomery (1972). Tradeable permits have been suggested as a solution to overexploitation of CPRs. Crocker (1966) and Dales (1968) first developed the idea of using transferable discharge permits to allocate pollution-control burdens: "(i)f we can't measure water quality we can at least measure the amount of waste that is dumped into natural waters" (Dales, 1968:78). Montgomery (1972) developed rigorous theoretical arguments for implementation of tradeable permits. Different types of wastes are made comparable with the damage ratios and expressed in some common denominator. Differences in the environmental sensitivity are also taken care of by equivalents of pollution for different areas. (I defer a discussion of problems of trading permits for non-uniform pollutants until later.) A market price exceeding the marginal costs of pollution reduction would induce the polluters to reduce more than required and sell the additional pollution rights in the market. The polluters with the marginal costs of pollution reduction exceeding the market price of pollution rights could purchase the pollution rights and thereby reduce their pollution abatement costs. The aggregate pollution abatement costs would thereby be minimal.

1.4. Governments or Markets

The policy debate was usually centered on a comparison of market and governmental performance. The market approach was usually found to be a cheaper

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[3] In the case of intertemporal externalities, however, we cannot count on the actors to negotiate the optimum solution, as future generations do not exist yet (Bromley, 1989).

solution. As Dales (1968) suggests, pollution rights' markets

> "would automatically set the correct level of the pollution charge (instead of its having to be set by some committee, after long and learned discussion) and would also automatically, and continuously, adjust the level of the charge to take account of economic growth. A simple market that can be operated by three or four people and small staff of stenographers to register purchases and sales is very much cheaper, and just as efficient, as a large bureaucracy replete with computers to give answers to complicated pricing problems. If it is feasible to establish a market to implement a policy, no policy-maker can afford to do without one. Unless I am very much mistaken, markets *can* be used to implement any anti-pollution policy that you or I can dream up." (Dales, 1968:100, italics in original)

This discussion has been occurring in fields of economics and political science since the mid 1970s (Baumol and Oates, 1975; Tullock, 1990; Tietenberg, 1974). Market instruments, in general, are considered to have some basic advantages, such as (1) achieving pollution abatement in a cost-efficient way; (2) making the polluters, rather than a government, decide how to reduce CPR withdrawal and for how much; and (3) reducing the possibility for political favoritism. In addition to theoretical analyses, a number of empirical analyses compared potential effectiveness of market incentives with CAC for given environmental problems (Hahn, 1989; OECD, 1989; Tietenberg, 1986).

Tradeable permits have static and dynamic advantages over CAC instruments. They are a cost-efficient ways of reducing negative externalities, as those polluters who can reduce pollution at lower than market cost will do so, and those with higher than market costs of pollution reduction would purchase pollution permits (Atkinson and Tietenberg, 1982). Burtraw (1996) argued that permits bring cost savings over CAC instruments even without much trading. In terms of environmental effectiveness, tradeable permits (if enforced) ensure that the environmental target is met.

In addition to static economic cost efficiency, tradeable permits also have dynamic advantages over CAC instruments. Empirical results presented by Jaffe and Stavins (1995) confirm that market-based incentives create greater incentives for technology invention, innovation, and diffusion than CAC instruments. Milliman and Prince (1989) compare the effects of different market based incentives in environmental policy on adoption of new technology. They argue that auctioned permits and Pigouvian taxes provide the highest incentives to firms to adopt new technology, whereas free permits sometimes provide lower incentives.

Malueg (1989) argues, however, that in comparison to CAC instruments, emission trading may actually reduce some firms' incentives to adopt new technology, depending on whether the firm considering the new technology is a buyer or a seller in the emission credit market before and after the adoption of the new technology. Also, since demand for more effective pollution control technologies may decrease with the introduction of trading, it is possible that investment and research of new pollution abatement technologies may also fall after trading is introduced. Klaassen (1996) further pointed out that the effect of tradeable permits on innovation depends on who undertakes the research. If it is specialized firms, market incentives may create less clear-cut, more diffuse impacts on innovation.[4]

Tradeable permits are also easier to adjust when new information becomes available. They also perform better when there is either inflation or economic growth (increased demand for pollution). The increased demand simply translates into a higher price of permit whereas the fees have to be administratively adjusted.

In reality, environmental policy has, however, relied more on CAC instruments than on market incentives. This can be explained with the shortcomings of market incentives, such as the following: (1) uniform charges (allowances) may not correspond to the locally specific pollution situation; and (2) metering of actual pollution may be problematic, especially for small and mobile sources. On the other hand, the prevalence of CAC policy instruments can be explained by political preferences of the firms who would be controlled and by the preference of environmental advocates and bureaucracy. Buchanan, Tollison, and Tullock (1980) suggest that firms prefer standards to emission taxes because standards result in higher profits and also raise barriers to new entrants. Charges, on the other hand, do not preclude new entrants. Standards were also favored by environmental groups, organized labor, legislators, and bureaucrats (Stavins, 1998).

The policy analyses of market instruments were based on theories of private goods with well-defined property rights. In the case of private goods, well-defined and secure

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[4] Innovation does not depend only on the use of market incentives but also on the stringency of environmental policy; more stringent standards increase demand for pollution abatement technology.

property rights, and established and cheap markets, enable efficient exchange of property rights. If markets are competitive, details of market designs bear no importance. However, in the case of goods with insecurity of property rights and with a lack of information, the experimental literature and the empirical analyses of environmental markets indicate that the details are very important. If property rights are subject to costly case-by-case approval, users may prefer not to exchange the rights (Hahn and Hester, 1989b; UNCTAD, 1998). If measurement of the commodity characteristics is costly, special market institutions have to be designed (Barzel, 1991). If the information on valuation of the negotiated good is not publicly available (Cornes and Sandler, 1996), the market can have inefficient outcomes (goods are allocated to the individuals with lower valuation).[5] Cornes and Sandler (1996) review different mechanisms to deal with the lack of information, such as different bidding schemes that may increase efficiency in bargaining. What is needed, then, is a framework that allows a comparison of different markets, their performance, and the factors affecting their performance.

1.5. The Atmosphere as a Global CPR

The Earth's atmosphere provides a variety of services to living beings such as maintaining a balance from the incoming solar radiation and the reflection of energy from the Earth. Some human activities, however, are significantly altering the composition of the atmosphere, thereby reducing the protection provided to living beings. Specifically, many scholars believe that increased concentrations of *greenhouse gases*, such as carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, and sulfur hexaflouride, are exacerbating the *greenhouse effect* of our atmosphere. This may result in increased average temperatures, altered weather patterns, increased severity of droughts and storms,

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[5] Cornes and Sandler (1996) argue, however, that non-existence of property rights may not by itself lead us to conclude that there is inefficiency. The question, then, is which circumstances would it be socially advantageous to develop markets where private incentives do not exist? Perhaps the absence of a market indicates that other institutional arrangements exist that do a good job, considering the costs associated with a market.

and changes in the sea level.[6] Some attribute this effect largely to human activities such as fossil fuel combustion, industrial production, agriculture, and deforestation. It is suggested that the atmospheric concentrations of *greenhouse gases* (GHGs) can be reduced in two ways: (1) by reducing emissions of GHG and/or (2) by increasing the sinks[7] of these gases.

Even though there is contestation over whether the global climate is changing, what is causing the change, and what the consequence of such changes may be (Balling, 1992; Climate Change, 1995a; Global Warming Experiment, 1995; Santer et al., 1996; Tett et al., 1996), some countries have started addressing the risks associated with the increased concentrations of GHGs. Most developed countries have committed themselves, through the Kyoto Protocol to the Framework Convention on Climate Change, to reducing their net emissions of GHGs. Since fossil-fuel burning is the primary anthropogenic activity contributing to the problem, most countries have chosen to enact policies in the energy sector.[8]

International differences in emission reduction- and sink-enhancement costs have created incentives for international trading in emission reductions. Emitters from high-cost countries (such as the Netherlands and the United States) invest in low-cost countries (Eastern Europe, Indonesia, Russia, etc.) in projects that increase energy efficiency, result in lower carbon emissions per unit of energy, as well as enhance carbon sinks (afforestation and forest protection). Further, we have also seen the first international purchase of carbon storage services. Costa Rica offered the first carbon sequestration certification. Its national government buys carbon sequestration services domestically and then sells them abroad. The Kyoto protocol defined different options for

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[6] The changes may not necessarily be linear as initial changes may cause increased emissions of greenhouse gases now stored in natural sinks (carbon in vegetation and ocean, methane in Siberian permafrost).

[7] Carbon dioxide can be removed from the atmosphere through natural processes. A significant part of carbon is stored in oceans, soils, and growing biomass. Policy options for increasing carbon storage (increasing sinks) currently focus on growing biomass.

[8] Importantly, these policies may create benefits such as increased efficiency in energy use and reduced levels of local pollution irrespective of whether the threat of climate change is real or not.

international trading of emission reductions (emission allowances as well as emission reduction credits),[9] but has not yet developed clear implementation guidelines.

1.6. Various Institutional Arrangements for Privatizing CPRs

The problem of excess emissions of GHGs can be conceptualized as an overuse of an open access CPR. Since it is difficult to exclude those who use the atmosphere as a sink for gaseous emissions, extensive appropriation of atmosphere as a sink leads to deterioration of the protection that the atmosphere gives. In many other CPRs, however, the access to the resource and its use have been successfully limited and the deterioration thereby prevented.

Privatization of a CPR has long been suggested as a solution to curb deterioration of a CPR. Two different approaches to privatization have been proposed: (1) a Coasian approach, advocated by free-market environmentalists in which a resource is allocated among the users through their bargaining and trading; and (2) a tradeable permits approach, in which a governmental agency allocates the resource initially by issuing resource use permits to the users who can then trade the permits among themselves (Krutilla, 1999). The former has been suggested by free-market environmentalists, who argue that private ownership induces cost-effective behavior and pollution reduction as a private owner has to pay for the inputs (Anderson and Leal, 1991; Huffman, 1992; Stroup and Goodwin, 1992). As increased efficiency in use of resource also reduces the costs of inputs, a private owner is motivated to reduce the inputs and thereby the resulting pollution.

Unfortunately, the above logic is incomplete as it focuses only on the price of the input and misses other important variables in the decision model,[10] such as road

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[9] The Kyoto Protocol defines emission trading among the Annex I parties to the convention. The Protocol also enables countries and private emitters to invest in emission reduction in non-Annex I countries (*Clean Development Mechanism*), but the issues of defining the commodity and monitoring are challenging for the institutional design.

[10] Were this rationale correct, we would see all private car owners buying the most efficient cars. As we all know, the private ownership of cars in the U.S. has not resulted in high efficiency; on the contrary, the share of inefficient vehicles (and thereby polluting) is drastically increasing.

congestion and air pollution. Free-market environmentalists would probably argue that this is not a shortcoming of their model but a problem of low energy prices. To address the problem of low energy prices inducing too much pollution, they may suggest privatization. Private owners of clean air (or of property destroyed by polluted air) would protect clean air either in the direct market exchanges (when the victim and the polluter are in direct market relationship) or in court.

The problem with the above approach, as legal scholars point out, is not only in the effectiveness of courts, but also in the ability to point out the source of damage (Menell, 1991; Blumm, 1992; Brunet, 1992; Funk, 1992; Krier, 1992). The problems become obvious when we consider a real-world example of victims of global climate change. Think of an Eskimo who claims that his nutritional intake has been reduced due to the thawing of Arctic ice and whose trading among villages has been significantly affected because of shortening of the freeze period in which travel can occur. Or, imagine one of thousands of families who have lost a family member and their entire property due to increased severity of tropical storms. Now imagine this individual going to court and enforcing his property rights to the atmosphere with lower concentrations of greenhouse gases. Which court would the victim go to? How can she prove the causality of the action of the defendant for the decline of her property (for the doctrines of nuisance and trespass) or even loss of life of a family member (for the doctrines of negligence and strict liability). In light of these concerns, can we believe that this low probability of being sued in court would induce the defendant to reduce the risk of such dire consequences? How then can a decentralized approach to privatization of a CPR, with the resource users as primary actors defining the resource management regime, work in the global warming case?

Another possible privatization arrangement is that a bundle of tradeable rights is allocated to resource users by some recognized authority. The rights can be allocated by a regulatory instrument itself, by an existing governmental agency with a clear authority to manage the resource, or by resource users. If trading is allowed and is not too costly, the resource rights shift from the users with lower valuation to those with higher valuation of the resource. Many CPRs have been managed in this way in the U.S. These include groundwater (Blomquist, 1992; Ostrom, 1990), oil fields (Libecap, 1990), ocean fisheries (Pearse, 1992), and the atmosphere (Tietenberg, 1995). Tradeable rights, as other quantity regulations, allow for controlling the aggregate levels of resource appropriation. Further, tradeable rights provide dynamic incentives for adopting new technologies. Unlike some other incentive-based instruments (subsidies or tax refunds), resource rights do not burden governmental budgets.

Institutional arrangements seeking to prevent deterioration of a resource have to achieve multiple goals: (1) the mitigation of further deterioration of the resource, (2) the means to achieve this goal have to be cost effective,[11] (3) the arrangement should not impose significantly higher costs onto one group of users than on others, and (4) it should be flexible enough to change in light of new information. Compliance with the created institutional arrangement ensures that the resource deterioration will actually be mitigated and that mitigation burden will fall onto all resource users and not only on those who comply.

Measuring the success of an institutional arrangement in the real world is, however, more difficult, especially due to lack of data. Most analyses of markets for CPRs are fairly cautious when estimating the environmental impacts, especially for highly variable resources and highly variable environments. Those who explicitly measure the environmental effects warn us of leakage potential, that is, a shift of activity from regulated to non-regulated activities or actors. For example, reduced fishing effort in the ITQ fishery is accompanied with the increased fishing efforts in the non-regulated fisheries (McCay et al., 1995).

The real world exhibits successful and failing tradeable private property rights to flows from CPRs. The question then arises as to (1) which conditions are conducive to a

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[11] Krutilla (1999) argues that we need to include all stages of the policy process (policy formation, implementation, and monitoring/enforcement) when we assess cost-effectiveness of policy instruments. He points out that the welfare losses in the process of policy formation may be larger than the benefits in the other phases of the policy process. In this research, I do not consider the costs that occur to all participants in all policy process stages. I examine, however, how the processes may be linked and whether the implementation phase faces less friction if the regulated resource users participated in the policy process from the beginning, that is, formulated the policy themselves.

success of a marketable property rights arrangement, (2) which of these conditions result from the nature of the resource and its use, or, on the other hand, (3) which are a function of the institutional arrangement and are therefore subject to institutional design.

Many scholars study marketable property rights for a CPR from the first perspective. They examine theoretical requirements for a well-functioning market. Economists suggest that marketable rights are cost-efficient solutions to environmental problems, especially when (1) large numbers of sellers and buyers participate in markets; (2) there is certainty that government would not significantly alter the emission allocation and trading rules; and, (3) actors undertake a large number of transactions, thereby lowering individual transaction costs. Stavins (1995) suggests that the following factors are required for an effective allowance trading system: (1) differences in the costs of abating pollution among participants; (2) uniformity and mixing of a pollutant, that is, no significant local environmental effects that would reduce the spatial exchanges and segment markets; (3) patterns of costs and benefits, for example, in the case of significant uncertainty about marginal abatement costs, flat curve of marginal abatement costs, and relatively quickly falling marginal benefits, quantity instruments (such as tradeable emission permits) perform better than price instruments; and (4) tradeable permits work best when transaction costs are low. This approach tells us how the ideal market looks like and what the institutional design should accomplish. It does not, however, tell us anything about why some existing, real, and "messy" markets succeeded and others did not. What is missing is a tool with which we could measure how close markets were to the "ideal" markets, in which aspects they were closer to the "ideal" and which aspects actually caused the failure.

Others approach the question of market success by examining how the nature of a particular resource affects the performance of a market. These analyses usually focus on one or a few markets and search for the "obvious candidates" among resources (such as surface water, groundwater, timberland, and grazing land) (Krier, 1992). Hahn (1989) argues that the difference between the performance of the EPA emission trading and lead trading can be attributed to two major factors: (1) agreement/disagreement on property rights and the standards to define them and (2) ease of monitoring and enforcement.

Differences in these two factors lead to different political concerns and thereby development of different rules for trading. In the former case, there was no agreement on how much a firm can pollute, whereas in the latter case, there were regulations on how much lead can be added to gasoline. In the former case, the existing system for monitoring was weak, whereas in the latter case, monitoring was easy. Hahn (1989) therefore argues (even though he does not use this vocabulary) that the existing rules of resource use and the resource characteristics affect creation of market institutions and these in turn affect market performance. If taken to the extreme, this approach can result in a determinism in terms of which resources can be managed in one way and which in another. I agree that the characteristics of the resource affect the performance of the institutional arrangement. This link should not be viewed as deterministic, however. Resource characteristics affect the rules, but the rules are also affected by the existing legal framework and characteristics of the resource users.

1.7. Tasks and Contributions of This Dissertation

The existing literature examines particular markets in great detail and identifies some factors affecting success or failure of marketable property rights to manage a CPR. It is not clear, however, what the effect of these selected factors is when we look at a larger set of markets that performed with various levels of success. Further, if we want to draw lessons about potential carbon dioxide markets, which ones should we look at? Which variables do we consider? The existing literature lacks a theoretical synthesis that would enable us to place different institutional arrangements for carbon dioxide markets depending on the most important characteristics. I address these concerns in the subsequent paragraphs.

First, as Stavins (1998: 84) warns us, "all the successes with tradeable permits have involved air pollution: acid rain, leaded gasoline, and chlorofluorocarbons. Our experience (and success rate) with water pollution is much more limited ..., and in other areas, we have no experience at all." I include wetlands mitigation banking, because this market provides important insights for understanding the problems related to carbon sequestration, such as, evaluation of the baseline (that is, counterfactual emissions), termination of the project and how it affects the temporal character of carbon sink enhancement, and others.

Second, the existing analyses of multiple markets provide general design principles. The problem is that these design principles may sometimes be in conflict with each other and the question then arises as to which design principle is more important. For example, Jones and Corfee-Morlot (1992:21) summarize the lessons that can be learned from the US experiences in permit trading, such as the U.S. lead phase-out, California's Tradeable Emissions Program, and the SO2 allowance trading. They argue that a government should have a minimum role. On the other hand, Tripp and Dudek (1989) point out the need for clear legal authority of the administering agency to generate the rights, to implement, and to enforce the program, as well as the need for required knowledge and capacity of the administering agency. Even though these design principles seem to contradict each other, we are not able to examine their effects on the market performance if we have no common framework with which we could examine effects of particular factors on market performance.

The third question is which markets provide the most important insights for understanding a potential carbon market. For example, Stavins (1998) suggests that more can be learned from the lead phase-out program than from the SO2 program. Nussbaum (1992:39) examining the lead phase-out program argues, however, that "direct applications [for the study of global warming trading system] of some of the lessons learned in lead may not be possible." I would again argue that we cannot answer this question unless we have a framework with which we can compare different markets in terms of the traded commodity and market participants and examine how they affect market performance.

The major contribution of this dissertation is in its development of a framework that allows comparison of different markets. I look at two dimensions of a market: the commodity and the market participants. Both variables not only take a single value or two but exist along a continuum. For example, tradeability of a commodity is a continuum affected by multiple factors. I will build on the work of Ostrom and Schlager (1996), Schlager, Blomquist, and Tang (1994), and Eggertsson (1992) to examine what is the appropriate *domain* of a property right that is required for an effective market. Is it sufficient if resource users have the *operational-level property rights* (i.e., the right to access the resource and withdraw from resource or dispose of pollution)? Or, is it required that resource users also have the *collective-choice property rights*, for example, the right to manage the resource or the right to exclude other potential resource users (Ostrom and Schlager, 1996)? Further, I will build on the work of Barzel (1982) to point out that measurement costs—an important variable affecting tradeability of a commodity—depend on the characteristics of the commodity as well as on who measures them. Different markets can then be placed in the two-dimensional space of these variables. Based on these two characteristics, we can then examine variables conducive to the success of marketable property rights.

Trading in GHG emission rights has been proposed as a potential policy solution to curbing global climate change (Tietenberg, 1995). However, others have also critiqued it on grounds of high transaction costs (Richards, 1997). The study of the potentials of a carbon dioxide market could take two routes. First, one could study what the requirements are for a functioning market and then examine how a carbon dioxide market would meet these requirements. Second, one could examine the existing markets for environmental amenities (inputs to the production and sinks of pollution) and compare the potential carbon dioxide market to these markets.

In this research, I propose to take the second route. I will examine where on the continuum of commodity tradeability and market participants would different carbon dioxide market arrangements fall and suggest how the performance may be increased by changing the aspects of the commodity or market participants. This research will potentially help answer questions on alternative carbon market designs, such as: (1) can we have a successful carbon market with a case-by-case definition of commodity and how can we improve tradeability of this commodity; (2) which actors should be included in the trading and how will this decision affect market performance; and (3) how are the two aspects of the market, commodity and the market participants, related and how they jointly affect market performance?

Another shortcoming of the existing analyses is, however, a lack of focus on compliance, its links to liability systems, and the resulting market performance. Resource management requires monitoring and enforcement, and both activities are costly. Too rigid monitoring requirements were also indicated as an impediment to trading (Tietenberg, 1995; Hahn, 1989). No one, however, explicitly measures compliance. Some have even argued that a market mechanism itself would enforce the quality of a commodity. Dudek and Tietenberg (1992) argue that the market itself would impose compliance (similar to the secondary debt market). They suggest that actors would not purchase emission reductions from those whose emission reductions would have lower reputation. Scrutiny of domestic regulators in the certification of domestic compliance would tend to discount credits from lower reputation countries. "The market itself, reinforced by the decisions of regulators not to accept anything less than full emission value, would produce the required international enforcement" (Dudek and Tietenberg, 1992: 266). The question, then, is whether the burden of proof lays on the seller or on the buyer.

1.8. Overview of the Dissertation

In Chapter 2, I review the neoclassical and neoinstitutional theories in the context of providing solutions to curbing GHG emissions. Economists argue for adopting market-based instruments, as they exhibit the following characteristics: stimulate cost-efficient attainment of environmental policy goals; provide dynamic incentives for individuals to invest in pollution reduction; may result in pollution reduction beyond the policy goal; and allow for flexibility in goal attainment. However, market performance may be limited by high transaction costs borne by both individual actors and governments. Neoinstitutional theories therefore suggest examining multiple institutions, including markets, to minimize the total cost (including transaction costs) of reducing GHG emissions.

In Chapter 3, I develop an analytical framework that allows for comparing various CPR markets, their performance, and the factors affecting it. The framework is employed in the subsequent four chapters. In Chapter 4, I examine the sulfur dioxide allowance market, which is the most developed CPR market. Since this market seeks to reduce air pollution from electric utilities, it offers important insights for understanding the potential carbon dioxide market. In Chapter 5, I analyze markets for the rights to use atmosphere as a sink for pollutants that remain in the local environment. I study the early EPA trading programs for local air pollutants, the Lead Phasedown program, and the current RECLAIM market. In Chapter 6, I turn to markets for the rights to use the atmosphere as a sink for substances that affect us globally. I also examine the markets for rights to develop wetlands.

In Chapter 7, I discuss the implications of my analysis for potential carbon dioxide markets. This chapter presents the major policy contribution of my study. In the concluding chapter, I summarize the main findings of my study, discuss how they augment the existing literature on CPRs and marketable permits, and present some potential areas of future research.

CHAPTER 2

WHAT MARKETS FOR COMMON-POOL RESOURCES DO NOT HAVE IN COMMON

The previous chapter concluded that degradation of a CPR due to over exploitation (excess withdrawal or pollution discharge) could be halted if property rights to the resource are allocated among individual users and trading of these rights is allowed. This chapter first discusses which property rights can be allocated among users and who can allocate them. I review how the definition and exchangeability of the rights may differ based on the resource characteristics.

Then, I turn to individual markets for CPRs to point out large variability among these markets in terms of the allocated rights, the rules that regulated trading among right-holders, and performance of these markets. As the goal of this research is to examine potential carbon dioxide markets, I then review the lessons for devising these markets that scholars drew from the analyses of extant and past markets. Then, I present the existing institutional arrangements for potential international carbon dioxide markets. I conclude this chapter with a discussion of questions that existing analyses have not answered.

2.1. Property-Rights Regimes

If ill-defined property rights are an important ingredient of externalities (Cornes and Sandler, 1996), then defining property rights may be one solution to the problem. Dales (1968:76) suggested that "(i)t is high time that we began to devise some new forms of property rights, not to air and water, but to the *use* of air and water." As "(a) property right is enforceable authority to undertake particular actions related to a specific domain" (Commons, 1968, cited in Ostrom and Schlager, 1996), we would expect property owners to be able to design institutions to prevent deterioration of their resource and the imposition of negative externalities by others. The question then arises as to who can define property rights and what bundle of rights is necessary for the property owners to prevent a deterioration of the CPR and/or imposition of negative externalities. Let us briefly review the theoretical debate on these issues.

The solution to the "tragedy of the commons" (named by Hardin, 1968, but identified already by Aristotle) was suggested to be the assignment of property rights to resource users (Gordon, 1954; Hardin, 1968; Dales, 1968). The question, then, is who can assign the property rights? One suggested solution is that a government assigns property rights. In this case, the property rights can either be vested in the entire population or allocated among the existing users. In the former case, the resources are supposed to be managed by a governmental agency in the interest of the entire population. This property regime was used for protection of natural areas in the U.S. both at the national and the state level. This property regime exhibits its own problems, some of which were discussed in Chapter 1.[1] In the latter case, the rights to using the resource are allocated to existing users, whereas those who currently do not use the resource face entry barriers. For example, the Clean Air Act Amendments (CAAA) of 1990 allocated the right to discharge pollution to the existing electric utilities whereas the new entrants will have to purchase the rights as they enter the industry.

On the other hand, a small group of resource users, who have authority over the resource they use, can design rules of appropriating the resource that they jointly own. Reports of numerous studies indicate that such groups of individuals exercise governance and management activities to prevent a jointly owned resource from deterioration (Ostrom, 1990; Schlager, 1994; Tang, 1994; Agrawal, 1994; Blomquist, 1994; Lam, 1998; Ascher, 1995). The success of local management of a CPR depends on many factors, such as attributes of the resource, the community, as well as the extent of authority the community has over the use of its resources (Ostrom, 1990). Ostrom and Schlager (1996) point out that all types of property regimes, whether locally selected or externally imposed, try to design rules that reduce the social costs of open-access regimes. These different property-right regimes, however, perform differently depending on the attributes of the resource, the local community, and the specific rules used. The problem,

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[1] For more detailed discussion of public property problems in environmental management in general, see Baden and Stroup (1981); for land management, Libecap (1983); forests, O'Toole (1988), Libecap and Johnson (1979), Nelson (1995); and for differences between public management at the federal and state level, see Lowry (1996) and Koontz (1998).

then, is not rivalry and non-excludability in the consumption of a CPR, but a lack of rules regulating the appropriation of the resource.

Findings in the studies of local CPRs have their parallels in the studies of global CPRs, for example, global monetary regimes or global environment. The learning from local CPRs can be translated to global CPRs, even though a global CPR may be used by a larger number of users who are also more heterogeneous than those at the local level (Keohane and Ostrom, 1995).

The second issue related to property rights is the question of which bundle of rights is necessary for owners to prevent deterioration of a CPR and/or imposition of externalities. Ostrom (1997) points out that economists addressing the questions of property rights usually equate well-defined property rights with the right to alienate. If the property-rights holders cannot trade their resource for other resources, and if someone with a higher valuation and/or more efficient use of the resource cannot purchase the resource, the resource is not allocated efficiently (Demsetz, 1967, cited in Ostrom, 1997). Numerous studies of locally managed CPRs again indicate that a CPR resource can be protected from deterioration even if the resource users only hold a permit that entitles them to withdraw from the resource, but are not allowed to sell it. The question whether this is the most efficient use of the CPR remains open. One needs to recognize, however, that economic efficiency is not the only criterion of successful management of the resource. Local resource users may find fairness in access to the resource more important than economic efficiency.

Ostrom and Schlager (1996) discuss the bundles of rights that resource users potentially have. They differentiate among resource owner, proprietor, claimant, authorized user, and authorized entrant. The rights that are associated with each position are presented in Table 2.1. Let me illustrate the importance of the distinction among different rights on the case of Individual Transferable Fishing Quotas (ITQs). The right to access a fishery could be given to authorized fishers by an authorized agency, either a local government that manages the resource or a national agency. The authorized fishers have the right to access the resource (enter the fishery), to withdraw a flow from the stock of the resource in the amount of the quotas they hold, and to sell their individual rights

(ITQs). They cannot decide, however, who is authorized to enter the fishery, neither can they decide what total allowable catch will be divided among the quota holders. ITQs, which are frequently referred to as privatization, then, do not involve full ownership. If ITQs can be transferred at low transaction costs, then this property regime satisfies the economic efficiency criterion. However, as the total allowable catch is determined by the authorized agency and not by the resource users, the environmental effectiveness of this property regime on the regulated fish species is not ensured as it may exhibit some of the government failures discussed above.[2]

Table 2.1: Bundles of Rights Associated with Positions

	Owner	Proprietor	Claimant	Authorized User	Authorized Entrant
Access	x	x	x	x	x
Withdrawal	x	x	x	x	
Management	x	x	x		
Exclusion	x	x			
Alienation	x				

Source: Ostrom and Schlager, 1996: 133

In sum, it has been argued that the successful management of a CPR requires well-defined property rights, but not necessarily a full ownership. The bundle of rights required for successful management will depend on the goals of the management (I defer a detailed discussion of multiple criteria of successful institutional arrangements until later in this chapter), on resource characteristics, and on the resource users.

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[2] This is not to say that the rules governing the use of ITQs do not have an environmental effect. On the contrary, enforcement rules of the ITQ system can have a strong environmental effect on discard of by-catch.

2.2. Tradeable Permits

Environmental theory, simulation models, and empirical analyses of tradeable permits point out that tradeable permit markets do not necessarily meet the requirements for an efficient market and that they sometimes have negative environmental effects. In this section, I review the suggestions of the theory and simulation models. I turn to empirical analyses in the next section.

The following restrictive conditions must be met for trading of emission permits to achieve least-cost solutions: (1) certainty about property rights, (2) a competitive market in permits and product of the externality-causing activity, (3) cost-minimizing behavior of the CPR appropriators and/or externality generators, (4) low transaction costs, and (5) perfect enforcement. Empirical analyses of performance of marketable permits indicate that in the real world, some of these conditions are not easily met. I now turn to a review of the impacts of the above factors on the performance of tradeable permits.

Certainty about property rights ensures that the right-holders benefit from the investments in the reduction of externalities (they will be able to sell the access permits in the market). The levels of certainty depend on policy factors such as the commitment of the regulatory agency to this policy instrument, and on the physical and technological characteristics of the environmental problem (McCann, 1996; North, 1990; Dwyer, 1992; Hahn, 1989). The more variable and unpredictable is the environmental problem, the more uncertain are the future allocation of permits, trading rules, and qualifications for participating in the market.

Measurability of the CPR flow (or discharge of pollution) is another important issue related both to certainty about rights and to successful monitoring. Ostrom and Ostrom (1977) argue that measurability of a good or service (henceforth products) is key in decisions about its provision and production. Nelson (cited in Weimer and Vining, 1989) argues that a possibility of establishing the product's attributes either at the point-of-purchase (search goods) or through consumption (experience goods) affects measurement costs, thereby the organization of markets. This raises two questions: (1) which actor has the produce information about the product; and (2) do the participants trust each other about the presented information? Barzel (1982, 1991) argues that the party with lower costs will do the measurement if the parties trust each other. Different market practices can be devised to increase trust, such as warranties, professional certification, and share contracts.

Competition in the permit market as well as in the output market also affects the performance of the market in terms of efficiency and equity (Hagem and Westkog, 1998; Malueg, 1990). Market power causes loss in efficiency, but this can be reduced with appropriate permit allocation. This design may, however, entail intertemporal trade-offs. Implementation of tradeable permits may result in decline of social welfare even if the permit market is competitive but the output market is not. In this case, the loss of profits of some firms may outweigh the gains in consumer surplus resulting from the increased output. Malueg (1990) shows that social welfare may fall with the introduction of tradeable emission rights even though the emission rights market is competitive and there are no transaction costs, if the output market is not competitive.

Tradeable permits may not be cost-efficient if the permit holders do not minimize their costs. This is not as strange as it sounds. Many externality sources are large utilities that are regulated for non-environmental purposes. The existing regulation may, therefore, limit the regulatee's autonomy to take advantage of opportunities offered by emission trading (Foster and Hahn, 1995; Burtraw, 1996; Dwyer, 1992; Hahn, 1989).

High transaction costs, that is, costs of finding a trade partner, negotiating a contract, transferring the title, and enforcing the contract, impede trading, thereby reducing the number of successful trades (Foster and Hahn, 1995; Richards, 1997; Hahn and Hester, 1989b; Stavins, 1995; Tripp and Dudek, 1989; Alchian and Demsetz, 1994). Stavins (1995) further points out that with high transaction costs, the final equilibrium is also dependent on initial distribution of permits–which previously was thought as having no efficiency consequences (Montgomery, 1972).

Monitoring and enforcement of both resource rights allocations (prevention of cheating) as well as of market exchange are necessary for effective market-based exchanges. Malik (1990) and Keeler (1991) explicitly point out that the major advantage of tradeable permit systems--the ability of the regulating authority to determine the level of pollution--may be in danger with imperfect enforcement. Very simply, it is not only the price of the allowance and the abatement costs that enter the decision model, but also the penalty for the marginal unit of pollution. Noncompliance affects market equilibrium with a lower price than in the case of full compliance. Further, depending on the levels of penalties, tradeable permits may actually allow more pollution due to noncompliance than CAC standards (Keeler, 1991).

Property rights can be monitored and enforced by resource users/market participants themselves, or by an administrative agency. Even in the latter case, monitoring often relies on self-reporting. This raised concerns about environmental effectiveness of tradeable permits as it is easier to measure whether the prescribed pollution control devices are installed (in the case of CAC policy) than to rely on self-reporting of polluters (Mann, 1994). Further, empirical analyses of individual transferable fishing quotas indicate that the effectiveness of this instrument can be substantially different depending on what is monitored and enforced. If resource users' reports of fish landings are used for monitoring, then a potential for misreporting exists. Further, if users are not required to report data on the resource that they potentially destroy in the withdrawal process, then the reported impact on the resource may differ substantially from the actual damage.

Implementation of tradeable permits has identified some important shortcomings of this policy instrument. Allocation of quotas to CPRs as well as market rules can have substantial distributional effects (Libecap, 1990). Environmental effectiveness of tradeable permits was also shown to be less than expected due to the "leakage problem", that is, a shift of externality causing activity from the regulated resource to a non-regulated one. For example, reduced fishing effort in an ITQ fishery is often accompanied with the increased fishing efforts in non-regulated fisheries. Analyses of fishing quotas indicate that individual transferable quotas may work for individual species but do not work from an ecosystem perspective (McCay et al., 1995). In sum, environmental effects of markets for CPRs will depend on the characteristics of its resource, predominantly on its variability, existence of substitutes, and overlapping ecosystems.

2.2.1 Types of Tradeable Permits

The above-mentioned conditions and their effect on efficiency and environment differ across tradeable permit markets. One major characteristic is the type of tradeable permits. Tradeable permits can be of two distinctive types depending on their baseline and the actors who can participate in their market-based exchange. The first type, that is, an emission permit system, entitles permit holders to emit up to the maximum levels allowed by the permit. This system requires that an authorized agency determines the total flow from the resource for a given period (amount of pollution or total allowable catch; therefore, this system is also called a closed market) and then allocates this aggregate among polluters or appropriators of a CPRs. The second type -- emission reduction credit (ERC) system -- is based on quantifiable emission reductions that an emitter accomplishes and is awarded a corresponding credit by an authorized agency. This system requires no knowledge of the aggregate flow from the resource (or discharge) that is allowable to maintain the stock of the resource. Everyone with a capacity to reduce emissions can participate in this market (therefore, this system is also called an open market). This system, however, requires the accreditation of emission reduction projects. I discuss both systems in greater detail in Chapter 3.

Permit systems can be further examined based on whether or not the emission permits are differentiated with respect to the location (Tietenberg, 1980). This is of particular importance for externalities that exhibit geographically non-uniform effects. The undifferentiated discharge permit (UDP) system gives the same emission entitlement to any emitter regardless of where it is located. Differentiated systems, on the other hand, allocate permits (ambient permits) to permit holders based on their location. This system allows each permit holder to discharge one "standardized" unit of pollution, whereas the standardization refers to the receptor location. A separate permit system is designed for each of the key receptor sites. An i-th emitter, therefore, has to hold a portfolio of ambient permits (Baumol and Oates, 1975) for all receptor points in which it causes pollution in a period t

$$AP_{it} = \sum AP_{irt}. \qquad (2.1)$$

Ambient permit of the i-th polluter for the r-th receptor point is not equal to an ambient permit of j-th polluter for the same receptor point, as the dispersion of the emissions of these two emitters may not be the same. Trading of ambient permits is, therefore, based on ratios that reflect pollution dispersion from the two sources. This system is quite demanding for polluters, as they have to hold a portfolio of ambient permits. Trading of permits for each receptor point is based on pollution dispersion ratios, which in turn increases transaction costs.

The problem of trading ratios and multiple receptor points can be avoided if the entire area is divided into zones. An individual polluter then has to hold permits for all zones, but trading within a zone is on a one-to-one basis. This system still requires that the authorized agency issuing the permits know beforehand how many permits to issue in each zone. This requires complicated air quality modeling and emission inventories (Baumol and Oates, 1975). This system creates, however, potential for deterioration of environmental quality, as the quality depends not only on the quantity of emissions, but also on dispersion of particular emissions, on stack height, and other pollution characteristics. These problems can be addressed in a "pollution-offset system."

A "pollution-offset system" is based on emission permits allocated to individual emitters, but requires that each trade does not decrease environmental quality at each receptor point. If the environmental quality at one receptor point can decrease due to the transfer of offsets, then the offsets cannot be traded on a one-for-one basis, but at a ratio that reflects the pollution dispersion ratios. Baumol and Oates (1975) argue that this system faces lower transaction costs than the ambient permit system because the sources do not have to trade in multiple markets. It also does not require the receptor points to be determined beforehand; they can be determined for each trade if the problem of hot spots occurs.

2.3. Analyses of the Existing and Past Environmental Markets

In this section, I move away from findings of environmental theory and review empirical analyses of various markets for CPRs. This short review illustrates vast differences in the institutional arrangements and analytical approaches in measuring their performance and the contributing factors. Most of these programs regulate air pollution.

(1) The EPA's Emission Trading Program began in 1974. The *netting* program was designed to solve the dilemma of economic growth versus environmental quality. The program was targeted to areas that did not meet ambient air quality standards. By allowing internal trading, it enabled new sources of emissions to be built in the non-attainment areas. Trades were subject to approval at the state level. The program was further improved when external trading (*offsets'* trading) was allowed. The third step was achieved in 1979 with *bubbles*. This arrangement treated a plant as if there were a bubble over the facility and allowed the firm to focus on their aggregate emissions rather than each individual emission source (Hahn and Hester, 1989b; Klaassen, 1996). These initial emission trading programs were in general not considered successful. Klaassen (1996) found the performance of the offset trading program to be poor, even though the cost savings were impressive. Atkinson and Tietenberg (1991) suggest that the "bubble" trading has realized benefits smaller than expected. On the other hand, Hahn (1989) argues that both netting and bubbles experienced substantial cost savings. He points out, however, that most of the savings have been realized by internal trading.

Poor performance of these markets has mostly been attributed to non-uniform effects of pollutants. These pollutants had local air quality effects. Difficulties in monitoring restricted trades and resulted in different rules for different areas (Klaassen, 1996; Dudek and Palmisano, 1988). The effect of this difference on trading has, however, not been explored. Difficulties in monitoring and enforcement resulted in few trade approvals (Hall and Walton, 1996). Search costs were also very high (Hahn and Hester, 1989b).

(2) The U.S. Lead Phase-Down program was established to phase-out lead, used by petroleum refineries as a gasoline additive. The program had a clear time limitation. It was intended to operate for only five years, just enough to enable flexibility in reduction of lead content in gasoline. The market started in 1982, intertemporal exchange was allowed in 1985, and the program expired in 1987 (Hahn and Hester, 1989a; Kerr and Mare, 1997). The Lead Phase-Down was considered to be a major success (Hahn, 1989; Kerr and Mare, 1997; Hahn and Hester, 1989a). Hahn (1989:102) argues that the

program had high level of trading activity, "far surpassing levels observed in other environmental markets." The data on cost-savings were unfortunately not available. The success of this program has been attributed to the following characteristics of the program: (1) it was considered to be the closest of all markets to a theoretical market; it exhibited low administrative requirements (Hahn and Hester, 1989a); (2) the group of polluters was homogeneous; and (3) the resource users (gasoline refineries) had traded with each other extensively in the past (Hahn and Hester, 1989a; Hall and Walton, 1996, Kerr and Mare, 1997).

(3) Market for allowances for production of different CFCs (substances depleting the stratospheric ozone) was created in the U.S. in 1988 as a result of international cooperation. Producers and consumers were allocated baseline production and consumption allowances. Different *ozone depleting potentials* were taken into account. Allowances were grandfathered. The EPA was to be notified by participants about the intention to transfer allowances and responded within three working days. Allowances were transferable within producer and consumer categories. Imposing an excise tax on these substances eliminated the risk of windfall profits. There were thirty-four participants in the market. By 1991, eighty trades had occurred (Tietenberg, 1995). Trading of the CFC production and consumption permits faced uncertainty about property rights, which was reflected in uncertain baselines, frequent policy changes, and confiscation of banked rights (Klaassen, 1996). On the other hand, Tripp and Dudek (1989) argue that trading was successful. They do not, however, even mention enforcement problems.

(4) The sulfur dioxide emission permit trading was enacted by the Clean Air Act Amendments 1990 to tackle the problems of acid rain. Emission permits in the first phase of the program were assigned to 111 electric utilities. In the second phase (starting in the year 2000), almost all electric utilities will be required to limit their sulfur dioxide and nitrogen oxides emissions. The Chicago Board of Exchange operates regular auctions for the EPA. Private brokers also entered the market and reduced transaction costs. Acid rain trading is considered to be a great success (Ellerman et al., 1997a; Joskow and Schmalensee, 1998). Total abatement costs are significantly less than they

would be in the absence of trading (Stavins, 1998; Ellerman et al., 1997a), targeted emission reductions are not only accomplished but exceeded (Stavins, 1998; Ellerman et al., 1997b), number of trades is increasing through the life of the program (Stavins, 1998). On the other hand, Klaassen (1996) argues that trading volume is low.

The success of this market arrangement is attributed to the following factors: (1) reduction of transaction costs by services provided by private brokers (Joskow, Schmalensee, and Bailey, 1998); (2) no prior requirements for trades; (3) absolute baselines; and (4) important innovations for monitoring and enforcement (Stavins, 1998). On the other hand, Klaassen (1996) identifies two potential reasons for lower than potential trading volume in auctions: the auction design and the uncertainty related to the forthcoming deregulation of the industry.

(5) The Regional Clean Air Incentives Market (RECLAIM) covers sulfur dioxide and nitrogen oxides emissions in the Los Angeles region. As opposed to the EPA sulfur dioxide trading, this program targets smaller emitters of NOx and SO_2 (stationary sources that produce more than four tons a day of either pollutant). Allowances were allocated on the basis of actual historic emissions. As of June 1996, there were 353 participants in the program and they traded more than 100,000 tons of emissions with value exceeding $10 million. The program currently covers only stationary sources, though mobile sources can opt-in (Hall and Walton, 1996).

There is no agreement on how successful the RECLAIM is. McCann (1996) points out that after a year and a half, only about 2 percent of the Reclaim Trading Credits (RTCs) of those available in the next nine years were traded. On the other hand, Foster and Hahn (1995) do not address the question of success, but show that firms employ trading mechanisms that reduce the transaction costs (such as internal trading, and exchanges in clusters of pollutants). Hall and Walton (1996) attribute the success to two factors: (1) an agreement that the environmental targets are acceptable and necessary; and (2) the support of the program by two industries that gained from the program (oil refineries and electric utility), as the program ensured a moratorium on any changes for three years prior to the enactment.

In addition to the above-described national and regional markets for air pollution permits, markets were also created for water pollution permits, wetlands mitigation projects, fishing quotas, and groundwater withdrawal rights. Water pollution permit markets are fairly complicated, as they have to take into account the pollution dispersion models. Most of them were not considered successful (Tripp and Dudek, 1989).

(6) Wetlands provide environmental services, such as water purification, groundwater recharge, and control. These services are, however, difficult to monetize (King, 1998). Section 404 of the Clean Water Act of the U.S. (1993) requires the U.S. Army Corps of Engineers in cooperation with the EPA to issue permits for activities that discharge or fill material into waters, including wetlands. The program allows landowners, which destroy wetlands on their property, to purchase wetlands mitigation credits. These credits can be created by wetland preservation, restoration and creation, though they are not considered to be equally effective. The difference in their performance should be reflected in trading ratios (King, Bohlen, and Adler, 1993). These activities have been undertaken by private sector, public agencies, and by non-governmental organizations. The wetlands mitigation banking is being developed without detailed federal guidelines. Several states currently have mitigation banks, but Florida has the largest number. In 1992, the Environmental Law Institute studied the existing wetlands banks. There were 46 banks located in 17 states. Nearly 75 percent were state highway banks, ports, or local government banks, providing mitigation for public works. State departments of transportation operated twenty-two of the 46 banks. Private developers controlled six banks. Only one bank was commercial, offering permits for commercial sale. However, of the 64 proposed banks in 1992, 15 were private, proposing to offer credits for commercial sale; 17 were government-owned, but proposing to offer credits for commercial sale (Environmental Law Institute, 1993).

(7) Institutional arrangements protecting the overuse of ground water were created in Southern California (Blomquist, 1992). Local users noted the problems of overdraft and filed suits in courts to adjudicate the water rights. Once the courts adjudicated water rights (often the solutions were suggested during the negotiation among users), water markets developed in four out of seven basins. In these four basins, pumping rights were

quantified, individualized, and made transferable. Water was transferred in four ways: (i) water exchange, when those who had more than they needed offered water. No rights were transferred and all transfers were concluded within a year; (ii) transfer of water rights from one category of owners to another category of owners (e.g., from agricultural owners to municipal users). These transfers entailed no monetary rewards; (iii) lease markets that seem to be more active than exchange markets[3]; and (iv) permanent transfer of water rights.

(8) Individual tradeable quotas (ITQs) are extensively used in New Zealand, but are only slowly being developed in the U.S. The first market in ITQs in the U.S. was developed for surf clams and ocean quahog fishery in the Mid-Atlantic region in 1990. McCay et al. (1995) point out that the surf clam and ocean quahog fishery in the U.S. resulted in consolidation of ownership. Efficiency in the surf clam fishery increased (increase in number of fishing hours per vessel, and productivity per vessel). The number of fishing trips declined and the pressure to withdraw resource early in a season was reduced.

2.4. Lessons Learned from Comparisons

Some scholars reviewed multiple markets to understand what affects their performance and presented suggestions for a well-functioning market. Most of the suggestions focus on one or more of the following aspects: (1) requirements for the agency implementing the program, (2) allocation method, (3) definition of the commodity, (4) security of property rights, (5) flexibility of the program, (6) trading rules, and (7) reduction of transaction costs.

Regarding the agency creating and implementing a program, there are not many detailed suggestions. Authors point out that the agency must have the authority to implement the program and the required knowledge (Tripp and Dudek, 1989). There is no discussion of how different types of agencies affect the performance.

The allocation method is important as it affects market efficiency (as pointed out

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[3] Blomquist (1992) identifies two reasons for this: (a) leases can extend for more than a year and (b) can include the lessor's carryover right and the decreed pumping right.

by theoretical analyses) and political acceptability. The problem is, however, that the most politically acceptable allocation scheme--grandfathering--does not maximize efficiency (Jones and Corfee-Morlot, 1992; Stavins, 1995). Tripp and Dudek (1989) further point out that the program, which provides an equitable allocation scheme, may not be administratively simple.

There is also a broad agreement on the impact of the definition of the traded commodity. Several authors have pointed out that tradeable permit markets perform better than emission reduction credit markets (Stavins, 1995; UNCTAD, 1998). Cap-based allowance trading systems exhibited lower abatement and transaction costs, and greater environmental gains than emission reduction credit trading systems. The reason the latter were not successful lies predominantly in the fact that they had higher transaction costs and greater uncertainty in trading.

Several authors agree that security of property rights is essential for a successful trading (Klaassen, 1996; Dudek and Tietenberg, 1992; Dudek and Palmisano, 1988). They point out that the rules should not be changed often or at least not unpredictably. They also advise against discounting of allowances as they are traded. If necessary for environmental reasons, the reduction should be achieved by reducing the total cap of allowed emissions (UNCTAD, 1998). Not many, however, realize that there is a trade-off between increased security of property rights and flexibility of environmental targets (UNCTAD, 1998).

Monitoring and enforcement are considered to be one of the most important factors for successful trading. Some scholars point out the need for an independent auditing process (Jones and Corfee-Morlot, 1992), while others stress the need for sufficiently high penalties for non-compliance (Jones and Corfee-Morlot, 1992; UNCTAD, 1998). Banking is stressed as it increases the temporal flexibility of the emission control (UNCTAD, 1998), gives polluters more time to find trading partners, thereby increasing flexibility. It may also lead to earlier resource use reductions (Klaassen, 1996).

Flexibility is stressed both in terms of the need to change the targets of the program over time (Jones and Corfee-Morlot, 1992) and the need to allow multiple actors to participate in the trading program (UNCTAD, 1998).

As transaction costs are considered to be one of the most important impediments to trading, it is not a surprise that most scholars stress the need for reducing transaction costs. They point out that the regulatory agency should reduce barriers to private brokerage services and barriers to trades. Private brokers cannot only reduce transaction costs by finding potential partners, but also by assuming risks by buying, holding, and selling permits. Trade pre-approval should not be required and oversight of trades should be limited (Stavins, 1995; Klaassen, 1996; Dudek and Tietenberg, 1992). The regulatory agency should make trading data publicly available to further reduce transaction costs (Dudek and Tietenberg, 1992; UNCTAD, 1998). Though, on the other hand, it was argued that availability of data to the public could actually reduce motivations for trading due to a fear of having business secrets revealed to competitors.

2.5. Existing Institutional Foundations for an International CO_2 Market

At the Kyoto conference, developed countries agreed to limit their emissions of greenhouse gases; on average to reduce emissions by 5.8% from the 1990 level by 2008-2012. Major progress was achieved with the protocol allowing for maximum flexibility in achieving emission reductions. Three articles in particular address the flexibility issue and possibility of international cooperation: (1) Article 6 that allows Joint Implementation; (2) Article 12 that defines Clean Development Mechanism (CDM); and (3) Article 17 that defines emission trading. Though the Protocol does not explicitly say that countries may authorize legal entities to participate in emission trading, it also does not preclude that. The articles referring to the trading mechanisms are discussed in greater detail in the subsequent sections.

(1) The Bubble approach (Article 4 of the Kyoto Protocol) allows for a voluntary agreement among countries--who have committed to reducing emissions by a given percent (Annex I countries)--to meet their emission reduction targets jointly as a group. The Bubble approach, therefore, allows a subset of countries to negotiate their own rules of trading even though the entire group of parties has not agreed on rules and guidelines.

(2) Article 17 allows for emission trading: trading in emission allowances between governments of Annex I countries or alternatively, between private entities in those countries. The partners have to be in Annex I countries because only these countries have committed to reducing their emissions and can therefore be allocated allowances. If a national government allocates national allowances among private entities, these entities can engage in trading. The authors of the UNCTAD (1998) report argue that domestic allowance allocation is not a prerequisite for the private entities' international trading. What is necessary, however, is that national governments develop schemes for crediting emission reduction credits for private projects that can then be traded as a part of the national allowances.

(3) Joint implementation (Article 6) enables Annex I countries to engage in emission reduction projects jointly and divide the resulting emission reductions. The division scheme has to be negotiated prior to project approval. The bubble concept and joint implementation are different in that the former is a general emission target agreement whereas the latter is a project-specific agreement.

(4) Clean Development Mechanism (Article 12) enables joint projects between Annex I countries and non-Annex I countries (countries without emission reduction targets, mostly developing countries). A project assists the developing country in finding a sustainable technology, and in return, provides the private and/or public entity from the developed country with the certified emission reductions. A CDM project will be subject to the guidance of the Conference of Parties, that is, it will be certified by operational entities of the Conference of Parties. The emission reductions have to be real, measurable, and additional to any that would occur in the absence of the certified project activity. Any certified emission reductions resulting from clean development projects between the year 2000 and the beginning of the commitment period can be used for achieving compliance in the first commitment period (United Nations, 1997: Article 12).

In sum, the four mechanisms differ with respect to (a) the traded commodity--emission allowances (Article 17), Emission Reduction Units (Article 6), Certified Emission Reductions (Article 12); and (b) actors involved in these cooperative mechanisms--national governments of Annex I countries (Article 4), national government and/or firms from Annex I countries (Article 17), national governments and firms in Annex I countries (Article 6), and non-Annex I countries (Article 12).

Several authors have examined potential arrangements to implement these mechanisms. Though most of them focus on the U. S. (Richards, 1997; Environmental Law Institute, 1997a; Senator Jeffords initiative S.687:105), some extend the examination to the international level (Tietenberg, 1997a; UNCTAD, 1994; 1998).

Richards (1997) focuses on the sequestration projects for storing carbon in growing biomass. He points out that there is a trade-off between production and measurement costs of carbon sequestration projects. Measurement costs differ across sink preservation projects and sink enhancement projects. The former can be provided either by the government (local, state, or federal level) or by the private sector, whereas the latter faces such high measurement costs that it is better if they are provided by a government (he does not specify which level of government).

Richards (1997) suggests a four-element hypothetical carbon sequestration program. As the first step, federal government can engage in production of carbon offsets at federally owned lands and sell those to private firms. As a result, the government controls the production. He argues that this option has the following advantages: (1) it is one of the lowest cost options; (2) this may be the fastest way; (3) this way the government gains experience (with production, monitoring, and estimation) necessary for future policy implementation; and (4) by linking the carbon-sink enhancement projects to other functions of governmentally owned forests (recreation, watershed management, etc.), the commitment to keeping this timber out of wood markets is stronger than if the private sector were to provide carbon sequestration (Richards, 1997).

At the second stage, once the government is sufficiently experienced, large parcels of private land (over 500 acres) may be used to enhance sinks by afforesting marginal agricultural land. Government would pay a subsidy for carbon capture. In the third step, government would stimulate afforestation at small privately owned parcels. This policy of including smaller owners would decrease the production costs, but the transaction costs would probably rise significantly. This approach would be similar to the U.S. Department of Agriculture's Conservation Reserve Program. To keep the monitoring costs low, payment would depend on the input, not the output.

The Environmental Law Institute (1997a) report examines only the emission side of the global climate change policy. It suggests two distinct carbon dioxide market models, based on whether fossil fuels or economic activities causing the emissions are regulated. The report also discusses a combination of both models. A "fuel model" would apply to energy providers (coal and oil companies). This model would capture 98% of all CO2 emissions in regulating only 3,000-6,000 entities. It would provide allowances to coal, natural gas, and petroleum producers, exporters, and importers. Alternatively, the distributors of such products could be regulated. This model would affect a small number of entities but would cover almost all CO2 emissions from energy sources. An "industrial model" would regulate the major industrial users of energy and would capture approximately 67-80 percent of domestic CO2 emissions by covering electric utilities, transportation, and selected major manufacturing industries.

A tradeable credit system regulating emission from the electricity sector was proposed for the United States by Senator Jeffords. He introduced a bill with a tradeable credit scheme that would cover sulfur dioxide, nitrogen oxides, carbon dioxide, and mercury emissions from electricity sector (only units with generating capacity equal or exceeding 15 MW) (S.687:105) The proposed system is a tradeable credit system, based on general performance standards that are reevaluated every year on projected electricity generation for the next year. This approach does not bias against new sources. The EPA would change the emission cap, as new information becomes available. The system would begin in the year 2000 and would be completely implemented in the year 2005. In April of each year, the EPA would examine compliance for the previous year. It would compare actual emissions of a generating unit with the allowed emissions (calculated by multiplying the General Performance Standard for the previous year and the unit's electricity generation in the previous year). The units that emitted less than the amount of emission-right they were allocated, would be issued emission credits that could be sold and banked. The units exceeding the allowed emissions would have until July 1 to submit additional credits to cover their emissions. The penalty for the emissions exceeding the allowed emissions plus the obtained credits would be $100 per ton. Even though the proposed system would regulate multiple gasses, it would not allow interpollutant trading.

Three proposals have addressed international trading. In its draft protocol for the Kyoto conference, the United States proposed a tradeable permit system (Tietenberg, 1997c; United States Department of State, 1997). Each country (the Annex I countries and countries that opt-in but are not included in Annex I) would be assigned emission allowances for a carbon equivalent, grandfathered on the base of the 1990 emissions. The emission allowances would be allocated for multiple years. The proposal allowed for banking, buying, selling, and borrowing from the future (using allowances for the future years within the regulated period). Trading would occur among government agencies, private firms, non-governmental organizations, and individuals. Joint implementation would allow parties to the protocol to obtain emission reductions from the countries that are not signatories to the protocol.

The UNCTAD (1994) document examines potential rules and administrative structures for a global carbon dioxide market. It predicts that international markets will evolve in stages. In phase one, parties will engage in Joint Implementation projects. In phase two, trading will take place among parties with explicit emission reduction targets and entitlements (in the parlor of Kyoto Protocol, the emission trading, as authorized by the Article 17) as well as the non-Annex I countries that would either enter the market with certified emission reductions or gradually adopt binding emission reduction targets. Allowances would provide non-Annex I countries easier access to investment capital and technology transfers from Annex I countries. In the third phase, entitlement trading would expand in three ways. There will be a large number of participating countries, a greater proportion of trades will be performed by private entities, and a larger number of greenhouse gases will be included (methane would probably be the first to be added to carbon dioxide). The trading system will have the following characteristics:

- Significant reliance on domestic monitoring and enforcement;
- The use of international standards for domestic enforcement;
- Agreed procedures for veracity checks and adjustments;
- Mutually acceptable ways for resolving disputes; and
- Transparent procedures.

Developing international markets will require some actors assuming the role of market leaders who are willing to take risks in the initial stages of market development. Escrow agents, letters of credit, legal opinions and other intermediaries, must support transactions in markets with high performance risks. Although not stated explicitly, it appears that a need for a standardized definition of the commodity indicates that markets will most likely rely on carbon dioxide emission allowances and not on emission reduction credits.

The UNCTAD (1998) report focuses on emission trading, in particular on the design of an international trading system. It discusses alternative mechanisms for allocating allowances and also examines the requirements for effective international monitoring based both on self-reporting and on an international authority overviewing national monitoring systems. Clearly, the system would require high transparency. Emission reduction credits could be traded only after they are certified by an authorized organization. The report points out that both the certification of the forthcoming emission reductions and the verification of actual accomplished emission reductions would be necessary. Monitoring and enforcement functions would be performed by national institutions but international institutions would be required to ensure comparability of the national processes. Thus, although harmonization is not required, assurance is needed that emission allowances will be secure across differing national systems. Further, they argue that liability for emission reduction credits must rest with the seller. However, with only one long compliance period, buyer liability may be preferred. To minimize the negative effect of buyer liability on trading, that is, the erosion of the commodity, they suggest that liability could be imposed only on buyers whose annual emissions exceed the assigned annual amounts.

2.6.Questions Unanswered in the Existing Literature

Literature empirically examining various environmental markets is vast. Many scholars suggest that a "tragedy of the commons" can be solved by designing a marketable system of rights that entitle resource users to withdraw from the environmental resource or to discharge pollution into the resource. This system should ensure security of property rights and minimal transaction costs for monitoring and enforcing them. We are beginning to learn how to implement this in the complex world of global CPRs. In this pursuit, scholars draw on the lessons from other markets. The question, then, is whether and how we can design a market for global CPRs and which markets can we draw our learning from. I discuss this below.

Is it that markets are easily designed for some environmental resources and not for others? For example, Krier (1992:328) talks about "obvious candidates such as surface water, groundwater, timberland, and grazing land" but fails to explain why these are obvious candidates and how they are different from the less obvious such as wildlife and recreation areas, oceans, and air. How do we know whether a carbon dioxide market is an “obvious candidate”, or better, how can we design this market so that it functions? I expect one could take two routes. One could examine a theoretical ideal of a working market and try to create a carbon dioxide market so that it resembles the theoretical one as closely as possible. McCann (1996) provides a starting point for this route of inquiry. Alternatively, one could examine existing markets for environmental resources, which all depart from the theoretical ideal market, and study their performance. I propose to take this route in my research. The question is, however, which existing markets does one study? How do we know which markets are the closest to a potential carbon dioxide market? Below, I first summarize what has been suggested in the literature. Then, I briefly review the approach I adopt in this study.

Policymakers have been looking at different markets for ideas on how to design a potential carbon dioxide market or a market for multiple greenhouse gases. Most have looked at the existing U.S. sulfur dioxide trading system. The most prominent actor in this market is the electricity industry, which is also a large emitter of carbon dioxide (Environmental Law Institute, 1997a; Ellerman et al., 1997a). The following lessons and concepts can be directly transferred from the sulfur dioxide market to a carbon dioxide market: (1) a fixed emission cap that is set by a legislative branch to avoid costly litigation, (2) full banking and trading, (3) high-quality monitoring, (4) a transparent allowance tracking system, (5) high penalties for non-compliance, and (6) an opt-in program that allows non-regulated entities to enter the program (Environmental Law

Institute, 1997a).

However, the two markets differ with respect to the number of polluting gases that have to be regulated, number of polluters, and differences in characteristics of the gases and the polluters (Environmental Law Institute, 1997a). Ellerman et al. (1997a) also advise caution in drawing lessons for potential carbon dioxide markets from the sulfur dioxide markets, as the sulfur-dioxide market was built on accurate emission monitoring[4] and high penalties for non-compliance, and sulfur dioxide allowances were secure due to assigned emission cap that was unlikely to change. I argue that the security of property rights is not a dichotomous variable but a continuum. For example, though the certainty of the property rights may have been perceived as high, the CAAA states that allowances are not property rights and can be reduced over time. Clearly, even the security of sulfur dioxide property rights is uncertain.

The U.S. Lead Phase-down program was another market from which lessons for a carbon dioxide market have been drawn. Stavins (1998) points out the conceptual similarity between lead content of gasoline in the Lead Phase-down program and the carbon content of fuels in a potential CO2 market. The carbon content and emissions are in linear relationship, which was not the case in sulfur dioxide pollution. This view differs from that discussed above in terms of what attribute of the resource should be regulated. Those who see the sulfur dioxide market as a potential classroom for a carbon dioxide market, seem to adopt the "industrial model" of carbon dioxide trading. Stavins (1998), on the other hand, argues for a "fuel model" and therefore suggests targeting inputs, rather than outputs from the production process.

The approach discussed above draws lessons from a market that looks like a potential carbon dioxide market. Authors, who draw lessons from the sulfur dioxide market, chose this market because of the similarity in resource users--electricity generation is the major resource user in both cases. On the other hand, authors, who

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[4] The authors, however, do not realize two important points. First, initially the sulfur dioxide allowance system was built on guestimates of actual emissions and there was no monitoring system in place. Second, the current monitoring of sulfur dioxide allowance trading also requires all emitters to monitor and report carbon dioxide emissions.

draw lessons from the Lead Phase-Down, focus on the similarity in the resource use. Both, the Lead Phase-Down and the fuel model of a carbon dioxide market focus on the link between the use of an easily measurable input in the production process and the discharge of pollution (emissions are, in this case, a simple function of the used lead or carbon). The problem with this approach is that we do not know how similar these markets actually are. First, we do not know if other factors affect the similarity and, if so, how much. Second, we do not know how close the selected markets are to a potential carbon dioxide market in terms of the selected criterion, as no measure exists that would let us conclude this.

I propose to address the shortcomings discussed above by developing a framework that allows me to examine the impacts of attributes of the environmental resource (commodity) and the attributes of actors. Rules regulating resource use are the third important factor affecting performance of any institutional arrangement (Ostrom and Schlager, 1996). In this research, I examine rules as they pertain to either the commodity or the actors. In the analysis of the environmental resource, I focus in on the issue of measurability.[5] The importance of measurement of good's characteristics for provision of a public good was studied by Ostrom and Ostrom (1977), who point out the difficulty of unitization of a good. Barzel (1982) and Akerlof (1970) studied how problems in information availability and measurement of a private good's characteristics can be mitigated by designing appropriate market mechanisms. In this dissertation, I develop an index of measurability of a good/service to study its impact on market performance. Then, I examine how characteristics of actors participating in the market may affect market performance. After developing the framework that allows me to analyze performance of CPR markets, I turn to a study of potential carbon dioxide markets.

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[5] My focus on measurement should not indicate that I find security of a property right unimportant. I would rather argue that with increased measurability of a resource, security might also increase, as one aspect of security--the uncertainty related to the environmental resource--decreases.

CHAPTER 3

MARKETABLE PERMITS: A FRAMEWORK FOR ANALYZING THEIR PERFORMANCE

3.1. Introduction

This research analyzes the applicability of marketable permits for managing common-pool resources (CPRs), in particular, the atmosphere. Marketable permits transform CPRs into private goods, thereby facilitating the use of market processes for regulating their use. The existing literature examines CPR markets from two perspectives: it either compares them to a command- and-control approach or to a (theoretical) perfectly competitive market.

The first approach assumes that since CPR markets will not suffer from information problems or transaction costs, they will be more efficient than command-and-control policies. When the CPR users have different costs of reducing resource use (abatement costs), they will abate as long as costs of abating one unit of pollution are less than the market price of the pollution permit. On the other hand, they will purchase permits if the abatement costs are higher than the market price of the pollution permit. Similarly, in a resource withdrawal situation, if the net income (benefits of withdrawing minus the costs) exceeds the market price of the permit, they will continue withdrawing. If the net income is less than the price of the permit, they will sell the permit. Permit trading would therefore minimize aggregate abatement costs and maximize aggregate net income from the resource stream.

Past and extant CPR markets, however, experience low trading activity, raising concerns about the performance of these markets. Two causes are possible for low or no trading. First, CPR users have no incentives to trade. If the CPR users all have the same cost structures, trading brings no benefits. Similarly, if permit allocation corresponds exactly to the cost-minimizing allocation, CPR users cannot gain anything from trading. This is unlikely as resource permits are often allocated on the basis of past patterns of resource use. Second, there is also a possibility that the CPR users face different cost structures but do not trade due to high transaction costs. This aspect of CPR markets is examined in the transaction cost literature.

Searching for reasons for lower than expected trading, the second approach, relying on experimental work, compares a given CPR market to a theoretically perfect market. It examines the impact of market structure and trading rules on the performance of the CPR market. It offers useful insights about the sources of transaction costs in CPR markets, specifically insecure property rights, high costs of obtaining information about potential trading partners, and high monitoring and enforcement costs incurred by regulators (Stavins, 1995). This approach can lead to developing design principles that regulatory agencies should follow when creating markets.

This study builds on the above approaches and focuses on the question of which CPR markets should guide us in creating potential carbon dioxide markets. Clearly, actors have fewer incentives to trade if transaction costs are high. If so, can CPR markets be designed to resemble perfect markets? Which existing markets offer useful insights for designing potential carbon dioxide markets? How do CPR characteristics affect market performance? Do CPR user characteristics such as their number and use pattern affect market performance? If so, how? These are broad research questions addressed in this dissertation.

Unlike previous studies that focus predominantly on a single CPR market, this dissertation examines the following CPR markets: sulfur dioxide allowance trading, lead permit trading, early EPA local air pollutant permit trading, Regional Clean Air Incentives Market (RECLAIM), chloroflourocarbons (CFCs) production permits markets, and Wetlands Mitigation Banking. I employ the Institutional Analysis and Development framework (Ostrom, 1990) to examine the factors that affect performance of CPR markets. Market performance is operationalized with two groups of indicators: environmental effectiveness and market liquidity (number of trades, volume of trades, and dispersion of prices around the market-clearing price). Factors affecting market performance can be classified into four categories:

1. *CPR characteristics affecting resource measurability*. These include: *predictability* of the CPR stocks, availability of *reliable indicators* of resource flows, *spatial extent* of the resource, and *effects* of the resource use on the resource stocks

(uniform versus non-uniform effects);

2. *Characteristics of the CPR users.* If a small number of resource users appropriate a large proportion of the resource, the institutional arrangements regulating resource use are more likely to be developed and well-functioning;

3. *The external legal and regulatory environments* impact constitutional-choice level rules in all CPR markets. In some cases, they also impact collective choice and operational-choice level rules;

4. *Rules regulating CPR users and its use.* Three types of rules regulating CPR use are of particular importance: rules determining the *severity* of resource use limitation, rules regulating how the CPR is *transformed into a private good* (permit), and rules regulating *exchangeability* of permits. These rules impact the value and the security of the permits, thereby affecting the incentives for trading. The most important rules pertaining to the CPR users determine *who is regulated* and how the non-regulated resource users could *opt-in.* These rules affect exchange costs, thereby the number and the volume of trades. They also impact environmental effectiveness of the CPR markets.

3.2. Analysis Framework

3.2.1. Independent Variables: Factors Affecting Performance of CPR Markets

Factors affecting market performance can be grouped into four categories: (1) CPR characteristics affecting resource *measurability,* (2) characteristics of the CPR users, (3) external legal and regulatory environments, and (4) rules regulating the CPR use and users.

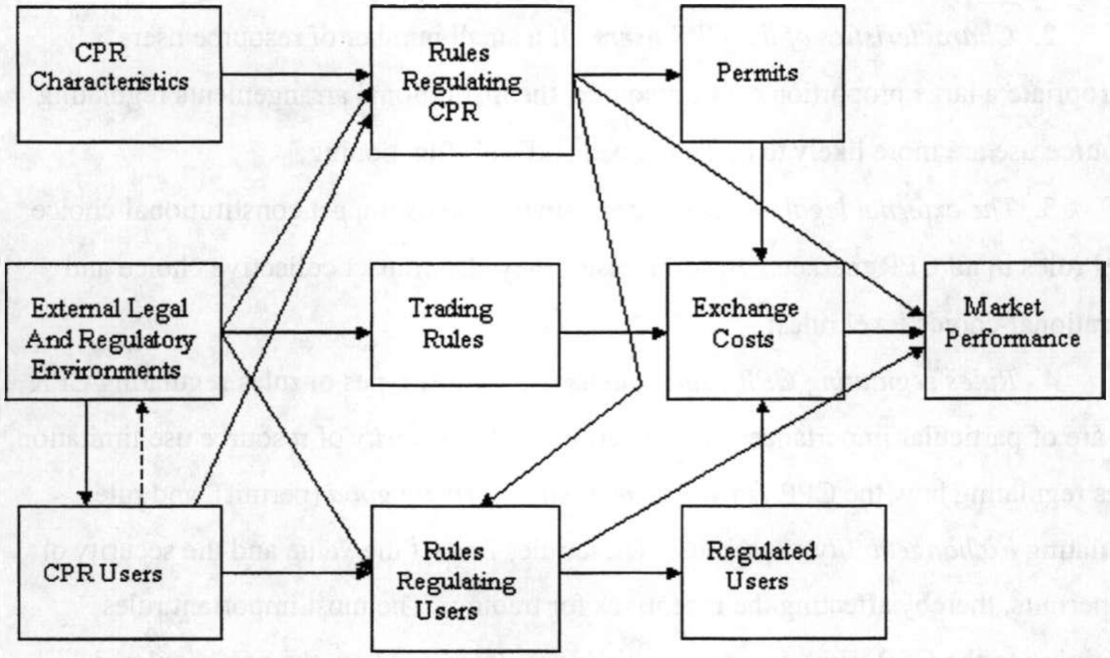

Figure 3.1: Factors Affecting Performance of CPR Markets

3.2.1.1. CPR Characteristics Affecting Measurability

CPR characteristics affecting resource *measurability* are: *predictability* of the CPR stocks, availability of *reliable indicators* of resource flows, *spatial extent* of the resource, *and effects of the resource use* on the resource stocks (uniform versus non-uniform effects). Resource flow from a CPR is presented in Figure 3.2. Let us assume that there are four resource users. Each withdraws a unit flow from the CPR stock. Though the graph presents withdrawal from a resource, pollution can be understood in a similar way with the material flows going in the opposite direction. The resource stock is depicted with a circle. This graphic representation assumes that we have a reliable indicator of the resource stock. This is not necessarily the case, posing a problem for resource management. Resource flows of various users (A1, A2, A3, A4) are also represented as circles. This also implies that we can measure the flow to each resource user.

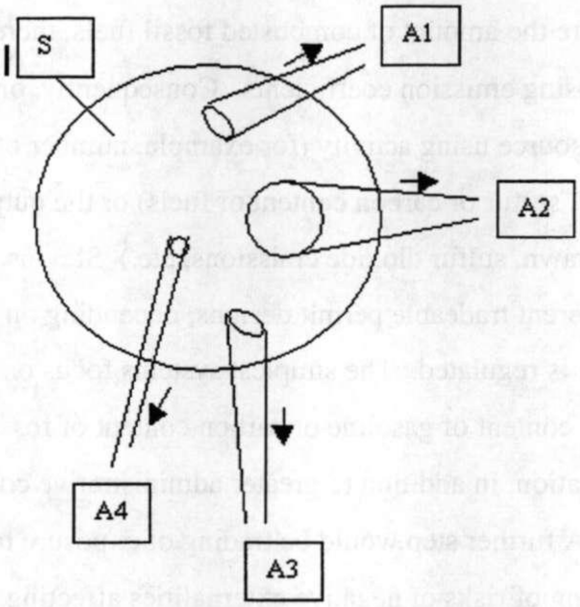

Figure 3.2: Withdrawals from a CPR

The situation in Figure 3.2 here represents the following withdrawal pattern: A1 withdraws two units; A2, five units; A3, two units; and A4, one unit. It is possible that a withdrawal of A2 is easily measured, for example, with continuous monitoring, whereas withdrawals of A1, A3, and A4 are not easily measured: these resource users may be mobile, and/or their use of the resource may be too small to justify continuous monitoring. The information on the withdrawal from A1, A3, and A4 may, therefore, not be equally reliable as the information on A2's withdrawal. If this is the case, the property right of the users A1, A3, and A4 cannot be equal to the property right of A2, whose withdrawal can easily be measured.

If there are no reliable **indicators of the resource stocks** or if there is low predictability of the resource, the rules will have to be easily adaptable over time as new information becomes available. However, frequent changes in the rules make permits insecure, thereby reducing the users' incentives to invest in them.

Further, if there are no reliable **indicators of the CPR flows**, rules could be created that rely on measurement of a use of related resources. For example, if no good measures of the use of the global atmosphere as a sink for carbon dioxide emissions are available, one could measure the amount of combusted fossil fuels, thereby estimating carbon dioxide emissions using emission coefficients. Consequently, one could regulate either the inputs into the resource using activity (for example, number of fishing hours, size of allowed fishing nets, sulfur or carbon content of fuels) or the outputs from the process (tons of fish withdrawn, sulfur dioxide emissions, etc.) Stavins (1995) points out the difference between different tradeable permit designs, depending on the point in the cycle at which the CPR use is regulated. The simplest systems focus on inputs into activities using CPRs (lead content of gasoline or carbon content of fossil fuels). The next step towards sophistication, in addition to greater administrative complexity, is emissions permit trading. A further step would be trading of exposure to negative externalities. Finally, trading of risks of negative externalities affecting health, wealth, or income would be the closest to the theoretical ideal. This comes, however, with increasing costs of monitoring and enforcement.

The **spatial extent** of the resources is of crucial importance. If the resource expands over large areas in which resource users cannot observe each other, they are less likely to be able to relate the changes in the resource stocks to different resource use patterns. Further, users of a larger resource will be less likely to meet face-to-face, communicate, and be able to create and maintain institutional arrangements to limit resource use, thereby protecting it from further destruction.

Another problem arises if the **effects** of the withdrawal of different users are **not uniform**. If the effect of A1's and A4's withdrawal of one unit on the stock of the resource is not equal, the property rights to a unit of withdrawal cannot be traded on a one-to-one basis. Rules have to be created that reflect different environmental effects of CPR use at different locations and enable their comparability.

To measure the effect of all four characteristics of a CPR, I create an index of resource measurability that can be applied to a variety of goods. A simple good whose stocks/flows have a high level of predictability, uniform use, small spatial extent, and highly reliable indicators would have a high value. Wheat would be an example of such a good. I expect a very low value of measurability index for a complex good like atmosphere, which is difficult to predict, and there are not many reliable indicators of the resource stocks and flows.

3.2.1.2. Characteristics of CPR Users

If a small number of resource users appropriate a large proportion of the resource, the institutional arrangements regulating resource use are more likely to be developed and well-functioning. When there is a small number of users, they may find it easier to solve the collective-choice dilemma and craft institutional arrangements to manage the CPR. However, even if the institutional arrangement is imposed by an authorized agency, it is easier to monitor a smaller group as transparency of the resource use is higher, thereby reducing the need for complicated monitoring. Further, sanctioning of violators could also be easier as resource users in small groups are more exposed to criticism and sanctioning. On the other hand, a small number of users decreases the potential for reducing costs through trade.

The number of CPR users may be directly related to the spatial extent of the CPRs. It seems that a global CPR would have a large number of widely dispersed resource users all over the world. This is indeed the case in many global CPRs. There are, however, also cases where the use of the CPR requires a special technology that is available to a relatively small number of users. For example, there is only a small number of CFC producers. The management of the atmosphere as a sink for CFCs can therefore be targeted to these producers.

A question then arises as to how we can effectively regulate a large number of CPR users. Can we regulate all of them at low costs? If not, which users do we have to regulate and which can we leave out? Do we extend the regulation in different phases, including previously non-regulated users? Further, can the non-regulated resource users opt-in for the management; if so, under what conditions? I address the rules regulating this issue later on in this chapter.

3.2.1.3. External Legal and Regulatory Environments

External legal and regulatory environments impact constitutional-choice level rules in all CPR markets. They determine who can create the rules to regulate the CPR and who decides which resource users are regulated and which are not. Creating an institutional arrangement is an important factor affecting performance that is not sufficiently stressed in prior studies. Kete (1992) and Stavins (1998) have analyzed the process of creating permit markets, but have not linked the creation of the institutional arrangement to its success or failure.

The external legal environment regulates what aspects of the property rights are given to the permit holders. Property rights subsume a bundle of rights such as the right to access, appropriate, manage, exclude, and alienate the resource (Ostrom and Schlager, 1996). The performance of an institutional arrangement therefore depends on which rights from the bundle are given to resource appropriators. If the resource users are given the right to manage the resource and they develop their own arrangements to protect the resource, the rules may better reflect the local characteristics of the resource and its users (Ostrom, 1990). Further, if the resource users can appropriate as well as manage the resource, they will be familiar with the rules. Higher familiarity with the rules can reduce exchange costs. Further, if resource users create the rules, they may view them as more legitimate and may therefore be more likely to comply with them. This will lead to higher environmental effectiveness of the institutional arrangement.

3.2.1.4. Rules Regulating the CPR Use, Users, and Trading

Rule formation is affected by the characteristics of the resource, the external legal and regulatory environment, and CPR users. Non-uniform pollutants require that both the quantity of the resource and the resource-use location are taken into account for an effective resource regulation. This reduces the potential for simple unit-to-unit permit trading. Complex trading rules have to be developed so that trading takes into account the varying environmental effects of the resource use. The unavailability of reliable information and the low predictability of the CPR stocks require that rules allow for flexibility in light of new information. The spatial extent of the resource affects the number and complexity of actors who all have to agree to a CPR management. I now turn to a detailed analysis of these effects.

Three types of rules regulating the CPR use are of particular importance: rules determining the *severity* of resource use limitation, rules regulating how the CPR *is transformed into a private good* (permit), and rules regulating *exchangeability* of permits. These rules impact the value and the security of the permits, thereby affecting the incentives for trading.

Severity of the resource use limitation. The rules prescribe how much the resource use has to be reduced. This aspect of the resource management is often missing in transaction-costs analyses (McCann, 1996; Klaassen, 1996; Hahn, 1989; Stavins, 1995; Tietenberg, 1995; Bailey, 1998). The severity of the CPR management targets can, however, significantly affect the success of the institutional arrangement, both in terms of environmental effectiveness as well as trading incentives (Hall and Walton, 1996).

The severity affects performance of CPR markets. First, if the targets are not restraining, they have a small environmental effect--the condition of the resource will not improve. Further, there will be few trades, as there is little motivation for investing in either the technology reducing the pressure on the resource--supply of permits--or purchase of the permits. This research therefore first examines how much the targets of the marketable system are restraining the resource use. High overcompliance, attributed to well-functioning marketable permit systems--SO2 allowance trading (Lapp, 1994)—may actually be a result of modest restrictions, rather than incentives created with the marketable permit system.

The effect of the severity of regulation on the CPR market performance can be illustrated with the resource pattern depicted in Figure 3.2. The unregulated withdrawals were 2, 5, 2, and 1 unit, respectively. Let us assume that the regulated withdrawal quantities are 1, 2.5, 1, and 0.5 units, respectively (the total resource use was reduced by half; each resource user had to reduce its use by one half). If this limitation is enforced, the CPR stocks will be decreased by five, rather than by ten, units. This then ensures environmental effectiveness of the institutional arrangement. The effect of stricter rules on the trading activity is, however, not clear. On the one hand, it is possible that the limitation is so severe that all resource users will hardly meet the requirements in the short term and no extra permits will be available for trading. On the other hand, a higher demand for permits and the resultant higher prices may create additional incentives to invest in technologies reducing the resource use. This may result in more numerous trades in the long term.

Rules regulating how the CPR is transformed into a private good. Two broad rules have been implemented to create a private good (permits) from a CPR. There are two major different approaches: standardized and case-by-case definition depending on their baseline and the actors who can participate in the market-based exchange. The first type (also called closed market) entitles the user to use the CPR up to the maximum level allowed by the permit. This system requires that an authorized agency determine the total flow from the resource for a given period and then allocate the aggregate among the CPR users.

The second type (also called open market) privatizes the CPR use reductions, when they are recognized by the authorized agency and awarded a corresponding credit. (In pollution control, these were called emission reduction credits.) This system requires no knowledge of the aggregate flow from the resource (or discharge) that is allowable to maintain the stock of the resource. Everyone with a capacity to reduce resource use can participate in this market. This system, however, requires the accreditation of the resource use reductions. I now turn to a detailed analysis of two approaches for a pollution discharge case.

The closed market system (for example, the system authorized by the Clean Air Act Amendments of 1990) is based on setting the maximum resource use rights (total emission allowances) for a period t (TEA_t), dividing that amount among polluters (EA_{it}), and enforcing that an i-th individual polluter does not emit more in period t than the amount of allowances she holds ($E_{it} \ngtr EA_{it}$). The individual polluter is not limited by the initially allocated allowances. She can purchase additional allowances for period t (EAP_{jt}) from other polluters (j-th polluter) whose emissions are lower than the allocated allowances ($E_{j\,t} < EA_{j\,t}$). Thus, though every polluter holds the permit to emit an allocated amount of the pollutant, if the allocated permit is not used in the period t, it can be sold to other regulated polluters or kept for future use. The flow from the CPRs (or discharge of pollution) is limited by the maximum amount of allowances (TEA_t). The rights to use the resource are quantified and allocated to polluters ($EA_{i\,t}$). If polluters use less than their allocated share of the resource, they can sell their rights.

This system (if enforced) ensures that aggregate emissions from all emitters do not exceed the allowed emissions for period t.

$$\sum E_{i\,t} \leq \sum EA_{i\,t} \tag{3.1}$$

If $E_{i\,t} > EA_{i\,t}$, the i-th polluter purchases additional allowances from the j-th polluter ($EAP_{j\,t}$);

if $E_{i\,t} < EA_{i\,t}$, the i-th polluter sells additional allowances to the j-th polluter ($EAS_{i\,t}$).

At the end of each period t, each polluter has to prove that her emissions do not exceed the initially allocated emission allowances plus the difference between purchased and sold allowances.

$$E_{i\,t} = EA_{i\,t} + EAP_{j\,t} - EAS_{i\,t} \tag{3.2}$$

Enforcement of the system further ensures that j-th polluter only sells allowances in the amount for which her allowances exceed its emissions.

$$EAS_{j\,t} = EA_{j\,t} - E_{j\,t} \tag{3.3}$$

As no allowances can be generated outside the system, the amount of sold/purchased allowances equals the amount of actual emission reductions.

$$\sum EAP_{i\,t} = \sum (EA_{j\,t} - E_{j\,t}); \quad i \neq j \tag{3.4}$$

The system thereby controls the total flow from the CPR or discharge of pollution.

The emission reduction credit (ERC) system (or open market) is based on individual emission standards. Each polluter is required to keep a given emission standard (es_i), defined as emissions by unit of input or by unit of output. Unlike the emission allowance system, the ERC does not control the aggregate emissions; it focuses on emission standards. The total emissions depend not only on the emission coefficient but also on the input (output). As the input is controlled by the polluters, the regulators cannot determine the aggregate level of emissions. This system is, therefore, less environmentally effective than the emission allowance system.

The system (if enforced) ensures that the i-th polluter's emission coefficient is not higher than the standard:

$$e_{i\,t} \leq es_{t}. \tag{3.5}$$

The i-th polluter can meet the standard by reducing his emissions or by purchasing ERCs from a j-th polluter whose emission coefficient ($e_{j\,t}$) is lower than the prescribed standard (es_{t}):

$$es_{i\,t} = (E_{i\,t} + ERC_{j\,t})/(\text{input}_{i\,t}) . \tag{3.6}$$

How, then, is the amount of ERC calculated? The j-th polluter, whose emission coefficient is lower than the prescribed standard, first has to prove this fact. Once this is established, then the ERCs for a period t are calculated using the following formula:

$$ERC_{j\,t} = (es_{t} - e_{j\,t}) \times \text{input}_{j\,t}. \tag{3.7}$$

If the ERCs are offered on the market in period t, i.e., before the period is over, then the input and actual emissions for period t have to be estimated. If the regulators are not comfortable with this scheme, they will allow only ERCs from the previous periods (t-x) to be sold. The formulae used in this short description of the ERC system illustrate the information requirements for this system. The formula (3.5) indicates that the compliance review requires establishing an emission standard. Further, it requires both data on emissions and the input data for each polluter. Another version of the system could be that regulators would not monitor all emissions, but only from the polluters who want to sell ERCs. This would reduce monitoring costs.

If no emission standard is available, a different version of the ERC system can be employed for voluntary emission reduction policy. ERCs related to a particular project could be calculated as the difference between the emissions that would have been released into the atmosphere had the particular project not been adopted and the emissions after the adoption of the project. This approach requires an agreement on the counterfactual emissions. When they are estimated, they have to be reviewed and approved by an independent agency. This administrative review increases the information requirements, thereby the transaction costs of this system (Ellerman et al., 1997a).

Each system has its advantages and disadvantages. Though the emission allowance system ensures the maximum level of withdrawal from a CPR (or pollution discharge), it also requires knowledge of what such acceptable levels are. It reduces transaction costs as the traded permit is standardized (emission allowance for a given amount) and issued beforehand. It is, however, limited to the participants who are issued the permits. One major disadvantage of the closed market system is that it requires knowledge about the pollution problem and the sources of pollution. Also, it requires political consensus about the initial quota allocation (Ayres, 1994). This system also creates barriers for new entrants (which is one way of buying the political consensus).

The ERC system, on the other hand, allows everyone to participate in market exchange, given that his/her emission reductions are certified. The quantification and certification of the emission reduction credits can, however, require a lot of time and effort. This has been a key learning from the initial EPA emission-trading programs such as bubbles, netting, offsets. This increases the exchange costs and may impede trading.

Rules regulating exchangeability of permits. If the resource use is not uniform—it has a varying effect on the stocks depending on its location—complex exchangeability rules have to be created. A unit of resource use at one location cannot be traded for a resource unit at another location as these uses impact the stocks in different ways. Several possibilities exist in theory to handle this issue and some have actually been implemented (Klaassen, 1996). The first option is to establish trading rules based not on the flows, but on the effect the flows have on the stocks. Let me illustrate this with the resource withdrawal situation presented in Figure 3.3. The discussion here refers to a resource withdrawal situation, but a pollution discharge is just its mirror image.

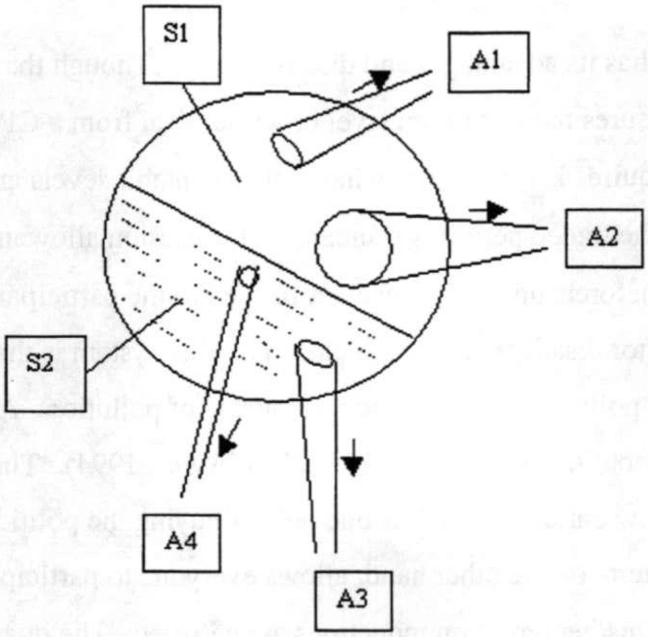

Figure 3.3: Withdrawals from a Non-uniform CPR

Let us assume there are two different sub-units of the stock S: S1 with lower sensitivity and S2 with higher sensitivity. The latter can, for example, have a higher sensitivity because the stock has lower rates of recharging or renewing. Assume further that a resource unit used by A1 or A2 decreases the stock S by one unit, but a unit used by A3 or A4 has a double effect, due to higher sensitivity. Hence, the resource use rights cannot be exchanged on a one-to-one basis. In this case, the trading ratios can express the negative effect a unit of resource can have on the CPR: in our particular case, a unit of resource used by A3 has twice the effect of the unit used by A1. Therefore, a permit of A3 or A4 could be traded for two units of A1 or A2. In a competitive market, the prices of resource use permits would reflect these trading ratios. As a result, the resource use would shift from the more sensitive sub-unit (S2) to the less sensitive one (S1).

The second option is to divide the CPR and resource use rights between the two sub-units and allow trading only within the two units (S1 and S2) and not between them. This option will create two smaller markets (M1 and M2). Perhaps, some economically beneficial trades would not occur due to location restrictions. As there would be no trading between resource users in units S1 and S2, there would be no reallocation of polluting activities.

The third option is to allow trading of resource users between the two sub-units but with restrictions imposed on either the stock status or the total flows of the resource use. Trading of the CPR withdrawal (pollution) rights could be allowed, for example, as long as the status of S1 and S2 exceed (do not exceed) thresholds of S1* and S2*, respectively. This rule was applied in the early EPA emission trading. Alternatively, trading could be allowed as long as the total flow of the resource in the sub-units is smaller than F1* and F2*, respectively. This puts a premium on earlier use of resource permits as it limits trading over time. It creates incentives to trade early and not to bank permits. All these options have higher transaction costs than a single zone trading, which has been successfully implemented for SO2 and lead permit trading (Klaassen, 1996).

I have discussed the non-uniformity as a physical characteristic of the resource. It is possible, however, that non-uniformity relates to the resource users. In the individual transferable quota systems, for example, small fishers and large industrial fishers were not treated equally. The latter were protected, and trading between the two groups was limited. The discussion of non-uniformity is also relevant for the global warming debate where non-uniformity is created by the rules. The current negotiations, especially the stance of some European countries, indicate that international trading could be limited by a requirement for prior domestic resource-use decrease, before permits can be purchased internationally. If this proposal is adopted, there would be two non-uniform uses of the CPR—domestic and foreign.

The above arguments refer to exchangeability in space. Permits can also be exchangeable in time. Resource use permits that are not used in the current period could be banked or sold for future use.

Bailey (1998) argues that state regulation on how allowances should be treated in the utility accounting increases the count of transactions (statistically significant effect) but does not have a statistically significant effect on the traded volume (interestingly, the coefficient has a negative sign). She suggests that this may be explained with two opposing effects: on the one hand, regulation may reduce the risks associated with prudent review—utilities in a state with regulation may be less worried about seeking out the best available transaction and instead purchase smaller bundles of allowances. On the other hand, a utility may be more comfortable seeking out the best possible bundle of allowances despite the increased transaction costs incurred by purchasing smaller packages of allowances.

Rules regulating CPR users. The most important rules pertaining to CPR users are those that determine who is regulated and how the non-regulated resource users could opt-in or could become regulated at a later time. If a large proportion of the resource users are not regulated, these markets may not be environmentally effective. The question of who is regulated and who is not is less important in open-market systems, as they allow all resource users to participate in the market.

Rules determining which CPR users are regulated have to be crafted carefully as they may result in significant "leakage", that is, a shift of the CPR use from the regulated to the non-regulated users. Therefore, it is necessary to identify the largest resource users and examine how their activity could shift. In some cases, rules can be created to prevent this shift, in others this may not be possible at low cost and in a short period of time. This shift can be regulated by specific rules stipulating the requirements that the non-regulated users must meet. These characteristics must also be closely monitored.

What can be done about the CPR users who are currently not regulated? Two important questions have to be addressed. First, can the non-regulated resource users opt-in for the management? Second, can we create an arrangement that phases-in the non-regulated resource users in subsequent stages? The answers depend on the characteristics of the CPR users and their use patterns. At first, opt-in seems like an option that would have positive environmental effects and facilitate permit trading. Non-regulated resource users can voluntarily accept the limitation on the use of a CPR in exchange for a share of a private good (market permits). They are interested in opting-in because they can reduce their use of resource at lower costs than the market price of permits. This leads us to conclude that market incentives stimulate resource users to exceed the requirements of the resource management, thereby reducing the pressure on the CPR more than they would have, had the trading of permits not existed. This rationale, however, has a caveat. Opt-in faces the challenges of adverse selection and moral hazards. It is likely that the resource users who opt-in for allocation of the permits would have reduced their use of resource even without the market incentives. If they were not allowed to opt-in, their resource use reductions would have occurred on the top of the reductions of the regulated resource users. By including them in the scheme and allocating them the resource permits, however, their reductions are offset by the increased use of those who purchase their permits. Thereby, opt-in may actually result in smaller reductions that would have occurred otherwise (Stavins, 1998; Montero, 1997). Rules allowing opt-in therefore have to address the issue of adverse selection.

The next question is whether the non-regulated users can be included in the regulation in the subsequent phases. For example, in the initial phase, only the large resource users are regulated. Their resource use is most likely better known and documented, and therefore regulated. Once more information is available and there is a better knowledge about the factors affecting the CPR and the trade, other resource users may be included. The challenge then is to eventually include all resource users, whose resource use can easily shift to other, non-regulated users.

Rules determining who is regulated impact the number of regulated resource users. The effect of the number of users on market performance is, however, not straightforward. On the one hand, increasing a number of market participants increases the probability of finding trading partners, thereby reducing the exchange costs. Further, the larger the market, the more likely brokers will enter the market. Both effects reduce the exchange costs and improve market performance. On the other hand, large markets can exhibit significant price volatility as large numbers and differentiation of actors impede the information flows among market participants (Ferlie, 1992).

Information available to the permit holders impacts exchange costs. Permit markets are new and permit holders have to obtain information about their own CPR appropriations, the information necessary for finding potential trading counterparts, and information about the trading rules and permit prices. If they have been involved in the creation of the institutional arrangement, they are more likely to know the trading rules and potential trading partners. Further, resource users will have better information about potential counterparts if they engage in the same economic activity. It seems that the lead permit program exhibited low search costs because all potential traders were oil refineries and have known each other.

Trading rules. One of the most important sets of trading rules determine who can participate in the trading. As lack of information is one of the major sources of high exchange costs, rules that allow brokers to enter the markets can reduce these costs, thereby improving performance of these markets. In these markets, brokers do much more than just match potential counterparts. For less standardized traded good brokers could provide standardization services (additional measurement that better defines property rights) and even insurance services.

3.2.2. Dependent Variables

This research examines performance of various CPR markets. The literature on policy instrument choice identifies a variety of indicators for evaluating policy instruments. Most indicators measure policy outcomes such as environmental effectiveness, economic efficiency, and distributional effects. Other indicators are process-oriented, focused on administrative feasibility (information requirements, monitoring, enforcement, compatibility with existing institutions, demands on resources required for implementation of the instrument) and flexibility.

The focus on trading performance indicators seems narrow because the goal of policy enactment is to solve a CPR problem, not to have perfect trading. As CPR use exhibits low excludability and rivalry, unconstrained use can lead to deterioration of the resource stocks. Each user's consumption causes negative externalities for other users. These negative externalities arise if the withdrawal from the CPR is too intensive or if discharge of pollution into a CPR exceeds its adaptive capabilities. The challenge then is to create rules of the CPR use so that the CPR does not deteriorate. Effectiveness in terms of protecting the CPR from deterioration, therefore, has to be a major criterion of performance of any institutional arrangement. I now turn to a short review of concerns related to measuring performance of marketable permits.

3.2.2.1. Environmental Effectiveness

The main purpose of any institutional arrangement is to alleviate the problems of excessive withdrawal from or excessive discharge of pollution into a CPR. This question can be answered if data is available about stocks of the CPR both prior to and after the enactment of an institutional arrangement. However, in some cases it may be technically impossible or extremely costly to measure the stocks of the CPR. In this case, it is helpful to focus on resource flows.

Stock changes resulting from anthropogenic factors can be estimated by measuring the withdrawal from/discharge into a CPR. If it is infeasible or expensive to measure the CPR flows, one can measure the inputs used in the CPR appropriation, for example, number of fishing hours or tons of combusted carbon. Reliability of this measure depends on the relationship between the inputs and the CPR use. For example, combustion of a ton of carbon always results in a given emission of carbon dioxide, irrespective of the burning technology, the source of carbon (for example, oil versus biomass), or the local environmental characteristics (wind velocity, humidity, and others).

Change in stocks may not, however, be a simple aggregation of the CPR flows. A change in CPR stocks may result from other, not only anthropogenic, factors. For example, stocks of fish may change due to weather, or concentration of carbon dioxide in the atmosphere may change due to changed flows of carbon dioxide from other carbon sinks (ocean, soil, and/or growing biomass). As these factors affect the resilience of the CPR, but are not under control of the institutional arrangement, they should not be included in the measure of environmental effectiveness. Nevertheless, they are still important for CPR management, as the predictability of the CPR affects the rules regulating the CPR use.

Some institutional arrangements regulating CPRs may attempt to affect the CPR only in the long-run. In this case, achievement of interim goals can be explored. For example, the Framework Convention on Climate Change sets as an ultimate objective to stabilize GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. This ultimate objective is to be achieved incrementally and progress tracked by the following targets: (1) reporting the use of the atmosphere, (2) establishing reduction targets, and (3) enacting policies to achieve the set reduction.

Another option for measuring environmental performance is to measure whether the institutional arrangement has achieved or even exceeded the set targets. However, caution is required when making judgement based on overcompliance. Overcompliance may be an indication of low targets rather than of a success in preventing the CPR deterioration.

3.2.2.2. Market Liquidity

Some markets have obvious problems such as sellers having difficulties in finding buyers, bidding and offers extending across a wide range of prices, and trading exhibiting high costs. How, then, can we then assess trading performance? It is clear that a market with no trading is not performing well as the major purpose of market creation is to facilitate trade. Newly developed markets go through a period of learning. Initially, there is little understanding about prices. The dispersion of bided prices is wide and transaction costs are high. With time, however, one would expect that a well-functioning, robust market would have smaller dispersions between the bid and the clearing prices. Perhaps, a smaller traded volume and high transaction costs are expected in all newly established markets. However, market design may impede trading, requiring major changes in the definition of the traded commodity, the trading rules, or in the way potential trading partners learn about each other. The challenge then is to disentangle these factors and I address this issue in more detail in the subsequent sections. This section focuses on market performance and its measurement.

The first question is whether trading volumes and the number of trades are useful and reliable indicators of market performance. In general, scholars do not view them so (Stavins, 1998; Bailey, 1998) and suggest cost savings as an appropriate indicator. Ellerman et al., 1997a) argue that larger trading volume is not necessarily better than lower trading volume. An optimal amount of trading is the one in which marginal abatement costs are equalized across actors. Therefore, if permits were allocated so that the allocation exactly reflects the cost-minimizing pattern of CPR use reduction, no trading will occur. Ledyard and Szakaly-Moore (1994) argue, however, that a mechanism should not be judged as highly efficient even though no trades occur. Focusing on efficiency could result in judging a mechanism efficient because the initial allocation of permits is close to the optimal. If no trading occurs, it is therefore necessary to reconsider appropriateness of the market.

Other indicators of market performance have been suggested by scholars who have examined various CPR markets. Schaltegger and Thomas (1996) point out the importance of high price volatility. When prices change substantially, emitters keep their permits and do not invest in pollution reduction. Schaltegger and Thomas (1996) do not consider the number of trades to indicate market performance, but point out their effect on other indicators of market performance, such as dispersion of prices around the market clearing price. Similarly, Ellerman et al. (1997a) argue that in a reasonably competitive market with good information, transactions are sufficient in number and frequency for readily recognizable market price "to become established, around which bids and offers cluster." They further suggest that a degree of backwardation of prices is an indicator of market performance; small differences between the current prices of current permits and the prices of later vintage permits indicate low transaction costs, high confidence in the value of future vintages, improved efficiency of spatial and intertemporal arbitrage, or a combination of all three. Arguably, when allowances are not continuing in perpetuity, for example, in the lead phase-down program, this measure cannot be used. Namely, the closer the vintage of the lead permits to the phase-out date, the lower the real permit price as they can be used for current compliance, but not banked for future.

When marketable permits are compared to other policy instruments such as command-and-control systems or permit system without trading, scholars often use cost savings to indicate the appropriateness of marketable permit systems (Stavins, 1998). However, cost savings are difficult to estimate. In most cases they are estimated theoretically by comparing models of individual behavior facing varying incentives of different policy instruments. For actual cost-savings of an implemented program, one would need to have an estimate of costs of reducing the use of the CPR by the same amount, but with alternative institutional arrangements.

Another option is to compare costs of resource use prior to enactment of the marketable permit program and afterwards. This approach was used to estimate cost savings of individual tradeable fishing quotas and SO2 allowances. The analyses indicate that it is difficult to disentangle the effects of permit trading from other effects. The reduction of fishing effort is portrayed as a positive effect of a tradeable permit system. However, a reduction of fishing effort can also result from other, non-related factors, such as weather, that increase the stock levels. Further, the reduction of fishing effort can result from the permit creation, not necessarily their trading.

Burtraw (1996) argues that the SO2 allowance system enabled cost savings without the trading. The flexibility in meeting the resource-use standards created incentives for inventions in coal rail-transportation and fuel-blending technologies, stimulated higher productivity in low sulfur mining, and improved the design and use of scrubbers. Thus, even without trading, substantial cost-savings were achieved in abatement of air pollution. It seems that the performance standards used in regulation of resource use and not trading stimulated these savings.

My analysis employs the following measures of trading performance: (1) trading volume, (2) number of trades, (3) proportion of regulated resource users who participate in the market' and (4) price dispersion (differences between individual prices and market clearing price).

3.2.3. Multiple Aspects of Performance

Most scholars argue that we need to look at multiple indicators when analyzing the performance of CPR markets. In addition to the above indicators, the following criteria are suggested: simplification of the resource-use control process; achievement of the objectives with which the programs were introduced; and provision of information regarding what is right and what is wrong with existing systems for tracking and controlling resource use (Dudek and Palmisano, 1988).

With any instrument that has multiple dimensions, the question arises as to how to compare and aggregate performance across these dimensions. When different dimensions of market performance (trading volume versus environmental effectiveness) require opposing institutional arrangements (the former would require one-on-one trading; the latter non-unit trading ratios), how do we judge the efficacy of the institutional arrangement? The question therefore is: which aspects of market performance are more important? This dissertation proposes that the most important criterion is environmental effectiveness. If the CPR deterioration is not prevented, we need to examine whether this is a result of nonanthropogenic factors, too modest environmental targets, ill-designed rules regulating the CPR use and users, poor monitoring and enforcement, or the lack of trading.

3.3. Analysis Methods

This study employs a case-oriented analysis. The research is performed in three steps. First, I study in detail the sulfur dioxide market; the most developed and active market. The detailed analysis of this market serves two purposes. First, it provides information necessary for operationalizing variables in my framework. Second, as this program is considered to have major similarities with the proposed carbon dioxide market, the analysis may provide some detailed insights for designing carbon dioxide markets. Sulfur dioxide allowance market and carbon dioxide markets share important attributes of the resource and the resource users: the CPR is affected by similar activities performed by similar actors; and they can be measured at the emission point.

At the second step, I examine whether or not the findings from the first market apply in other markets with different sets of resource users, different CPR characteristics, and different rules. I draw on published data from the following set of markets: lead permit trading, the early EPA regional air pollutant trading, Regional Clean Air Incentives Market (RECLAIM), CFC production permit trading, and Wetlands Mitigation Banking.

This dissertation focuses on the markets consciously crafted by regulators and other actors. This selection process introduces a selection bias (King, Keohane, and Verba, 1994) and allows me to study only the situation where markets are functioning and not where markets were considered to be ineffective and were therefore not created. A focus on the existing markets, therefore, biases the study towards better performing markets.

In the third step, I focus on potential carbon dioxide markets. I employ the findings from the previous two steps to identify the most important factors of market performance. I focus on the incentives for actors to participate in the market: electric utilities as large emitters, owners/managers of existing forests, and owners/managers of future forests (the latter two as suppliers of sequestration projects). My study focuses on the following issues: (1) who will produce and provide carbon permits either by reducing emissions in electricity generation or by growing biomass, thereby sequestering carbon; (2) who will approve the permits; and (3) how different approval processes may impact the performance of the market. Due to the characteristics of the carbon sequestration projects, this study will carefully examine the institutional arrangements that will allow for continuous, long-term monitoring and enforcement (Ayres, 1994).

Secondary data is used in this research. This has both advantages and disadvantages. The advantage is that the data collection takes less time and fewer resources. It also allows the researcher to use a larger data set for quantitative analysis. However, the researcher cannot affect the scope and detail of data collection. The data that are compared and combined do not necessarily measure the same concepts and this could potentially undermine the internal validity of the research results.

CHAPTER 4

SULFUR DIOXIDE ALLOWANCE TRADING

4.1.The Atmosphere As a Sulfur Dioxide Sink: Why Are We Concerned?

The use of the atmosphere as a sink for sulfur dioxide ($SO2$) and nitrogen oxides (NOx) has local and regional environmental effects, most commonly described as acid rain. Acid rain was discovered in the early 1970s by scientists at Yale and Cornell universities. When coal and oil are burned, sulfur and nitrogen from the fuels are released as sulfur dioxide and nitrogen oxides. Increased concentrations of these pollutants in the atmosphere reduce visibility and impact human health. Increased $SO2$ emissions are associated with increased amount of sulfate aerosols, particles that can be inhaled. Higher levels of sulfate aerosols are associated with increased morbidity and mortality from lung disorders. Nitrogen oxides reach with volatile organic compounds and form ozone that is also associated with increased morbidity and mortality.

These compounds can be carried hundreds of miles, depending on the wind velocity, and finally fall on the earth surface in dry or wet form. Further, as they react with water, oxygen, and oxidants in the atmosphere, they form a solution of sulfuric and nitric acid. Pure rainwater is slightly acidic because of the weak carbonic acid, created as rain reacts with carbon dioxide in the atmosphere. The atmosphere containing sulfur dioxides and nitrogen oxides, however, makes the wet precipitation more acidic. Acid rain dissolves aluminum silicates, makes the aluminum available to the plants. Trees are dying due to acid rain and clear-cutting in New England, New York, North Carolina, Tennessee, Georgia, Ohio, Indiana, and Kentucky (Little, 1995). The aluminum clogs the root system and stops the intake of needed nutrients. Acidity in the rain dissolves minerals in soil and they are washed away; the soil is depleted. Further, the fallen leaves and pine needles, and other dead material from the trees, builds up on the floor and prevents tree-saplings to grow. Further, acid rain causes acidification of lakes and streams, especially those with limited ability to neutralize the acidity. According to the National Surface Water Survey, acid rain caused acidity in about 75 percent of the surveyed acidic lakes and about 50 percent of the acidic streams. Acid rain also accelerates the decay of building materials.

Sulfur dioxide and nitrogen oxides are primary causes of acid rain. In this chapter, I focus on sulfur dioxide only, as emission trading was developed only for sulfur dioxide. Use of the atmosphere as a sink for nitrogen oxides was regulated by prescribing average emission standards. Several states in the northeast are slowly developing regional markets for NOx. These markets, however, are only evolving and are significantly different; they are open market systems, based on emission reduction credits rather than on emission allowances.

4.2. SO2 Allowance Market Analysis

4.2.1. Independent Variables

4.2.1.1. CPR Characteristics Affecting Measurability

Predictability of CPR stocks. The resource of interest is the atmosphere and its use as a sink for SO2 emissions. When the atmosphere is used as an SO2 sink, the increased ambient concentrations result in acid wet and dry deposition, damaging aquatic systems and some types of vegetation. The negative effect depends not only on the concentrations levels but also on the ability of the ecosystem to neutralize the increased acidity. Increased concentrations of ambient sulfur are not difficult to measure, neither are the concentrations in the dry or wet deposition. It is, however, very difficult to establish a standard level of deposition that provides a given level of protection to a selected ecosystem. These standards may be more easily developed for aquatic systems, but very difficult for other ecosystems that are also at high risk, such as high elevation forests. Even the-state-of-the-art data collection and modeling does not support development of satisfying standards (EPA, 1999b).

Availability of reliable indicators of resource flows. SO2 emissions were estimated even before the Clean Air Act Amendments (CAAA) of 1990 with a materials balance approach. The sampling of fuel input is performed routinely to ensure the quality of fuel delivered to the plant, and commercial aspects of coal supply depend on the accuracy of protocols for measuring in-fuel sulfur content. These measurements, however, were not considered to be sufficiently trustworthy for emission trading, as not all sulfur is emitted to the atmosphere--part remains in the ash, and emissions to the atmosphere can be reduced by the use of additives or sorbents in combustion (fluidized-bed method) or in the exhaust stack (scrubbers). Obtaining data from stack measurements also requires some assumptions on the homogeneity and velocity of the flue-gas stream. Ellerman et al. (1997a) argue that these assumptions are equally problematic as those involved in the material balance.

The CAAA require a continuous emission monitoring of SO2, NOx, and CO2 at the stack. If a firm chooses to use other measurement techniques and devices, it must prove that the measurement is equivalent to the continuous emission monitoring. Equipment is certified initially and there are periodic quality control procedures as well as procedures for filling in the missing data. Units report hourly emissions on a quarterly basis. The data is recorded in the Allowance Tracking System maintained by the EPA. This tracking ensures that sufficient amounts of SO2 allowances exist for each unit as well as that the averaging of NOx emissions complies with the regulatory requirements.

Spatial extent of the resource. If the emission stacks are low, the effects of the emission are localized. However, negative local effects of emissions prompted the emitters to build higher stacks. This results in winds carrying these substances thousands of miles away based on the wind direction. The use of the atmosphere as a sink for SO2 and NOx emissions first had only local effects but with the change of technology, the effects became regional.

Effects of the resource use on the resource stocks (uniform versus non-uniform effects). Local concentrations of SO2 and NOx emissions, and their effects on visibility, health, and acidity of precipitation depend on the location of the polluter and the wind direction. There are several downwind states in the northeast of the U.S., whose own use of the atmosphere as a sink for pollution is small, but due to the winds direction, they get acidic deposition from other upwind states (Midwest). This disparity caused some of the downwind states to limit the trading in SO2 allowances to the region and no export of allowances to the upwind states. The limitations were, however, declared unconstitutional and therefore had to be removed.

4.2.1.2 Characteristics of CPR Users

Major sources of SO2 emissions are presented in Table A1, Appendix A. In 1989, a year prior to enactment of the CAAA, the major sources of sulfur dioxide were: utilities (predominantly coal burning) that accounted for 69 percent of the national emissions, industry and manufacturing accounted for 12.7 percent, industrial combustion for 11.6 percent, and transport for 3.6 percent. Nitrogen oxides, on the contrary, were mostly emitted from small, non-point sources. Transport accounted for 43.0 percent of national emissions, utilities for 32.4 percent, and industrial combustion for 15.6 percent. The major users of the atmosphere as a sink for SO2 emissions are therefore large electric utilities, until recently substantially regulated by the federal and, to greater extent, state legislation.

States' utility regulation can affect the SO2 allowance market in two ways. First, it can directly prescribe technology that is to be used to reduce emissions. I discuss this aspect in more detail in the next section. Second, states can affect the allowance market indirectly by regulating allowed rate of return, the depreciation rate, and its approval of particular emission reduction strategies. These can differ among emission compliance strategies. Cost recovery rules are in domain of state regulatory commissions. As utilities were ensured a fair rate-of-return on their investment, a state regulatory agency had to review and approve their expenses. If a state wanted to stimulate the use of scrubbers, it could treat them as pre-approved capital investments whose costs can be passed onto consumers even before the installment. If it wanted to discourage the use of allowances as a compliance method, it could create a rule that their costs can only be passed onto consumers in the year when they are used for compliance. This discourages purchasing and banking of allowances for future use. Further, revenue from selling allowances can be treated as a capital gain and may be required to be passed onto consumers as a rate reduction. This also reduces motivation for trading. The Environmental Law Institute report (1997a) points out that the regulation of the utility industry by the Federal Electricity Regulatory Commission (FERC) and the Public Utilities Commission (PUC) was identified by the GAO report as a significant impediment to trading in the SO2 market. FERC and PUC provided little guidance regarding cost recovery rules. The GAO report found that out of 80 utilities that would benefit from buying allowances, only 2 decided to do so. More recent data show that the amount of trading has increased significantly, and over 2 million allowances were acquired by utilities in 1996 (a total of 4.8 million allowances were acquired from 1994 through 1996, with 2.9 million in 1996). Of these, 1.9 million were intra-utilities' transfers between units and 2.9 million acquired from other utilities, brokers, or fuel companies. Similarly, Fullerton, McDermott, and Caulkins (1996) argue that state regulation may increase costs of trading.

Statistical analysis of trading data, however, does not support the hypothesis of a significant effect of regulation on trading. Ellerman et al. (1997a) argue that states' regulation has not significantly impaired trading. Allowances were traded in all 24 states containing Phase I-affected units, as well as 10 of the 23 states that have only Phase II-affected units. Bailey (1998) observes that state regulations are often a reflection of the supply of additional allowances; states with large amounts of excess allowances created rules that motivate trading (Wisonsin, Connecticut, Pennsylvania). Her statistical analysis does not support the hypothesis of a statistically significant effect of state regulation on trading.

Reducing emissions of sulfur dioxide requires long-term planning. Both options for reducing emissions--building a scrubber or switching to lower sulfur coal--require a longer period to be realized. Scrubbers are a long-term investment that requires thorough planning. Coal supply contracts are typically long-term contracts and do not enable major short-term changes of the characteristics of sulfur content (Ellerman et al, 1997a). Utilities, therefore, have difficulties in reacting rapidly to price signals in emission allowance markets.

Further, one could argue that as electric utilities have an ensured rate of return on the invested capital, they do not minimize costs. This reasoning, however, is changing rapidly with the deregulation of the industry. Costs of generating electricity are becoming a major factor in the electricity market for wholesalers.

4.2.1.3. The External Legal and Regulatory Environments

External legal and regulatory environments impact constitutional-choice level rules in all CPR markets as they determine who can govern the resource use and formulate the policies. The collective-choice level institutions determine the rules of policy making and management that will affect the operational choice level decisions--decisions about the appropriation, provision, monitoring, and enforcement (Ostrom, 1990). Until 1963, regulating the use of the atmosphere as a sink for emissions was a prerogative of local governments. The negative effects of the use of the atmosphere were not thought of as having effects larger than a local scale. During the mid-twentieth century, it became obvious that air pollution is not only a local-scale process. Environmentalists were demanding the federal government to step in and in 1963, the Clean Air Act was enacted that gave the federal government investigative and abatement authority. The second air quality bill of 1967 left the primary responsibility for clean air with local and state governments. The pressure of environmentalists for federal air quality standards increased again in the early 1970s. The 1970 Clean Air Act authorized the Environmental Protection Agency to develop the standards. States were given the task of developing state implementation plans (SIPs) to achieve the standards. The standards were, however, not enforced and deadlines for achieving them were extended. Environmental agencies again pressed for changes in federal air quality policies and even filed a suit against the EPA stating that its new regulations were leading to a deterioration of air quality in some regions. Pressed by the court decision, the EPA had to agree to a change in the law. One of the changes gave more flexibility to industry in meeting the standards. In 1979, a "bubble" policy was enacted that gave the industry the flexibility in deciding at which plant will it meet the emission reduction requirements, thereby giving the flexibility at the operational choice-level decisions to the resource users.

The 1990 Clean Air Act Amendments addressed the use of atmosphere as a sink for emissions in various ways. On the one hand, they determined various geographic areas based on their level of local air quality and set various deadlines for meeting the air quality standards. The amendments, however, also addressed the use of atmosphere as a sink for emissions that cause regional and also international environmental consequences, that is, the emissions of sulfur dioxide and nitrogen oxides causing acidification of dry and wet precipitation, called acid rain. The bill itself listed the worst polluters. It listed 263 so-called *Table 1* units that had to reduce their sulfur dioxide emissions by 10 million tons by the year 2000. The bill itself therefore determined who had to limit the use of atmosphere as a sink and for how much. The bill determined that permits to use the atmosphere (allowances) will be allocated to the *Table 1* units based on their historical heat input (between 1985 and 1987) and a given rate of emissions per unit of heat input (2.5 pounds per mmBtu). The bill did not prescribe, however, how the listed units have to change their resource use pattern not to exceed the allocated resource use permits.

Title IV of the CAAA enacts a permanent cap on annual SO2 emissions. The cap was established by a political process and set in the law itself. The law itself states that allowances are not property rights. This is an attempt to avoid the takings issue if government decides to change the overall cap. The resource users have no right to determine the quantity of the total allowances for a given year. They also have no legal protection if the federal government decides to change the cap. Their customary rights, that give them the right to use the allowances, to sell, or to bank them, however, were sufficient for a well-functioning market. (The functioning of this market is addressed in the second section of this chapter.)

4.2.1.4. Rules Regulating CPR Use, Users, and Trading

Rules regulating CPR use.

Severity of resource use limitation. The 1990 CAAA allocated the rights to use the atmosphere as a sink to the *Table 1* units--the units with the greatest emissions--but did not regulate anyone else's resource use. In aggregate, the *Table 1* units were allocated 5.5 million tons sulfur dioxide allowances for 1995, when their emissions amounted to only 4.45 million tons of sulfur dioxide (Table 4.1).

Table 4.1: Emissions and Allowances of the Phase I Units

	1995	1996	1997
Emissions (million tons)			
Table 1	4.45	4.76	4.77
Substitution and Compensation	0.86	0.65	0.70
Opt-In		0.04	0.08
Total	5.31	5.41	5.47
Annual Allowance Allocation (million tons)			
Table 1	5.55	5.55	5.55
Substitution and Compensation	1.33	1.18	1.04
Other *	1.86	1.57	0.56
Total	8.74	8.30	7.15
Cumulative Allowances Carried over to the Next Year			
	3.43	6.29	7.96

Note:
* Other allocations consist of Phase I Extension, opt-in, small diesel, conservation, and EPA annual auction allowances.

Source: EPA Acid Rain Score 1996, Results of the Sulfur Dioxide Program, 1997; Preliminary Summary Emission Reports, ww.epa.gov/acidrain/.

The allowances were allocated according to the formula by which each unit receives an amount equal to an emission rate of 2.5 lb of sulfur dioxide per million of Btu heat input during the base period of 1985-87.

Additional allowances (for substitution and compensation units, for opt-in units, for the EPA annual auctions, and other purposes) amounted to 3.19 million allowances, whereas emissions of the substitution and compensation units amounted to only 0.86 million tons. In total, the regulated resource users were allocated 8.74 million allowances. Their use of the atmosphere in 1990, when the CAAA were enacted, amounted to 9.76 million tons (Table A2, Appendix A). The resource use restriction was therefore not very severe; it required a reduction of resource use by about 10 percent. This reduction may still be viewed as severe, given that the demand for electricity is growing. However, the heat-input (the input required for electricity generation) has increased by 7 percent between 1990 and 1995.

Rules regulating how the CPR is transformed into a private good. Title IV of the 1990 CAAA establishes a cap of aggregate allowances that are allocated to the regulated CPR users. An allowance entitles the allowance-holder to emit one ton of sulfur dioxide. The right to use the atmosphere as a sink for emissions is standardized--nominated in an absolute value, rather than a flow of resource over time. No prior approval is necessary for transfer of the right. These rights to the use of the CPR are enforced with a continuous emission monitoring system. An allowance tracking system contains data on allowances held by an account as well as data on the use of the CPR (emissions of SO2). The data on both is compared at the end of each calendar year. If a resource user sells some allowances and at the end of the year holds a smaller amount of permits to use the CPR than its actual use, it has time during the reconciliation period to obtain the missing permits. The fact that the seller had missing allowances at the end of the period does not affect the buyer or the characteristics of the good (permit) it purchased. An allowance from any source has the same expected value; there is no uncertainty related to the actual right that the buyer purchases.

The permit to use the CPR in this case is therefore defined prior to the transfer and does not depend on the characteristics of the seller of the permit. It is a standardized good, defined in an absolute value (one ton of SO2), rather than a flow of resource over time (for example, 500 tons of S02 in a given year). There is no uncertainty related to the existence of the permit for the buyer.

Rules regulating exchangeability of permits. Three aspects of exchangeability of permits are important for functioning of the allowance market: (1) exchangeability of an allowance in space; (2) in time; and (3) exchangeability of purchase of allowance with other forms of meeting individual resource-use limits.

Exchangeability in space might be limited if resource use has non-uniform spatial effects. In this case, a use of unit of the CPR at one location can have different environmental effects than the use of resource at another location. Where there is a prevalent wind circulation, there are some resource users who are up-wind and others who are down-wind from those who face the negative effects of the use of the CPR. For example, if an electric utility in the Midwest purchases allowances and emits sulfur dioxide, the states down-wind (the northeast) will face the negative effects of these emissions. It is therefore possible that those who are down-wind would require that exchange ratios of units of resource use reflect the negative effects of the resource use. Northeastern states have tried to limit the amount of resource use permits that can be sold to the up-wind resource users, but this interstate trade limitation was decided to be unconstitutional.

Exchangeability in time can also be limited. If the authorized agency decides to phase-out the use of the resource, it may limit the use of the current resource use rights in the future. It can devise rules so that the resource right in a time t+1 is given a right to a smaller amount of the resource as in time t. This discounting in time can significantly limit trading, if the buyers intend to bank the resource use permits for future use. This was not the case with the sulfur dioxide allowances, but it could be if the allowances were not denominated with an absolute value, but as a share of the total cap, a case quite common with some other resources. In the case of uncertain resource status, the authorized agency may have to change the cap over time and does not necessarily have all the required information to announce in advance how the cap will be changing.

The third aspect of exchangeability of resource use permits is in its comparison with other ways of meeting the resource use limits. For example, the authorized agency may devise rules that affect the accounting of the resource use rights. In particular, Public Utilities Commissions can regulate how allowances, their costs, and the revenue from allowances are calculated.

If the exchangeability limitations can be assigned a probability distribution, one could argue that the market price of the allowance would reflect these limitations and that they would not obstruct trading. Not all of these limitations can, however, be predicted with a probability distribution--there may be no past experience to serve as an approximation for the potential future changes or the information about the future state of the resource may not be available. This uncertainty then obstructs trading.

In the case of sulfur dioxide trading, exchangeability in time was not a problem. The issue of exchangeability in space was raised by some northeastern states, who attempted to limit interstate trading of allowances. This limitation was, however, examined in court and declared unconstitutional. Exchangeability of allowances versus other ways of meeting the resource use limitation (investment in scrubbers) was limited.

Rules regulating CPR users. The rules regulating CPR users affect the market functioning in two major ways, first by determining who is regulated and second, how non-regulated users can opt-in. These rules affect exchange costs, thereby the number and the volume of trades. They also impact environmental effectiveness of the CPR markets.

Who is regulated? Title IV of the 1990 CAAA regulated the use of atmosphere as a sink for sulfur dioxide emissions for 263 electricity-generating units (listed in the CAAA as *Table 1* units). All of these units were using the atmosphere more than an average unit (their emissions per unit of heat input were over 4 pounds of sulfur dioxide per million Btu, whereas the average emission rate of the Phase II units was less than 1.

Additional 1.86 million allowances were allocated as Phase I Extension allowances, small diesel, conservation allowances, and in EPA annual auction allowances. The extension allowances offer an explicit incentive for scrubbing, as they provide extra allowances that effectively delay the onset of Phase I for *Table 1* units retrofitted with a scrubber by January 1, 1997 (to cover the construction period for retrofitting).

Additional 1.33 million allowances were allocated to the substitution and compensation units. Provision in Title IV allows for different units to be brought in and achieve reductions instead of the *Table 1* units. The majority of opt-ins in the Acid rain program was temporal (units scheduled for phase II opted to be included in the phase I). Not many non-regulated industries opted in. Recently, the EPA approved an opt-in representing a trade from an industrial source to a utility in compensation of the shut-down of the industry's electricity-generating plants. Alcoa will receive approximately 89,000 allowances per year for three electricity generating units. Dupont will receive approximately 8,000 allowances for shutting down four steam generating boilers in 1996, and will give them to the Tennessee Valley Authority, from whom Dupont will now buy the steam. Ellerman et al. (1997a) attribute this fact to high transaction costs of finding partners for substitution outside the electric utility branch. In 1995, there were 175 units by 42 utilities that were listed as the substitution units.

The question of who is regulated versus who is not regulated affects the possibility of leakage, that is, the shift of the use of the CPR from the regulated activity to the non-regulated users. In the case of the regulation of sulfur dioxide emissions from electric utilities, the potential for leakage was substantial. As all electric generators are linked with the transmission lines and as electricity is a completely homogeneous product, the substitution of electricity generation by the non-regulated users was possible. Also, industrial and residential electricity users could substitute purchases of electricity by generating electricity themselves (industrial sector) or by switching to other fuels (heating in the residential sector). This substitution is, however, more involved than the substitution among electricity generators, as it requires investment in new equipment. The data on emissions from electric utilities (see Table A1, Appendix 1) indicates that the former shift had not occurred, the total emissions from electric utilities follow the trend of emissions of the Table 1 units. Similarly, the data for total national emissions in the period after 1990 indicate that the latter shift also did not occur.

Voluntary compliance: opt-in and substitution units. Units that are not regulated with the existing regulation can opt-in or become substitution units to provide emission reductions for some of the regulated units. The motivation for having the use of a CPR limited is not obvious without looking at the incentive structure offered by the regulation. There are three groups of factors affecting the decision to opt-in. First, units opt-in counting on the information asymmetry, which would result in the allocation of excess allowances. Selling these excess allowances would generate revenue. This actually increases the aggregate emissions. The potential danger of this increase was realized when the opt-in was allowed. The allowance- allocation formula for the substitution units was highly contested and a detailed method was litigated to ensure that substituting units are not those who have already achieved all the required emission reductions. The emission rate, which was used in the calculation of their allowances, had to be the lowest of the following emission rates: (1) actual 1985 emission rate; (2) allowable 1985 emission rate; (3) the 1989 or 1990 actual emission rate (whichever was greater); or (3) the most stringent federal or state allowable SO2 emissions rate applicable in 1995-99 as of November 15, 1990.

The problem then is to obtain the most accurate information on the current emission rates of the opt-in units. In 1990, one of the years to be used in the formula, compensation-substitution units emitted on average 1.61 lb of SO2/mmBtu. However, in 1995, the first year of the regulation, these units emitted only 0.9 lb/mmBtu (Table 4.1). This disparity caused excess allowances to be allocated to the opt-in units.

The second reason for opt-ins are low control costs. Reducing aggregate emissions by these low-cost units decrease the social costs of compliance due to the flexibility effect. This is the benefit of opt-in to society. A question arises whether this benefit in lower emission reduction costs outweighs the costs of potential increases of aggregate emissions. The answer depends on (1) the slope of the emission reduction benefit and cost curves; (2) the amount of the emission reduction substitution between the original and opt-in units (that influences the difference between the two cost curves); and (3) the original emission reduction target (as we move the emission reduction target right towards the equilibrium, the marginal costs increase and the marginal benefits decrease, thereby reducing the social costs of unneeded allowances).

The third motivation for opt-in is not in the SO2 regulation but in a related issue. The units that opted-in for the SO2 regulation had their NOx grandfathered at the level when they opted-in. If it is less costly to reduce SO2 emissions than NOx emissions, the units see an economic rationale for SO2 opt-in. As both SO2 and NOx are precursors of acid rain, reducing emissions of SO2 and not NOx and the resulting environmental effect of the opt-in is therefore not clear.

Rules regulating trading. Trading rules determine who can trade in the market and what rules regulate a transfer of allowances. There are two different markets of sulfur dioxide allowances: an annual EPA auction, and private markets. The first annual EPA auction was in 1993, and the private market developed in 1994. In either market, there are no limitations as to who can trade allowances. Initially, the major sellers and buyers in the markets were the 263 regulated units who have to reduce their SO2 emissions already in the first phase of the regulation (by the year 2000). The second group of traders were the generating units whose emissions will be regulated in the second phase (after year 2000), so-called Phase II units. Given the organization of the electricity generation and distribution, generating units are a part of an operating company that in many cases is a part of a larger holding company. There is no limitation as to who can trade with whom. However, rules regulating the requirements for reporting a trade can also have an effect (Lile, Bohi, and Burtraw, 1996). Trades within the same operating company (class 1) are likely to have lower transaction costs than trades between different operating companies within the same holding company (class 2). In some cases, class 2 trades can have higher transaction costs than interutility transactions--the Public Utilities Holding Company Act (PUHCA) requires special reporting for holding companies. These costs may be even higher when two companies within the parent company are located in different states that have different regulatory rules.

Brokers, such as Cantor Fitzgerald Environmental Brokerage, NY; Fieldston Washington, D.C.; Emission Exchange Corp., Escandido play an important role in this market. Their presence reduced search costs and thereby transaction costs (Ellerman et al, 1997a). Increasing the number of brokers helps potential trading partners find each other. Some brokers, however, not only serve as intermediaries, but also purchase allowances, transfer them on their account, and sell them when the market changes.

The EPA auction serves multiple purposes. First, if the market becomes very tight and the prices of allowances increase, the entry barriers for new generating units who have to purchase all emission allowances may become too high. The EPA auction is therefore one market in which allowances can be purchased by a given maximum price. Further, the EPA auction provides information on the allowance prices (Bohi and Burtraw, 1997). On the other hand, it has been argued that the existing trading rules skew the trading prices and, thereby, provide poor price information.

In the subsequent section, I operationalize the effectiveness of the program. For a given CPR management problem, the central issue is the successful management of the resource and prevention of its deterioration, that is, environmental effectiveness. I then turn to an analysis of market liquidity.

4.2.2 Dependent Variables

4.2.2.1. Environmental Effectiveness

There is no clear agreement on whether the sulfur dioxide allowance system is an environmental success or if it merely accomplished what would have been accomplished without it. I propose to look at the environmental effectiveness from various perspectives. First, I make it clear that the environmental effectiveness is a function of the allocated allowances (the primary allocation) and the enforcement of the allocations. This aspect is independent of the institutional arrangements that are used for the secondary allocation of the allowances. Further, the local acid deposition and its effects depend on the local environments and the ability of the ecosystems to neutralize increased acidity. Both major environmental authorities on this issue --the EPA and the National Acid Precipitation Assessment Program (NAPAP) -- have reported that emissions of SO2 have indeed been reduced. They both also notice a decline in sulfur concentrations in air, wet and dry deposition in the eastern United States, the area most at risk. The NAPAP report is, however, more cautious in attributing the causality link to Title IV of the CAAA and points out that it is too early to determine this (National Science and Technology Council, 1998).

Second, if the emission reductions exceed the required amount, the reasons may be in the high market liquidity and the incentives provided by the market arrangement, or it may be a result of other non-related factors. I address both--the effect of the incentives for overcompliance provided by the trading of allowances as well as some alternative explanations.

The emission cap, legislated in Title IV of CAAA itself, if enforced, determines the minimum level of emission reductions. The first step in the analysis of environmental effectiveness therefore has to review the emission reduction targets. On the one hand, Ellerman et al. (1997a) argue that the emission cap for the year 1995 did not significantly limit the emissions. Given the emission rate in 1993 (a period just prior to the beginning of the compliance period) and the actual heat input of the regulated units, the expected emissions without the regulation were about 8 million tons. The allocated allowances amounted to 8.7 million tons for 1995. Therefore, the allowances were not restrictive. In addition, major emission reductions were noticed already in 1994. Even though one could argue that these emission reductions are actually caused by the anticipation of the beginning of the compliance requirements in 1995, most authors attributed these reductions to lower prices of low-sulfur coal (Ellerman et al., 1997a; Bohi and Burtraw, 1997). The price of delivered low-sulfur coal decreased due to the deregulation of rail transportation in the late 1980s, an unrelated event.

On the other hand, emission reductions in the year 1995 are noticeable. The *Table 1* units, which had 5.50 million ton allowances, emitted only 4.45 million tons, which is more than 3 million ton reductions from the counterfactual case (emission rates of the year 1993 multiplied by the heat input of the year 1995). In total, all Phase I affected units reduced emissions from the counterfactual level by 3,888 million tons. About one half of the emission reductions were achieved by scrubbers (45 percent). Only 26 units installed scrubbers that contributed to nearly one half of the reductions--two-thirds of the reductions or 1.14 million tons came from only seven units. It is necessary to point out that there was a large overinvestment in scrubber technology. The investments were made based on the predicted prices of emission allowance in the range of $250 or even over $300 per tons. If the costs of reducing emissions with scrubbers amount to $265 per ton (Ellerman et al., 1997a), then one can understand the investment in scrubbers.

About one half of emission reductions resulted from coal switching. Ellerman et al. (1997a) also argue that about 40 percent of the 1995 emission reductions occurred in three states (West Virginia, Pennsylvania, and Ohio) that experienced no pre-1995 emission reductions. At least for these states one could argue that emission reductions are surely a result of the 1995 regulation. Their analysis, however, is not clear with respect to what proportion of the emission reductions is merely a compliance with the Title IV allocations and how much is exceeding the allocations. As the Phase I units were only allocated 5.5 million allowances and they emitted 4.45 million tons, only 1.05 million tons of emission reduction represents over compliance that can (or cannot) be attributed to the fact that the market was enacted for emission allowances.

It has been argued that Title IV has fostered significant innovation and investment both in utility plants and also in the rail industry. Such innovations have resulted in reduction of compliance costs from an estimated $1.3 billion under traditional regulation to $725 million in 1997, and are expected to reduce it from $4.5 billion to $2.5 billion under Phase II. The ELI (1997a) report lists $2 billion in investment in rail technology and another $6 billion in low-sulfur coal-fields. Innovation also took place in the utilization of existing plant and equipment. Possibilities for mixing low-sulfur coal with high-sulfur coal, conventionally considered to be problematic due to different moisture, heat, and ash content of the two fuels, improved significantly. Technology of scrubbing also improved and reduced the need for spare modules (ELI,1997a). The fact is that 3.43 million allowances were banked for future use in 1995. The cumulative amount of banked allowances in 1996 was 6.29 million allowances. In 1997, the cumulative amount of banked allowances still increased but at a lower rate. At the end of 1997, 7.96 million allowances were banked for future use (Table 4.1).

4.2.2.2. Market Liquidity

Analyses of sulfur dioxide allowance trading are numerous, predominantly due to the publicly available allowance tracking system, which records all allowance transfers, and due to publicly available data on the EPA annual auctions, both quantities and prices. Most analyses focus on the number of transactions (Ellerman et al., 1997a; Lile, Bohi, and Burtraw, 1996; Bohi and Burtraw, 1997; Bailey, 1998; Tietenberg, 1997c), though the number of transactions is a contested measure of trading activity. The trading data is further complicated by the fact that many allowances are transferred between units within larger companies or between the units and the higher levels of aggregation, for example, between the electricity generating unit and the owner utility. Some researchers add the analysis of prices and their changes over time (Lile, Bohi, and Burtraw, 1996; Ellerman et al., 1997a). In this section, I first analyze the data sources for the analyses of trading, that is, the Allowance Tracking System (ATS) and its characteristics, as the treatment of some of the related issues can potentially affect the outcome of the trading analyses. Then, I turn to a detailed analysis of the market, the traded volumes, the characteristics of the EPA auctions and the private market, and the allowance price trends since the first EPA auction. I analyze the disparities among prices and discuss what they reflect about the market.

Allowance tracking system (ATS). The main goal of the ATS is to monitor compliance and not trading and this goal significantly affects the possibility of using the data for policy analyses purposes. The ATS system contains no price information, as this may be strategically important information in the era of utility competition. Transactions are listed only when they become important for proving compliance with the emission allocations (Lile, Bohi, and Burtraw, 1996). However, we can also notice a large amount of recorded purchases by fuel suppliers and brokers, when none of them have any compliance requirements. This suggests that the ATS is more than merely a record used for compliance review. The regulated units are usually a part of large utilities or even holdings that also engage in emission trading. There is also a significant emission exchange between these units owned by the same owner, which complicates analyses of market exchanges. The EPA codes trades based on the owners of the allowance account. The most recent coding is for the year 1997, whereas transactions in the year 1998 and the first months of the year 1999 have not been coded yet. Any analysis of allowance transactions therefore first requires coding of the transactions in the last two years.

As ATS contains no price data, this information is obtained from other sources. EPA keeps records of bid- and offer prices for all annual auctions. Prices of allowances exchanged in private markets are only recorded by brokers. Some of them make the weekly average prices available; individual exchange prices could not be obtained. All conclusions on price dispersion are, therefore, based on the auction data.

Traded quantities. Before looking at the number of allowance transactions, a decision has to be made on two aspects of trading. First, what is the importance of intrautility transfers, and second, how to treat banking of allowances. Intrautility transfers are negotiated among members of the same utility or holding company. The transfer occurs at a zero price; allowances are merely reallocated. Since 1994, when allowances were first transferred outside EPA auctions, intrautility transfers represented a large portion of all allowance transfers (Table 4.2).

Table 4.2: Allowance-Exchanges, March 1993-May 1999

	1993	1994	1995	1996	1997	1998	Jan.- May 1999
Private Market							
Allowances	0	858,372	2,666,851	4,394,019	8,418,954	8,168,157	4,042,377
Transactions	0	63	339	575	838	736	392
The EPA Annual Auctions (spot and advance)							
EPA Allowances	150,010	175,400	176,000	275,000	300,000	275,000	275,010
Transactions	66	66	71	81	64	41	48
Private Allowances	10	1,200	1,400	0	0	0	10
Transactions	1	3	4	0	0	0	1
Reallocations and Intrautility Trades							
Allowances	0	8,410,357	13,879,654	4,239,218	7,321,096	5,144,250	2,223,721
Transactions	0	150	273	516	634	826	341

Source: The EPA Allowance Tracking System database.

In 1994, the intrautility transfers accounted for nearly 90 percent of all transfers. In 1998, they represented only 38 percent of all transfers. This indicates that transaction costs of allowance trading was substantial in the first few years and intrautility transfers were a way of reducing transaction costs.

The second issue related to allowance transfers is allowance banking. If regulated units choose to keep their allowances for the future rather than trade them, this reduces the traded quantity, thereby indicating a poorly functioning allowance market. On the other hand, one could argue that banking is an exchange in time and that it reflects costs minimization over time periods. This is indeed the case. However, if this is the predominant situation in a market, then we can conclude that the spatial aspects of allowance exchange are less important. In this case, it makes less sense to invest in costly development of an allowance market, when banking already minimizes costs for individual resource users. In 1995, the following use of the allowances has been recorded: 4.76 million were used by the utilities where they were allocated, 0.53 million were traded among utilities, 3.4 million were banked (2.91 by phase I utilities, 0.29 million sold to Phase II, and 0.22 million to third parties) (Ellerman et al., 1997a).

How much trading is sufficient? When can we talk about a functioning market? The answer to these questions is not clear. Is more trading necessarily better than less trading? In a theoretical analysis, the answer is easy. The optimum trading is achieved when the marginal costs of emission reductions are equal across all resource users--additional trade would not reduce anyone's costs of emission reduction. In practice, the information necessary to conduct a marginal cost analysis is not available. What can be measured, however, is the amount of allowances exchanged. The number of allowances exchanged in the private market and in the EPA annual auctions from 1993 to May 1999 is presented in tables 4.2 and 4.3.

Table 4.3: The EPA Annual Auctions: Bidding Activity

	1993	1994	1995	1996	1997	1998	1999
Number of Bids – Spot Auction							
Successful	36	37	46	47	41	21	27
Unsuccessful	70	66	43	92	118	88	50
Number of Bids – 7-Year Advance Auction							
Successful	30	19	17	25	17	20	21
Unsuccessful	35	92	20	67	58	34	11
Number of Bidders – Spot Auction							
Successful	21	17	26	29	23	11	11
Unsuccessful	/	9	8	13	20	25	12
Number of Bidders - 7-Year Advance Auction							
Successful	13	11	7	11	9	3	11
Unsuccessful	/	11	2	9	8	9	1
Allowances – Spot Auction							
Bidden	321,354	294,354	255,371	911,735	1,224,582	767,097	5,000,567
Sold	50,010	50,000	50,600	150,000	150,000	150,000	150,010
Offered	145,010	108,001	58,306	158,000	150,000	150,000	152,510
Allowances – 7-Year Advance Auction							
Bidden	238,406	489,399	236,928	404,634	553,406	509,009	253,055
Sold	100,000	100,000	100,400	100,000	125,000	125,000	125,000
Offered	130,500	147,000	107,000	107,000	125,000	125,000	125,000

Source: EPA Allowance Auction Results, http://www.epa.gov/acidrain/auctions/

A well-functioning market will have a larger proportion of all allowances exchanged than a poorly functioning market with high transaction costs. The extent of trading also depends on the difference in the abatement costs and the initial allocation of the allowances. I have addressed these issues in detail in the methodological chapter.

Sellers and buyers. The largest sellers in the private markets over the entire examined period were utilities, in average selling slightly more than one fourth of all allowances, and engaged in slightly more than one quarter of trades (Tables A3 and A4, Appendix A). Their share of sells has steadily increased throughout the observed period, accounting for 32 percent of the sold allowances and 33 percent of the trades in 1998, and for 49 percent of the sold allowances in the first quarter of 1999 and 60 percent of the trades in the same period (Figure A1, Appendix A).

The second most important seller of allowances were fuel companies that over the entire period (1994-May 1999) accounted for about 24 percent of the sold allowances and 26 percent of the trades. Their share was increasing until the beginning of 1999, when it slightly decreased: 11 percent of the sold allowances and 19 percent of the trades. This significant presence of fuel suppliers in the SO2 allowances market has important implications for other markets. Title IV of the CAAA regulated electric industry, that is, those who use the CPR as a sink for pollution. The use of the CPR was thereby regulated at the user end. Alternatively, inputs into the activities that use the CPR could have been regulated. For example, fuels--extracting industry or suppliers--could have been assigned SO2 allowances, as was the case in the lead phase-out program (discussed in greater detail in the subsequent chapter). The SO2 market indicates that the non-regulated actors, whose activities are impacted by the regulation of their buyers, use the flexibility of the market approach to decrease the negative effects of the regulation on their economic activity. The existence of the market made it possible for the suppliers of high-sulfur coal to purchase allowances in the market and bundle them with the sales of the high-sulfur coal.

The third major group of sellers are Phase 2 electricity generators, that is, the electricity generators whose use of the CPR will become regulated in the year 2000. They accounted for 16 percent of the sold allowances and 15 percent of the trades. Brokers were another equally important group of sellers. They accounted for about 14 percent of the sold allowances and the trades during the entire examined period. Phase 1 electricity generators, the only actors who were allocated SO2 allowances from the EPA, accounted for 12 percent of the allowances and the trades. They were the most important sellers in 1994, the first year of the private market operation (54 percent of the allowances and 43 percent of the trades). This is understandable as they were the *only* ones to be allocated the emission allowances. Their importance as sellers, however, rapidly declined in the second year itself (they accounted for 19 percent of the sold allowances and the trades). In this year, Phase 2 generators became the most important sellers of allowances (accounting for about 41 percent of the sold allowances and 18 percent of the trades). The year 1998 warrants special examination. Allowance prices experienced a large price spike in the summer of 1998. In this year, the share of utilities in allowances sales increased (from 21 percent 1997 to 32 percent in 1998; from 16 percent of trades in 1997, to 33 percent in 1998). This fact has been seen as a potential reason for the price spike in the summer of 1998 (interview with the editor of Fieldston publishing). I examine this argument later in this chapter.

Utilities are also the most important buyers of allowances (Figure A2, Appendix A). Throughout the examined period, they accounted for about one third of the purchased allowances and for about 31 percent of the trades. Their share of the purchased allowances was the largest in the year 1995 (when they accounted for one half of all purchased allowances and one third of trades). In the next year, they lost their importance as buyers while brokers increased their share. In the subsequent years, they increased their share, but never reached the 1995 level again.

Fuel suppliers are the second most important buyers of allowances, accounting for 28 percent of the purchased allowances and 30 percent of the trades throughout the examined period. Their market share was meager in 1994 (4 percent of the allowances and 14 percent of the trades), but increased rapidly by 1997, when they accounted for more than one third of the purchased allowances and nearly one third of the trades.

Brokers were the third most important group of buyers. Throughout the examined period they accounted for about 16 percent of the allowances and 20 percent of the trades. Their share of the market was the highest in 1996 (about one fourth of the purchased allowances) and reached the lowest in 1999 (only 7 percent of the purchased allowances).

The data for the first quarter of 1999 reveal another interesting aspect. Phase 1 generators accounted for about 13 percent of the purchased allowances, whereas their share in any other year has never reached 10 percent. This higher share can be explained with the fact that the data for this year reflects only the situation until May 1999. The first few months of each year have a particular importance for the regulated CPR users--so-called reconciliation period. Phase 1 generators have a few months at the beginning of each year to purchase additional allowances in case their emission in the previous year exceeded their allowances. Therefore, the data for the first few months may be slightly skewed towards Phase 1 generators as they may need to purchase additional allowances.

However, a similar pattern in 1999 is exhibited by the phase 2 generators, who do not have to meet the emission requirements and therefore do not need to purchase additional allowances during the reconciliation period. The data may be indicating that as we get closer to the beginning of the more strict restrictions on the use of the CPR (Phase II starts in 2000), the regulated entities have become more important players in the allowance market.

This analysis indicates that the conclusions on the shares of various groups in the private market based on the number of allowances or number of trades coincide. This indicates that there are no major differences in average sizes of purchases/sales of allowances across various groups of actors. This fact, however, differs from the characteristics of the EPA annual auctions (Figure A3, Appendix A). Over the entire examined period, the EPA auction market was strongly dominated by utilities (48 percent), brokers (9 percent), fuel suppliers (15 percent), and other actors (13 percent), if measured with number of purchased allowances (the left panel of Figure A3). On the other hand, when the presence in the market is measured by number of trades, environmental organizations become the third most important buyer (17 percent) after utilities (31 percent) and other actors (24 percent). Clearly, there are some very small buyers who bid a lot and are engaged in many transactions, but do not purchase significant number of allowances (environmental organizations and other actors). These actors may be using the EPA allowance auction because of the free access to this market. It is likely that had this market not existed, they would have not bidden at all.

Allowance price trends. The trends of SO2 allowances' trades in private markets during January 1997 to May 1999 are presented in Figure 4.1 with two curves-- the curve with diamonds represents the offer prices and the curve with squares the bid prices. The market clearing prices of the annual EPA auctions in 1997, 1998, and 1999 are represented with individual columns.

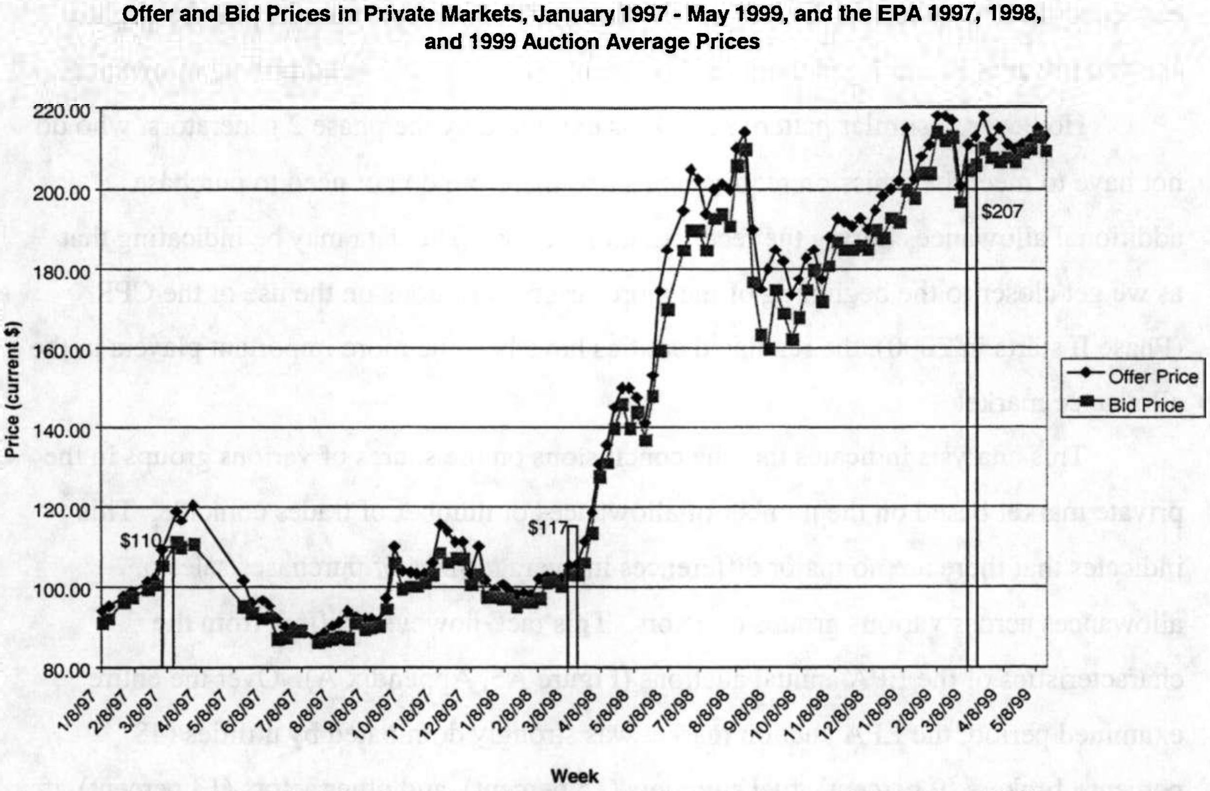
Offer and Bid Prices in Private Markets, January 1997 - May 1999, and the EPA 1997, 1998, and 1999 Auction Average Prices

Figure 4.1: Weekly Average Allowance Prices, January 1997-May 1999

Even though the EPA auctions operate only one day a year, their market clearing prices do not differ significantly from the prices in private markets that operate every working day. Private markets have been active since 1994, but weekly price data is available only after 1996. The continuous private market prices actually do not differ much from the auction prices. However, as the annual auctions last one day each year, it is not likely that that day's trading would affect the prices so significantly. Also, the importance of the auctions in the total number and volume of trades is reducing with time and can therefore not affect the level of prices in the private markets.

Initial allowance prices in early 1997 are much lower than the predicted prices due to several factors. Imperfections in the allowance market, driven largely by defects in the EPA auction matching process, are considered to be one reason for the price discrepancy (Bohi and Burtraw, 1997; Ellerman et al., 1997a). Another reason for low allowance prices was considered to be a large overinvestment in the pollution abatement technology--scrubbers--by utilities. Utilities were forced to invest in scrubbers (Bohi and Burtraw, 1997; Ellerman et al, 1997a). Also, Title IV explicitly stimulated utilities to install scrubbers as they were granted extension allowances for such investment. The investment decisions were made based on the basis of high allowance price estimates and therefore the over-investment. The average cost of emission reduction by scrubber is $322 per ton of removed SO2 (EIA, 1997a). The overinvestment of pollution-abatement technology resulted in oversupply of allowances and therefore lower price. The overinvestment may be a reasonable explanation for the initially low prices. However, after March 1998, allowance prices started increasing and have experienced an increasing trend since then. The price increase could not be explained with the supply side, as the overinvestment in the technology is still present (emission quotas have not decreased, which would decrease supply of available extra allowances and increase the demand).

Another important reason for low allowance prices was lower than expected prices of low- sulfur coal (Bohi and Burtraw, 1997). Coal switching is the cheapest method of reducing SO2 emissions, in average costing only $113 per reduced ton of emissions for the same level of electricity generation (EIA, 1997a). Interestingly, lower-than-expected low-sulfur coal prices were, on the other hand, explained by lower-than-expected allowance prices (Ellerman et al., 1997a). On the one hand, the first relationship is possible. Prices of low-sulfur coal were so low due to the decrease in transportation costs. Technological development and deregulation of railways resulted in lower prices of transportation, an important factor for low-sulfur coal that is located significantly further from the major users than the high-sulfur coal, that is for most states available locally. The second argument, linking low prices of low-sulfur coal to low-allowance prices also has some merit, at least in the initial years of the trading program. Fuel suppliers are major buyers of sulfur allowances and they bundle them with high sulfur coal. This reduces the sulfur-premium for coal prices and thereby keeps the low-sulfur coal prices down. One could argue that the links between the coal prices and allowance prices would be rather weak as the coal prices are determined in long-term contracts. However, over the years, the length of coal contracts is decreasing, a trend attributed to deregulation of the electric industry and the generators' pressure to reduce costs and re-define terms of contract. Between 1985 and 1985, the percentage of long-term coal contracts has remained fairly steady (just below 30 percent); major changes, however, are noticeable for medium- and short-term contracts. Medium-term coal contracts accounted for about 50 percent of all coal contracts in 1985, whereas in 1995 they accounted for only slightly more than 30 percent. The share of short-term contracts increases as a mirror image from slightly more than 15 percent in 1985 to nearly 40 percent in 1995 (EIA, 1998).

Both arguments, however, lose their explanatory power already in the second half of 1997 with the first allowance price increase (Figure 4.1) and then more significantly after March 1998 with major allowance price increases. Both EPA auction data (Table 4.4) and the weekly private trading data (Figure 4.1) reveal an increasing trend of allowance prices. The EPA annual auction prices (the auction is in March of each year) in 1997 were about 62 percent higher than in 1996. The first months of 1998 did not exhibit high price increases (1998 auction prices were only 5 percent higher than the auction prices in 1997). Figure 4.1, however, illustrates a major increase in prices after April of 1998.

Table 4.4: Trends in Auction Allowance Prices

	Spot Auction			6-Year Advance Auction			7-Year Advance Auction		
	Average Price	I_{base}	I_{chain}	Average Price	I_{base}	I_{chain}	Average Price	I_{base}	I_{chain}
1993	156.60	100.00	/	/			136.00	100.00	/
1994	159.20	101.66	101.66	148.00		/	149.00	109.56	109.56
1995	132.00	84.29	82.91	131.00		88.51	128.00	94.12	85.91
1996	68.14	43.51	51.62	65.36		49.89	64.21	47.21	50.16
1997	110.36	70.47	161.96	105.51		161.43	104.16	76.59	162.22
1998	116.96	74.69	105.98	/			111.05	81.65	106.62
1999	207.03	132.20	177.01	/			179.79	132.20	161.90

Note: The average price is weighted by the purchased quantity.

Source: The EPA Auction Data.

Prices of low-sulfur coal, on the other hand, have not increased, but continued to decrease (see Table 4.5). For example, the costs of coal, delivered to utilities, for coal types with the lowest sulfur content (less than 0.5 percent of sulfur) slightly decreased in 1997 in comparison to 1996, and subsequently decreased by 5.25 percent in 1998. To be able to understand the large increase of allowance prices as we approach the beginning of Phase II, we need to examine the demand for allowances.

Table 4.5: Price Index for Coal Receipts, by Sulfur Content

Sulfur Content (%)	94/93	95/94	96/95	97/96	98/97
Less than 0.5	95.81	97.58	97.31	99.98	94.75
<0.5< < 1.0	100.30	103.35	97.90	98.14	98.99
1.0< < 1.5	100.88	93.10	97.84	98.84	100.50
1.5< <2.0	97.52	90.11	103.33	100.13	98.66
2.0< <3.0	97.16	93.83	99.49	96.56	100.87
More than 3.0	101.24	92.07	95.23	99.99	104.73

Source: Cost and Quality of Fuels for Electric Utility Plants, 1994-1999.

Changes in demand may help explain not only the general trend of allowance price increases but also the major deviations of the weekly prices from the general trend during the period between June 1998 (average weekly price of allowances increased from $149 to $165 in a week) and the middle of August 1998 (when the average weekly price amounted to $214). The same period experienced a major increase of demand for electricity. If the increased demand stimulated increases in supply, then the coal-burning units would also face higher demand for allowances, which would in turn explain the higher allowance prices. If the rationale holds, we would then expect to see the following:

(1) the periods of higher allowance prices would coincide with the increases in the demand for electricity (or follow with a short lag, required to start using the additional generating units);

(2) a change in the market structure, with Phase 1 units becoming more important buyers of allowances; and

(3) a higher than average share of traded allowances of current or past vintages, as only these can be used at the end of the year to comply with the emission caps.

The EPA allowance trading data and the average weekly allowance price data do not support any of these hypothesized changes. First, there were three periods with the increase of electricity demand, July 1997, May 1998, end of June 1998, and July 1998 (FERC, 1998). Allowance prices do not experience any additional price increases during these periods. During July 1997, allowance prices were actually declining, similarly during May 1998. At the end of June 1998, when the increased demand drastically increased electricity prices, allowance prices were increasing with the same trend as throughout the summer of 1998. The reason that the short-term increases in demand for electricity are not necessarily reflected in the higher allowance prices lies in the technology used to meet peak demand. The units that are used to meat peak-load demand are burning either gas or oil, as they require a shorter period for bringing them into operation. Coal-burning plants provide base-load and their utilization cannot be changed fast enough to accommodate short term changes in demand. As natural gas and oil units are not regulated by Title IV, they do not need to purchase additional allowances.

The EPA emission trading also does not support the hypothesis that increased demand for electricity would alter the allowance market structure, either in terms of importance of specific groups of buyers, or in terms of the vintage of allowances. The structure of sellers and buyers in 1998, as well as during the high price period, is presented in Table 4.6.

Table 4.6: Sellers and Buyers in the Private Market for SO2 Allowances
(Percent of Total Number of Trades)

Year 1998		
Participant Group[1]	Sellers	Buyers
Broker	14.9	22.1
Environmental	0.1	0.5
Fuel Suppliers	31.1	31.5
Others	5.8	6.4
Phase 1 Units	7.1	4.8
Phase 2 Units	7.1	2.1
Utilities	32.7	31.1
All[2]	100.00	100.00
June 1 through August 17, 1998		
Participant Group	Sellers	Buyers
Broker	13.4	26.2
Environmental	0.6	1.3
Fuel Suppliers	30.2	33.6
Others	6.7	4.7
Phase 1 Units	8.7	4.0
Phase 2 Units	12.1	0.0
Utilities	26.8	30.2
All[2]	100.00	100.00

Notes:
(1) The sales in the EPA auction are omitted from the analysis, to enable a comparison between the two periods.
(2) The percentages may not sum up to 100 percent due to the rounding.

Source: The EPA ATS database.

The period that experienced an allowance price-spike, that is, June through August 18, 1998, is not different from the average situation in 1998. In both cases, utilities and fuel suppliers are major buyers, each accounting for about one third of all transactions. Phase 1 units account for only about 4 percent of transactions in both periods. Similarly, the structure of purchased allowances by their vintage does not differ between the high allowance price period and average 1998 data. Allowances of the current vintage or issued in the past (these can all be used for compliance at the end of the year) represent 55.9 percent and 59.5 percent, respectively.

Availability of the price information. Another important indicator of market performance is availability of price information and the resulting reduction of deviations in bids. One would hypothesize that a well-performing market would be associated with more complete the information and with smaller deviations of the individual bids from the market-clearing price. If the information on the market-clearing price is available, rational market participants would bid marginally above the market-clearing price. The biding and matching rules, however, affect the bidding strategies. As no data on prices of individual transactions in the private market is available, this analysis has to rely on the data on EPA auctions.

I assume that the availability of the information on auction prices only improves over the years. Each year, interested sellers or buyers can review the price data for previous auctions. Given this assumption, I hypothesize that these markets would perform better, that is, the individual bids would not vary significantly from the market-clearing price. Standard deviation, calculated for the auctions over years, would then decline. The EPA auction bidding price data, however, do not support this hypothesis (Table 4.7). The data suggest that variability is not decreasing over the time. The coefficient of variation in spot auction, which is not weighted by the bidden quantity, decreases in 1994, but then again increases in 1995 and 1996. Variation of auction prices in 1997 is significantly lower than in 1996, but then it again increases in 1998 and 1999 (Table 4.7, bottom panel).

Table 4.7: Variation of Auction Bid Prices, 1993-1999

Weighted

Year	Spot Auction			6-Year Advance Auction			7-Year Advance Auction		
	Coefficient of Variation	I_{base}	I_{chain}	Coefficient of Variation	I_{base}	I_{chain}	Coefficient of Variation	I_{base}	I_{chain}
1993	0.048	100.00	/	/			0.073	100.00	/
1994	0.027	56.25	56.25	0.026	100.00	/	0.023	31.51	31.51
1995	0.016	39.58	59.26	0.062	238.46	238.46	0.036	49.32	156.52
1996	0.017	35.42	106.25	0.060	230.77	96.77	0.027	36.99	75.00
1997	0.013	27.08	76.65	0.037	142.31	61.67	0.022	30.14	81.48
1998	0.014	29.17	107.69	/	/	/	0.010	13.70	45.45
1999	0.024	50.00	171.43	/	/	/	0.029	39.73	290.00

Coefficient of Variation = $\sqrt{\{[\sum(p_i-p_c)^2 \times q_i / \sum(q_i)] / n-1\}} / p_c$

Not Weighted

Year	Spot Auction			6-Year Advance Auction			7-Year Advance Auction		
	Coefficient of Variation	I_{base}	I_{chain}	Coefficient of Variation	I_{base}	I_{chain}	Coefficient of Variation	I_{base}	I_{chain}
1993	0.528	100.00		/			0.590	100.00	
1994	0.240	45.45	45.45	0.176	100.00	/	0.211	35.76	35.76
1995	0.266	50.38	110.83	0.256	145.45	145.45	0.187	31.69	88.63
1996	0.473	89.58	176.69	0.359	147.16	203.98	0.355	60.17	189.84
1997	0.154	29.17	32.56	0.208	118.18	57.94	0.189	32.03	53.24
1998	0.173	32.77	112.34	/	/	/	0.089	15.08	47.09
1999	0.204	38.64	117.92	/	/	/	0.188	31.86	211.24

Coefficient of Variation = $\sqrt{\{\sum(p_i-p_c)^2 / n-1\}} / p_c$

One could argue that this increase of variability is not an indicator of poorer availability of information, but rather of irrational behavior of some small, irrelevant players in the market. This argument can be illustrated with Figure 4.2, where the circles represent each individual bid. The axis y represents the difference between the individual bid and the market-clearing price (positive and negative). The size of the circle represents the bidden quantity. Figure 4.2 illustrates a situation where some buyers bid a very high price but a very small quantity. This situation is a good reflection of the EPA auctions, where we see environmental organizations and university students bid with a high price for only one allowance. As they are buying only one allowance, they can afford bidding very high. The question is why do they bid so high if they know the market clearing prices. The answer may lie in the EPA reporting. All successful bidders are listed by the name in the reports of the annual auctions. Ensuring this free promotion may then, rather than the lack of information, motivate high bids. These small bidders should then be considered outliers and eliminated from the analysis. I accomplish this by weighting the price difference of the individual bids by the bidden quantity. Weighted coefficients of variation are presented in the top panel of Table 4.7. The data indicate that market participants are learning over the years. Variation in bid prices in the 1999 auction is about 50 percent smaller than it was in the first auction in 1993. The data, however, also indicate that variation in 1999 was over 70 percent higher than in 1998. We can conclude that participants are learning about this market over the years. Individual years, however, can exhibit substantially higher variability than the trend would predict.

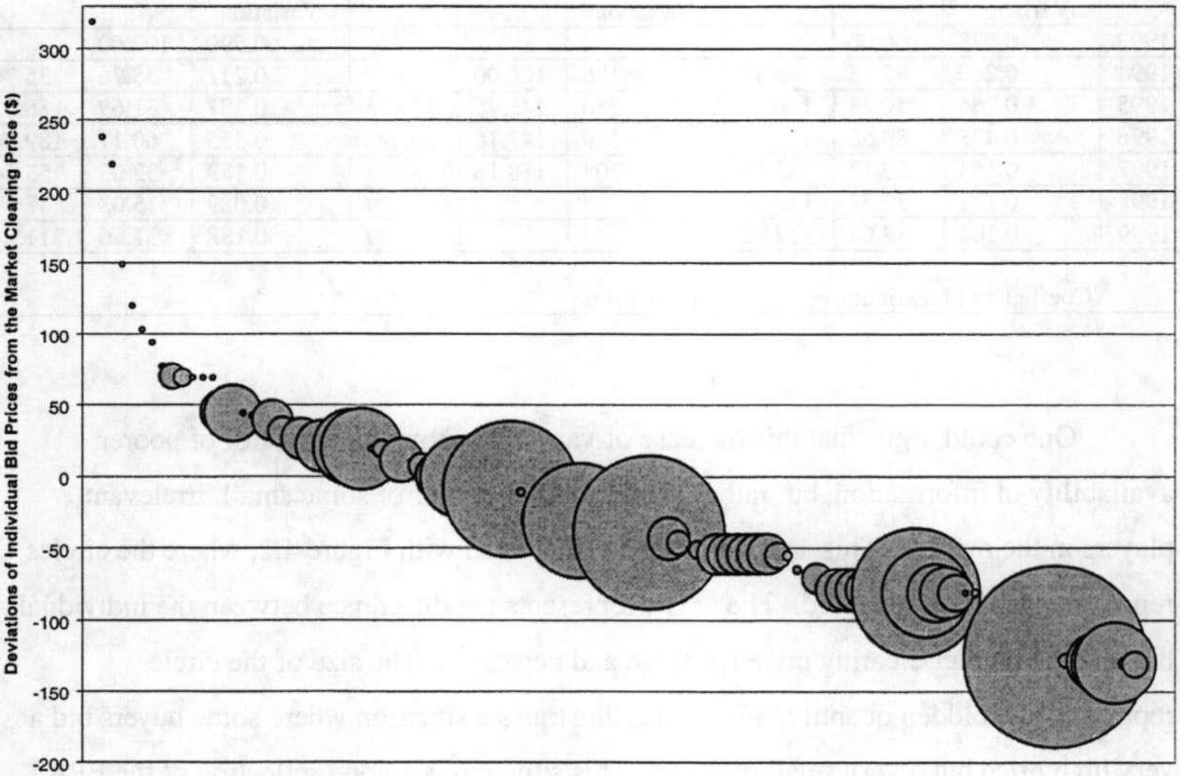

Figure 4.2: Diversions of Individual Bids from the Market-Clearing Price

Trust in the customary property rights. If property rights are allocated, enforced, exchangeable, and if resource users face different costs of reducing the use of the common-pool resource, we would expect an active market to develop. The question then arises as to what type of property rights is required for an active market. Arguments identifying advantages of tradable property rights over command-and control management of common-pool resources usually argue for secure property rights. If secure property rights, protected from being withdrawn by the authorized agency from the circulation (takings issue), do not exist, we would not see any active markets. If property right holders do not have a trust in the future of the rights, they would not trade them.

Title IV of the CAAA explicitly states that emission allowances are not property rights. The authorized agency (in this case the EPA) has the right to reduce the total allocated amount (the cap) of allowances. This uncertainty, then, would impede trading of the SO2 allowances. Analysis of the allowance trading, both volumes and prices, however, indicates differently. First, we can notice no backwardation of allowance prices--the price of allowances of future vintage are not lower than the prices of current-vintage allowances. The data on prices of allowances of two different vintages are presented in Table 4.8. Average prices in spot auction are slightly higher than average prices in advance market (allowances that can be used only 7 years later). This moderate difference was identified by Ellerman et al. (1997a) as indicating the uncertainty of the future value of allowances. They argued that the real prices in the spot and advance markets should be the same in absence of transaction costs.

Table 4.8: Disparities between Average Prices for Spot and 7-Year Advance Auction

Year	Average Spot Price (dollars)	Average Advance Price (dollars)	PPI	Future Spot Price Estimate (dollars)	Internal Rate of Return (no change in the Market) (%)	Long-Term Interest Rate (%)	Difference between the Rates (% points)
1993	156.60	136.00	102.05	180.50	4.13	5.66	1.53
1994	159.20	149.00	100.16	160.99	1.11	6.28	5.17
1995	132.00	128.00	101.76	149.15	2.21	7.14	4.93
1996	68.14	64.21	102.36	80.23	3.23	6.19	2.96
1997	110.36	104.16	101.54	122.82	2.38	6.65	4.27
1998	116.96	111.05	98.49	105.14	-0.78	5.71	6.49
1999	207.03	179.79	100.85	219.67	2.90	5.36	2.46

Notes:
Price is averaged across all successful bids, weighted by the purchased quantity.
PPI is calculated for March of each year.
Seven year treasury constant maturity rate for March of each year is used.
Future spot price is estimated by using the current spot price and taking into account inflation (PPI), that is, we assume no change in demand and supply.
Implicit internal rate of return (d) is estimated as follows: (1+d) = Future Spot Price Estimate/Average Advance Price

Source: EPA auction database, Federal Reserve Bank (www.stls.frb.org/fred/data/irates/gs7) and Bureau of Labor Statistics (http://stats.bls.gov/news.release/ppi.nws.htm).

The price in advance market depends on at least two groups of factors: (1) the sellers' and buyers' expectations of future supply and demand that will affect prices of allowances in the future; and (2) the right holders' expectations of the security of the property right. The fact that allowance holders do not hold a true property right but only a costumary right does not seem to introduce insecurity of the traders and therefore cannot be impeding trading. I illustrate my argument with a comparison between the allowance prices in the spot and the advance market (Table 4.8). In 1993, the average spot market prices amounted to $156.60 for one allowance. The average price in the advance market amounted to $136.00. If the right holders assumed a perfect security of the future allowances, and no change in the supply and demand of allowances after 7 years (the advance market), they would estimate the value of the allowance in 7 years would be the current value, adjusted for inflation (Purchaser price index). The value of the allowance in nominal dollars after 7 years would then be $180.50. If we treat a purchase of allowances in advance market as an investment into an asset, then we can calculate an implicit rate of return of this investment, which turns out to be 4.13 percent

($180.50/$136.00=(1+d). An alternative investment of funds with the lowest risk would be a purchase of treasury bills. The seven-year treasury constant maturity rate for March 1993 was 5.66 percent. This investor was therefore willing to invest in the advance allowance market with an implicit rate of return lower than the lowest risk long-term investment. If this rationale is correct, then the investors must have not only thought of this investment as secure as treasury bills, but actually having a larger demand (or lower supply) in the future than exists in the current market. As indicated in Table 4.8, the implicit rate of return for advance allowance purchase was lower than the low-risk interest rate throughout the studied period. The fact that allowances are actually not defined as property rights and as such protected from "takings" did not seem to impede trading, or the insecurity of the rights was perceived to be worth the risk, given the possibility of demand exceeding the supply of allowances in the future.

The fact that trading in options, swaps, and futures was developed further indicates that allowance holders did not seem to be affected by the "insecurity" of the rights in the SO2 market (Ellerman et al., 1997a). Table A7 (Appendix A) presents the number of transactions in a given year (columns) by the vintage year of the allowances (rows). In 1994, there were 69 transactions that involved package of allowances of 1995 vintage. In 1995, the beginning of the compliance period, over one quarter of transactions in private markets involved a packet of allowances that can be used for compliance only in the future. This indicates that already at the beginning of this new institutional arrangement for managing this regional common-pool resource, the right holders felt secure about the future of allowances. They were purchasing allowances to ensure compliance with the environmental regulation and to potentially trade them in the future. It is therefore not necessary that holders of resource use rights have a complete right to be able to use the rights. The SO2 allowance holders do not have the ability to affect the number of allowances allocated each year and their rights are even not secure from takings, the way property rights to other resources (for example, land) are. Yet, a fairly liquid market evolved over the years.

4.3. Conclusions

The examination of the SO2 allowance trading suggests that a market can be used for allocating regional CPRs whose appropriation has moderately non-uniform effects. Electric utilities, whose economic decisions are still considerably affected by the state regulation (or a lack of it) of accounting practices, did actively trade. Their importance in the market (both as sellers and as buyers) was the highest in the first year and then drastically decreased, as other participants entered the market. The last year again reveals increased importance of the regulated CPR users, as they approach Phase II of the regulation, when a major increase in demand for allowances is anticipated. Trading activity did not seem to be affected by the fact that the CPR users did not have complete property rights and intertemporal security of the rights.

The environmental goals for reducing sulfur concentrations in the air and subsequent acid deposition were attained. Eastern states, facing the highest risk of acid deposition, have noted decreases in both sulfur concentrations in dry deposition (a 30 percent decrease between 1989 and 1995) and in acid rain (about 25 percent decrease in 1995). Nationally, ambient concentrations of sulfur dioxide decreased by 17 percent between 1994 and 1995. These were all the desired outcomes of the institutional arrangement regulating the CPR use, though the targets were focused on SO2 emissions, rather than on concentrations.

SO2 emissions were reduced nationally. No major shifts of emissions from the regulated activities to non-regulated activities occurred. Trading also did not cause major shifts in regional use of the CPR--most utilities were used in the states where they were allocated (EPA, 1999a). The target for reducing the CPR use has not only been met but significantly exceeded. It is not possible, however, to attribute this outcome to any single factor. One could definitely not argue that the flexibility offered by the market arrangement stimulated the overcompliance. On the contrary, this flexibility could have caused a slight increase in the use of the CPR over the counterfactual case (Montero, 1997). Other factors, for example a decrease in the price of reducing the CPR use, caused by factors unrelated to the CPR market (decrease in transportation costs of low-sulfur coal) have largely contributed to overcompliance. The industry has also benefited from other advancements in technology (improved scrubbing and fuel-mixing) technology, which may have been affected by the future potentials of the SO2 market.

Further, overcompliance has been attributed to factors that reveal a governmental intervention in the SO2 market, rather than a free market success. A large source of the extra allowances in the market came from the units that had installed scrubbers. These decisions were made on a grossly overestimated allowance price expectations. State regulatory commissions' accounting rules, their co-financing of the investment, and the allocation of extension allowances for an investment in scrubbers are all factors contributing to the overinvestment and the resulting overcompliance.

[illegible]

[illegible]

CHAPTER 5

ATMOSPHERE AS A CPR:
EPA EMISSION TRADING, RECLAIM, AND LEAD PHASEDOWN PROGRAM

This chapter examines marketable permit systems for managing atmosphere air as a pollution sink, when its use has local and non-uniform effects. Two different approaches to managing atmosphere as a pollution sink have been used in the U.S. environmental policy. One type of marketable permit systems focuses on the users and processes causing pollution (the EPA Emission Trading and RECLAIM). The other type focuses on the producers/suppliers of the polluting product (Lead Phasedown Program).

5.1. Using Atmosphere As a Sink for Pollutants That Remain in the Local Environment

The problem of deteriorating local air quality dates back to the 1950s. This led to the Air Pollution Control Act (APCA) of 1955. Though the APCA mainly provided funds for research, it also introduced the federal government's intervention in ensuring air quality.[1] The Clean Air Act (CAA) of 1963 increased the role of the federal government. The Clean Air Act Amendments of 1970 mandated a federal agency--the Environmental Protection Agency (EPA)--to list substances causing local air deterioration and set the maximum allowable concentration level for these pollutants.

The EPA listed six major criteria pollutants whose excessive air emissions significantly impact human health and public wealth: ground ozone[2], carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter (PM), and lead. Ozone is formed at the ground level when volatile organic compounds (VOC) and nitrogen oxides (NOx) chemically react in the presence of sunlight and high temperature. Therefore, the highest levels of ozone are experienced in summers. Carbon monoxide is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in

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[1] Prior to that, air pollution was considered to be a local matter, to be addressed by local- and state-level regulations.

[2] Ground-level ozone should not be mistaken for stratospheric ozone, discussed in Chapter 6. Ground-level ozone is a result of pollution and is damaging to one's health. Stratospheric ozone, on the contrary, protects human health and materials from excessive damaging radiation (UV-B radiation).

fuels. Nitrogen dioxide (NO2) is also caused by fossil fuel burning. It is an acid rain and ozone precursor. It causes respiratory problems. The health and environmental effects of SO2 were addressed in Chapter 4. Air particulates include dust, dirt, soot, smoke, and liquid droplets that are emitted into the air by factories, power plants, cars, construction activity, fires, and natural windblown dust. The major effects of particulates on human health include respiratory problems and cardiovascular diseases, and carcinogenesis. The major source of lead in the air during the 1970s was transportation, but now it is the industrial sector. Lead can enter the human body in various ways, such as inhalation and ingestion in food or water. The EPA also set standards for the use of air as a pollution sink; that is, emission standards.

5.2. Regulating Polluting Processes: EPA Emission Trading and RECLAIM

As the overuse of air as a pollution sink has local consequences, air quality management units were created at the local level to address these issues. The EPA and states subdivided the United States into Air Quality Control Regions, units responsible for air quality management. If the ambient quality in an area was worse than the standard set by the EPA, the area was designated as "non-attainment." This was not merely a declarative issue. Non-attainment areas faced severe development limitations, such as denial of permits for construction of new facilities, unless they improved their air quality.

In spite of the last 30 years of air quality regulation and 20 years of various types of emission rights trading, there still are some areas that continue to suffer from serious air pollution. In 1985, the EPA estimated that up to 32 metropolitan areas might not attain the standards by 1987. The major non-attainment areas were located in the northeastern part of the U.S., Florida, the California coast, and the urban areas around the Great Lakes. As of August 1999, there were still 77 areas that did not meet standards for one or more of the above-listed criteria pollutants.[3] Figures B1-5 in Appendix B depict the non-

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[2] Ground-level ozone should not be mistaken for stratospheric ozone, discussed in Chapter 6. Ground-level ozone is a result of pollution and is damaging to one's health. Stratospheric ozone, on the contrary, protects human health and materials from excessive damaging radiation (UV-B radiation).

[3] In 1999, thirty-three areas (about 92.4 million population) did not meet the ozone standards. Twenty areas (34.1 million population) did not meet the CO standards. Thirty-three areas (4.7 million population)

attainment areas in the U.S. as of August 1999. Some of the above areas have persistently failed to meet the standards (the northeast and California), whereas areas of Florida and the metropolitan areas around the Great Lakes have improved their local air quality. The northeast and California are therefore the two most obvious candidates for my analysis. The northeast has been slow to develop a MPS, whereas the South Coast Air Quality Management District (SCAQMD) in California has had a MPS in place since the 1970s. Therefore, I will focus on SCAQMD.

In February 1977, the California legislature created the South Coast Air Quality management District (SCAQMD). South Coast Basin borders Pacific on the West, and the San Gabriel, San Bernardino, and San Jacinto mountains in the north and in the east (area of 13,350 square miles). It has light winds, heat inversion layer, and sunlight, all creating potentials for local air quality problems (National Academy of Public Administration, 1994). The local climate characteristics as well as active development have contributed to the failure in meeting the federal NAAQS in the 1970s as well as in the 1990s.

SCAQMD used marketable permit systems to reduce the local air pollution in the 1970s and 1990s. Two different systems were used with different results. The Clean Air Act Amendments (CAAA) of 1970 enacted development limits for non-attainment areas. No new facilities (new sources in the terminology of the Act) were allowed to be built in the area unless their planned emissions were offset by emission reductions of existing facilities. The EPA developed four mechanisms that allowed for flexibility in meeting the emission reductions. In this chapter, I first review this initial EPA trading arrangement. Then, as the SCAQMD still failed to meet the federal NAAQS and state clean air standards for NOx and SO2, a new MPS was devised in 1994. The new system was based on marketable permits--Regional Clean Air Incentives Market (RECLAIM). The rest of this section examines RECLAIM.

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did not meet SO2 standards. Seventy-seven areas (29.3 million population) did not meet the PM-10 standards, and 9 areas (1.2 million population) did not meet the lead standards.

5.2.1. Independent Variables

5.2.1.1. CPR Characteristics Affecting Measurability

Predictability of the CPR stocks. When air is used as a sink for unwanted by-products and these pollutants accumulate in the local atmosphere, it is the concentrations rather than the emissions that cause negative effects. National ambient air quality standards are expressed in volume concentrations for SO2, PM10, CO, Ozone, NO2, and lead. The EPA and the states have divided the United States into Air Quality Control Regions. If air in a particular area does not meet the National Ambient Air Quality Standards, the area is designated as a "non-attainment area." An Air Quality Control Region can be designated as a non-attainment area for one pollutant but not necessarily for other pollutants (National Academy of Public Administration, 1994).

Ozone concentrations are measured as a 1-hour average concentration. An area is in attainment if the highest values do not exceed the National Standards more than one day per year, and the area has met the standard for three consecutive years. The seasonal aspect of the problem focuses measurement on the period between May and October in most areas, whereas some areas in the South and Southwest require all-year measurement. The carbon monoxide standard is measured as an 8-hour non-overlapping average. To be in attainment, an area must not exceed the standard more than once a year and must meet the standards for two consecutive years. Sulfur dioxide concentrations are measured as annual arithmetic mean and as a 24-hour level average (primary standards) and a 3-hour level average (secondary standard). To be in attainment, the areas must not exceed the annual mean and not exceed short-term standards more than once a year. In 1971, particulate matter was regulated as a total suspended particulate (TSP). Development in technology in the late 1980s allowed for further specification of standards for small particulates (in diameter less than 10 micrometers).

There are more than 30 measurement locations throughout the South Coast Air Quality Management District. These can measure the stocks of the resource, that is, the concentrations of pollutants in the air. However, applicability of these measures to the policy issues has been criticized. First, the measures of pollutant concentrations are used for evaluation of the effect of resource use policy, but meteorology research indicates that 60-80 percent of variability in daily maximum ozone concentrations depends on weather in many locations in the eastern U.S., in the Midwest, and the California coastal areas. Lis and Chilton (1994) argue that the used design value (the fourth highest measured ozone concentrations in a three-year period) does not meet the needs of resource use management. They argue that an average value, rather than the highest values, would be a better measure for policy analysis. On the other hand, from a health perspective, the highest values are important. As high ozone concentrations cause health effects, it is the highest values that are of interest, not an average.

The above discussion also illustrates the problems of predictability of the resource stocks. If 60-80% of the variability in concentrations results from weather aspects (wind speed, temperature, and others), then we cannot predict the effects of the resource flows on the resource stocks with high precision. In addition to the effects of weather variability, we face the limitations of the human ability to model air pollution based on the location of the emissions. Depending on which model is used, the required emission reduction, which is enacted in a State Implementation Plan, can vary drastically (Liroff, 1986). This natural variability of resource stocks then requires a corresponding variability in the amount of rights that can be used in a given period. The variability in temperatures can be somewhat addressed with the resource use rights having a time component. The new markets, which are being developed on the East Coast, limit the trading season to the high ozone season.[4] This, however, does not apply to southern California, which faces ozone problems throughout the year.

There are other aspects of resource variability that additionally limit its predictability. Variability in wind speed and other weather components do not have seasonal aspects. To account for these factors, they would have to be measured daily. Corresponding daily emission limits would have to be devised. This would require continuous emission measurement, emission reporting, and daily emission aggregation. A single day or a number of days with constant weather would be a commitment period.

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[4] They do not limit the use of atmosphere as a sink in colder seasons.

The rights to use the resource would then be allocated for this shorter period. If no banking were allowed, the targeted ambient air quality standards could then be more realistically accomplished. Banking, on the other hand, would create potentials for "hot-spots" (days with high levels of the resource use). This type of resource then requires shorter compliance periods, which correspond to the fluctuations in the factors affecting the resource stocks, and does not allow banking of unused rights.

Availability of reliable indicators of resource flows. Resource flow, that is, air emissions, can be measured with varying reliability for various resource users and various pollutants. Stationery sources, such as power plants, can install devices into the stacks that continuously measure emissions of SOx and NOx. Continuous emission monitoring (every 15 minutes) is required in RECLAIM for SOx and NOx emissions (Regulation 20, Rules 2011 and 2012). [5] It is not cost-effective, however, to continuously measure emissions from mobile sources. Emission rates are measured once a year during the emission test, required in most states that face ozone problems.

Spatial extent of the resource. When atmosphere is used as a sink for pollution, some polluters stay in the local atmosphere and have local effects, others get transported and have regional effects. Some have global effects. So, even though air is used as a sink for pollution in all cases, there are different spatial extents of the effects on resource stocks. The extent of the effect depends on the wind directions and speed, on the height[6] at which the pollutant is emitted, and on the atmospheric chemistry of the pollutants. The resource management then has to be at the spatial level at which the negative effects of the resource overuse are felt.

Effects of the resource use on the resource stocks (uniform versus non-uniform effects). A unit of resource flow (for example, one ton of emissions) at one location may

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[5] In addition to emission monitoring, NOx, regulation also requires continuous process monitoring.

[6] The history of air pollution, especially Nox and SOx emissions, clearly indicates that the height of stacks is an important variable in the spatial extent of the pollution effects. In the beginning of industrialization, air emissions caused significant local air pollution effects. To avoid these, engineers suggested building higher stacks. The local air pollution was indeed reduced, but the areas down-wind then started feeling the negative effects of the use of air as the sink for pollution in the up-wind areas.

or may not have the same effects on the resource stocks at various locations. In the South Coast Air Quality Management District, a ton of criteria pollutant, emitted in the coastal area, affects air quality not only in this area but also in the inland area, due to direction of prevalent winds. RECLAIM rules regulating exchangeability of resource use rights, therefore, have to reflect these characteristics. The trading is then locally limited, which ensures the desired environmental effect, but the liquidity of market is reduced. In these cases, therefore, we face an explicit tradeoff between the environmental effectiveness and market liquidity.

5.2.1.2. Characteristics of CPR Users

Transportation accounts for more than one half of emissions of five important pollutants. Ozone's two major precursor gases (NOx and VOC) come predominantly from transportation and industrial facilities. Seventy-seven percent of nationwide CO emissions originate from transportation sources. [7] Therefore, CO regulation has focused on urban areas with dense traffic. NOx is formed when fuels are burned at high temperatures. Two major emission sources are transportation and stationary fuel combustion sources (electric utilities and industrial boilers).

Industrial and commercial sectors are the second most important users of air as a pollution sink. Major sources of ambient SO2 are coal and oil combustion, steel mills, refineries, pulp and paper mils, and non-ferrous smelters. Major existing sources of lead are non-ferrous smelters and battery plants, while the transportation's share has decreased significantly as a result of he Lead Phasedown Program.[8] The industrial and commercial sectors together account for 42% of the volatile organic compound (VOC) emissions. The residential sector generates 11 percent of the VOC and insignificant portions of sulfur oxides and particulates (National Academy of Public Administration, 1994). Transportation and industrial sector are therefore the most likely candidates for regulation.

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[7] The largest contributor are highway vehicles.

[8] Transportation accounted for about 80% of lead emissions in 1985 and only 33% in 1993.

5.2.1.3. The External Legal and Regulatory Environments

The 1970 Clean Air Act Amendments regulated the resource stocks, resource flows, and entry of new resource users into an area. The resource stocks were regulated with the National Ambient Air Quality Standards. The resource flows were regulated with technology standards for emissions of both, stationary and mobile sources.[9] Entry of new resource users into an area was limited by the requirement that they offset their future resource use by ensuring reduction of the resource use by existing resource-users. I discuss these regulations briefly in the subsequent paragraphs.

The National Standards were established for SO2, CO, NO2, particulates, hydrocarbons, and photochemical oxidants. Later, the photochemical oxidants' standard was changed to ozone standard and lead standard was added. The EPA devised two categories of National Ambient Air Quality Standards. Primary standards would ensure protection of human health. They had to be attained at any cost. Secondary standards were set at the level that would protect the human wealth and their attainment was subject to cost-benefit considerations.

The country was divided into 247 planning areas (Air Quality Control Regions). States were given nine months to prepare State Implementation Plans that would bring the Air Quality Control Region under their jurisdiction into compliance with the National Standards by 1975. The State Implementation Plan had to be approved by the EPA. If states failed to meet the National Standards, the EPA had the authority to pass and enforce a more stringent regulation, even to shut down major polluters. In 1970, states had limited capabilities to meet the standards. Emission inventories did not exist, air quality monitoring was poor and unreliable, and capabilities to model the impact of emissions on air quality were limited (Liroff, 1986).

In addition to National Ambient Air Quality Standards, the EPA set emission standards for equipment. Standards differed with respect to the area in which the source would be located (attainment versus non-attainment) and with respect to the origin of the source (existing versus new/modified source). Emission standards were usually less stringent for existing than for new sources, and less stringent for sources in attainment

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[9] Permissible emission levels were set for CO, hydrocarbons, NOx (Liroff, 1980).

areas than for ones in non-attainment areas. Emission standards were implemented by states through construction and operation permits. Major sources[10] are subject to more stringent emission standards than minor sources (Hahn and Hester, 1989b). Major sources always require construction permits, whereas requirements for permits for minor sources depend on State regulations and differ across states. This difference in the treatment between minor and major sources is an important motivation for emission reduction and/or purchase of emission rights. Standards regulating application of technology, thereby regulating emission rates, are presented in Table 5.1:

Table 5.1: Emission Standards, by Area and Source

Source	Attainment Area	Non-attainment Area	Prevention of Significant Deterioration Area
Existing		Reasonably Available Control Technology	
Major modification	New Source Performance Standard	Lowest Achievable Emission Rate	Best Available Control Technology
New	New Source Performance Standard	Lowest Achievable Emission Rate	Best Available Control Technology

Source: Liroff (1980)

The Lowest Achievable Emission Rate is defined for each source. This standard may not be less stringent than the New Source Performance Standard. It reflects the most stringent emission limits from the State Implementation Plan or the most stringent emission limits achievable in each industry. The New Source Performance Standard is determined by the EPA, usually at the industry level. The EPA was only slowly developing these standards. The Reasonably Available Control Technology was required for existing sources in non-attainment areas. For many categories, the EPA provided guidance in setting these.

The CAAA of 1970 also regulated entry of new resource users into a non-attainment area. New sources in a non-attainment area had to obtain ERCs from existing sources in the area.[11]

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[10] The cut-off between the minor and major source differs across states. The EPA defines it at 250 tons per year, but states can make this limit more stringent. There is also a group of sources of specific industrial categories (about 27 of them) that have the cut-off at 100 ton/year.

[11] New sources in Prevention of Serious Deterioration areas must meet other regulatory requirements.

The combination of stock, flow, and new user regulation failed to bring many Air Quality Control Regions into compliance by 1975. In 1976, the EPA required a revision of State Implementation Plans in more than half of the states, to achieve the National Ambient Air Quality Standards by 1979. These revisions required the Reasonably Available Control Technology to be adopted by existing sources. The problem was, however, that this technology was technically ill-defined (Liroff, 1980). As the National Air Quality Standards were not met by 1975, the deadlines were postponed several times. The CAAA of 1977 extended the deadlines to 1982, and in some cases to 1987. Revised State Implementation Plans were to be submitted by 1979, and states lacking approvals of the revisions by July 1, 1979 would face federal sanctions, such as a block of federal highway funding and/or a ban on new construction in the area. The 1977 amendments also developed a program for Prevention of Significant Deterioration of air in areas meeting the standards. The program was designed on a pollutant-by-pollutant basis. Permissible "increments" were defined for SO2 and particulates concentrations. In 1978, the PSD program was implemented.

The 1990 Clean Air Act Amendments (CAAA) defined seven types of pollutants: VOC[12], particulates, SOx, NOx, CO, lead, and hydrocarbons. Particulates of two sizes were regulated: less than 2.5 micrometers (PM-2.5) and less than 10 micrometeres (PM-10). The attainment deadlines were set for 2000, in some most severely polluted areas, such as South Coast Air Quality Management District, for 2010.

States regulate who can use the resource by issuing construction permits. They also regulate the flow of resource for each resource user, as the permits prescribe emission standards. Further, operators of equipment emitting- or controlling- air pollution, have to obtain a permit. Permits and rules are enforced by districts and/or local- or state- prosecutors. Civil penalties between $1,000 per day and $50,000 per day are possible. Violators can be prosecuted for misdemeanor criminal penalties.

Local governments have the authority to manage local air quality. In California, for example, local authorities are given the authority to issue permits and create offset systems. In 1976, the District was created. The law became effective in 1977. In 1986,

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[12] The 1990 CAAA regulated emissions of VOC, but NAAQS regulated ozone concentrations. VOC is one of the precursor gases that form ground ozone.

the South Coast Air Quality Management District proposed an ambitious plan to attain clean air standards by 2007. The Management Plan was adopted in 1989. [13] The South Coast Air Quality Management District is responsible for controlling emissions from stationary sources (about 31,000 business operate under its permits) (SCAQMD, 1998).[14] Regional Clean Air Incentives Market (RECLAIM) was developed in cooperation with public agencies, the business community, trade unions, environmental organizations, and financial institutions (Schwarze and Zapfel, 1998).

5.2.1.4. Rules Regulating CPR Use, Users, and Trading

The early EPA emission trading allowed four types of transfers of ERCs: offsets, bubbles, banking, and netting. Bubbles and netting are, by definition, internal trading. Offsets can be both internal and external, whereas banking allows for a deposit of ERCs either for future use by the facility creating them or for future sales.

Offsets were enacted in 1976 and were under state jurisdiction. When a major emission source wanted to locate in a non-attainment area, offsets were mandatory. They could be obtained internally, that is, from facilities owned by the same owner, or in the market. An offset buyer had to meet the following requirements: (1) the new source meets the Lowest Achievable Emission Rates; (2) the offset applicant is in compliance with regulations with all other sources in the Air Quality Control Region; (3) offsets are not exchanged at 1:1, but at a ratio that ensured air quality improvement; and (4) the Air Quality Control Region has its State Implementation Plan approved by the EPA (Liroff, 1980).

Bubbles have been allowed since 1979. Initially, they had to be approved by a federal agency. Later, some states developed generic bubble regulations. Bubbles were used by an existing plant with multiple emission sources. They allowed a facility to treat the entire facility as one emission point and achieve emission reductions at the most cost-effective sources. In 1982, the EPA placed a temporary and informal suspension on

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[13] The plan was focused on technology forcing. It also required major emitters of toxic pollutants to assess their emissions and make a public statement. This potential public pressure motivated the polluters to reduce their toxic emissions below the threshold.

[14] Mobile sources are under jurisdiction of the California Air Resources Board.

consideration of bubbles in non-attainment areas. Being an informal rule, it probably did not significantly reduce the number of applications. However, it slowed down the approval process (Hahn and Hester, 1989b). Bubble approval data indicate that states approved far more bubbles than the federal regulators. The problem with bubbles was that they were only allowed in 1979, seven years after the enactment of the CAAA of 1972. Between 1972 and 1979, most facilities undertook investments to reduce emissions and could not benefit from the new flexibility in emission reductions.

Netting allows an existing facility undergoing a modification to use the emission reductions at one point to account for the increased emissions, caused by a modification of the used technology. Bubbles and netting are different only in terms of when they are used. Bubbles are used for an existing source, and netting for an existing source that is planning a modification and had to obtain a permit for it. Netting has been a part of the early EPA trading since 1974. By the end of 1984, several hundred firms had used netting.

Banking allowed firms to hold unused ERCs either for future use of for future sale. It has been allowed only since 1979. There were no federal regulations for banking, and state rules differed significantly (Hahn and Hester, 1989b). State rules had to be approved by the EPA. As of 1986, only five states had their regulations approved, but eight more agencies had developed banking regulations.

All these forms of trading increased flexibility for a resource user to meet the requirements to reduce the use of atmosphere as a pollution sink. All these instruments, however, do not require market exchange. Bubbles and netting did not require external markets. Only offsets are a form of external trading, and banked credits can potentially be used in the future external markets. I therefore focus most attention on offsets and banking.

Rules regulating the CPR use. Companies proposing to construct and operate a facility that emit any of the criteria pollutants are required to obtain a permit. A permit specifies the emission reduction control technologies and defines monitoring requirements. It constitutes a contract between a company and a state or federal regulators. In addition, in non-attainment areas, new sources had to obtain emission offsets from the existing emission sources in the area. The use of air as a sink for pollution was regulated by limiting the access to the resource (permit required to construct and operate a facility) and limiting the extent of the resource use by prescribing what level of technology has to be employed.

In 1994, major SOx and NOx emitters were allocated tradeable permits that gave them the rights to emit a given quantity of pollution. The rules regulating the use of the resource are reviewed in the next three sections.

Severity of resource use limitation. Resource use limitation differs across resource users (new versus existing sources) and levels of resource stocks (attainment versus non-attainment of the National Ambient Air Quality Standards). In the 1970s, a non-attainment area could not allow any industrial growth without offsetting the existing emissions. New, and after 1979 also existing resources, had to use specified technologies. Because the severity of use limitation differed for attainment and non-attainment areas, the trading levels are not directly comparable across areas.

It is not surprising that offsets were used more often than banking. Offsets were mandatory in the non-attainment areas. Banking was allowed for units that were located in attainment areas, where the demand for ERCs was not high (Hahn and Hester, 1989b). Severe resource use limitation, one could argue, would increase the demand for offsets and, therefore, increase trading. However, stringent limitations can make it impossible to create ERCs, thereby limiting the supply. The latter was identified as a potential reason for limited trading in the non-attainment areas (National Academy of Public Administration, 1994).

In the RECLAIM, each facility is allocated Reclaim Trading Credits (RTCs) for equipment or processes that emit NOx and SO2. The allocation is based on historic emissions. Rather than base the allocations on average emission levels, peak levels between 1989 and 1992 were chosen. RTCs in the initial year are allocated on the basis of the maximum throughput in the period between and emission factors published in the Regulation. The allocation for 2003 is also calculated based on emission tables, allocations for each year in between are calculated as a linear value between the two allocations. Allocations for each year after 2003 equal the 2003 allocation (Rule 2002).

The peak level rather than average level base is less restrictive for the facilities. In addition, if the level of resource use in 1987, 1988, or 1993 exceeded the starting allocation of the resource use rights (based on years 1989-1992), additional rights were issued to the resource user. These rights, however, were not tradeable (Rule 2002).

The use of resource is scheduled to decline over years. The rights to emit NOx will decline by 7.1 percent per year between 1994 and 2000. The right to emit SOx will decline by 4.1 percent per year during the same period. The scheduled annual reductions in the amount of rights to emit NOx and SOx between years 2000 and 2003 amount to 8.1 and 9.2 percent, respectively. The quantity of the rights to use air as a sink for emissions of NOx and SOx is to remain constant after 2003 (Gangadharan, 1997).

New facilities, wanting to locate in the area and to use the resource, have to purchase emission rights (similar to the EPA policy in the 1970s). They will not, however, have to meet the reduction targets (Rule 2005s and 2002). Their permit is not approved unless they demonstrate that Best Available Control Technology will be applied and that they will not significantly affect the resource stocks (air concentrations of NOx and SOx).[15]

Monitoring of the resource use in the SCAQMD is not at comprehensive as it is in the national regulation of SO2 emissions. Continuous emission monitoring is mandated only for about two-thirds of participating facilities. Enforcement is also more difficult. To assign a penalty for non-compliance, SCAQMD has to file a law suit in a court. It is not clear whether financial sanctions will be imposed at all (Schwarze and Zapfel, 1998). As monitoring is not as complete and enforcement not as easy in RECLAIM as it is in the national SO2 markets, we can expect to see less trading in the RECLAIM market than in the national SO2 markets.

<u>Rules regulating how the CPR is transformed into a private good (permit)</u>. The air quality regulations in the 1970s were based on ERCs. If a resource use was less than the entitlement, the user received ERCs that could be sold. The amount of ERCs was, however, uncertain. First, there was uncertainty about the baseline with which the actual resource use would be compared. The following options were considered: historical

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[15] Rule 2005 determines what processes are to be applied to demonstrate this.

resource use, the extent of use allowed in individual permits, or the extent of resource use identified in the State Implementation Plans. At least 20 states used historical resource use when calculating the baselines. Most states adopted resource use levels allowed in individual permits. The high allowable rates were, however, criticized by environmentalists as a source of "paper credits" (Hahn and Hester, 1989b). In 1986, the EPA clarified the baselines for calculation of ERCs, thereby reducing the uncertainty. We can then expect to see an increase in trading activity after 1986.

The second source of uncertainty was related to the actual levels of resource use. As emissions were calculated, not measured, the actual level depended on the calculation method. Resource users, therefore, never knew their own levels of resource use, as they did not know how it would be estimated. The methods of calculating ERCs had to be approved for each trade and neither seller nor the buyer knew how many ERCs are actually involved in the trade. In the review process, SCAQMD also discounted the submitted ERCs, as the facility would have to meet future stringent emission targets. The extent of discounting was not known beforehand
(National Academy of Public Administration, 1994).

Further, banking exhibited additional uncertainty. If a facility wanted to bank unused ERCs, there was no assurance the ERCs would not be discounted or even confiscated, if the NAAQS were not met. Not many states had clear banking regulations. Twelve states and/or local regulatory agencies had informal banks, not governed by formal rules and regulations. These banks, however, did not stimulate trading. These banks were based on informal arrangements between a firm and regulators, and could be used for internal trades only.

The above-discussed uncertainties were reduced in RECLAIM. The system is based on allocated rights to use the resource. Rule 2000 defines a RECLAIM Trading credit (RTC) as "a limited authorization to emit a RECLAIM pollutant in accordance with the restrictions and requirements of District rules and state and federal law." Each RTC entitles the holder to emit one pound of RECLAIM pollutant in the year for which the RTC is issued. This eliminates the uncertainties related to baselines. With a large share of resource users continuously monitoring the resource use (emissions of pollutants), the data on actual resource use are also available.

RECLAIM, however, did not address two other uncertainties exhibited in the early EPA trading. First, since RTCs are not property rights, they are not protected under "takings" laws. The regulation explicitly states that the RTC is not a form of property[16] and that it can be conditioned, suspended, or terminated.[17] If the property rights are not secure, trading is bound to suffer.

Exchangeability of permits. The use of air as a sink for the criteria pollutants has non-uniform effects. A unit of resource used at one location has different effects on the stocks than a unit used at another location. A pound of pollutant emitted in the coastal zone does not stay there. The constant winds could take it to the inland areas, thereby increasing the concentrations of the pollutant. This characteristic of the resource use requires non-uniform exchange rules. Some pollutants are spatially transferred further while others stay closer to the initial point of emission. The EPA 1975 exchange rules reflected these differences. For SOx, particulates, and CO, the trades had to occur with sources in the immediate vicinity. For hycrocarbons and NOx, the offsets could originate anywhere in the area. Further, the distance between the resource-use right seller and the buyer affected the exchange ratios. The further apart the buyer and the seller were, the more discounted were the offsets. If the sources were relatively close, pre-determined ratios were used. If the distance exceeded 30 miles, air pollution modeling was required. The discounting factors and sophisticated air pollution modeling, required for such trades, impeded trading.

Exchange rules also reflected the intent of the regulatory agency to improve air quality. ERCs were not exchanged at a 1:1 ratio, but rather at a 1.2:1 or even 1.3:1 ratio. These exchange ratios also affect price calculations. Sellers want to receive payment for all ERCs they sell, but buyers want to pay for only the ERCs that they can use.

RECLAIM simplified the exchange rules. Rather than devising complicated formulae for calculating exchange ratios, the area was divided into two homogeneous

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[16] Rule 2007 (b) 3: "An RTC shall not constitute a security or other form of property, but may be used as a collateral or security for indebtedness."

[17] Rule 2007 (b) 4: "The District reserves the right to amend the RECLAIM rules in response to program reevaluations pursuant to Rule 2015 - Backstop provisions, or at other times. Nothing in District rules shall be construed to limit the District's authority to condition, limit, suspend or terminate any RTCs or the authorization to emit which is represented by a Facility Permit."

areas: the coastal and the inland. Trading was allowed within areas. Facilities in the inland area were allowed to purchase RTCs from the coastal area. Facilities in the coastal areas, however, could only purchase RTCs originating in the coastal area. This resulted in higher prices of RTCs from coastal areas. In the long run, one would expect that some facilities in the coastal area would close down and shift to the inland area. In the short run, however, the shift did not occur.

RECLAIM does not allow exchange of RTCs across time periods. Facilities with different compliance periods can trade RTCs, but RTCs can only be used in the year for which they are issued. This rule does not stimulate early achievement of environmental targets. But, it does prevent occurrence of temporal hot-spots, that is, significantly higher extent of the use of resource in some periods.

Rules regulating CPR users. This section examines the rules that define which resource users are regulated and how the non-regulated resource users can opt-in for regulation. Once a resource user opts-in, it is allocated the resource user permits. If its use is less than the allocated level, it can sell the excess rights. These rules affect the resource stocks by identifying actors who need to curb resource use. The opt-in rules can significantly improve cost-effectiveness of resource-use limitations. On the other hand, opt-in rules can also result in "paper-trades," thereby diminishing resource stocks. Second, the number and characteristics of the regulated resource users affect the level of exchange costs, thereby affecting market liquidity.

Resource users are regulated depending on the following aspects: (1) the level of resource stocks. The most stringent regulation of resource users is in the non-attainment areas, the focus of this study (SCAQMD); (2) the history of resource use by a given resource user (its presence/absence in the resource area and its past compliance); and (3) the planned future resource use (major or minor user). Two aspects of resource-user regulation need detailed examination: rules regulating access to resource and rules regulating extent of resource use.

Access to resource--construction and operation of new equipment that emits criteria pollutants--is highly regulated. Permits are required for new sources that wish to locate in the area and for existing resources that wish to modify existing equipment. The difficulty of obtaining access depends on the planned future use of the resource. RECLAIM defines major users as emission sources that emit (or have the potential to emit) 10 tons or more per year of NOx or 70 tons or more per year of SOx (Rule 2000). Such users seeking access to the resource face more demanding procedures, such as air modeling of the effects of the resource flow on the resource stocks (Appendix A, Rule 2005). The definition of a major user is more challenging for modified sources. The question is whether the resource user seeking permit for modification has to reach cut-off prior to or after the application of modified equipment. With the 1979 change, the EPA made this requirement more stringent, defining major sources as those that emit 100 tons of pollutant per year prior to the application of pollution control (Liroff, 1980). In addition to their presence/absence in the resource area, federal rules also examine the past resource use by the applicant. Resource users have to prove their equipment/facilities are in compliance with limitations on resource use (42 U.S. C. Section 7511 a (e)). Further, applicants have to demonstrate that the benefits of the new facility outweigh the environmental and social costs, resulting from their location.

Once a resource user is given access to the resource area, the rules regulating the extent of resource use continue to depend on the past resource use and the planned future use. New major resource users are more limited in terms of how much resource they can use. The equipment they use has to meet the Lowest Achievable Emission Rate, which are more stringent than the Reasonably Available Control Technology standard that the existing sources have to meet.

The major difference between the early EPA trading program and the RECLAIM is in the kind of resource users they regulate. The former is focused on new sources and is based on ERCs. By 1975, it was clear that many areas were not meeting the National Ambient Air Quality Standards. This could have resulted in denying permits to new sources in these areas. The problem then was how to allow development without further deterioration of air quality. In 1976, the EPA adopted a new policy, allowing major resource users[18] to gain access to resource, but they had to purchase offsets. The EPA

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[18] Sources with allowable emissions exceeding 100 tons/year of particulate matter, SOx, NOx, or non-methane hydrocarbons and sources exceeding 1,000 tons/year of CO.

also regulated the extent of resource use.[19]

RECLAIM, on the other hand, focuses on the existing sources (and also regulates new sources).[20] As of 1992, about 30,000 firms obtained permits in the Basin, but only facilities emitting more than 4 tons or more from permitted equipment per year are included in RECLAIM. There are approximately 390 facilities in the NOx market. They account for about 65 percent of the emissions from permitted stationary sources in the Basin. There are about 41 facilities in the SOx market. They account for about 85 percent of reported emissions from all permitted stationary sources. Stationary sources, however, account for only 40 percent of the air pollution in the area, whereas mobile sources account for 60 percent. (SCAQMD, 1998). It is therefore important to allow mobile sources to opt-in and enter RECLAIM.

RECLAIM allows for three programs that non-regulated resource users can employ to opt-in and enter RECLAIM. Rules 1610 and 2008 regulate how ERCs can be obtained from old car scrapping and transferred to RTCs. Scrapping refers to a process by which a motor vehicle is permanently removed from service. A minimum of 100, but a maximum of 30,000 vehicles per year can be used for ERCs from old car scrapping. The old car must have at least three more years of useful life remaining, must be registered in the Basin, and must have passed the emission check. The Rule 1610 (e) defines which parts must be destroyed to comply with the scrapping requirements. The rule explicitly lists how the ERC is calculated and prescribes how the vehicle has to be inspected. The car scrapping ERCs can be converted to RTCs at a 1.2 discount factor.

Since 1997, an opt-in program is in place that enables other, non-regulated owners of equipment (or manufacturers of equipment) to generate ERCs that can be converted to RTCs. If a polluter or a manufacturer of products, which emit pollutants, changes the technology, thereby reducing emissions, these reductions are credited as Area Source Credits. Specifically, if emission reductions are real, quantifiable, permanent, enforceable, and surplus (Rule 2506 (d) 2C), if the source is in compliance with all applicable regulations, and if the emission reductions do not result from a shutdown or production decrease, then ASCs can be obtained for those emission reductions. The

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[19] These sources had to meet the Lowest Achievable Emission Rate. Emissions beyond this rate would have to be offset. At this point, it was not clear what the Lowest Achievable Emission Rate was.

[20] New resource users purchase the resource use rights at a ratio 1:1.

ASCs are converted to RTCs only for the year in which they were issued. The conversion is at a ratio of 10:9.

There is also a third program--Air Quality Investment Program--which is actually an investment fund, operated by the SCAQDM. In this program, emission reduction providers can submit proposals to the SCAQMD executive office that reviews the program. Non-RECLAIM sources are eligible to submit proposals and RECLAIM sources can use them to meet their emission reduction requirements (Rule 2501).

A large number of regulated resource users having options for opt-in should result in a more liquid market than the early EPA trading. The environmental effects of a wider regulatory scope--a large number of users are regulated--are expected to be positive. Environmental effects of a large number of opt-in options, however, is an empirical question.

Rules regulating trading. Trading rules differed between the early EPA trading and the RECLAIM, primarily because the early EPA trading is based on ERCs, requiring case-by-case certification, whereas RECLAIM is based on RTCS (allocated permits).

Trading in the early EPA program was impaired by the fact that each trade required the traded good to be defined. In 1985, the EPA issued the Emission Trading Policy Statements. The guidelines defined the creation of exchanged goods and the certification process. Offsets can be created in the following ways: changing the inputs into the production process; installing emission control devices; closing a unit of facility; and reducing the emission rates.

Emission reductions have to meet the following criteria: (1) they have to be real and surplus, that is, they have to exceed any required reductions; (2) they must be quantifiable, using accepted procedures. Obtained permits were used as a baseline; (3) the emission reductions have to be permanent, that is, they must continue throughout the life of the new or modified resource that will use them. This is an important aspect that increases monitoring and enforcement requirements. To ensure the permanence of the offsets, restrictions may be put on the future capacity use and the hours of operation; (4) they have to be enforceable. This is achieved by incorporating them into a permit, which is legally binding and enforceable. The process of changing permit is, however, lengthy and this slows down the exchange process.

After an emission reduction project is certified by local authorities, it becomes an ERC that can be sold or placed in a formal or informal banking system (National Academy of Public Administration, 1994).[21] Trading ratios were used to account for non-uniform effects of resource use (as discussed above) and to improve the resource stocks. In 1986, the EPA proposed a change in trading rules. The new rules required that trades in non-attainment areas impose an additional 20 percent emission reduction for both sellers and buyers. As this would significantly reduce trading, the same goal should rather be accomplished by increasing the scope of trading (Hahn and Hester, 1989a). To understand the viability of this suggestion, one needs to examine the procedures to change the rules.

The scope of trading can be increased by regulating a wider number of resource users or by allowing opt-in. Both require a change in rules, though changes at different levels. To regulate additional resource users, a change in collective-choice rules (Ostrom, 1990) is required, whereas allowing resource users to opt-in and enacting additional emission reductions requires a change in operational rules. The latter may be easier to accomplish. Further, environmental effectiveness can be improved by developing a better emission inventory that enables a more reliable calculation of actual, rather than paper, emission reductions (Hahn and Hester, 1989a). This requires changes in operational-level rules and is therefore easier to accomplish. Hahn and Hester (1989a) suggest another alternative to imposing additional emission reductions on traders. They suggest developing federal guidelines for emission banking. This would increase the supply of ERCs, thereby increasing trading. But, increased trading is not the ultimate goal of the CPR management; it is an improvement of CPR stocks. Increased market liquidity results in improved CPR stocks only when trading stimulates reductions of resource use beyond the reductions incorporated in resource-use rights.

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[21] The SCAQMD developed two ERC banks that enabled small emitters (community bank) and emitters that provide essential public services (a priority reserve for offsets) with easier access to ERCs. These ERCs were traded at a 1:1 ratio.

RECLAIM resource users are divided into two groups in terms of compliance. Half of them have a compliance period January 1 through December 31; the other half, July 1 through June 31. Trading between the groups is allowed. These trading rules reduce the potential for fluctuations in trading activity just before the end of the compliance period.

RECLAIM allows brokers in the market. Brokers are expected to reduce transaction costs, thereby increasing market liquidity. The importance of brokers has increased over time (Gangadharan, 1997).[22] There are several brokers in the RECLAIM market, such as Cantor and Fitzgerald, Justice and Associates, and Sholtz and Associates. Sholtz and Associates hold an automated auction, called the Automated Environmental Credit Exchange-ACE, and Pacific Stock Exchange, Dames & Moore. Brokers organize auctions twice a year (Schwarze and Zapfel, 1998). All trades in an auction are at an identical market-clearing price, rather than at multiple prices as in the SO2 allowance market. Brokers usually charge a commission for all assisted trades (for example, a penny per pound from both buyers and sellers, or a minimum $200 fee). The ACE charges a fee of $100 and about 3 percent of any successful trade (Gangadharan, 1997).

Another trading mechanism, operated by SCAQMD, is expected to reduce transaction costs. SCAQMD operates an electronic Bulletin Board System that records a list of potential buyers and sellers and their bids/offers. Firms then contact each other and negotiate. Early research indicated, however, that this option is not widely used (Gangadharan, 1997).

5.2.2. Dependent Variables

5.2.2.1. Environmental Effectiveness

The Los Angeles South Coast Air Basin is a non-attainment area for ozone, CO, and PM-10 (40CFR 81). Los Angeles, Orange County, Riverside County, and San

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[22] The RTCs are transferred to the broker's account at price zero until they are sold. Gangadharan (1997) reports that of all transactions (1886) through February 1996, 72.1% (1260) of the transactions were at price 0. In the first period of her research (through September 15, 1995), the share of transactions at price 0

Bernardino County (all in the SCAQMD) are also designated as maintenance areas[23] for NOx. These counties together constitute the second largest urban area in the U.S., with the lowest wind speed of the nation's largest areas. In addition, the area has abundant sunshine and a very low ability to vertically disperse pollutants (1997 Air Quality Management Plan), both contributing to severe local air quality problems.

Attainment of standard is measured with continuous measurement of concentrations of the criteria pollutants at selected locations. The violations of the standard are recorded and counted. The larger the number of days with air pollutant concentrations higher than the standard, the more severe is the environmental problem. Therefore, there is progress if the number of days when the concentrations exceed the federal and/or state standards, decreases. Figure 5.1 depicts the trend in percentage of days when the SCAQMD exceeded the permissible concentrations.

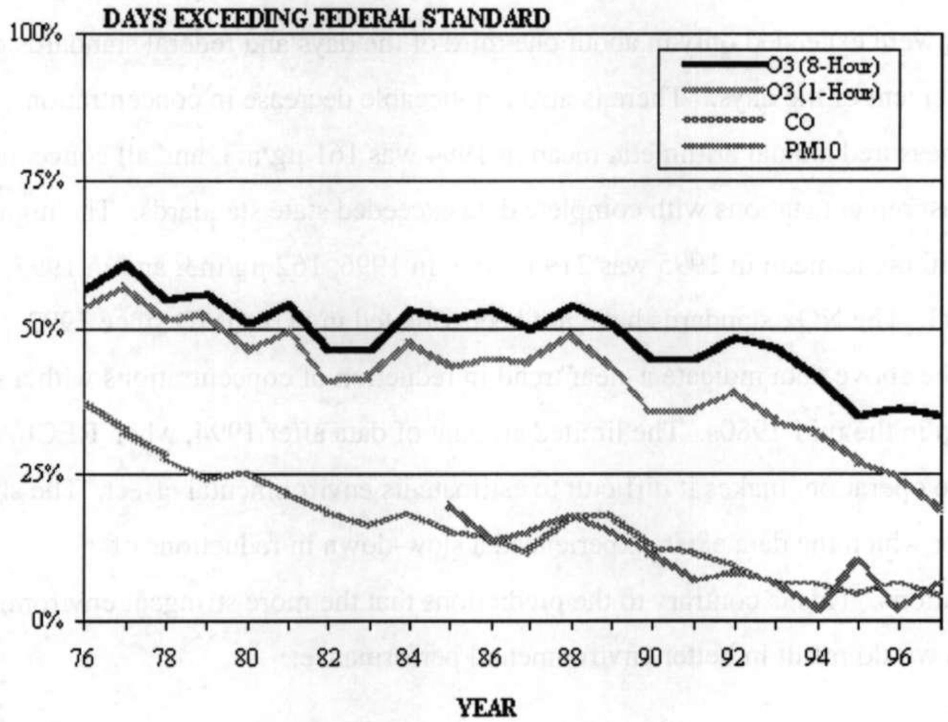

Figure 5.1: Air Quality in the SCAQMD, 1976-1997

Source: Current Air Quality and Trends in the South Coast Air Quality Management District, 1999, http://www.aqmd.gov/smog/97aqr_f3.html, September 4, 1999.

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[23] An area is designated as a maintenance area if it was a non-attainment area in the past.

In the late 1970s, this area exceeded the permissible concentrations of ozone standards for more than half of days and exceeded the permissible levels of CO standards for more than 25 percent of days. After a short period of increases in ozone violation days in 1977, the area experienced a decreasing trend in violation days until 1982, when a period of stagnation or even slight deterioration starts. In 1988, the number of days in violation again started declining. In addition to a decline in number of days in violation, there is also a reduction in average concentrations of pollutants. In 1994, the highest concentration was 0.30 ppm, measured as hourly concentrations. In 1995, the highest was 0.26 ppm. In 1997, the maximum hourly concentration measured was 0.17 ppm (Current Air Quality Trends, 1999). As noted above, the major causes of ground ozone are nitrogen oxides and volatile organic compounds. RECLAIM addressed only the former.

In 1985, the PM-10 state permissible levels[24] were exceeded in about 65 percent of the days and the federal standard [25] in about 5 percent of the days. In 1995, state standards were exceeded only in about one third of the days and federal standards only about 2 percent of the days. There is also a noticeable decrease in concentrations. The highest measured annual arithmetic mean in 1994 was 161 µg/m3, and all concentrations at all measurement stations with complete data exceeded state standards. The highest annual arithmetic mean in 1995 was 219 µg/m3, in 1996, 162 µg/m3, and in 1997, it was 163 µg/m3. The NOx standards have not been violated in SCAQMD since 1992.

The above data indicate a clear trend in reduction of concentrations with a short stagnation in the mid-1980s. The limited amount of data after 1994, when RECLAIM started the operation, makes it difficult to estimate its environmental effect. The short period, for which the data exist, experienced a slow-down in reductions of concentrations. This is contrary to the predictions that the more stringent environmental standards would result in better environmental performance.

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[24] The California State standard for PM-10 is 50 µg/m3.

[25] The federal standard for PM-10 is 150 µg/m3 (annual arithmetic mean).

5.2.2.2. *Market Effectiveness*

This section examines market liquidity of the early EPA emission trading and RECLAIM. The former was based on ERCs, which required case-by-case review by the EPA (generic rules applied to some bubbles), whereas the latter was based on allocated emission rights.

Number of trades. The early EPA trading mechanisms were enacted in the mid-1970s. By the early 1980s, there were single trades only, insufficient to be termed as well-functioning and active markets (Vivian and Hall, 1981, cited in Hahn and Hester, 1989b). These initial trades indicated many possible problems that MPSs could have. Liroff (1980) describes the initial offset trading in the late 1970s as paper-project trading. He argues that most offsets in this period were due to low environmental requirements.[26] These offsets were to be discontinued with the CAAA of 1977, when the EPA required that all existing sources adopt the Lowest Achievable Emission Rate technology. Only emission reductions beyond this rate would count as offsets.

The ERC trades required involving local environmental agencies to broker the deals. It was not a free functioning market. The trade between the Standard Oil Company of Ohio (SOHIO) and Southern California Edison (SCE) is illustrative of this fact. The former wanted to build a terminal and oil storage facility in a non-attainment area. In 1978, an offset trading agreement was signed. SOHIO paid SCE $78 million to install a scrubber on its facility. The trade was brokered by state officials who brought the two partners to the negotiation table "kicking and screaming" (Liroff, 1980:18). The deal was contingent upon the IRS tax treatment of the investment and the FERC agreement that the investment would be an allowable part of the SOHIO rate base. The

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[26] Delaware, Maryland, D.C. and West Virginia required a substitution of emulsified asphalt for cutback asphalt for a majority of their roads. Pennsylvania, on the other hand, did not have this requirement and therefore had more projects available for offsets at lower costs. Wolkswagen in 1976 obtained offsets for photochemical oxidants from the state of Pennsylvania for free. The offsets were obtained by changing paving practices. Similarly, an oil refinery used the asphalt substitution as a source of its offsets. If the RACT were used as a baseline, these offsets would not have been allowed, as the emulsified asphalt technology was widely available (Delaware, Maryland, D.C., and West Virginia had a majority of their roads paved with this technology) and economical with oil price increases (Liroff, 1980).

EPA and California state regulators worked with both IRS and FERC to obtain such treatment.

After the initial learning period, the number of trades increased. The data are not available at one central agency, as only bubbles were in federal jurisdiction, whereas offsets, netting, and banking were under the states' jurisdiction. The best review of trading activity is presented by Hahn and Hester (1989f) and their data correspond to those presented by Liroff (1986). They report that netting was the most widely used. Netting brings significant savings, as it allows that the source classifies as a minor source. Thereby, the firm avoids more stringent emission limits, modeling, monitoring, which can all be costly.[27] Then, firms also avoid costs of permitting, between $5000 to $25,000 per source. Further, firms avoid delays in approval of construction, which, according to some studies, is the highest-ranking motivation for netting (Hahn and Hester, 1989b). Unfortunately, detailed data is only available for 1984. In this year only, 900 sources applied for netting in the entire U.S.A. [28] An extrapolation of this annual data suggests that there were between 5,000 and 12,000 netting trades, with 8,000 being the most likely number.

Offsets were the second most used form of trading. Between 1977 and 1980, approximately 1,500 sources used offsets, and between 1981 and 1986, 500 sources used offsets. Traded offsets represented a small proportion of total emissions. For example, in 1985[29], there were 5 NOx external offsets in the SCAQMD, with 575 tons/year total volume traded, which represented less than 0.5 percent of total emissions. There were only 2 external SOx offsets, with 310 tons/year traded, which represented less than 0.5 percent of total emissions, at an average price of $3,000. There were 42 external trades of VOCs, with 2,142 tons/year total volume accounting for only 1 percent of total emissions. A study by the National Commission on Air Quality found that external offsets were a very small proportion of all offsets (Hahn and Hester, 1989b).

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[27] Hahn and Hester (1989) estimate that netting saved about $100,000 to $1 million per source.

[28] In this year, more than 900 facilities out of 15,303 that applied for permits as minor sources, used netting (estimate is based on the analysis of selected permits for minor sources; 360 permits, out of which 5.9 percent used netting). Of 15,139 sources that received permits as minor sources, 761 avoided being permitted as a major source.

[29] This was the first year in which any other pollutant than VOCs was traded.

By July 1986, there were only about 130 bubbles approved, 42 of them by the EPA, and about 89 by states under state generic bubble rules. The large majority of them were for VOCs, mainly due to the fact that most states had VOC generic bubble rules. In July 1986, however, there were an additional 62 VOC bubbles being developed. The high number of VOC bubbles was attributed to the 1987 deadline for meeting ozone NAAQS (Hahn and Hester, 1989).

In summary, netting is the most frequently used mechanism, followed by offsets and bubbles. This is surprising, as netting only pertains to modification in facilities, not to new and existing facilities, and the number of sources applying for equipment modifications is much smaller than the number of existing and new sources together. As offsets are mandatory, it is not surprising that they are the second most used mechanism.

Banking almost did not exist. In 1989, only nine states had ERC banks. Of all the banks, only Louisville, Kentucky, had an active bank. Eighteen firms have deposited 26,000 tons per year of ERCs in the bank. In addition, two firms with EPA pre-approved bubbles have used ERCS from the bank. The bank has provided offsets for 9 external and 19 internal trades. Other banks had little activity (Hahn and Hester, 1989b)

In 1994, RECLAIM was enacted in the SCAQMD. Initial trading was very modest. In the first year of the policy, there was only one substantial trade. Union Carbide's Torrance sold Reclaim Trading Credits (RTCs) for 1,700 tons for $1.2 million. This accounted for about 4.5 percent of the 1994 allocated RTCs (37,511). This is an average price of $700 per ton (Johnston, 1994). However, by the beginning of 1994, there were about 456 external trades of NOx RTCs and about 70 trades of SOx RTCS. Detailed data by area are presented in Table 5.2.

Table 5.2: Number of Transactions by Area and Pollutant (January 1994-February 1996)

Pollutant	Area	All Transactions	
		Total Number of Transactions	Number of Transactions at Positive Price
Nox	Coastal	1382	445
	Inland	146	11
SOx	Coastal	339	70
	Inland	19	0

Source: Gangadharan (1997; Table 5).

Table 5.3 breaks the trading data by trading parties. Some transactions occur at price zero. These are either internal trades or transfers of RTCs from a facility to a broker. At the point of transfer, no price is determined, as the price depends on for how much the broker can sell the RTCs. As the RECLAIM trading rules require a record of price, price zero is usually entered. The largest share of all transactions represents those in which facilities sell to brokers (about one third of transactions). These transactions, however, also have the lowest prices. The reason is that most of these transfers are of a consignment nature and the recorded price is 0. Of the 324 transfers from a facility to a facility, only 100 were at non-zero price. This suggests that 224 were internal trades. A large number of transactions are with "others" as sellers and facilities as buyers. This most likely indicates transactions from non-identified brokers to facilities. Interestingly, there were also 85 transactions of RTCs from brokers to facilities that occurred at price zero. Gangadharan (1997) reports that those transactions indicate that brokers could not sell the RTCs in consignment at the reserved price. This suggests that facilities are still learning about the clearing prices in this market.

Table 5.3: Transactions of RTCs, by Actors and Prices (January 1994-February 1996)

Seller / Buyer	Total Number of Transactions	Number of Transactions at Non-zero Price	Mean Price
Brokers / Brokers	63	0	0
Facilities / brokers	595	1	0.15
Others / brokers	156	0	0
Brokers / facilities	227	142	0.43
Facilities / facilities	324	100	0.28
Others / Facilities	315	213	0.78
Brokers / others	29	14	0.39
Facilities / others	117	20	0.34
Others / others	60	36	0.39

Note: Others include environmental and health organizations, some identified brokers, and individual speculators.

Source: Gangadharan (1997: Table 9).

RECLAIM also allows non-regulated resource users to opt in. For example, RTCs can be purchased from non-regulated actors (car drivers). Between 1993 and June

1998, AQMD granted credits for more than 22,000 cars scrapped under the AQMD Rule 1610.[30]

Proportion of regulated resource users who participate in the market. Netting was by far the most widely trading form in the early EPA trading period. Hahn and Hester (1989b) analyzed trading in 1984 in great detail. In 1984, there were 17,148 permits issued for new and modified sources by state and local agencies, of which 15,303 were minor sources and the rest of them major sources. Nine hundred of the minor sources used netting. A detailed analysis of EPA of 360 issued permits indicates that 21 (5.9 percent) of these sources would have been considered major, had they not used netting. If we assume that this percentage holds not only for the examined sample of 360, but also for all minor sources, we can estimate that about 900 sources used netting to avoid being classified as major sources (the most important reason for using netting). This estimate assumes major sources were not using netting. This estimate does not make distinction between the attainment and non-attainment areas. However, in 1984, netting was not allowed in non-attainment areas for about six months. If we assume that the proportion of minor sources located in attainment areas corresponds to the proportion of major sources in non-attainment areas (67 percent), then only about 600 facilities out of 17,148 used netting to obtain permits for new or modification sources (about 3 percent). The percentage of resource users using other forms of trading (offsets, bubbles, and banking) is much lower.

There are approximately 390 facilities in the NOx market and about 41 facilities in the SOx market (Gangadharan, 1997). From January 1994 through February 1996, there was a total of 1,886 pounds of pollutant traded. In 1995, only about 95 facilities actually traded in the NOx market (about 24 percent).

Price dispersion. There was a substantial price variation in the early EPA trading, as the data reported by Hahn and Hester (1989b) indicate. In 1985, there were 42 VOC

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[30] Old car scrapping was modeled after a Unocal 1990 purchase of 8,376 old cars. The purchase of old cars and their elimination from the roads was estimated to have reduce emissions by 13 million pounds (Johnston, 1994). Unocal purchased pre-1971 cars for about $700. This translates to about $1,000 per short ton of emission reductions.

external offsets. The mean price was $2,500 per ton, with individual prices ranging between $850 to $3,250 per ton. Price variation for other pollutants is more difficult to judge as there was a very small number of external offsets for other pollutants[31]. There were two for sulfur dioxide, with the mean price at $3,000, and prices between $2,900 and $3,000 per ton. There were five external offsets of nitrogen oxides with a much wider price range (between $2,000 and $5,500 per ton), with the mean price of $5,000 per ton. Prices for particulates' offsets ranged between $1,250 and $2,100.

Data on RECLAIM NOx trading (Gangadharan, 1997) indicate an even more substantial variability, which is contrary to our expectations that traders learn over the years. The price variation analysis is based on data on 526 transactions during 1994 and 1995.[32] The average price was $0.53 per pound (or about $1,060 per short ton) and standard deviation $0.73. The price range was between $0.001 per pound (about $2 per ton) and $3 per pound (about $6,000 per short ton).

Prices in the coastal zone are higher than the prices in the inland zone for both NOx and SOx (Gangadharan, 1997). The average price of NOx in the coastal zone (445 trades) was $0.59 per pound and $0.25 per pound for SOx (70 trades). In the inland zone, the average price for NOx was $0.049 (11 trades). There were no SOx trades in the inland zone. [33] This variation can be explained by the fact that coastal facilities are not allowed to purchase RTCs in the inland zone, whereas the inland facilities can purchase both inland and coastal RTCs. This restriction reflects the characteristic of the local air pollution in this area--non-uniform effect of emissions. These price variations are expected given trading restrictions.

There are other price variations, however, that are surprisingly high. An average price of an RTC sold by broker to a facility is $0.43 per pound. If an RTC is sold by facility to facility, the average price is $0.28 per pound (Gangadharan, 1997). It is then 43 percent more expensive for a facility to buy from a broker than to buy from another facility. Still, there were about 142 trades that included brokers as sellers and facilities as buyers and about 100 trades that included facilities as buyers and sellers. The question,

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[31] 1985 was the first year in which pollutants other than VOC were traded.

[32] There were 1,886 transactions during 1994 and 1995, but 1,360 of them were at zero price--internal transactions or transfers of RTCs to brokers to be sold under consignment.

then, is what do these price differences tell us about exchange costs. If it pays to buy from a broker, even at a 43 percent higher price, than this indicates that the costs of searching a trading partner are still extremely high in this market.

Prices of RTCs with the issue date in the future are higher than prices of current RTCs.[34] An RTC with expiration in 2003 or above is on average about \$0.48 more expensive than an RTC with expiration in 1995. This suggests that the effects of expected increase in demand for RTCs more than outweigh the discounting and the uncertainty about the future status of the RTCs. We need to note that the RTCs are explicitly not given a status of property rights. Similar, though not that strong, trends were noticed in the SO2 market.

The RECLAIM market has one aspect that has not been introduced in other markets, that is, two overlapping compliance periods. One half of the facilities have compliance periods ending in June and the other half in December. The two overlapping compliance cycles reduce the possibilities of drastic price increases or decreases at the end of the uniform compliance period. If there is a shortage of RTCs and many facilities need to purchase them to be in compliance, prices could drastically increase. In the case of excess RTCs, facilities may hold an excessive number of RTCs throughout the compliance period and sell them for very low price at the end of the compliance period. This would result in lost opportunity for locating other sources in the area (California Institute of Technology, 1993). I could not find monthly trading data to examine whether the two compliance periods have accomplished this goal. Price data for the two cycles indicates, however, that there are some differences between the two groups of facilities. Average prices differ quite substantially. The average prices in the second cycle are about 34 percent higher than in the first cycle (\$0.44 in cycle 1 and \$0.59 in cycle 2).

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[33] The averages are based only on transactions with non-zero prices.
[34] Banking of RTCS is not allowed in RECLAIM.

5.2.3. Marketable Permit Systems for Polluting Processes Using Atmosphere As a Sink: A Summary

The SCAQMD trading data suggests three important learnings about the effects of institutions on environmental effectiveness and market liquidity of marketable permit systems. First, a shift from ERCs (based on case-by-case definition and approval) to RTCs (predefined and allocated emission rights) does not necessarily result in drastically improved resource stocks, when predictability of the resource stocks is low and the effects of resource flows on resource stocks local and non-uniform. Market liquidity, however, improves. The number of trades increases, traded rights represent a larger proportion of the resource use, and specialized agents enter the market. Generalization of the SCAQMD trading data to other AQCRs, however, is limited. The SCAQMD exhibited a more active market than other areas. This has been attributed to the following reasons: high demand caused by industrialization, more stringent requirements in classification for major emission sources[35], and high standards for existing sources, making it more difficult to use netting instead of offsets (Hahn and Hester, 1989b).

The trading data suggests two further important learnings about the effects of rules on market liquidity, clarifying the theoretical predictions. First, the shift from case-by-case review of the traded good (ERC) to a predefined and allocated good (RTC) does not necessarily improve all aspects of market liquidity instantaneously. The RTCs market still exhibits high price variation. Second, the concerns that limited, rather than full, privatization of a CPR is required for a functioning market in CPR are not confirmed. The rights to a given flow from the resource do not have to be complete to be traded. It is sufficient that the resource users have the right to use the resource, not necessarily to manage it. The explicit statement that the emission rights are not property, thereby not protected by law, had no negative effect on trading.

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[35] Twenty tons/year rather than the EPA standard of 100 of 250 tons/year.

5.3. Regulating Producers of Polluting Products: Lead Phasedown Program

The Lead Phasedown Program sought to reduce the use of air as a sink for lead pollution by focusing on the single largest user--gasoline-burning on-road vehicles--from nearly 172,000 short tons per year in the 1970s to less than 1,400 short tons in 1995.

In the 1970s, gasoline combustion was the major source of lead in the atmosphere. Since the 1920s, lead was added to gasoline to increase the octane level. High concentrations of lead in the atmosphere motivated the regulation of lead content in gasoline. In 1973, gasoline contained about 2-3 grams of lead per gallon. The EPA lead policy issued lead standards that were to be tightened over time, and lead as gasoline additive was to be phased out in 1987. As a result, highway traffic is not a source of lead air emissions. The following section reviews factors that contributed to this major reduction in use of atmosphere as a sink for lead emissions.

5.3.1. Independent Variables

5.3.1.1. CPR Characteristics Affecting Measurability

Predictability of the CPR stocks. Lead concentrations closely follow lead emissions. Due to the short residence time of lead, changes in emission levels are quickly--within a year--followed by changes in concentrations (Szejnwald Brown, Kasperson, and Swedis Raymond, 1993). This makes it easier to devise the necessary resource use reductions to accomplish the required effects on the resource stocks.

Availability of reliable indicators of resource flows. Lead content per gallon of gasoline can be measured, but continuous measurement of lead in produced gasoline was considered to be too expensive. Lead content in gasoline was therefore measured in samples and the values were averaged over a three-month production (the compliance period). The averaging approach creates potential for hot-spots, that is, concentration of the resource use at a given point-- in this case, in a point in time. This problem is, however, not serious in gasoline production, as gasoline from various refineries is combined in a pipe-line network.

Spatial extent of the resource. The extent to which air pollution travels depends on the state of the pollutant (gaseous, vapor, or particulate) and the speed of the wind. The spatial extent of lead is not very large. In the past, the concentrations were the highest in the vicinity of highways. Currently, the highest concentrations are measured in the vicinity of lead smelters and battery factories (EPA, 1997). The concentrations decrease drastically as the distance increases.

Effects of the resource use on the resource stocks (uniform versus non-uniform effects). Lead emissions have a non-uniform effect on lead concentrations. Concentrations depend on meteorological influences such as wind advection (that is, surface wind), horizontal dispersion, and vertical mixing. Wind direction and speed are the most obvious element affecting ambient concentrations of air pollutant. Mixing height is a function of season (lower mixing-heights in the fall and winter), and is also affected by temperature inversion. The highest concentrations of lead occur at the edge of roadways and decrease with the distance from the roadway. Fine particles are carried beyond the immediate area of roadways. This requires that lead concentration monitoring occur not only at the road site, but also at a neighborhood level.

5.3.1.2. Characteristics of CPR Users

The 1981 shares of lead emissions by various activities are presented in Table 5.4. Gasoline combustion accounted for nearly 86 percent of lead emissions, whereas the next largest contributors, such as primary lead smelting, coal burning, and waste oil combustion, each accounted for about 2 percent of the total emissions.

Table 5.4: Estimated 1981 Atmospheric Lead Emissions for the United States

	Annual U.S. Emissions (metric tons/year)	Percentage of U.S. Total Emissions
Gasoline combustion	31,815	85.9
Waste oil combustion	754	2.0
Solid waster disposal	290	0.8
Coal combustion	863	2.3
Oil combustion	205	0.6
Gray iron production	268	0.7
Iron and steel production	484	1.3
Secondary lead smelting	573	1.5
Primary copper smelting	27	0.1
Ore crushing and grinding	296	0.8
Primary lead smelting	837	2.3
Other metallurgical processes	49	0.1
Lead alkyl manufacture	223	0.6
Type metal	77	0.2
Portland cement production	65	0.2
Miscellaneous	218	0.5
TOTAL	37,032	100

Source: EPA (1984:7).

The Lead Phasedown Program focused on gasoline refineries. Gasoline production is fairly concentrated with 75 percent of the refineries accounting for about 30 percent of the production and 25 percent of the largest refineries accounting for the remaining 70 percent of production. Due to proximity to the market and high transportation costs, the small refineries, however, may play an important role in some markets (Nussbaum, 1992). Modern refineries (mainly located on the West Coast) were capable of producing gasoline at the 0.7 gplg level.

5.3.1.3 The External Legal and Regulatory Environments

The EPA began regulating lead content in 1973. Initially, standards were set for leaded and unleaded gasoline together, as the unleaded gasoline represented a very small portion of the production. [36] Between 1979 and 1983, the regulations limited the lead content to 4 gplg. This standard, however, was not binding for most refinieries (Kerr and

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[36] In 1975, the share of unleaded gasoline was 13 percent (EPA, 1995). In 1982, it rose to about 50 percent. In 1995, it was about 99 percent, when the ban on leaded gasoline was introduced.

Mare, 1997). In 1983, the EPA enacted a phasedown program, aimed at eliminating the use of lead by 1987.

5.3.1.4 Rules Regulating CPR Use ,Users, and Trading

Rules regulating the CPR use.

Severity of resource use limitation. At the peak in 1970s, average content of lead in a gallon of gasoline was about 2 grams per liquid gallon (gplg), but could be as high as 4 gplg. The initial regulation allowed averaging across leaded and unleaded gasoline, as unleaded gasoline at that time represented a very small proportion of production. In 1982 , the regulation focused on leaded gasoline only. The standard of 1.1 gram of lead per gallon of gasoline was introduced for refineries. Throughout the first period--from 1983 to the end of 1985--the actual lead content was significantly below the standard. Refineries were banking the lead use rights. With the enactment of a tighter standard on July 1, 1985 (0.5 gplg) and 0.1 on January 1, 1986, refineries had to use the banked rights to comply with the standards.

Rules regulating how the CPR is transformed into a private good. Refineries were allocated rights to use lead as a gasoline additive for each quarter of a year, based on their quarterly production of gasoline, multiplied by the currently valid lead content standard. They could sell all unused permits in the market without a case-by-case review.

Rules regulating exchangeability of permits. Allocated rights to lead use were fully tradeable within the commitment period. No prior EPA approval was required for transferring the permits. In 1985, banking was allowed, enabling refineries to bank the unused rights for the last two years of the program (1986 and 1987), when the leaded gasoline would be phased down. With banking (exchangeability of rights across time periods), trading became more active and new actors entered the market. As gasoline could be blended with alcohol, gasoline suppliers could blend gasoline with alcohol, thereby reducing lead content per gallon and creating lead-use permits. At the end of 1984, there were about 100 blenders. By late 1985, the number grew to 900. Many of them, unfortunately, did not know how to report lead usage and many trades included rights that could not be claimed legitimately (Nussbaum, 1992). Brokers also entered the market. Their role was, however, different from the role of brokers in the SO2 allowance market. They did not claim ownership rights, but were merely intermediators in the market. Consequently, they could not speculate in the market.

<u>Rules regulating CPR users</u>. Gasoline combustion was the major user of air as a sink for lead pollution in the 1970s and 1980s. The EPA regulated the amount of lead refineries were allowed to add into gasoline. Refineries were used to trading with each other. In addition to trading gasoline, they would add the lead rights. For them, trading lead rights resulted in "little more paper work costs than the addition of a contractual paragraph and, perhaps, the price of stamp" (Nussbaum, 1992:32).

<u>Rules regulating trading</u>. Trading of lead permits did not require prior EPA approval. This resulted in substantial errors in reporting. In 1986, the U.S. Government Accounting Office sampled 374 reports and found that 35 percent contained errors. Approximately 36 percent of the erring partners were refineries, 49 percent were blenders, and 14 percent were importers. The problem with enforcement was that the incorrectly calculated permits could not be traced. With the increase of trading, rights would change hands several times. As the rights did not have serial numbers, it was impossible to identify the source of the illegitimate lead permits.

Brokers were allowed in the market. They faced the same information problems as the traders themselves. Large traders did not rely on brokers due to high costs; it was mostly small traders who used their services.

5.3.2 Dependent Variables

5.3.2.1 Environmental Effectiveness

In 1970, prior to the regulation of lead content in gasoline, on-road vehicles emitted nearly 172,000 short tons of lead. The total emissions of lead into the atmosphere are presented in Table 5.5. These emissions decreased from 220,000 short tons in 1970 to just under 5,000 short tons in 1995. The major reductions occurred in the 1970s and 1980s. The highest emission decreases were accounted for by on-road vehicles. These vehicles reduced their emissions from 172,000 tons in 1970 to 62,000 tons in 1980, and to only 1,400 tons in 1995.

Table 5.5: Lead Emissions, 1970 through 1995 (in short tons)

Source Category	1970	1990	1990	1995
Fuel combustion: electric utilities	327	129	64	63
Fuel combustion: industrial	237	60	18	17
Fuel Combustion: other	10,052	4,111	418	413
Chemical & Allied Products	103	104	136	80
Metals processing	24,224	3,026	2,169	1,937
Other industrial processing	2,028	808	169	55
Waste disposal and recycling	2,200	1,210	804	842
On-road vehicles	171,961	62,189	1,690	1,387
Non-road sources	8,340	3,320	197	191
TOTAL	219,471	74,956	5,666	4,986

Notes: Total may not be equal to the sums of categories due to rounding.

Source: EPA (1995:15).

The average lead content in gasoline fell from about 2 grams per liquid gallon (gplg) in 1973 to 0.6 and 0.7 gplg in the first quarter of 1985. At that time, the standard was 1.1 gplg. In the third quarter of 1985, the average lead content fell to 0.4 gplg. In the same year, the standard was tightened to 0.5 gplg (Nussbaum, 1992). In 1987, at the end of the Lead Phasedown Program, no refinery asked for additional time to be able to comply with the 0.1 gplg standard (Nussbaum, 1992).

5.3.2.2 Market Effectiveness

Number of trades. At first, the amount of traded rights was small. In 1983 and 1984, between 167 and 345 trades occurred. Initially, lead permit trading accounted for about 7 percent of the used lead. By the end of 1984, this share increased to 20% (Nussbaum, 1992). In 1985, banking was allowed for the first time. The heaviest banking was expected to occur in the second quarter of 1985, but less in the third and fourth quarter, when the lead standard was tightened. About 10.2 billion grams of lead rights were banked (equivalent to about two years of lead use in gasoline). Along with banking came a sharp increase in trading activity. Many resource users found the flexibility in time (banking) more important than the flexibility in space (trading). About one half of reporting resource users used banking. Banking also allowed more time to seek out potential trading partners. The price of lead rights increased, which led to entry of new actors in the market (brokers and gasoline blenders) (Nussbaum, 1992).

Proportion of regulated resource users who participate in the market. There were 300-400 oil refineries included in the Lead Phasedown Program. From the beginning of the trading in 1983 to the end of the program in 1997, between one fifth and one-third of the facilities purchased lead rights (Nussbaum, 1992). Kerr and Mare (1997) indicate the great importance of internal trading. About 67 percent of trades in their sample, covering the second half of 1983 and 1984, were internal.

Price dispersion. The value of lead rights rose with the introduction of banking. Initial prices were about three-quarters of a penny per gram. Then, prices rose to slightly over 4 cents per gram. Price information was not collected and reported by any entity in the market. The only way to learn the price was to negotiate the price with potential trading partners (Kerr and Mare, 1997).

5.3.3. Marketable Permit Systems Regulating Producers/Suppliers of Polluting Product: A Summary

By focusing on the gasoline producers, the Lead Phasedown Program drastically reduced the use of atmosphere as a sink for lead emissions. Between 1988 and 1997, the maximum quarterly average lead concentrations decreased by 67 percent. At the end of the program, all gasoline refineries met the standards and required no extensions. The CAAA of 1990 (section 218) eliminated the last remnants of leaded gasoline in 1996.

Some opt-in was allowed, but the gasoline blenders played a minor role in the market. The program exhibited active trading and banking, even though no price information was publicly available, and brokers played only a limited role (predominantly for small traders). The regulated users were, however, a homogeneous group, who were used to trading gasoline on a daily basis. Trading lead-rights, therefore, imposed no additional exchange costs on them.

CHAPTER 6

LAND AND GLOBAL ATMOSPHERE: WETLANDS MITIGATION BANKING AND CFC PRODUCTION QUOTAS

This chapter examines marketable permit systems for managing the use of land, providing services that are valued by the owners of the land and by non-owners, and the use of atmosphere as a sink for pollution that has global effects.

6.1. Converting Wetlands and Depleting the Ozone Layer in the Atmosphere

Wetlands perform multiple functions and provide various services that are valued by the owners of the wetlands as well as by the public. A wetland is an area in which water plays a central role--it affects the soil and the vegetation. Various definitions of wetlands have been developed by agencies regulating and studying them.[1] All definitions, however, are based on four aspects: (1) integration of physical, chemical, and biophysical elements; (2) the central role of water; (3) the presence of hydric soils (formed under saturated conditions); and (4) presence of vegetation adapted for saturated conditions (hydrophytic vegetation) (Heimlich et al., 1998). The functions provided by wetlands depend on the wetlands' characteristics, such as their location, size, and relationship to adjacent land and water areas. Most often-cited wetlands functions are: fish habitat, waterfowl habitat, fur-bearer habitat, vegetation, pollution assimilation, storm-water/runoff attenuation, floodwater storage, sediment/nutrient trapping, storm surge/wave protection, groundwater recharge/discharge, natural area/open space, climate control, biodiversity support (King and Herbert, 1997). Wetlands' owners benefit from some of these functions, as shown in Table 6.1.

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[1] The definition developed by the U.S. Fish and Wildlife Service (FWS) has been used by scientists and in non-regulatory definitions and mappings of wetlands. A different one has been developed by the U.S. Army Corps of Engineers for Section 404 of the Clean Water Act. The Department of Agriculture uses its own definition.

Table 6.1: Wetlands and Their Services to Owners and Others

	Owner		Others			
	Forestry	Fisheries	Recreation	Flood Control	Water Quality	Endangered Species
Function	Tree growth medium	Fish habitat	Wildlife habitat	Flood retention	Water filtration	Wildlife habitat
Service	Commercial timber harvest	Commercial fishing	Recreational harvest, bird-watching	Reduced flood flow	Cleaner water	Biodiversity

Source: Adapted from Heimlich (1998:14).

Wetlands conversion results in the loss of services to the public and also some services to the owner. The owners lose the commercial timber harvest and commercial fishing, but obtain agricultural land or income from selling the land. Significant amounts of wetlands have been converted in the past. When Europeans settled the territory of today's U.S., wetlands amounted to 220 million acres (Heimlich et al., 1998). From then to the 1950s, about 800,000 acres of wetlands were converted each year. At this time, agriculture was the major push factor for wetlands conversion, accounting for about 80 percent of conversions. After the 1950s, the conversion rate decreased significantly. In the period from 1982 to 1992, roughly 80,000 acres of wetlands were converted each year. In this period, agriculture accounted for only 20 percent of wetlands conversion, whereas urban development accounted for 57 percent (Heimlich et al., 1998). As I discuss in Chapter 7, due to the preservation nature of wetlands policy, wetlands mitigation banking (WMB) provides useful learnings for developing markets for carbon sequestration projects.

The ozone (O3) layer is found in the earth's atmosphere at about 6 and 31 miles above the ground. It is formed in the stratosphere in the process of ultraviolet radiation splitting normal oxygen molecules into atomic oxygen,[2] which then reacts with other O2 molecules and forms ozone (O3). In this process, the dangerous UV-B radiation[3] is absorbed. By the early 1970s, scientists discovered human interference with the stratospheric ozone. The substances causing the damage were Chlorofluorocarbons

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[2] The resulting atomic oxygen can then react with the O2 molecules and form ozone (O3), react with another triatomic ozone and form O2, or react with other substances in atmosphere.

[3] Between 280 and 320 nanometers.

(CFCs) emitted on the earth's surface, but reaching the stratosphere due to their chemical stability.[4]

The reason for concern about the ozone depletion and the increased UV-B radiation is that the latter is associated with skin cancers and cataracts. The U.S. EPA estimated that continued depletion of the ozone layer could result in an additional 800,000 cancer deaths in the United States over the next century (McKinney and Schoch, 1998). Further, increased UV-B radiation can adversely affect photosynthesis process, metabolism, and growth of a number of plants. Phyto-plankton, which forms the basis for many food chains, is also susceptible to increased UV-B radiation.

Due to a U.S. ban on CFCs for their use in aerosols, U.S. manufacturers developed a substitution for CFCs. Hydrochlorofluorocarbons (HCFCs) are less stable in the atmosphere, therefore less likely to reach the stratosphere where they would react with ozone. Also, scientists report that bacteria could be used to degrade HCFCs into simpler substances, thereby reducing the risk of ozone layer depletion. However, some other ozone-depleting substances, such as halons (a class of fluorocarbons containing bromine atoms that react with ozone), methyl chloroform, methyl bromide, and carbon tetrachloride (used as solvents) continue to be widely used.

The international community limited the use of the ozone-depleting substances (ODSs) in a set of protocols to the Vienna Convention. Countries accepted limitations to their production and consumption of ODSs. Only the U.S., however, developed a system of tradeable rights to use atmosphere as a sink for ODSs. The analysis of market effectiveness of the program, therefore, reflects the U.S. market, not an international market. As I discuss in Chapter 7, due to the global nature of the problem, markets for ODSs provide useful insights for thinking about carbon emission markets.

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[4] The chlorine atoms in the CFC molecule react with the stratospheric ozone and form a ClO molecule. This molecule is, however, not stable. The oxygen in the molecule reacts with a free oxygen atom. The released Cl atom then again reacts with ozone molecules.

6.2. Wetlands Mitigation Banking

6.2.1. Independent Variables

6.2.1.1 *CPR Characteristics Affecting Measurability*

Wetlands perform various functions and provide services based on their site features, location, size, and relationship to adjacent land and water areas. The variation in the characteristics and the resulting functions of wetlands creates problems for policy based on general principles and requires a case-by-case approach.

Predictability of the CPR stocks. Wetland acreage is estimated by the U.S. Fish and Wildlife Service by using sample data obtained from aerial photographs (Heimlich et al., 1998). Data on wetlands functions and services, however, can only be obtained by performing measurements on each wetland and examining their role in the entire watershed. Attempts were made to propose a classification of wetlands: highly valuable wetlands that should receive the largest protection to the least valuable wetlands where alterations should be allowed. Some states (for example New York) use this approach with mixed results. The U.S. Army Corps of Engineers (henceforth the Army Corps) and the EPA addressed this issue in their guidelines suggesting that small projects with minor environmental impacts should be reviewed with small vigor. The classification of wetlands raises the issues of agreement between environmental advocates and developers on which wetlands fall into which category. Boundary lines would have to be located between different classes of wetlands and the NAS Wetlands study of 1995 could serve as a guide (Zinn and Copeland, 1999).

Availability of reliable indicators of resource flows. Data on wetlands conversions are available only for the projects that require permit from the Army Corps. This excludes most of the agricultural conversions, conversions of small and isolated wetlands, as well as drainage of wetlands. When an application is filed with the Army Corps, the wetlands are analyzed in detail. Even this data, however, have been criticized for focusing on the on-site features of wetlands and ignoring the fact that wetlands may or may not perform all functions, based on the location of the wetlands. King and Herbert (1997) suggest an alternative four-attribute system for measuring attributes of wetlands: (1) wetlands features, which are site specific characteristics (such as size and hydrology). The features establish the capacity that wetlands will perform various functions; (2) Wetlands functions are "the biophysical processes that take place with a wetland" (such as carbon cycling and nutrient trapping); (3) Wetlands services are the "beneficial outcomes that result from the ecosystem functions" (such as better fishing and hunting, clearer water); (4) Wetlands values can be defined in economic terms as "willingness to pay" for the wetlands services associated with the wetlands functions.

Spatial extent of the resource. The larger the spatial extent of the resource, the larger the number of users, and the more difficult it may be to devise institutional arrangements for managing the resource. On the other hand, the larger the spatial extent of the resource the larger the potential number of market participants, thereby the larger potential for market liquidity.

Wetlands perform various functions and services. Functions are performed irrespective of the wetland's location. The services, however, depend on the location of the wetland. Some of the functions, such as water purification and flood prevention have an effect limited to the watershed. As the federal and most of the state wetlands regulations are based on the water quality regulation (Clean Water Act), watershed is the most likely unit at which the institutional arrangements are created.

Other functions, such as biodiversity protection and recreation provision, may have a much larger spatial extent. These functions of wetlands became more important only recently and only in a few states. California, for example, enacted a general habitat protection policy, which focuses not only on wetlands and their functions in a hydro system but also on their habitat provision.

Effects of the resource use on the resource stocks. Conversion of a given wetland affects the entire watershed. The extent of the effect, however, depends on existence of other wetlands in a given watershed and on the characteristics of the converted wetlands.

This variation in the effects of the wetlands conversion is reflected in the need to define wetlands mitigation on a case-by-case basis. Wetlands mitigation cannot be standardized. Given the current knowledge of wetlands functions, an acre of wetlands mitigated cannot be expressed in a unit that would be used as an exchange unit in a market. This significantly increases transactions costs as the exchange good has to be defined for each one transaction.

6.2.1.2 Characteristics of CPR Users

Of the 124 million acres of wetlands in 1992, about 12.5 million are owned by the federal government, about 92 million by private owners, and about 15 million by municipal, county, or state government. Most of the wetlands conversions occur on private lands. Conversion of wetlands to farmland was the most important source of the wetlands loss (accounted for about 80 percent between 1954 and 1974), but its importance significantly decreased in the 1980s (only about 20 percent) (Heimlich et al., 1998). Until 1985, farmers' payments from the federal government depended on crop base acreage, which provided an incentive to convert wetlands to farm land. Of the roughly 92 million acres owned by private owners, about 77.5 million acres (or 84 percent) are farmed or naturally farmed and subject to the Food and Security Act Swampbuster provisions. There is no "reliable way" of estimating the amount of wetlands that are subject to Section 404 of the CWA, although most likely, both Food Security Act and Fish and Wildlife wetlands are included (Heimlich et al., 1998).

As most of the wetlands are located on private land, one would expect that regulation of wetlands would constitute "takings". Takings refer to taking of private land or severely limiting its use by the government without giving compensation for the reduced value of the private property. However, using the fifth amendment to protect private property and convert wetlands was not a widely used strategy. By May 1993, only 27 cases involving takings' claims have been filed as a result of the CWA, Section 404 permit program. Ten of these cases were decided in favor of the Army Corps, three determined as takings, and 14 were not decided. Since 1993, over 30 new cases have been filed. Five were decided by 1997, with only one of them found to involve "takings".

6.2.1.3 The External Legal and Regulatory Environments

There are several federal- and state-level voluntary and regulatory programs that limit wetlands conversion and/or motivate wetlands restoration, but the CWA of 1972 and 1977 is the major regulation affecting wetlands. Section 404 of the CWA (1972, 1977) authorizes the Army Corps to issue permits for conversion of wetlands. The review is not a narrow, regulatory process, but a process that allows public review and input in decision making (Heimlich et al., 1998). Permit applicants must indicate that the required priority steps were taken prior to applying for a permit. Avoiding and minimizing the negative effects of the projects have to be done prior to compensation and the latter should only be done for the unavoidable effects (Heimlich et al., 1998).

Two types of permits are issued by the Army Corps: a general permit and an individual permit. The general permits cover actions by private landowners that will have a small environmental effect. These activities are regulated with the so-called Nationwide permit program No. 26 (33 CFR §330). Nationwide permits are issued for 5-year periods, and must then be reviewed by the Army Corps. In 1995, 13,837 activities were undertaken under the General Permit No. 26 provision, accounting for 5,020 acres of wetlands loss, which were offset by 5,809 acres of wetland mitigation. In December 1996, the Army Corps reissued 37 existing nationwide permits and 2 new permits.

In 1996, the Army Corps made revisions to strengthen the environmental restrictions of the General Permit No. 26. At the same time, the Army Corps announced that they would replace the Permit No. 26 with activity-based permits in two years—the proposal was issued on July 1, 1998. Final permits were expected in September 1999. The activities include: passive recreational facilities, residential, commercial, and institutional activities affecting one-third to three acres (Zinn and Copeland, 1999).

The individual permit allows interagency review, which can significantly slow down the process of obtaining a permit. The EPA has a veto power over these permits. Threats of delay by the Fish and Wildlife Service amount to the same, according to the critics. Neither the Army Corps nor the EPA have a systematic surveillance programs to detect unauthorized activities (Heimlich et al., 1998).

Section 404 of the CWA authorizes states to assume permitting responsibilities, but only two states, Michigan (1984) and New Jersey (1992), had done so. By 1978, 15 states had legislation specifically regulating wetlands; in 1984, about 30 states had programs regulating coastal wetlands, but usually not inland wetlands. In 1996, 44 states had wetlands statutes or laws. Forty-six relate wetlands policies to the federal water quality policies, such as Section 404 of the CWA. Forty-six states have wetland definitions comparable to those in federal programs (Heimlich et al., 1998). States can develop more stringent water quality standards and can deny or put conditions on the Army Corps permits or licenses. By 1998, only Michigan and New Jersey assumed responsibility for Section 404 of the CWA.

In addition to Section 404 of the CWA, there are multiple federal voluntary programs protecting wetlands. Swampbuster is a wetlands protection program for agricultural lands. It was enacted in 1985 and was designed to remove federal farm program benefits when farmers converted wetlands to agricultural production. The National Resources Conservation Service has the authority to make wetlands determinations under Section 404 on the agricultural lands. Since 1995, the Natural Resources Conservation Service has suspended making the determinations, except on request, because of the controversy over wetland delineation. The U.S. Department of Agriculture's Farm Service reports that over $11 million were denied to producers on approximately 15,000 acres between 1987 and 1996. The question remains whether this small number indicates poor enforcement or actual positive effect of the policy in deterring wetlands conversions.

The Wetland Reserve Program began as a nine-state pilot program and is now the largest wetlands restoration effort (Heimlich et al., 1998). Landowners can place easement on farmed wetlands in return for payments that are based on the land value reduction. All easements under this program were permanent until the 1996 Farm Bill and 1997 appropriations were implemented. The Farm Bill made it an entitlement, extended its authorization through 2002, and capped enrollment at 975,000 acres. In 1999, there were over 665,000 acres in the program, almost 40 percent enrollment in the states of Louisiana, Mississippi, and Arkansas. Most of the land is enrolled under permanent easements, only 5 percent under 10-year restoration agreements (Zinn and

Copeland, 1999). By the middle of 1997, 533,026 acres of wetlands were enrolled in 3,200 contracts under the Wetlands Reserve and the Emergency Wetlands Reserve Program. Programs include permanent easement or 30-year easement contracts. Payments for the 30-year easement amount to about 50-75 percent of the payments for permanent easements. Restoration cost-sharing by the federal agencies can amount to 75-100 percent for permanent easements or from 50-75 percent for 30-year easements. In this program, landowners may sell other partial interests, such as easement beyond 10 years (for example, for mitigation banking). The Wetlands Reserve Program easement allows for hunting, fishing, and timber production.[5] The rights to these wetlands' services can be sold to other private conservation organizations (Heimlich et al., 1998).

This study focuses on wetlands mitigation banking (WMB). WMB provides the flexibility in achieving the policy goal of no net-loss of wetlands. They enable those who want to convert their wetlands to obtain permits to do so and purchase wetlands mitigation credits from those who can permanently provide wetlands' services.

6.2.1.4. Rules Regulating CPR Use, Users, and Trading

Rules regulating CPR use.

Severity of resource use limitation. Wetlands mitigation is obligatory for all owners of wetlands. They have to obtain a permit from the Army Corps for filling a wetland, unless they meet the requirements for the general permit No. 26. However, even though the federal regulation does not require mitigation for such projects, state and local regulations may. The Army Corps permitted conversion for about 11,600 acres in 1993. In fiscal year 1994, they received 48,292 permit applications. Ninety-one percent of these (affecting 17,000 acres) were approved. Nine percent were withdrawn, about half of which qualified for general permits or did not require permits. Only 358 permits (less than one percent) were denied. The Army Corps estimate that additional 50,000 activities are authorized under the general permit each year. In FY 1996, more than 64,000 permits were requested, more than 85 percent were authorized under the general

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[5] Sixty percent of the wetlands in the U.S. are forested.

permit, with the average waiting period of 14 days. A general permit is a permit by rule: most do not require pre-notification or approval. Less than 10 percent were required to go through the more detailed evaluation, with the average review duration of 104 days. Only 129 applications for individual permits were denied.

Rules regulating how the CPR is transformed into a private good. WMB operates on two principles. On the one hand, private or public entities purchase or dedicate existing wetlands for preservation or other areas for wetlands creation. Of the 23 operating wetlands banks in 1995, the largest number was created by an Army Corps permit (13 banks). The remainder were created with a contract between the Army Corps, the EPA, and the bank owner. In many cases, the Fish and Wildlife Service and the local Departments of Natural Resources are involved (IWR 96-WMB-9). For some wetlands banks, ownership is complete. For others, predominantly for the trusts, the long-term protection is assured with a conservation easement, whereas the initial owners may still continue with uses that do not interfere with the wetlands preservation objective (for example, commercial fishing or hunting).

In 1995, USDA's Natural Resources Conservation Service and other federal agencies published the final guidance for the establishment, use, and operation of mitigation banks. Mitigation credits cannot be generated by any federal program, such as the Wetlands Reserve Program or the Fish and Wildlife's Partners for Wildlife Program. Wetlands mitigation banks can be established by restoring or creating wetlands; preservation can usually not be used as the sole basis for a bank establishment. The wetlands in a wetlands bank have to be protected in perpetuity with conservation easements or transfer of title to an appropriate federal or state agency or nonprofit conservation organization. Wetlands credits are calculated on a case-by-case basis. In some cases (wetlands trust funds), the credits can be sold even prior to creation of the wetlands and accomplishment of the designated success criteria.

Rules regulating exchangeability of permits. Exchangeability is in most cases determined on a case-by-case basis. There are, however, some general rules in terms of temporal and spatial exchangeability as well as exchangeability in terms of types of wetlands. WMB credits can only be used within the same watershed. In some cases this means 300 square miles (as in Fox River Watershed) or 4,000 square miles (in the case of Pine Flatwood bank) or (14,000 square miles) in the case of Vandross Bay, South Carolina (IWR 96-WMB-9). This requirement is present in all wetlands banks, surveyed by the IWR in 1995. There are exemptions to the rule. When mitigation cannot be accomplished within the same watershed, the trading ratio is increased.

Another general rule applies to the timing of the WMB credit sales. Some banks allow for selling WMB credits when the bank is approved and not even constructed yet. The share of credits that can be sold at this time is usually less than 25 percent. These credits are then usually sold at a high trading ratio, sometimes even 2:1, given the uncertainty of the mitigation success. The second share of the credits can usually be sold after the initial steps of bank creation have been accomplished (for example creation of the required hydrology). The trading ratio then falls to 1.5:1. After a bank has met all of the requirements (usually the required vegetation planting, survival, and composition), the rest of the credits can be sold at a 1:1 ratio. Some banks, however, operate as trusts. In this case, a larger proportion of the credits can be sold before the owner starts the creation (50 percent is common). This type, however, often requires financial deposits at a given amount per acre that guarantee wetlands creation or at least make the funds available, if the bank owner fails to create the wetlands of agreed quantity and quality (IWR 96-WMB-9). The trading ratios depend on the method of wetlands bank creation as well. For example, the Virginia Restoration Trust plans a minimum of 2:1 for wetlands restored or created, and 10:1 for wetlands preserved.

Rules regulating CPR users. Section 404 of the CWA (1977) limits the scope of wetlands' users too narrowly. It is focused on discharge of materials into wetlands. It omits many wetlands' users, whose activities also adversely affect wetlands. These include normal agricultural use, silvicultural activities, diversion of water rather than filling of material, and flooding of the wetlands. The program therefore addresses only about 40,000 acres of the 290,000 annually lost acres.

Further, regulation of wetlands' use is limited to large wetlands. About 20 percent of the wetlands are excluded because they are below the threshold size.

Environmentalists view the General Permit as a threat to small and isolated wetlands. According to some critiques, nation-wide permit No. 26 resulted in a loss of tens of thousands of acres each year. The limit for the No. 26 permit should be reduced from a maximum of 10 acres to three acres, and the limit should be imposed on the length of the project impact on the water body (Sierra Club, 1998).

Lastly, multiple values are not represented in the required evaluations; the only focus in the permitting process is on water quality (Zinn and Copeland, 1999). As a result of the above concerns, the Army Corps is phasing out the nation-wide general permit 26 over a period of two years, starting in 1997.

6.2.2. Dependent Variables

6.2.2.1. Environmental Effectiveness of Mitigation Banking

Wetlands mitigation banking is used by owners of existing wetlands, who convert them and are required to compensate for the unavoidable loss of wetlands. Essentially, WMB allows substitution of existing wetlands by newly created or restored wetlands. The major question about the environmental effectiveness of WMB is therefore related to the effectiveness of substitution of newly created or restored wetlands in comparison to the existing wetlands. I discuss this issue in greater detail in the section 2.1.4.

Environmental effectiveness of WMB cannot easily be judged as most of the banks started only in 1992. It is possible, however, to measure the number of wetlands acres provided by the WMB. Data in Table D1 (Appendix D) indicate that WMB represents only a very small fraction of the wetlands restoration activity. Voluntary programs administered by various federal and state agencies are far more important for restoring wetlands. These programs, however, cannot be used as an alternative by developers, who convert their own wetlands. It would be wrong to attribute the small importance of WMB entirely to the design of the program. Demand for WMB credits depends on how strict the limitations for the use of wetlands are, i.e., how strict is the implementation of Section 404 of the CWA. I address this issue in more detail in the section 6.2.1.4.

In addition to small contributions to restoration efforts, WMB has been criticized for their negative spatial effects. King and Herbert (1997) report that WMB in Florida, the state with the largest number of wetland mitigation banks, results in a shift of wetlands from urban to rural areas. In rural areas, demand for land for development is lower, and wetlands mitigation can be supplied at lower costs. King and Herbert (1997) argue that rural areas are not necessarily where wetlands are needed. Wetlands' functions depend not only on their specific properties but also on their role in a given watershed. For example, urban areas can face high risks of flooding due to larger proportion of surface being built up, thereby not being able to absorb water. Creating or restoring a wetland in a rural area will not help mitigate this particular risk in urban areas.

6.2.2.2 *Market Effectiveness*

Trading activity. The Environmental Law Institute (ELI, 1993) identified 46 existing wetlands mitigation banks in 1992, most of them in California and Florida. These banks were mostly owned by governmental agencies (department of transportation, port authorities, or local governments, accounted for 75 percent of the banks). Only four banks offered compensation credits for commercial sale, with one of them privately owned and three owned by public agencies or nonprofit organizations.

The number of wetlands banks has increased since the early 1990s. The Institute for Water Resources (IWR) reports of 77 ventures offering wetlands mitigation credits for sale as of the summer of 1995. Twenty-four of those were in operation, the remainder were either in the planning or proposal stage. The capital structure of the operating banks indicates a strong role of non-profits and governmental agencies in WMB. Out of 24 operating wetlands mitigation banks, 9 were capitalized with exclusively private sources and were pursuing the maximum net return objective. Of the remaining 15 banks, only 2 were pursuing the maximum net return objective; the remainder, a break-even or cost-plus financial objective (IWR 96-WMB-9). By February 1997, 108 wetlands banks were identified, out of which 43 were selling wetlands mitigation credits.

There are no aggregate data on WMB credits and the liquidity of this market. Data are available only for selected wetlands banks. The IWR surveyed six wetlands banks in detail (IWR-96-WMB-9). Their size and trading are presented in Table 6.2.

Table 6.2: Trading Data for Selected Wetlands Banks

Name of the Bank	Year of Bank Creation	Area (Acres)	Total Credits Sold
St. Charles	1994	48	34[1]
Cottonwood	1994	40	8
Pine Flatwood	1992	NA	NA
Vandross Bay	1994	804	100[2]
Delta Land Trust	1994	NA	NA[3]
Hebron	1992	33	33
Bid Island	1992	192	100

Notes:
[1] This is the entire amount of credits allowed to be sold.
[2] A total of 145 acres were allowed to be sold.
[3] Fifty percent of the credits can be sold only 3 years after planting trees.

Source: IWR 96-WMB-9.

The data indicate that some banks manage to sell all credits that they are allowed to sell at this point in time. The agreement or contract with which wetlands banks are created determines how soon and how many credits a bank can sell, to avoid the risk of selling "paper" credits. Four surveyed banks sold nearly everything they could, given their selling time-line. Some banks, however, did not manage to sell anything. A detailed analysis of the Delta Land Trust, located in the Mississippi Delta Region, indicates how strict rules for creation of credits can slow down the selling. This bank faced a requirement of a minimum size, which was difficult to meet. Further, the agreement allows 50 percent of credits to be sold only three years after planting trees. In comparison to other banks, this bank faces fairly restricting rules. Other banks are also limited in terms of how early and how many credits they can sell. However, most of them are allowed to sell at least 30 percent of credits after establishing the required hydrology. The second set of credits (usually about 30 percent) can be sold when the vegetation is planted, and the last set of credits can be sold only after a given vegetation survival rate has been established (IWR 96-WMB-9).

Some states have developed more detailed guidelines and broader policies for preservation of land that provides services to the public. In 1995, a new state policy that focused on habitat was adopted in California. If an owner destroys a particular habitat type (riparian habitat, habitat of species listed on the endangered species list, wildlife corridors), he/she must compensate for the resource impacts elsewhere. In 1998, forty-three conservation banks were created or in the process of being created in California. Some were as large as 6,000 acres (for example, the ARCO bank, which allows continuous oil and gas operations, selling credits to other landowners). Of the existing banks, the rate of utilization (sales of credits) varies significantly from 0 to 84 percent, with an average of 20 percent utilized (A Catalogue of Conservation Banks in California, 1999).

<u>Proportion of regulated resource users who participate in the market</u>. No aggregate data of the WMB market are available. Case studies of selected wetlands banks indicate, however, that the banks are only allowed to sell credits to those resource users whose resource use has a small impact on the resource stocks. Most analyzed projects limit the market of their credits to those who obtain the general permit No. 26. This means that the market is limited to the resources users with very small impact on the stocks of the resource.

<u>Price dispersion prices</u>. of wetlands credits vary significantly. This is understandable, given the fact that the WMB credits are defined for each case, based on the functions and services of the converted and the mitigating wetlands. In addition to the variation resulting from the differences in the wetlands functions, there is a large price variation based on the costs of creating/restoring wetlands for mitigation. The differences reflect less the restoration technology and more the costs of land. The values of wetlands are estimated to be between $1,000 in non-metro areas and $2,676 in metro areas (Heimlich et al., 1998). The estimates are based on amounts that are actually paid for easements or fee title rights to wetlands by the Nature Conservancy, the North American Waterfowl and Wetlands office of the U.S. Fish and Wildlife Service, and USDA's Wetlands Reserve Program. These prices reflect the current wetlands protection policy. Prices are significantly lower for acquiring rights to wetlands that have less conversion potential than for those with higher conversion potential. Also, restoration

may be cheaper than acquiring rights for wetlands with high potential for conversion, as former wetlands may be located on marginal land.

Another source of price variation is the nature of the credit provider, i.e., the financial objective of the WMB. For example, prices of WMB credits are much lower with the banks that are capitalized by non-profit capital and have a break-even objective: Cottonwood Creek, California ($25,609 per acre); Pine Flatwood, Louisiana ($1,700 per acre); Ohio Wetlands foundation ($12,000 per acre). On the other hand, credit from a bank that has a maximizing net-return objective can cost as much as $45,000 (Fox River). The two sources of variation may, however, be related. It is possible that the maximizing net-return banks are created predominantly in the areas with high demand for mitigation and high costs of creating/restoring wetlands. Due to a lack of data, I cannot examine this effect.

6.2.3. Marketable Permit Systems for Limiting Land Conversion: A Summary

WMB plays a very small role in the U.S. policy of no net-loss of wetlands. Institutional factors, limiting who can use mitigation credits to compensate for the wetlands loss, are the major reason. Further, the WMB has been criticized for creating wrong incentives. Due to multiple functions provided by wetlands, it is easier to measure the provision of wetlands' services for wetlands restoration and creation projects than for wetlands preservation. The WMB therefore focuses on the former. This creates incentives for resource users to first engage in destructive resource uses and only subsequently recreate the original form of the resource with costly projects. Further, as market pressure requires cost-minimization of the provided goods, the supply of WMB credits shifts to areas with lower costs. These are urban areas, where the wetlands' services may be less important than in urban areas. Data on environmental effectiveness and market liquidity suggest that the small market is facing important information problems. Prices of credits vary drastically across various providers.

6.3. Stratospheric Ozone Layer Depletion

6.3.1. Independent Variables

6.3.1 1. CPR Characteristics Affecting Measurability

Predictability of the CPR stocks. Stratospheric ozone depends on various factors, such as the seasonal cycle, El Nino Southern Oscillation, occasional volcanic eruptions, long-term ozone trend, and solar cycle (Hollandsworth and Binder, 1999). Predictions about the ozone layer require disaggregating the effects of various factors on the ozone dynamics.

Predictability of resource stocks is very limited now. Hollandsworth and Binder's (1999) model estimates a 2.2 percent reduction in ozone per decade, with only 0.28 percent uncertainty. The model includes the seasonal cycle, solar cycle, long-term trend, seasonally varying trend and Quasi-Biennial Oscillation in ozone. The long-term trend is affected by emissions of ozone-depleting substances (ODSs). The extent of this effect can be estimated only with large uncertainty. This low predictability of the resource stocks results in our inability to affect the resource stocks with the policy design.

Availability of reliable indicators of resource flows. For measuring emissions of ODSs we have to rely on production data. Based on their atmospheric life-time, the molecular weight of bromine and chlorine, and the substance's ability to be photolytically disassociated, various ODSs have different potential to destroy ozone molecules (CAAA, Article 601). By multiplying data on ODSs production by their Ozone Depleting Potential, we can estimate the quantity of resource stock that will be depleted due to emissions. Current measurement devices cannot, however, measure each individual ODSs emitter.

Spatial extent of the resource. The ozone layer covers the entire earth, but there are regional variations in its thickness, measured in Dobson units (DU). This essentially measures the density of a mixture of molecules. The average value is 300DU. We would expect the highest levels of ozone to be in the tropics, as the intensity of solar ultraviolet radiation is the highest in these areas. However, the ozone levels are the lowest in the tropics and the highest in the higher latitudes. This is caused by the stratospheric circulation that redistributes ozone (Newman, 1999).

Effects of the resource use on the resource stocks: uniform versus non-uniform effects. As ODS deplete the global atmosphere, one would expect that a unit of ODS emitted anywhere on the earth's surface would deplete the global ozone layer to the same extent. The effects of increased chlorine concentrations on the ozone, however, are not uniform. First, the increased chlorine levels affect various heights of the ozone column with different intensity. The largest depletion is measured at 40 km above the earth. There the trend is approximately 7.5 percent decrease per decade. At lower levels, the reduction of ozone is less. The ozone loss is minimal at approximately 30 Km above the earth's surface. This variability, however, cannot be taken into account in policy design as it cannot be affected by humans.

Second, the variability of the ozone layer can depend on the latitude. The latest measurements indicate that the maximum ozone depletion for both hemispheres occurs in the high latitudes, where trends are close to 6 percent reduction per decade (at between 40 and 45 Km in the ozone column) and about 8 percent in the southern hemisphere (above 40Km). There is less depletion in the tropics and even positive trends at the equator (Hollandsworth and Binder, 1999).

6.3.1.2. Characteristics of CPR Users

ODSs are used in a variety of products and processes, resulting in large variations between resource users. CFCs are widely used in plastic foams (32 percent), solvents (21 percent), car air-conditioning (20 percent), other refrigeration (17 percent), medical sterilants (6.5 percent), and aerosols (3.5 percent) (Cook, 1996). How do we then define who uses the atmosphere as a sink ODSs? The primary users are the substance manufacturers. Their number is fairly small, both internationally and nationally. The secondary users are those who use the substances in their manufacturing processes. They can use the substances, but not build them into the end product (using solvents in cleaning processes), or build the substances into the products they sell (refrigerators, halons in fire extinguishers). The regulation focused on manufacturers of substances, as there were only a small number of them and were considered easier to regulate.

6.3.1.3. The External Legal and Regulatory Environments

In 1987, the international community signed the Montreal Protocol, thereby limiting the use of the ODSs. In 1990, the London Protocol was signed by 93 countries. It set the targets to phase out production of CFCs, most halons, and carbon tetrachloride. Methyl chloroform production is targeted to end by 2005. In 1992, the Copenhagen Protocol set the 75 percent reduction target for 1994, and the phaseout date to January 1996 for all CFCs. For developing countries, the deadlines were postponed by at least 10 years. An international fund was established that is financed by developed countries. The fund is administered by the World Bank and assists projects that reduce ODSs consumption in developing countries.

In the U.S., production and consumption of ODSs were regulated by imposing production and consumption limits as well as by imposing tax on these substances. In 1989, the U.S. Congress enacted an excise tax on production, sales, and imports of ODSs. The Omnibus Budget Reconciliation Act of 1989 (OBRA-89) introduced taxation on the first set of ODSs: CFC-11, 12, 22, 113, 114, 115; Halons 1211, 1301, and 2402; carbon tetrachloride; and methyl chloroform. In 1992, in response to the London Protocol, the carbon tetrachloride and methyl chloroform were added (OBRA-92). In 1992, the EPA issued deadlines for phasing out the production and consumption of Class I substances (CFCs, carbon tetrachloride, methyl chloroform, and halons) (57 FR 33754). The phase-out schedule was accelerated in 1993 (58 FR 65018 and 69235) and 1995 (60 FR 24970).

End users were also regulated. Standards were set for servicing the equipment using CFCs (57 FR 31241 and 60 FR 21682). Standards for car air-conditioning substitutes were established (62 FR 68026). The 1990 CAAA (Article 610) also banned nonessential products containing CFCs or HCFCs (flexible and packaging foams, most aerosols, and pressurized dispensers) (58 FR 4768 and 69637). CAA (article 611) required labeling of products that contained or were manufactured with ODSs (EPA, Title VI of the CAA)

6.3.1.4. Rules Regulating CPR Use, Users, and Trading

In the subsequent section, I focus on the rules regulating the use of CFCs and halons in the U.S. and examine how they potentially affected the ozone (environmental effectiveness) and the market liquidity. Other ODSs are not analyzed, as only these two groups were included in the permit trading. A system of tradeable permits for the class II substances was also drafted and is currently open to public comments (40 CFR Part 82).

Rules regulating CPR use.

Severity of resource use limitation. In 1987, when the Montreal Protocol was signed, the U.S. accounted for one-third of global CFCs production. The U.S. companies sold more than $500 million worth of the chemicals every year. The goods and services involving CFCs were worth $28 billion annually. Installed equipment of about $128 billion relied on use of CFCs.

In 1989, the U.S. banned some uses of CFCs and scheduled other ODSs for a phase-out by 1986. The severity of resource use limits is therefore comparable to the Lead Phasedown Program. However, some of these substances were taxed. The tax rates for each substance were calculated by multiplying the basic rate by the ozone depleting potential of each substance (Hoerner, 1996).

In 1989, the manufacturing, imports, and floor-stocks of listed ODSs were taxed. In addition to the substances, products containing (for example, car air-conditioners) and manufactured with (electronics cleaned with CFCs) were also taxed.[6] The following tax rates were enacted: $1.37 per pound for 1990 and 1991, $1.67 for 1992, $2.65 for 1993 and 1994, and $5.35 in 1995. After that, the taxes would increase by $0.45 each year,

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[6] To keep the U.S. producers competitive, exports received tax rebates.

which results in \$5.80 in 1996 and \$6.25 in 1997.[7] Hydrofluorocarbons (HCFCs) are not taxed, neither is methyl bromide (pesticide).

Prices of some substances (CFC-11 and 12) were immediately doubled due to the excise tax. These substances accounted for more than two-thirds of the production of the five CFCs, originally covered by the Montreal Protocol. By 1995, the taxed price was nearly triple the untaxed price. Hoerner (1996) attributes the drastic reductions in CFC production in 1990 to the tax introduction, rather than to the allowance cap. Allowances were already assigned in 1989, but the production had not fallen so drastically, whereas in 1990, the first year when the tax was paid, the production decreased substantially.

Given the steep tax rates, it is impossible to estimate the partial effects of MPS of taxation. The severity of quantity limitation in the CFC and halons market was comparable to the lead phase-down program. The excise taxes, however, also had an impact on the actual reduction in the use of CFCs and halons. They may have also affected the liquidity of the market for CFC and halon permits. High taxes most likely strengthened the environmental effectiveness of the MPS. As they increased the costs of using these substances, the demand for these substances was most likely reduced. It is not clear, however, what effect they had on market liquidity. Decreasing demand for these substances most likely decreased the production, thereby decreasing the demand for production permits and their prices.

Rules regulating how the CPR is transformed into a private good. The right to use the atmosphere as a sink for ODSs was expressed as the right to produce a given amount of these substances. However, as manufacturers produced substances with various ODPs, the issue of assigning rights arose. Should the permits be allocated for each substance, or should they be allocated as an ODP weighted aggregate? Under the first system, each user is allocated permits for each ODS. Under the second system, the user is issued ODP-weighted allowances.

The CFC and halon trading systems were initially based on weighted averages. The CAAA of 1990 enacted substance permits. If the user wanted to trade allowances for

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[7] The basic tax does not cover halons and the CFCs used to foam insulation--they are taxed at a lower rate. Use of these substances for medical purposes is also taxed at a lower rate.

another substance, the EPA calculated the trading ratio based on the ODP. This way, the EPA could track who has allowances of which substance. This is important from two perspectives. First, the EPA has to report annual production and consumption of ODSs to the UNEP secretariat. If the allowances are issued for each substance, the reporting is easier. More importantly, if allowances are issued for each substance, the EPA knows who holds allowances for which substance. At the time of reducing allowances or completely phasing out a substance, the information is available on whose allowances are being reduced. If the allowances are based on ODP-weighted averages, information about which substances were the base of the allocated permits is lost. The EPA does not know how much to issue to which user next time the permits are issued (EPA, 1999d).

Rules regulating exchangeability of permits. Exchangeability of permits is based on the ODPs of the substances, and the origin of the substance (manufactured or recycled). Difficulties in distinguishing between manufactured and recycled substances results in illegal trades of these substances. Each manufacturer must have a sufficient amount of permits to cover the production of the substances. Each consumer must have a sufficient amount of consumption permits to cover the purchased substances. Each transfer of substances must be accompanied with a transfer of permits. If substances are imported from countries that do not have limits on CFC production, no transfer of permits is possible. The transfers of substances from the Article 5 parties are therefore limited to recycled substances. It is, however, impossible to make a distinction between a recycled and manufactured substance, unless the recycling process is carefully documented. This poses important problems for compliance, and results in illegal trade. Close examination of the flow of recycled substances, their origin, and the recycling capabilities of the industry in those countries, indicates that a large number of CFCs and halons are illegally exported to the United States and EU predominantly from China, India, and Russia. The economic motivation is clear. The excise tax and domestic production reduction and phaseout increased the price of these substances in non-Article 5 countries, such as the United States. The price of domestically reclaimed halon 1301 is about $26 per kg, whereas the price of supposedly recycled halon from China is $7.5 per kg (EIA, 1998). Article 5 countries are now the largest producers of these substances (Tables C1-C14).

Rules regulating CPR users. Permits to produce ODSs were allocated to five CFC producers, three halon producers, fourteen CFC importers, and six halon importers (Lee, 1996). This is the smallest group of regulated users of all examined markets. As this group is also very homogeneous and has a history of trading within the group, identifying potential partners was not too difficult or costly.

Ozone-depleting substances do not have any other sinks than the atmosphere, so the possibilities for opt-in are very limited. If ODSs were destroyed, that is, decomposed into less stable substances that would not reach the stratosphere, this could be a source of opt-in permits. There are no economic options for destroying CFCs, and the possibilities for destroying HCFCs with special bacteria are currently only at the exploratory stage.

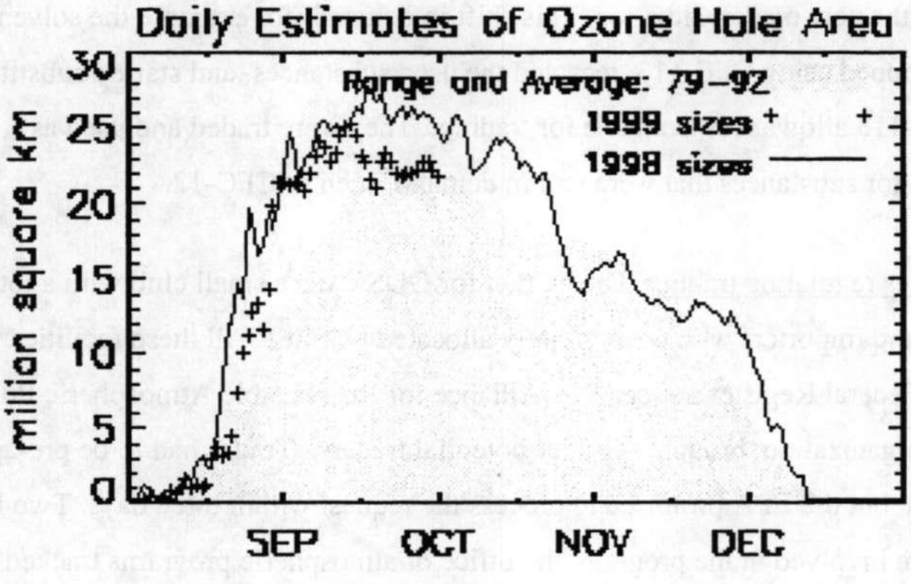
Users of CFCs and halons (or products containing these substances) were allocated consumption permits. The EPA estimated that in the 1980s, there were more than 10,000 CFC and halon user sectors (Lee, 1996). Their emissions were regulated with standards. For example, the CAAA of 1990 enacted standards for CFC-recycling equipment for air-conditioners and refrigerators. Users, however, also adjusted their use patterns to the new market situation. This shift in demand (for example the solvent industry stopped using CFC-113, recycled the used substances, and started substituting) made CFC-113 allowances available for trading. They were traded and used as allowances for substances that were still in demand, such as CFC-12.

Rules regulating trading. The market for ODSs was a small club with a total of 28 producers and importers who were initially allocated permits. All these facilities were listed in a Federal Register notice. The Alliance for Responsible Atmospheric Policy, an industrial organization, brought together potential traders. Trades had to be pre-approved by the EPA, but the EPA promised to process the request within three days. Two EPA offices were involved in the program: the office of atmospheric programs tracked allowances, and the Office of Enforcement monitored compliance. As the definition of traded good and quantity did not depend on a case-by-case review, but on issued allowances, the approval only required that the two offices cross-checked their data. All these aspects suggest that the exchange costs were low. The EPA did require that one percent of the traded permits be permanently retired to ensure environmental improvement. This amount is, however, less than in other markets.

6.3.2. Dependent Variables

6.3.2.1 Environmental Effectiveness

The use of the atmosphere as a sink for ODSs resulted in depletion of the ozone layer. Typically, the ozone hole occurs during the fall and fills up again in December. The size of the hole is estimated to be more than 10 km in September and October. In November, it is about half its peak size and it goes back down to nearly zero in late December. Figure 6.1 depicts the fluctuation in the size of the ozone hole between September and December since the 1970s. In the late 1970s and throughout the 1980s, the mean value of the ozone hole area did not exceed 11 million square kilometers. In 1998, the hole measured ranged between 20 and 27 million square kilometers (NASA, 1999). The daily estimates of the ozone hole area show an improvement from 1998 to 1999.



Source: ftp://jwocky.gsfc.nasa.gov/pub/eptoms/images/qcplots/zmqcsz.gif

Figure 6.1: Daily Estimates of Ozone Hole Area, 1979-1999

Limiting the use of atmosphere as a sink for ODSs reduces the size of the ozone hole. Current reductions in ODSs emissions may, however, bring gradual results. CFCs can take as long as 15 years to reach the stratosphere from the earth's surface. Further, as some of these substances have a 75-100 year life expectancy, the concentrations of chlorine in the atmosphere will remain high.[8] This will cause an estimated loss of ozone layer of 10-30 percent over the northern latitude (McKinney and Schoch, 1998). The short-term effectiveness of the program, therefore, has to be measured in terms of reducing the use of atmosphere, that is, reducing the production and consumption of ODSs, as there are no natural sinks of these substances.

ODSs emissions were limited by a series of international agreements. These agreements succeeded in limiting, and in some cases phasing-out, the use of ODSs in developed countries. Developing countries (defined in Article 5 of the Montreal Protocol and therefore called Article 5 countries) were given approximately 10 additional years to phase-out each group of ODSs. This allowed them to increase their use of the ODSs, as they historically contributed only a small fraction of the use and releases of ODSs (see Figures E1 through E7, Appendix E, for the share of developed countries, depicted in red, and the share of developing countries, depicted in blue).

Developed countries (non-Article 5 countries) substantially reduced their ODSs use, exceeding their reduction targets. The production and consumption of the regulated substances over time is depicted in Tables D1-D14, Appendix D and in Figures E1 through E7, Appendix E. As ozone-depleting potentials (ODP) of various ODSs differ, the production data in tons are not directly comparable. Therefore, the produced/consumed tons of each substance are multiplied by the ozone-depleting potential of each substance and expressed in ODP tons. The production and consumption reduction targets for developed countries are calculated based on the production and consumption data for the base year and the internationally negotiated targets (UNEP, 1999). The Russian Federation was in a special position, as its baseline included planned production in the factories that were under construction at the time of signing the

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[8] The estimated natural concentrations (caused by volcanoes) are about 0.6 parts per billion (ppb). Currently, the concentration of chlorine is about 3.6 ppb. If the CFCs production were completely phased-out by developed countries by 1996, atmospheric concentrations of chlorine would still be expected to reach 4.1 ppb by the end of this century.

Montreal Protocol.[9] The Russian Federation is an important player in the market for ODSs. It is one of the major sources of illegally traded ODSs. The subsequent paragraphs briefly review accomplishment of the production and consumption reduction and phase-out targets by groups of countries.

CFCs production and consumption were phased-out by developed countries by 1996.[10] Developing countries did not have to reduce their use of CFCs, they actually increased it. However, as Figure E1 indicates, developed countries reduced their production and the consumption by 1989 much below their targets. They actually reduced their CFCs use so much that the total world production and consumption of CFCs were still within the targets for developed countries (green labels in the Figure E1, panels A and B). In the second commitment period (1994), developed countries again overcompensated for the developing countries' increase in CFCs use. In 1996, developed countries also met their production and consumption targets. At that time, however, their reduction beyond the targets could not compensate for the increase of production in the Article 5 countries, as depicted in with the yellow labels in Figure E1.

The above data on target accomplishment are aggregated across all developed countries. An analysis of success in accomplishing individual countries' targets indicates that some countries are not meeting their targets. In 1989, Japan and Australia fell short of meeting the production freeze target. They exceeded their production targets by 14,746 ODP tons and 689 ODP tons, respectively. As Table D2 (Appendix D) indicates, Japan could not meet the 1989 consumption freeze targets either and exceeded its consumption target by nearly 17,000 ODP tons. By the next two commitment periods, however, Japan reduced its consumption in excess of the targets.

The dynamics of producing and consuming **halons** were similar to that of CFCs. As Figure E2 illustrates, in the first commitment period (1992), the developed countries decreased their production and consumption to levels significantly below the targets (204,785 ODP tons and 195,792 ODP tons, respectively). This more than compensated for the unlimited production and consumption of halons in developed countries. In the

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[9] The data on the planned capacity was not available to the researcher. Therefore, the data on the Russian Federation base-year production is underestimated and the estimates of the goal accomplishment (calculated as the difference between the actual production and the target) may be negative.

second commitment period (1994), developed countries still met their targets, but the increase in production and consumption of halons in developing countries increased the global figure significantly. These countries then experienced further increase of both production and consumption of halons after 1994. Tables D3 and D4 indicate, no developed country had problems meeting its production targets, but Austria exceeded its consumption limits in 1992.

Other fully halogenated CFCs are produced only in developed countries (see Table D5 and Figure E3, left panel). The largest manufacturer was Japan, which accounted for about 70 percent of the world production. The U.S. and four European countries (Germany, the Netherlands, U.K., and the Russian Federation) also manufactured them. All countries met their production targets. The right panel of Figure E3 illustrates the consumption dynamics. Developed countries were meeting their reduction targets. Developing countries, however, experienced significant increases in consumption in 1994. The bulk of this increase (1,290 ODP tons) occurred in China. By 1996, the global aggregate was again well within the consumption targets set for developed countries.

Data on the production and the consumption of **carbon tetrachloride** (Figure E4) again indicate that the developed countries met their targets in both commitment periods (1995 and 1996). Developing countries also reduced both production and consumption, even though they were not facing any immediate reduction targets. Individual countries' data (Tables D7 and D8) indicate that South Africa and the Russian Federation could not reduce their production to the 1995 target levels, but exceeded them by about 1,700 ODP tons and 2,700 ODP tons, respectively. In 1996, however, South Africa already reduced production by more than required, whereas the Russian Federation still faced difficulties in meeting the reduction targets.

Methyl Chloroform was produced almost only by developed countries (see Figure E5, left panel). The developed countries had no problem reducing the production (except the U.K., which exceeded its production level by about 800 ODP tons in 1994). As the figure indicates, the actual production was about one half of the allowed

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[10] A small share of 1986 production was allowed for essential uses and for production for developing countries.

production levels in 1993 and 1994. The substance was successfully phased-out in 1996. Consumption was also phased-out in the developed countries, whereas the consumption in the developing countries has decreased from about 4,700 ODP tons in 1989 to less than 2,400 ODP tons in 1996.

Hydrochlorofluorocarbons were considered to be an environmentally safe substitute for CFCs. The Montreal Protocol created a market for them. As a result, their production and consumption rapidly increased between 1989 and 1996 from a total of about 13,800 ODP tons in 1989 to about 29,600 in 1996 (Figure E6, left panel). Subsequent protocols limited only their production. The first commitment period with the consumption limits for developed countries was 1996. In this year, developed countries stayed within their consumption limits (Figure E6, right panel and Table D12). Developed countries consumed about 24,600 ODP tons and developing countries consumed about 4,800 ODP tons. The consumption limits for developed countries, however, amounted to a generous 36,400 ODP tons. No single country had problems in meeting its individual consumption limits (Table D12). Developed countries faced further consumption reduction targets after 1996. At this point in time, however, the data on consumption after year 1996 are not available.

Methyl bromide's production and consumption data indicate first a decline and then an increase of production in 1991 (Figure E7 and Tables D9 and D10). Developed countries met the 1995 target of freezing their production at the 1991 levels (Figure E7, left panel). The data, however, indicate an increase in production in 1996. The next production and consumption target was in 1999, when developed countries had to reduce their production by 25 percent from the 1991 base levels.[11] The estimated 1999 target for all developed countries is 32,000 ODP tons. The actual production in 1996 exceeded 36,000 ODP tons in developed countries. This suggests that developed countries may face difficulties meeting the 1999 target, unless the production trends changed significantly after 1996.

The international efforts to curb the use of atmosphere as ODSs' sinks raise two important issues. First, have the protocols substituted one ODS with another that is then

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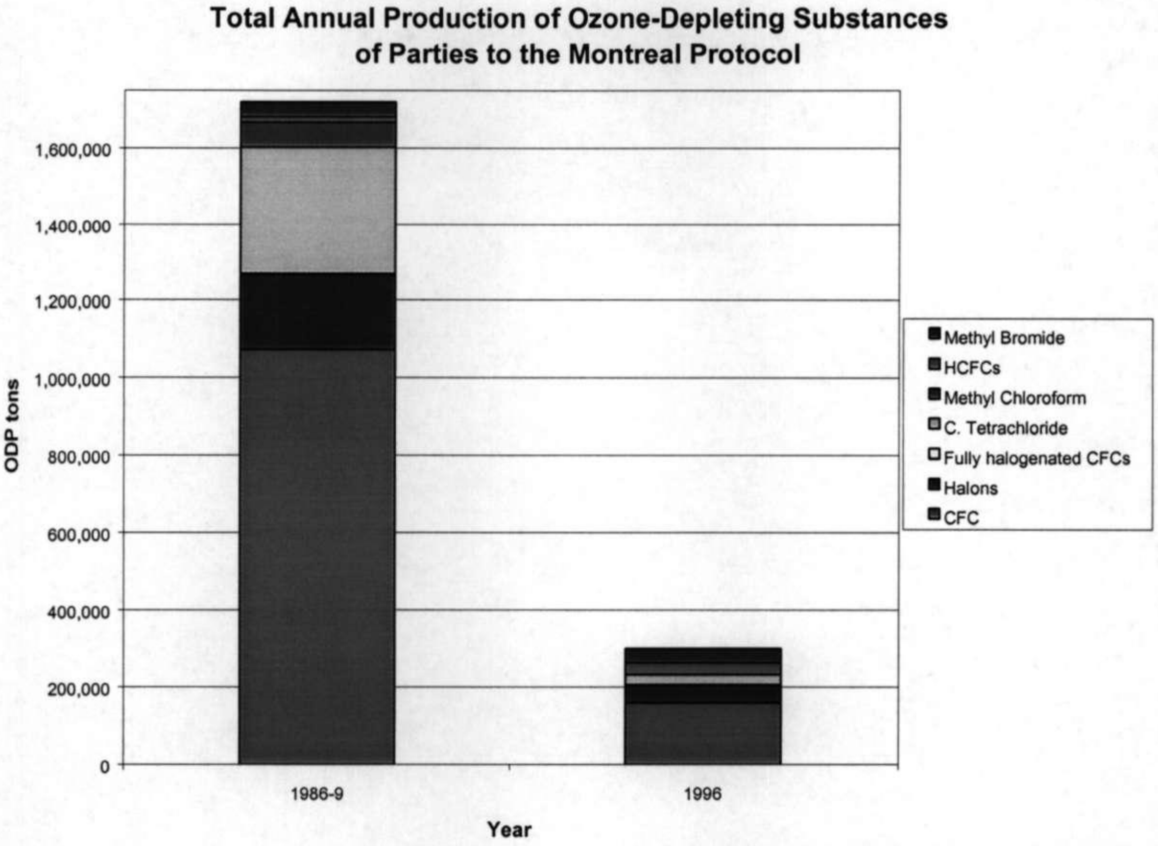
[11] In addition to the allowed production, developed countries may produce 10 percent of the base-year production to meet the demand of the developing countries.

produced in such large quantities that the concentrations of chlorine actually increase? Second, is there a shift in ODSs' emissions from one region to another region without global reductions? The answer to both questions is negative (see Figure 6.2).



Source: UNEP Secretariat (1997).

Figure 6.2: Production of Ozone-Depleting Substances in Countries, Parties to the Montreal Protocol (in Ozone-Depleting Potential tons)

In the 1980s, the average annual production of ODSs by all parties to the Montreal Protocol was 1.7 million ODP tons.[12] In 1996, the last year for which data are available, the total production was only 0.3 million ODP tons. The international agreements have substantially reduced the use of atmosphere as a sink for ODSs.

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[12] The ODSs production data in the 1980s is only available for the base year for each substance. For some substances, this is 1986, for others 1989. The average annual production in the late 1980s is calculated by summing up the base-year data for various substances, when all data may not be from the same year.

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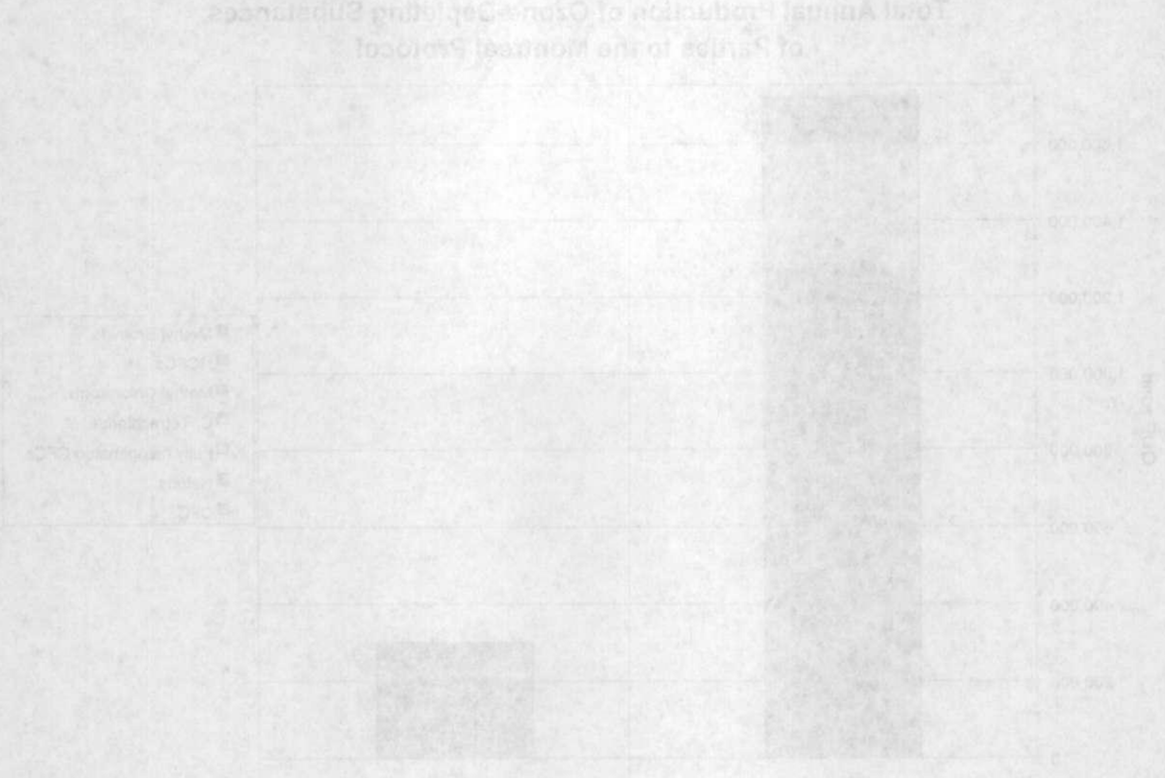

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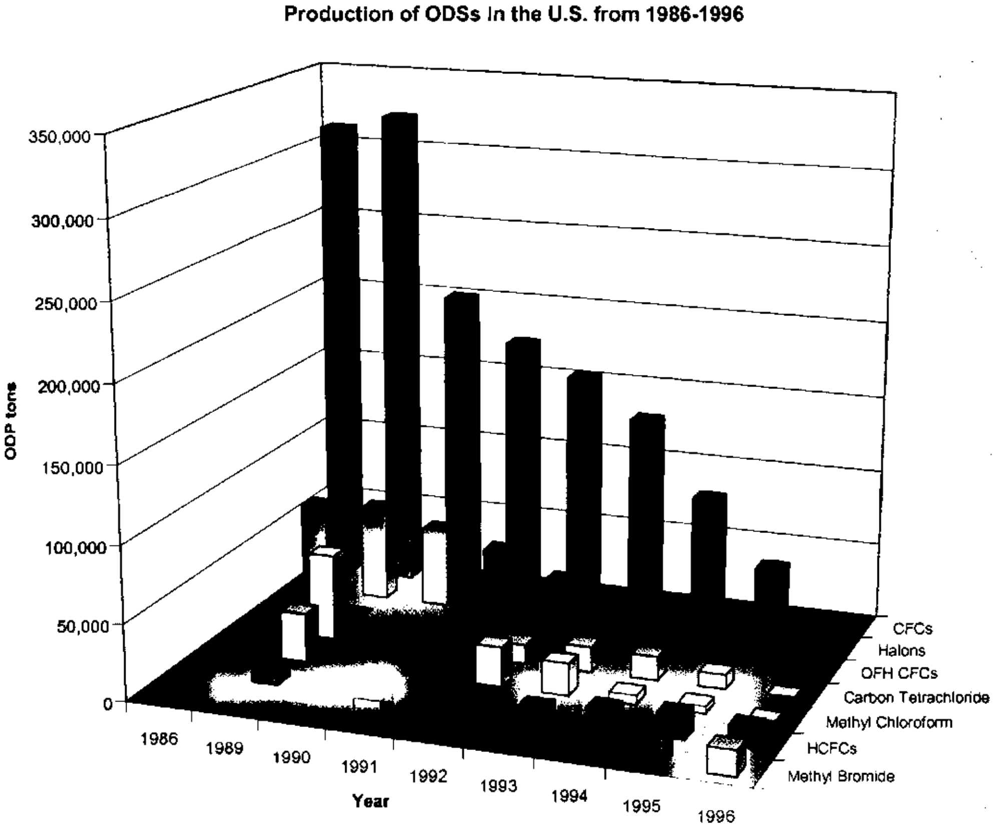
The U.S. ODSs' production is depicted in Figure 6.3. In 1989, the U.S. produced over 400,000 ODP tons of ODSs, while the total ODSs production in 1996 did not exceed 50,000 ODP tons.



Source: UNEP Secretariat (1997).

Figure 6.3: Production of Ozone-Depleting Substances in the USA from 1986-1996

Lee (1996) argues that permit trading helped American companies to exceed the Montreal Protocol targets. He argues that due to allowance trading, the U.S. could reduce its 1990 production of CFCs by 40 percent, even though it was only required to freeze at the 1986 levels. In 1991, when the production was supposed to be 15 percent lower than in 1986, the actual level was about 50 percent lower. He argues that the drop in anticipated costs of reducing CFC production from $3.55 per kg of CFC to $2.45 was a result of the marketable system, which lowered the administrative costs and offered the

The U.S. ODSs' production is depicted in Figure 6.3. In 1989, the U.S. produced over 400,000 ODP tons of ODSs, while the total ODSs production in 1996 did not exceed 30,000 ODP tons.

Source: UNEP Secretariat (1997).

Figure 6.3. Production of Ozone-Depleting Substances in the U.S. from 1986-1996.

Lee (1996) argues that permit trading helped American companies to exceed the Montreal Protocol targets. He argues that due to allowance trading, the U.S. could reduce its 1990 production of CFCs by 40 percent, even though it was only required to freeze at the 1986 levels. In 1991, when the production was supposed to be 15 percent lower than in 1986, the actual level was about 50 percent lower. He argues that the drop in unit costs of reducing CFC production from $3.55 per kg of CFC to $2.45 was a result of the marketable system, which lowered the administrative costs and offered the needed flexibility to meet the reduction goals. There is no question that allowance trading offers flexibility.

However, the trading data for 1989 and 1990 suggest modest trading levels. Each year, allowances for not more than 1 million kg CFC were traded between companies. The major overcompliance that Lee (1996) identifies in year 1990 could then not be attributed to trading. Further, let us examine how other countries fared in comparison to the U.S. Other countries have not enacted domestic trading arrangements, but still overcomplied as much as the U.S. or even more. UNEP secretariat data on CFC production (see Table D1) indicate that in 1989, when the non-Article 5 parties were expected to freeze[13] their CFC production at the 1986 level, all major CFC-producing countries overcomplied. However, the U.S. actual production was 6 percent below the allowed, whereas the production of France, Germany, and the U.K. was 29, 23, and 33 percent, respectively, below their allowed production. Therefore, we cannot say that trading in the U.S. allowed for significant overcompliance.[14]

Substantial taxation of ODSs in the U.S. could also be another reason for large overcompliance (Hoerner, 1996). ODSs production trends, the Montreal Protocol targets, and the excise tax rates are depicted in Figures E8-E14.[15] The CFC production data illustrate my argument rather well (Figure E8). In 1989, the Montreal Protocol target amounted to 342,123 tons of ODP, and the actual production to about 320,000 ODP tons. This constituted an increase, rather than a decrease, from the 1986 levels. In 1990, the first year of the CFC excise tax, which doubled the price of CFCs, U.S. producers decreased their production to 200,000 ODP tons.

6.3.2.2 Market Effectiveness

Only the United States has developed a system of marketable rights for manufacturing ODSs. The subsequent analysis therefore examines the U.S. experience

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[13] A 10 percent production increase was allowed for exports to developing countries.

[14] Lee's argument seems more plausible if we look at halons' data. Their U.S. production in 1992 (the freeze year) was 60 percent below the allowed level, whereas Japan's production was only 36 percent and France's production only 39 percent below the target.

[15] Some ODSs were not taxed (for example, methyl bromide, other fully halogenated CFCs, and HCFCs (Figures E12, E13, and E14, respectively).

only. There are a small number of trades across national borders due to transfers of permits between resource users of the same owner. However, an active international market for trading in ODSs production permits does not exist.

Number of trades. The EPA collected data on transfers of CFCs and halons' permits, but it has not made the data publicly available. Alliance for Responsible Atmospheric Policy, an industrial organization that brokered many of the trades, did not return many calls the researcher made. Therefore, the analysis of trading data are based only on one published source. Permit trading trends are presented in Tables 6.3 and 6.4.

Table 6.3: Number of Trades Involving Ozone-Depleting Substances *

	1989	1990	1991	1992	1993	1994	1995
International	0	0	0	2	5	10	5
Intra-company	0	0	0	45	40	40	30
Inter-company	5	15	45	170	125	140	60
TOTAL	5	15	45	217	170	190	95

Notes:
* Total of CFCs, halons, carbon tetrachloride, and methyl chloroform.
All numbers are approximate.

Source: Lee (1996).

The published data are aggregated across all substances and it is not clear from the publication (Lee, 1996) whether or not the units are multiplied by the ODP. Therefore, the presented data can only be used to examine trading trends over time, not interpollutant trading. Data on number of trades and number of traded permits indicate increases in trading activity over time. However, as we approach the phase-out deadline, the number of trades and the number of traded permits decrease.

Table 6.4: Traded Permits* (in millions kg)

	1989	1990	1991	1992	1993	1994	1995
International	0	0	0	1	10	12	10
Intra-company	0	0	0	10	15	27	10
Inter-company	1	1	80	73	67	55	40
Total	**1**	**1**	**80**	**84**	**92**	**94**	**60**

Notes:
*Total of CFCs, halons, carbon tetrachloride, and methyl chloroform.
All numbers are approximate.

Source: Lee (1996).

Limited data on trading within the groups of ODSs indicate increases in trading activity of CFC-12, the substance that was most costly to replace. Between 1992 and 1994, CFC-12 allowance trade increased from 14 million kg to 26 million kg (Lee, 1996). The inter-pollutant trading allowed for additional flexibility in meeting the reduction targets. In 1994, producers were allowed to produce only 25 percent of the 1986 baseline annual production of CFC. However, some substances were produced at levels significantly below the permissible levels. CFC-113, CFC-114, and CFC-11 were produced only at 7, 10, and 10 percent, respectively (Lee, 1996:34). Others exceeded the permissible levels due to inter-pollutant trading. CFC-12 (car air-conditioners) and CFC-115 (supermarket refrigeration systems) were produced at 39 and 84 percent of the baseline production.

There were very few international trades. Those occurred between the U.S. and Canada. Many were, however, intra-company trades. The Dow Chemical Plants traded methyl chloroform production quotas and Du Pont eliminated its production of CFC-11/CFC-12 at its Canadian facility.

An active black market evolved, especially for substances used in car air-conditioning (such as CFC-12). Since 1993, illegally imported CFC-12 has become widely available. The reason for illegal imports are high costs of ODS due to high excise tax. Lee also attributes the spread of black-market to the "success of the marketable permits system itself in restricting CFC supplies and increasing costs" (Lee, 1996:36).

There are no data available on the proportion of regulated resource users who participate in the market. The Alliance for Responsible Stratospheric Policy supposedly has data on permit prices (personal interview with Vera Au, EPA), but the researcher was not able to access them.

6.3.3. Marketable Permit Systems for Preventing an Overuse of a Global CPR: A Summary

Depletion of the ozone layer, a global CPR, was addressed at the international level by negotiating quantified reductions in the ODSs production. The largest ODSs producers committed to reduce and over time phase-out their ODSs production. Only the

United States assigned ODSs production permits to individual producers. International market in permits did not exist. The presented study therefore focused on the U.S. domestic markets.

Reductions in production of some ODSs substantially exceeded the required reductions. Due to inter-pollutant trading, production of other ODSs could continue without restrictions. An excise tax was enacted at the same time that first doubled and then tripled the prices of some ODSs. Without more detailed analysis, it is impossible to estimate partial effects of permit trading and taxation on the overcompliance.

CHAPTER 7

THE ATMOSPHERE AS A CARBON DIOXIDE SINK: WHAT THE KYOTO PROTOCOL ADDRESSED AND WHAT IT LEFT OUT

This chapter examines the debate on the overuse of the atmosphere as a sink for carbon dioxide and other gases and examines how these emissions negatively affect the global climate. It analyzes the characteristics of the use of the atmosphere as a carbon sink and the characteristics of the users. The chapter also reviews the Kyoto Protocol that outlined the basis for trading in emission rights.

7.1. Overusing the Atmosphere As a Carbon Sink: Why Are We Concerned?

The atmosphere protects the earth from the external environment and keeps the earth habitable. A layer of multiple gases, such as water vapor and carbon dioxide, allows the radiation from the sun to enter the atmosphere and prevents the waves of infrared radiation to exit the atmosphere. This "trapping" of heat creates the so-called greenhouse effect and enables life on the earth. Without this effect, the average temperature of the earth would be lowered by about 64 ° F. The heat trapped in the atmosphere is redistributed by winds and ocean currents over the earth's surface. It is redistributed between the earth and the atmosphere by evaporation and subsequent precipitation. Climate is, therefore, controlled by the long-term balance of energy between the earth and its atmosphere.

Increased concentrations of greenhouse gases in the atmosphere, caused by fossil fuel burning, land use practices, and industrial production have changed the energy balance beyond its natural variability (Climate Change, 1995a). Fossil fuel burning accounts for 80 to 85 percent of the carbon dioxide emissions, whereas net emissions from deforestation are responsible for 15 to 20 percent of current carbon dioxide emissions. Methane is the second most important anthropogenic greenhouse gas, emitted during rice cultivation, cattle and ship ranching, material decay in landfills, leakages from coal mining, oil drilling, and methane transportation. Human activities have increased methane concentrations in the atmosphere by about 145 percent above the natural level. Nitrous oxide, another GHG, is produced by agricultural and industrial practices. Anthropogenic nitrous oxide emissions result in concentrations exceeding the natural levels by about 15 percent. Chlorofluorocarbons and tropospheric ozone are also potent greenhouse gases.

The increased concentrations of GHG have changed the earth's energy balance by about 2.45 Wm^{-2} (watt per square meter). The heat trapping potential, or the so-called global warming potential (GWP), differs across gases: the highest for carbon dioxide (1.56 Wm^{-2}), then methane (0.47 Wm^{-2}), and nitrous oxide (0.14 Wm^{-2}). The potential differs, however, with respect to time horizons (Climate Change, 1995a). For example, the global warming potential of a methane molecule is 56, if the time horizon is 20 years; 21 if the time horizon is 100 years; and 6.5 if the time horizon is 500 years. The potential of a nitrous molecule is 280, 310, and 170 respectively for the same time periods. GWP is an index that expresses the relative radiative effects of the GHG emissions with carbon dioxide as a reference gas (IPCC, 1995a).

Measurements of carbon dioxide concentrations and surface temperatures indicate a significant human-induced global climate change. Globally, the average temperature at the earth's surface has warmed between 0.5 and 1° F since the late nineteenth century. The period after 1990 has experienced the four warmest years since 1860. Further, the sea level has risen by about 4 to 10 inches since the nineteenth century, mountain glaciers have shrunk, and the northern hemisphere's snow cover has declined since 1973. Long-term data based on the observations of deep ice-core indicate that the temperature change in the last century has been higher than century-to-century temperature changes in the last 10,000 years.[1] Higher temperatures will alter weather patterns, hydrological cycles, and vegetation patterns, thereby increasing the danger of some diseases in the moderate zone.

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[1] These data are contradicted by the satellite and radiosonde measurements. Satellite-based measurements of temperatures at higher altitudes indicate global cooling, not global warming. The differences in the temperature trends at different altitudes do not deny the global warming, but only indicate different factors affecting the variability and persistence of climate patterns at different altitudes.

7.2. Potential Carbon Dioxide Permit Markets

7.2.1. Independent Variables

7.2.1.1. *CPR Characteristics Affecting Measurability*

Predictability of CPR stocks. Carbon dioxide is the most potent greenhouse gas, given its GWP and emitted quantities. This chapter, therefore, focuses on carbon dioxide. Though the Kyoto Protocol allows for including other GHG, as this would provide more cost-effective options to reduce GHG emissions, I do not include other gases in my analysis. The reason is that the individual sources of their emissions cannot be measured with high reliability (IPCC, 1995b; Victor, 1999). As a result, policies for limiting their emissions cannot be easily monitored and enforced. These gases may, however, be added to the carbon permit markets once their measurement techniques become more reliable.

Burning fossil fuels is not the only carbon source, and the atmosphere is not the only carbon sink. Carbon circulates in a global cycle. Figure 7.1 depicts the major carbon reservoirs and flows. In 1980, the net release of carbon was about 7 Pg (peta gram) of carbon.[2] About 5 Pg are released through combustion of fossil fuels, 0.1 Pg from producing cement, and about 1.8 Pg from changing land use. Land change could either release carbon (deforestation) or store carbon (reforestation). Deforestation releases carbon stored in biota, as trees hold about 20 to 100 times more carbon per unit of area than crop land. The data on carbon releases and accumulations in the reservoirs do not balance with the former exceeding the latter (Houghton and Skole, 1990).

In addition to the above uncertainty about the roles of carbon sinks, there is a debate about the effects of increased carbon concentrations, as both negative and positive feedback factors exist. As the global climate warms, liquid-water droplet clouds will replace ice clouds. This will increase the reflectivity of clouds, reducing global temperatures by an estimated 5.2 °C to 1.9 °C (Jastrow, Nierenberg, and Seitz, 1990). There are other factors, such as volcanic eruptions and aerosols, that also increase the

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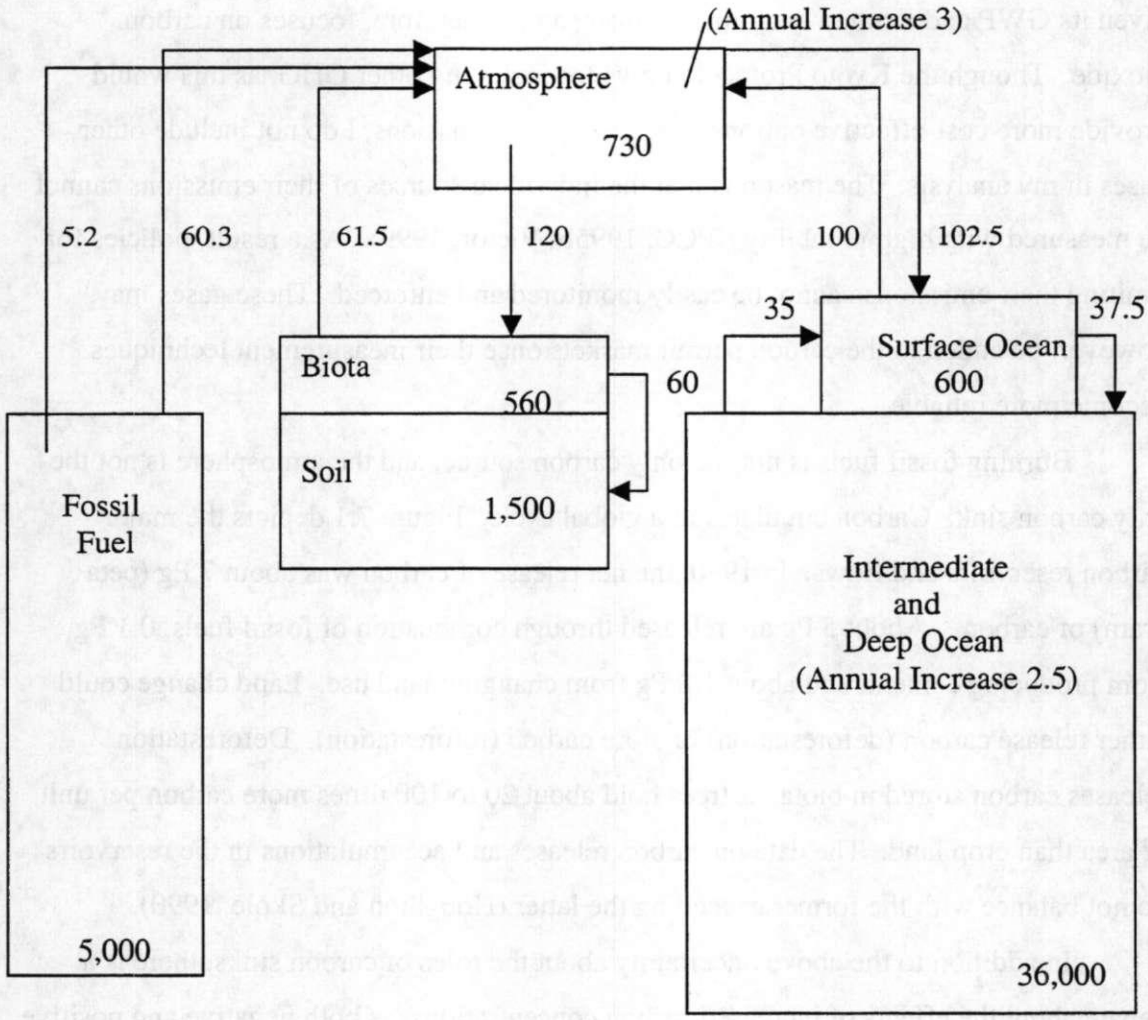
[2] Pg stands for peta gram. 1 peta gram = 1×10^{15} grams; that is, 1 billion metric tons.

reflection of sun radiation from the Earth. On the other hand, there is a positive feedback, potentially enhancing the global warming effect. Increased global temperatures will increase the amount of water vapor in the atmosphere. Since water vapor is itself a greenhouse gas, global warming will be enhanced. The increased levels of water vapor in the atmosphere may, however, also affect clouds. This could further affect the amount of sun radiation that is reflected back or absorbed by the earth.



Source: Houghton and Skole (1990:395).

Figure 7.1: Major Carbon Reservoirs and Flows in the 1980s, in Pg of carbon.

<u>Availability of reliable indicators of resource flows</u>. Flows of carbon from various reservoirs can be estimated with varying levels of precision. The most easily measured carbon flow is from fossil fuel burning. The amount of emitted carbon is directly related

to the fuel's carbon content, irrespective of the combustion temperature. For example, combustion of natural gas, liquid fuels, and coal releases 13.78, 19.94 and 24.12 kg of carbon per billion joules of energy, respectively (DOE, 1990).

The measurements of carbon flows from/to biota are currently only at an experimental stage and even estimates are limited in number. Storing carbon in biomass depends on the biomass growth, which depends on multiple factors. Similar to a production function, widely used in economics, scientists have attempted to develop models that would enable analyses of growth dynamics without long-term data (Bossel and Schäfer, 1989; Nautiyal and Belli, 1989). There is, however, no agreement on how precise are production methods for biomass modeling. There are multiple factors affecting growth and biomass, such as forest type, stand age, available water (Grigal and Ohman, 1992), altitude, soils and moisture (Faber-Langendoen, 1992), soil texture, nutrient and slope aspect, and the position on the slope (Muller, 1982).

Factors affecting biomass growth can potentially change as the global climate changes. Increased levels of carbon dioxide in the atmosphere have been found to have fertilizing effects (Sandenburg, Taylor, and Hoffman, 1987a; Leverenz and Lev, 1987; Kramer and Sionit, 1987). The effects will differ within and across species. Higher carbon dioxide concentrations appear to increase water-use efficiency and compensate for temperatures below and above the equilibrium. Further, climate change will cause major shifts of forest communities. New forest communities will have to be defined. Species with wide environmental tolerances, high reproductive output, and superior competitive abilities will be favored. These species will immigrate and change species frequency and dominance (Randolph and Lee, 1993).[3]

<u>Spatial extent of the resource</u>. Using the atmosphere as a sink increases carbon concentrations all over the globe. This requires international cooperation on any policy to mitigate climate change. If a resource user reduces his/her resource use, he/she will

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[3] Frequency is "expressed as the percent of sampling plots in which a species is represented by at least one stem"[3] dominance "refers to the biomass that a species contributes to stand structure" (Randolph, 1994: 42).

only benefit from the reduction, if other users do not increase their use.[4] This requires establishing intricate monitoring systems. An important issue is who should establish them and at what level of aggregation. The subsequent discussion examines these issues in the context of establishing carbon trading mechanisms.

Effects of the resource use on the resource stocks (uniform versus non-uniform effects). Carbon dioxide emissions anywhere on the earth increase global concentrations by the same amount. It is, therefore, not important where carbon dioxide is emitted or sequestered. This creates opportunities for finding the cheapest ways of reducing resource use within and across countries.

The effects of the global warming will, however, differ across local environments. As relatively small changes in the temperature and precipitation can result in substantial changes in runoffs, it is very difficult to assess local effects of the global climate change. Maximum warming would occur in winters in high northern latitudes. Warmer temperatures will lead to more vigorous hydrological cycles, more severe droughts and/or floods in some places and less severe droughts and/or floods in other places (IPCC, 1995a). With a complete collapse of the West Antarctic Ice Sheet, all of south Florida, more than 25 percent of Louisiana, and part of Washington, D.C., would be permanently submerged. Composition and the geographic distributions of ecosystems and crop yields will change (Randolph and Lee, 1993; IPCC, 1995a). The effects of these changes on the local economies are difficult to estimate. Mendelson et al. (1997) estimate that economies of Africa, Asia, Latin America, and Oceania will bear substantial costs, whereas North America and Europe will reap benefits from climate change.

The variation in the perceived impacts of climate change influences the willingness of individuals, industries, and countries to participate in a global attempt to mitigate it. This influence is important both at the negotiation and implementation stages. Countries facing higher costs of climate change are more likely to comply with the devised rules.

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[4] Adaptation to the global climate, for example, building a higher dam for protection from ocean-level increases or developing more heat or drought-resistant species for a given local environment, on the other hand, requires cooperation of a smaller number of actors.

7. 2.1.2. Characteristics of CPR Users

This section reviews the two most important users of atmosphere as a carbon sink--the energy and the forest sectors. The former is the major source of anthropogenic emissions, the latter can be either a carbon source or a sink. Table F1 in Appendix F presents the energy use and related carbon emissions for the OECS countries in 1992. Total carbon dioxide emissions from the energy sector amount to about 10,000 million tons. The United States is the largest emitter, accounting for nearly 5,000 million tons of carbon dioxide, followed by the EU, accounting for about 3,000 million tons, and Japan, accounting for about 1,100 million tons. Luxemburg has the highest per capita use of the atmosphere as a carbon sink with 29 tons of carbon dioxide. The U.S. is the second largest per capita user, followed by Canada and Australia. In the U.S., electricity generation accounts for about one third of the emissions, transportation for another third, and residential and commercial energy together account for about 12 percent of the carbon emissions.

Though electricity generation is the largest emitter, its share could change over time and its future role is not straightforward. In the past, its share decreased, mainly due to the use of nuclear energy in electricity generation. In the future, however, we cannot expect that nuclear energy will meet the increasing demand for electricity.[5] Unless renewable sources increase their share in electricity generation, the increased demand for electricity will result in increased carbon emissions. Electrification of the industry may, however, also decrease carbon dioxide emissions. There are technologies whose adoption would result in increased end-use energy efficiency, thereby reducing energy demand and emissions.[6]

Emission trading systems are more cost-effective if there are large differences in emission reduction costs. By including only Annex I countries in the system, a large group of countries with potentially low emission reduction costs is left out of the system.

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[5] Energy intensities, measured with a ratio between energy and GDP, have been falling for most of the developed countries. The energy/GDP elasticity is less than one, while the electricity-GDP elasticity has been generally above one. This indicates that there has been a shift in energy mix towards electricity (Nathwani, Siddall, and Lind, 1992).

Many developing countries exhibit very high energy-intensities. Thus, investments in energy efficiency in these countries would bring substantial savings in their energy use. For example, on average, Chinese coal-fired boilers are about 25 percent less efficient than in industrialized countries. If the Chinese boilers could be brought up to the efficiency level of industrialized countries, their emissions could be reduced by 15 to 20 percent. With more than 63 percent of primary energy supply coming from coal, this would reduce China's total emissions by 5 percent (AEA, 1998). The question, then, is how can the international community employ low-cost emission reduction options without forcing the host countries to agree to an emission cap that would provide a reliable emission baseline against which the project emission reductions could be calculated? I address this question in more detail section 7.2.1.4.

Changes in land use also impact carbon flows from/to the atmosphere. Owners changing their land-use practices, can therefore become users of the atmosphere (flow of carbon from the land to the atmosphere) or providers of sink services (storing carbon in growing biomass). Various forms of biomass, such as herbaceous crops and algae systems can store carbon, but forests are the most cost-effective options. Table 7.1 presents the largest forest owners in the U.S. The federal government is the largest single owner of forests in the U.S., accounting for about 20 percent of the forested land. About three-fourths of forest in the U.S. are privately owned.

Table 7.1: Timberland Ownership in the United States, 1992

Owner	Area (10^3acres)	Percentage
Federal Government	96,655	19,7
States	27,356	5,6
County/Municipal	7,484	1,5
Total Public	**131,493**	**26,9**
Forest Industry	70,455	14,4
Farming	82,484	16,9
Other	205,121	41,9
Total Private	**358,061**	**73,1**
Total Public and Private	**489,555**	**100,0**

Source: Richards (1997:160).

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[6] These technologies include electric process heating, industrial electrotechnologies, electric vehicles, information technologies, possibility of telecommuting, use of electric heat pumps for space heating and cooling as well as for water heating.

Forest management practices can affect the amount of carbon released/stored in the forests. Carbon storage in existing forests can be increased by the following practices: (1) lengthening forest rotation cycles, (2) modifying forestry management practices to emphasize carbon storage, and (3) adopting low-impact harvesting methods to decrease carbon release (Richards, 1997: 24). Measuring the actual carbon storage is difficult due to the uncertainty about the amount of soil carbon lost during harvests and the amount and rate of debris decomposition after the harvest (Sedjo, 1995). A shift of harvests from the managed site to another site (the leakages) is another major challenge for measuring carbon storage of these projects.

It is not clear whether the private or public forest owners would be a better provider of carbon storage services. Parker (1993) suggests that small non-industrial, private forest-lands are usually poorly managed, with little concern for regeneration. On the other hand, Barber, Johnson, and Hafild (1994) argue that reforestation is better on private land. Richards (1997) suggests that decisions on who should be managing forest for carbon storage depends on the relationship between measurement and production costs. For carbon sequestration projects with high measurement costs, the lower production costs of privately providing these services may not outweigh the high measurement costs. Public forest may therefore be more cost-effective in providing carbon storage services in the initial periods. If the carbon storage services were to be provided by private forest owners, these projects may first be focused on large landholdings. Ownership distribution of private timberland in the U.S. is presented in Table 7.2. Richards (1997) recommends limiting the size of the land, providing carbon storage projects, to 500 acres or more. Though this would cover about 52 percent of forests, it would require monitoring only about 1 percent of all private timberland owners.

Table 7.2: Size Ownership Distribution of Private Timberland in the USA

Size of Holding (acres)	Percent of Owners	Percent in Category or Greater	Percent of Land	Percent in Category or Greater
1-9	71.3	100.0	3.3	100.0
10-49	15.0	28.7	8.4	96.7
50-99	5.9	13.7	9.9	88.3
100-499	7.0	7.8	30.8	78.4
500-999	0.5	0.8	8.1	47.6
1,000 +	0.3	0.3	39.5	39.5

Source: Richards (1997:180).

Carbon storage can also be provided by planting woody biomass where none previously existed. Such projects include: (1) afforestation of agricultural land, (2) reforestation of harvested and burned land, (3) adoption of agroforestry practices, and (4) establishment of short-rotation woody biomass plantations (Richards, 1997: 24). The early estimates of carbon sequestration costs assumed a given level of sequestration activity. The costs varied from \$3 to \$16 per ton of carbon sequestered in tropical agroforestry, from \$3 to \$60 in tropical plantation, from \$2 to \$50 in temperate plantation, from \$3 to \$27 in Boreal plantation, and from \$1-\$4 in Boreal protection (Sedjo, 1995:317). More sophisticated studies take into account the increasing costs of land as the level of sequestration efforts increases. Moulton and Richards (cited in Sedjo, 1995) estimate that sequestration costs in the U.S. range from \$5-\$10 for the first 60 million tons, to \$40/tC as the annual sequestration increases to 800 million tons and total land involved amounts to 340 million acres.

It is therefore important to examine the ownership distribution of private farmland that could be converted to forests. Ownership distribution of private farmland in the U.S. is presented in Table 7.3. Richards (1997) recommends limiting the size of the projects providing carbon storage to 500 acres or more. This would cover about 77 percent of farmland, but require monitoring of only about 18 percent of farmland owners.

Table 7.3: Size Ownership Distribution of Private Farms in the USA

Size of Farm (acres)	Percent of Owners	Percent in Category or Greater	Percent of Land	Percent in Category or Greater
1-9	8.8	100.0	0.1	100.0
10-49	19.7	91.2	1.1	99.9
50-99	1439	71.5	2.3	98.8
100-499	38.9	56.6	19.7	96.5
500-999	9.6	17.7	14.4	76.8
1,000 +	8.1	8.1	62.4	62.4

Source: Richards (1997:180).

7.2.1.3 The External Legal and Regulatory Environments

International environmental policy requires cooperation and agreement of interested parties. As every country is sovereign and no international police exists to coerce compliance with international environmental laws, cooperation requires that countries agree on the extent of the problem and its potential solutions.[7]

Over the last decade, international cooperation to stabilize concentrations of greenhouse gases at a level that would prevent catastrophic outcomes has evolved significantly. The United Nations Framework Convention on Climate Change (UNFCCC) was signed and ratified by a large number of countries. There was wide agreement on the potential negative effects of climate change if business as usual continues. Developed countries (Annex I countries in the parlor of the convention) accepted primary responsibility for addressing these issues, while developing countries (non-Annex I countries) were expected to take action if the resources were made available (see Table F2, Appendix F for the list of Annex I countries).

The UNFCCC introduced Joint Implementation as a means of enabling developed and developing countries to cooperate in their efforts to reduce greenhouse gas emissions or to enhance sinks. Joint implementation was interpreted as projects reducing emissions or enhancing sinks in one country that is financially supported by at least one other

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[7] For more on the effect of costs and benefits of global climate change on negotiation outcomes see Dolšak (forthcoming).

country.[8] A great majority of the projects occur in the energy and land-use sectors and are developed and implemented between governments (ELI, 1997b). All Joint Implementation projects have to be approved by both parties to the UNFCCC and have to result in emission reductions beyond the emission reductions those that could be accomplished in absence of the project (additionality criterion).

Only the third conference of parties in Kyoto brought some agreement on policy instruments and the extent of flexibility that could be used in global climate policy. The Kyoto Protocol (UNFCCC, 1997) sets legally binding targets for reducing emissions of the following GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (see Table F2, Appendix F). The emission reduction targets pertain to a basket of all these gases and a party can reduce emissions across gases as per their national needs, as long as it meets the overall emission reduction target. On average, the countries committed to 5.8 percent emission reductions from the 1990 level by 2008-2012.

But for one aspect, the protocol followed closely the U.S. proposal for establishing a tradeable permit system (U.S. Department of State, 1997). Both systems are based on emission permits that are allocated to Annex I countries, based on their 1990 emissions. Countries can meet their emission reduction targets by reducing the emissions of any of the GHGs at home or investing in emission reductions elsewhere. Countries can set joint emission reduction targets (Article 6). This option was especially important for the EU, as their economies have multiple linkages. Emission permits can be purchased from other Annex I countries (Article 17). Annex I parties can also invest in emission reduction/sink enhancement projects in non-Annex I countries in so-called Clean Development Mechanisms (CDM) (Article 12). Quantified and certified emission reduction credits (ERC) from those projects can be used as emission allowances to meet the emission reduction targets. In the section on rules, I examine the rules for creating and exchanging ERCs for emission allowances. The only issue that the U.S. proposal and the final Kyoto Protocol did not agree on is flexibility in time. The U.S. proposal

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[8] A number of countries developed Joint Implementation programs, including Australia, Bolivia, Canada, Chile, Cost Rica, Ecuador, Germany, Guatemala, Japan, Mexico, the Netherlands, Peru, Poland, and the United States.

allowed for banking as well as borrowing from the future, whereas the Kyoto Protocol allowed for banking, but required compliance with emission targets in each period.

At first, it is not clear why Article 6 is even included in the Kyoto Protocol (Interview with Joe Goffman, EDF, October 1998). Joint implementation allows private entities from Annex I countries to invest in emission reduction projects: "any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emission by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of economy ..." (The Kyoto Protocol, Article 6). As all Annex I parties established their emission caps, any emission reduction beyond the target frees up emission allowances. However, not all countries will necessarily establish national systems of allowances. Article 6 therefore allows for easy transfer of accomplished emission reductions from one country to another when both countries have emission reduction targets that prevent a leakage of emissions to another activity in the same country. As non-Annex I countries do not have emission caps, the leakage of emissions from the project is a serious issue that can substantially decrease environmental effectiveness of the ERC trading.

International cooperation on managing forests as global carbon sinks is not evolving as fast as the cooperation on the emission part of atmosphere use. Environmental organizations and citizens opposed the initial proposal for a global forest convention in 1999. They found that the globally agreed solution would reduce the goals to the lowest common standard that could be agreed upon. As an alternative, they suggested that the existing agreements be utilized, distorting trade policies removed, customary rights to the land and forest secured, illegally harvested forest products limited, and strong standards for forest concessions for international organizations established. The proposal was signed by environmental organizations such as Green Peace and the World Wide Fund for Nature International (Infoterra, 02/27/97).

In the U.S., about 15 states passed laws regulating forest management between 1937 and 1955. The laws are focused, however, on reducing fire hazards. Some states later updated their forest regulations (Oregon, Washington, California), but timber production remains the major topic, less so water management and endangered species. Neither harvest rates nor locations of clear cuts are regulated. Monitoring and enforcement are limited, and compliance is basically voluntary (Cubbage, O'Laughlin, and Bullock, 1993).

This brief review suggests that existing international and domestic U.S. laws do not provide the legal environment that would entail sanctions for failing to meet targets for reducing carbon emissions or enhancing its sinks. The only way international commitments could be enforced and sanctioned is by establishing issue-linkages. Parties to the UNFCCC that do not comply with the agreed targets could be forced to comply by limiting the international/multilateral loans for which they apply. This approach, however, allows for sanctioning of borrowers only and not of lenders! Another issue linkage that could be used is trade restrictions. This would, however, require that the WTO allow for using trade restrictions to force compliance with internationally negotiated environmental targets.

7.2.1.4. Rules Regulating CPR Use, Users, and Trading

Rules regulating CPR use.

Severity of resource use limitation. Analyses of national CPR markets suggest that marketable permits perform better when the resource use is severely limited by an authorized agency and the limits are enforceable at low costs. Given that only countries are parties to the Framework Convention on Climate Change, marketable permits for global atmosphere will have to rely on national emission limits enforced by national governments. Internationally, compliance with national limits will have to be reviewed periodically and non-compliance at the country level sanctioned.

At the international level, no supranational authority exists to enforce the emission caps. Since countries are sovereign, they alone decide whether or not to participate in the climate change efforts. If global emissions are capped, the emission allowances can be allocated among participating countries on the basis of gross national product (GNP), population, historical emissions (a version that is currently adopted by Annex I countries), or a weighted average of those indicators. Each scheme would have winners and losers. As these schemes approach the problems from very different perspectives, it is difficult to say which one is more correct. Allocation based on GNP would allocate a large proportion of the allowances to the countries with higher GNPs. The rationale for this allocation is strictly economic; allowances are necessary for production and should therefore be allocated to the most productive use--therefore allocated on the basis of final output. This allocation would cause significant losses for developing countries with low GNPs and they are therefore not likely to agree to such a scheme. A similar logic could be employed at a domestic level. Firms would obtain emission allowances based on the revenues they generate. This would shift pollution from activities with low value-added and high energy-intensities to activities with high values and lower energy-intensities.

Allocations based on population have a political rationale; each human being in the world should be allowed to the same use of the resource that is common to the entire world, that is, the global atmosphere. This scheme would allocate substantially more allowances to developing countries. This could actually be used as an incentive to achieve their cooperation in the attempts to mitigate global climate change. Developed countries would have to purchase the allowances from developing countries, which would result in large financial transfers to developing countries. A version of this allocation method could be employed at a national level. Emitters would be allocated allowances based on the number of employees.

A more practical way of assigning emission caps is to allow each country to set its own cap. For example, Annex I countries could cap their emissions at the levels committed in the Kyoto Protocol. These caps are internationally agreed to and known to all parties. Based on the emission cap the countries have set for themselves in Kyoto, each country could issue allowances to its own emitters and allow them to trade them domestically and internationally. This system would be similar to the existing Acid Rain trading scheme: (1) the traded commodity would be a standardized emission allowance; and (2) compliance monitoring and enforcement would still be performed by national agencies, but reported to an international body, most likely to the Secretariat to the UNFCCC. Article 17 of the Kyoto Protocol lists explicitly that Annex I countries may participate in emission trading for the purpose of fulfilling their commitments. The

Article requires that the trading is supplemental to domestic emission reduction efforts, but does not prescribe the proportion of the allowances that can be traded internationally.

Emission allowances could also be auctioned. This allocation method is more plausible at the national than at the international level, but even at the national level it was not implemented. At the international level, no organization exists that could collect these large sums of money. Countries with large emissions (U.S., China, India) would not be willing to spend money to buy the right to emit. Differential requirements or hybrid schemes therefore seem to be the most politically viable option. Countries would be allocated the allowances, but the initial allocation would be controlled for per capita GNP, so that countries with low incomes face lower emission reduction targets. Further, side payments could be used to induce developing countries to participate.

Another allocation scheme could be based on historical emissions. This scheme advantages past polluters over future ones. This protection of existing polluters from the new entrants has helped the SO2 regulation gain support from the polluters. However, it is unlikely that this scheme would gain support at the international level. Developing countries, who are starting to industrialize, would not agree to limiting their emissions based on their low past emissions. The historical base is also unfair. The current climate change problems are caused by the accumulated carbon dioxide in the atmosphere, i.e., by the effects of the past industrialization of developed countries. Allocating the future emission rights based on historical emissions would actually allow the past polluters to benefit instead to pay for pollution. The current emission targets, agreed to in Kyoto, are based on the historical base (in most cases 1990).

The above discussion suggests severe difficulties in setting the resource use limits. In Kyoto, Annex I countries have committed to quantified emission reduction targets (presented in Table F2 in Appendix F). On average, the countries committed to reduce their CO2 emissions by 5.8 percent from the 1990 level by 2008-2012. Most countries committed to 8 percent reduction, some countries to a freeze of future emissions at the 1990 levels, and some countries committed not to increase their emissions by a given percentage. In comparison to national CPR markets, Annex I countries have a very long period to accomplish fairly modest emission reductions. These emission reductions could be accomplished at a fairly low price. The U.S.

Administration projects that the emission reductions negotiated in Kyoto could be achieved in the U.S. at about $14 to $23 per ton of carbon equivalent, which translates to a gasoline price increase of 4 to 6 cents per gallon (AEA, 1998). In light of the gasoline price increases in the first trimester of 2000, when the price of gasoline increased from about $1 to over $1.50, a price increase required for carbon emission reductions would not be drastic.

On the other hand, an analysis of emission trends between 1990 and 1996 indicates that the Kyoto targets will not be met easily by most Annex I countries. Table F2 presents emission trends between the base-year (for most countries 1990) and 1996. Of all countries with stable economies, only Germany, Luxemburg, and the United Kingdom could reduce their emissions by 1996. The other group of countries that reduced emissions from their base years (in most cases 1992) are economies in transition, such as the Czech Republic, Latvia, Lithuania, the Russian Federation, and Ukraine. Their emission reductions are, however, generated due to higher base-year emissions and significantly reduced economic output in current years. Data available at the fifth conference of parties in Bonn, October 1999, indicate that lenient environmental targets for the Russian Federation, Ukraine, and Central and Eastern Europe could result in supply of about 370 million metric tons of carbon equivalent (Lelani, 1999).

To prevent these "paper" emission reductions to enter the market and jeopardize the success of the agreement, the emission reduction targets will have to be renegotiated (Victor, 1999). Such renegotiations of collective-level rules (Ostrom, 1990) could take very long. Alternatively, a change in trading rules (operational level rules) has been recommended (Lelani, 1999). For example, only those emission permits that have been created without shrinking economic activity could be allowed to enter the market.[9] The difference between the allocations and the actual emissions would then not be allowed to enter the market in its entirety. In the case of global carbon emissions, this scheme unfortunately creates incentives for a shift in electricity generation from coal-based to nuclear-based generation.

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[9] A similar issue arose in the discussions on ERCs based on shot-downs. In some cases, when the targets were very severe (such as early EPA trading programs), the shot-downs were the only source of emission rights' credits. In other markets, the shot-downs were not a legitimate source of credits.

Deciding quotas for future emissions of countries with very low current emissions is another difficult issue. All domestic emission permit systems required that the new resource users purchase rights to use the resource. This rule created barriers for new entrants and it was therefore supported by the regulated industry. In an international arena, the newcomers are countries that cannot be easily precluded to access the resource. Their access, however, could be sanctioned by issue linkages. To elaborate, total emissions of Africa account for 3 percent of global emissions. These countries have not contributed to the existing resource overuse, whereas the largest contributors have benefited from centuries of unrestrained resource use. The new comers should, therefore, either be allowed to increase their emission, or their attempts to reduce future emissions should be given the status of emission reduction targets.

The link between the severity and the accomplishment of targets is not as straightforward in the global commons as it is in those that do not require international cooperation. Severe targets can result in accomplishment of the targets and can stimulate targets. Too severe targets, which cannot be met by many resource users can, however, destroy the international agreement.

Rules regulating how the CPR is transformed into a private good. Pursuant to the Kyoto Protocol, quantification, certification, and verification protocols for clean development mechanisms are being developed. These modalities and procedures seek to ensure "transparency, efficiency, and accountability through independent auditing and verification of project activities " (UN, 1997: Article 12). At this stage, we can identify the concerns that need to be addressed and suggest the most likely ways these requirements will be met. This section therefore reviews the current development of these procedures and analyzes how the general principles of (1) real, measurable, and long-term benefits related to the mitigation of climate change and (2) additionality of reductions (UN, 1997: Article 12) would be examined. In particular, it focuses on the following questions: what is required for certification and verification of ERCs resulting from CDM, and who should perform these tasks?

The certification and verification of emission reductions are extremely important as both investors and home countries have incentives to overstate emission reductions.

Investors use ERCs to comply with their emission targets (UN, 1997: Article 3). As these projects bring emission reductions at lower costs than domestic emission reductions, they are motivated to achieve as high as possible an amount of emission reductions from these projects. When they search for potential projects, they look for the ratio of emission reductions per unit of the investment. As host countries compete for funds from investors, they are also interested in overstating the project emission reductions. The fact that the host countries and, therefore the domestic emitters, do not have national emission targets to meet makes the overreporting even easier. It is obvious that overreporting will be widespread if there is no strong monitoring and verification of the projects. This section also briefly reviews the question of who should bear the burden of proof.

ERCs would be created in countries that have no country-wide emission baselines and are not a part of national compliance plans. Those countries also have no country-wide emission monitoring in place. The logic is that if a particular project reduces emission beyond what would be the regular trend, these excess emission reductions could be transferred from non-Annex I countries to Annex I countries. Annex I countries could then use the transferred ERCs to meet their emission reductions. Creation of ERCs therefore entails procedures for quantifying the reductions, examining their additionality, and verifying if they actually occurred as proposed.

Quantification methods employ one of two alternative methodologies: counterfactual emissions or a general benchmark rule. These methods are reviewed below.

The first method is based on the emissions that would have occurred, had the project not been undertaken. If this situation can be reliably estimated from the historical data and if no element of strategic behavior exists, this rule seems to provide a satisfactory baseline. Two historical baselines can be used; country-wide and project-based. A country-wide baseline would include all indirect effects of a particular project. For example, an emission reduction project affects emissions in a particular activity, as well as those emissions that result from products that are used in this project, that are replaced by the project, or complemented by the project. The country-wide baseline would also allow to take into consideration all distortions of the national policy, such as fossil fuel subsidies. As budgets become tighter, many countries may reduce production and consumption subsidies. The resulting price increase may decrease emissions. This decrease is not related to the CDM project and should therefore be included in the calculation of the emission baseline.

Country-wide baselines, however, experience a variety of problems. It is noticed that all countries in general overreport their baseline emissions. Further, the crediting process requires the baseline emission over the entire lifespan of the project. Estimating a country-wide emission baseline--affected by such a large number of factors--over the entire life-span of the project seems nearly impossible. As it is obvious that neither project baselines nor country-wide baselines offer a perfect solution, a combination of both may be the best approach. Project baselines could be estimated and then adjusted for different assumptions for country-wide emission trends. By assigning weights reflecting the probabilities of these outcomes, one could calculate a weighted average estimate of project emissions.

The second approach to quantifying emission reductions is to use a predetermined threshold. Each project that can qualify for a CDM would be assigned an average level of emission reductions. Each CDM developer could either agree with the predetermined emission reductions or they would have to prove that their project actually results in higher emission reductions. The project-specific baselines could result from a universal standard that would be applied prior to the projects. Alternatively, case-by-case specific thresholds could be developed in the initial stages of each project and these would establish standards for subsequent decisions. This method would require that there is a limited number of types of CDM projects whose emission reductions are fairly easy to quantify. The larger the number, the closer this method resembles the case-by-case review and its high transaction costs. The disadvantage of the threshold method is, however, that initially, a fairly small number of CDM types would be adopted, which may exclude a plethora of cost-efficient projects. As the understanding of carbon flows and their measurement improves, the number of projects could increase.

Once the emission reductions are quantified and certified, they could be transferred to investors or sold on the market. They could, however, be used only for compliance once they have been verified. The question then arises as to who is authorized to perform the certification and verification tasks. They could be performed by a supranational body (for example, the conference of parties), by national governments, or by private actors. Table 7.4 presents the tasks and the potential actors who could perform them.

Table 7.4: Primary Responsibility for Information Collection, Reporting, and Processing

Actor	Monitoring	Evaluation	Reporting	Verification
Companies reducing emissions	✓	✓	✓	
CDM project developers	✓	✓	✓	
Traders			✓	
Consultants	✓	✓		
Private accreditors				✓
Nongovernmental organizations	✓	✓	✓	✓
Governmental agencies	✓		✓	✓
UNFCCC secretariat/ clearinghouse	✓	✓	✓	✓

Source: UNCTAD (1998:38).

Private entities reducing emissions and the CDM project developers will have the primary responsibility to report the emission data. The reported emission data has to be monitored by national governments and reported to the UNFCCC. The Conference of Parties is the appropriate body to define the parameters of the certification process and exercise the general overview. It is, however, not capable of performing day-to-day certification tasks. This authority will most likely be delegated to subordinate organizations that would further delegate to specific governmental units or private organizations. This delegation would require that these organizations meet certain criteria: (1) sufficient and appropriately experienced staff and resources and (2) acceptance of, and willingness to apply, the standard certification and verification criteria set the by Conference of Parties and the governmental authorities. Verification will be performed by governmental agencies or private accreditors, but non-governmental organizations could also be considered to be reliable third-party verifiers.

Once quantified and certified, emission reduction credits from CDMs could be transferred. There is, however, a large amount of information asymmetry between the entity reducing emissions (ERC sellers) and the ERC buyers. Who then is liable if the verifiers, that begin work when the ERCS are submitted for compliance, were to discover discrepancies between the projected (and purchased) amounts and the actual amounts? I analyze the issues of liability in the section on trading rules.

Rules regulating exchangeability of permits. There are three aspects of exchangeability of permits that require closer examination: (a) exchangeability of emission reductions across gases, (b) exchangeability in time, and (c) exchangeability between emission allowances and ERCs. For all three aspects of exchanges, exchange ratios should be determined by the scientific advisory board to the Convention, not by market mechanisms.

As the emission reduction targets allow that emissions of a group of gases can be reduced, we need to devise systems for comparing and aggregating emissions of these gases (UN, 1997; Schaltegger and Thomas, 1996). The Global Warming Potential has been suggested as the ratio at which the gases would be compared. As Global Warming Potentials differ across time, different exchange ratios may be required for emission reductions occurring in near-term than for those occurring in long-term. This is, however, not the only aspect that differs across the gases. Due to technological constraints, the GHG emissions are measured with a varying level of reliability. Carbon dioxide emissions, especially from fuel combustion, can be estimated with high levels of reliability. On the other hand, emissions of methane are much more difficult to measure. These variations should be reflected in the exchange ratios to enhance the environmental effectiveness of the permit trading system.

Exchangeability across time periods needs to be addressed as well. As carbon dioxide emissions do not have local effects, banking of early emission reductions could be allowed for their use in the future. The question is, however, whether the banked emission reductions should be discounted over time, as more information on the resource stocks becomes available. Discounting over time reduces the motivation for banking and early emission reductions. Not allowing for discounting, however, increases the danger of overusing the resource as the resource use limits are based on inaccurate information. The trade-off between market liquidity and environmental effectiveness of the trading system could be resolved by devising rules that allow for the use of ERC for a given period without discounting. Once that period is over, they can, however, be discounted--an option that was used in RECLAIM.

The third issue that affects exchangeability of emission rights is the variations in reliability of measuring various emission reduction in different projects. For example, it may be easy to measure emission reductions resulting from a switch from coal to natural gas in electricity generation or from storing carbon by planting a given area with a given tree species. It may be, however, more difficult to measure the carbon stored by changing timber harvesting techniques. The issue of exchangeability ratios would not occur if we only allowed for emission allowances to be traded (Article 17). The issue would also not arise if we allowed only verified actual emission reductions to be traded. A verification process that would occur prior to transfer would make ERCs comparable to emission allowances. If, however, trading of ERCs is allowed before the actual emission reductions occur and are verified, then we need to devise a system that incorporates the variations in measurement reliability.

If there are a large number of emission reduction projects, a large number of exchange ratios would have to be devised. Rather than having as many exchange ratios as resource users, various resource users and emission reduction/sink enhancement projects could be classified into categories and exchange ratios between categories determined. There could be n-types of projects that are allowed to provide ERCs. A smaller number of project categories would be created. These categories would be based on reliability of the emission reduction/sink-enhancement information.

There are two different options of classifying projects into the categories. Under the first option, the scientific advisory board of the UNFCCC establishes categories of resource use and lists all potential resource users that fall into each category. Assume that we have two countries, A and B, with three types of resource users. Resource user 1 emits carbon into the atmosphere by burning fossil fuels. Resource user 2 plants trees and removes carbon from the atmosphere. Resource user 3 changes forest management--applies fertilizers or changes the harvest management and post-harvest treatment. The scientific advisory body could then establish three categories of projects: emission reductions, reforestation, and forest management changes. In this categorization, type 1resource users fall into category 1 no matter whether they are located in country A or B; type 2 resource users into category 2, and type 3 resource users into category 3. The scientific advisory board could then determine the exchange ratios among categories. For example, one unit of resource flow from category 1 equals 1 unit of resource flow from any other resource user. One unit of resource flow by resource users of category 1 equals 1.5 units from category 2 (irrespective of the user location) and 2 units from category 3 (irrespective of the location of resource users).

There are, however, large variations in the reliability of measuring resource flows across countries. For example, it may be easy to measure reforestation in some countries, due to availability of continuous spatial data (provided by remote sensing) while these methods may not be available in some other countries. Given such variations, the scientific board can do two things. One, it can prescribe which measurement methods are acceptable for projects in each category and require this type of measurement for every single ERC provider. This approach, however, imposes high measurement costs on some resource users, who may be able to measure carbon flows with a comparable reliability with alternative and cheaper methods. Alternatively, project providers could be given autonomy to list projects into categories. These categorizations will be reviewed regularly by third-party auditors at the time of ERC verification. The effectiveness of this system would depend on the allocation of liability between sellers and buyers. I address this issue in the section on trading rules.

Rules regulating CPR users. With a large number of small users of a given resource, the policy has to focus on the largest users, as it may be too expensive to monitor all users. Leaving a proportion of users non-regulated creates potentials for a shift of the resource use from the regulated to non-regulated users (leakage). The more closely related the users are, the higher is the leakage potential. For example, if all regulated resource users contribute electricity to the same transmission network, it is simple to switch electricity generation from the regulated to non-regulated users. On the other hand, if the switch to non-regulated users requires high investments (such as establishing a new transmission network), the switch will be quite expensive, and therefore less likely.

Two opposite approaches have been adopted when regulating a large number of resource users from various industries. The *deep and narrow* approach is narrow in the regulatory scope, but regulates all users in a given group. For example, of the wide array of users of the atmosphere as a carbon sink, only electricity generators would be regulated, but all of them would be regulated. In contrast, the *wide and shallow* approach would regulate a wide scope of activities, but only the largest users in each group. These approaches and their consequences for opt-in and leakage potentials are reviewed below. I first review the emission allowance trading aspect of the market and then turn to the issues related to carbon storage.

Two alternative models of carbon dioxide emission trading scheme have been proposed in the United States--the industrial and the fuel model (ELI, 1997a). The industrial model, which moderately resembles the existing Acid Rain model, would be an example of the deep and narrow approach. It could regulate emissions of electricity generation, transportation, and most important industrial emitters and would address about 86 percent of the total emissions; if focused only on electricity generation and automobile manufacturers, it would address about 67 percent of emissions (ELI, 1997a). Emissions by sector of activity and by fuels are presented in the Table 7.5.

The industrial model with a narrower scope would regulate utilities and vehicle manufacturers and capture 67 percent of emissions by regulating less than 2,100 entities. This compares to the Acid Rain regulation that regulates about 2,000 entities and captures about 70 percent of the SO2 emissions. Regulating the key manufacturers (those with the highest energy consumption) such as cement, paper mills, petroleum refining, organic chemicals, and steel industries would capture an additional 11 percent of the emissions but would also increase the number of regulated entities to somewhere between 4,000 and 10,000 (ELI, 1997a).

Table 7.5: Carbon Dioxide Emissions by Sector and Fuel in 1996 (in million metric tons)

Sector		Coal	Natural Gas	Petrol	Total
Residential	Electricity	160.9	14.5	5.4	180.8
	Non-electricity	1.4	77.4	27.3	106.1
Commercial	Electricity	147.3	13.2	5.0	165.5
	Non-electricity	2.1	47.4	15.3	64.7
Industrial	Electricity	151.3	13.6	5.1	170.0
	Non-electricity	59.3	142.8	104.8	306.9
Transportation	Electricity	0.6	0.1	0.0	0.7
	Non-electricity	0.0	10.5	457.9	468.3
Total	Electricity	460.1	41.4	15.5	517.0
	Non-electricity	62.8	278.1	605.3	946.0

Note: I assume that all sectors use electricity generated by the same fuel mix. The breakdown of each sector's electricity emissions by fuel is estimated with the following shares: coal 89 percent, natural gas 8 percent, and petrol 3 percent, based on the data of electricity generation emissions by fuel.
Source: EIA (1997b: Tables 5, 6, 8, 9, 10, 11, 12).

The fuels model would apply to energy providers (coal and oil companies) and would capture 98 percent of all CO2 emissions by regulating only 3,000-6,000 entities. The trade-off between the proportion of the regulated emissions and the number of regulated entities is therefore more favorable in the case of the fuel model. If extraction of the fossil fuels was regulated, there would be 863,000 entities; whereas if the distribution was regulated, there would only be about 3,600 coal companies, 200 oil refineries or 2,000 oil companies, and 133 gas pipeline companies to regulate. The smaller number of regulated entities would impose lower monitoring costs. Regulation at the point of distribution would further allow for the non-combusting fuel use to be exempt from regulation. Regulation at the point of extraction would, however, prevent leakage of emissions from the fuels distributed by larger to smaller distributors.

The above models include carbon emissions, but not carbon sequestration. Limited availability of data on carbon released and stored in forests does not allow for including existing forests into the carbon inventories in all countries. The countries having the most developed measuring devices were only slowly including forests into their national communications to the Secretariat to the FCCC. This suggests that including carbon sinks into the emission allowance system is not likely. It is possible, however, to allow for opt-in in the forestry sector.

Including carbon sinks in the trading mechanism increases the flexibility in reducing resource use, but also increases the number of resource users that have to be monitored and creates potential for leakage. Section 7.2.1.2. pointed out the need to focus on the largest forest and farmland owners. Public actors own about 27 percent of the timberland in the U.S. If forest harvesting was limited on this land, the resulting increases in timber prices would create incentives to increase the harvesting on private lands. However, the dedicated carbon sinks in the public forests would most likely continue to be managed for carbon sinks, which would reduce the need for periodic monitoring of the forest cover.

Private forest and farmland owners would also be able to opt-in for the regulation and provide ERCs. The issues of credit quantification and monitoring have been addressed before. In this section, I focus on leakage problems. For example, a private farmland owner commits to plant trees on his land and keep them growing for a given period. Or, a forest owner commits to longer rotation periods. There are two possibilities for leakage. One is under the owner's control and can be addressed within the trading system. The second one is a result of a free timber market and can only be addressed by a separate regulation. A private owner can commit to carbon sequestration on one part of his land, but increase the harvest, thereby increasing carbon emissions on the rest of his property. This can be avoided by creating incentives to commit the entire land owned to the carbon sequestration management. Opt-in regulation could require that the entire property be subject to carbon sequestration management. As many owners will initially experiment with small portions of this land until they better understand carbon sequestration options, the suggested 100 percent criterion may significantly reduce the number of these projects. Another option would be to take into account the unregulated proportion of the land when quantifying the ERCs. Assume there is an owner who has three parcels of land, one of 1,000 acres and two of 400 acres each. Only one of the small parcels is dedicated to carbon sequestration. The ERCs from this parcel could then be discounted by a factor taking into account that only 400 out of 1,800 acres are managed for carbon sequestration.

Rules regulating trading. Given the measurement difficulties and the variations in national policies, trading rules will have to address three major operational choice issues: (1) who can trade emission permits and the ERCs, (2) when can ERCs be traded, and (3) who is liable for emission reductions, should the verification process discover discrepancies in claimed emission reductions. These issues are addressed below.

In an international system, emission caps are country-wide. National governments then decide whether or not they wish to allocate the allowances among the domestic polluters and how. In terms of economics, it makes more sense to allocate allowances to private entities in systems where the most economic activity is in the private sector. Several countries, however, may choose not to allocate domestic allowances, but they may still trade internationally. For example, many European countries have already enacted carbon taxation and may not want to change the selected policy instrument. They may comply with the allocated emission targets, but not rely on trading. The question, then, is whether private entities in such countries can trade emission allowances internationally. Theoretically, this would be possible. The private entity would have to obtain an emission reduction certificate from its government or from an agency authorized to issue ERCs. At the point of ERC transfer, the government would have to adjust its national emission target accordingly.

The countries that choose to enact domestic emission allowances would still have to decide if private firms can trade internationally, or whether only governments should engage in international trades. Four trading situations are feasible. These four trading options will face different transaction, monitoring, and enforcement costs; different liability issues; and different power relationships between sellers and buyers. Trading by private parties would improve the cost-savings but would also increase monitoring costs and program complexity (Harrison, 1997).

A government to government trading. For example, the U.S. government could purchase allowances from the Russian government. This trading would most likely be among countries who have not enacted domestic emission allowances. The seller could offer its internationally committed emission quota or ERCs from domestic firms. The former is not very likely, as it explicitly indicates that internationally committed emission targets were too high. It is more likely that the seller would be offering ERCs from national firms. If a national government offers ERCs for sale, this simplifies the liability issues for the buyer, but also reduces the buyer's bargaining power.

Private firms to private firms across borders. For example, a coal-powered utility from the U.S. could purchase emission allowances or ERCs from a gas-powered utility in Russia. As CDMs currently require a demanding project description specifying all aspects of the contract and a case-by-case approval, the initial projects will most likely be bilateral and negotiated with the help of environmental or other non-governmental organizations and/or private entities. These will bring together the interested parties and help prepare the project documentation required for project approval. The bilateral approach resembles the pre-Kyoto Joint implementation projects and appears to be favored by many Annex I parties. It emphasizes the needs of investors and the interests of their private sectors. All issues of the projects would be defined in a contractual manner between the investor and the project host and her country. This approach gives the investor and the project-host and her country the maximum flexibility in defining the nature of the project, the financial contributions, and the sharing of CERs. This approach requires, however, a broker who puts the investor in touch with the potential host and independent process that certifies the emission reductions.

Intracompany international trading. For example, a car manufacturer, who sells cars in two countries, could reduce car emissions in one country in exchange for not having to reduce the emissions from those cars in another country. Such intra-firm trades occurred in the CFC market and offered substantial cost savings to manufacturers. Such trades exhibit low search- and exchange-costs. If both countries enacted their emission quota to national polluters, this transfer would entail only the shift of allowances from the owner's allowance account in one country to the account in the other country and the corresponding changes in the national allowances.

Private firms trade with governments. For example, a private utility in the U.S. could purchase emission allowances from the Russian government that would reduce its domestic emissions. Governments of developing countries could apply for ERCs and sell them in an organized international market themselves. This approach was adopted by Costa Rica for its carbon sequestration projects. The Costa Rican government actually purchased the sequestration services from its forest owners and then sold them internationally. This increased the seller's bargaining power and reduced the liability problems for the buyers.

An alternative to direct bilateral approaches would be a system with brokers as intermediaries. The intermediaries would collect ERCs that have varying levels of uncertainty. They could provide various kinds of services: collecting information on projects and providing it to interested parties, providing funding to interested CDM hosts, and providing insurance to buyers. These services could be provided by private brokers or a multinational CDM fund. What is important is that this role be separated from the certification process, otherwise perverse incentives would be created for the ERC certification entity.

The second issue pertains to uncertainties about the quantities of traded ERCs. Emission reduction potentials for some projects can be easily measured during project development while for others, only a few years after the beginning of the project (carbon sequestration). At what point in the creation process should ERCs be traded? Various national markets addressed this issue differently. Some required that the project be certified by an authorized agency prior to the transfer (early EPA air emission trading programs). After approval, the entire amount of emission reduction credits would be transferred in one installment. Other programs, such as wetlands mitigation banking, still required pre-approval, but only allowed partial transfers of rights at various stages of the project life, subject to submission of required proofs to the verification agency. The more difficult it is to measure the aspects of the transferred good, the more checks are required in the transfer process. A system of partial transfers can be devised in which the seller is allowed to sell ERCs in the amount that has been identified in the verification process.

The question of liability arises if the ERCs are transferred before the final verification. If the buyer purchased ERCs for which the verification process reveals that they did not actually occur, the question arises as to who is liable to provide the additional emission reductions, the seller or the buyer? In the case of seller liability, the seller would have to provide the additional emission reductions. If the trading partners are located in different countries, enforcing this liability becomes more difficult. As the possibility exists that the ERC seller would close business after the ERC transfer, the seller's national government would have to guarantee the emission reductions. For buyer liability, the buyer would have to provide additional emission reductions. This system creates incentives for buyers to consider a number of indicators regarding the seller's ability to deliver emission reductions. The initial joint implementation projects illustrate the issues related to buyer liability. The expert panel, which was established to evaluate Joint Implementation projects in the U.S., suggested a set of guidelines for these projects (59 Fed. Reg. 28442). First, the host country must submit written notification from a designated government agency that the project is acceptable. Second, the project must show that the reductions are verifiable. It has to include monitoring plans and an agreement to have the project verified by a third party. Third, the project proposal must show evidence of environmental impact assessment to identify the project's broader environmental benefits. This is to ensure that the project is correctly priced to take into account various externalities. Fourth, the evaluation process must also consider local issues, such as human health and employment--again to enable marginal costs pricing. Fifth, project participants would have to submit annual reports on the reduced emissions and the share of those reductions for each project participant. Private credit-ranking systems may develop to provide the information on the reliability of ERCs from different parties. This difference in reliability would most likely result in different prices for ERCs. This would partially transfer the costs of lenient certification to sellers and reduce their incentives to cheat.

7.3. Conclusions

In sum, this chapter proposed rules regulating a market permit system for managing the atmosphere as a global carbon sink. Given the large number of activities using the atmosphere as a carbon sink and significant potentials for leakages, I proposed a narrow and deep approach to regulating resource users. Due to difficulties of measuring carbon storage, I suggested that emission allowances be allocated to actors emitting carbon through fossil fuel combustion.

Actors storing carbon would be allowed to opt-in for regulation. Emission reduction credits originating in opt-in projects would not be exchanged on a one-to-one basis. The exchange ratios would be set by a regulatory agency and would reflect the variation in measurability of resource use across countries. Rather than prescribing one measurement standard that would be required for all resource users, a scientific advisory board to the UNFCCC would establish categories of projects with comparable measurement reliability. Project developers would have the autonomy to categorize their projects.

Due to potentials of resource-use shift from the opt-in activity to other activities of the same user, the agency certifying the emission reduction credits would discount projects that encompassed only a small proportion of the resource use's activity.

When the ERCs would be submitted for compliance, they would be verified. Buyer's liability for the ERCs would create incentives for buyers to rank ERC providers. Different rankings would be reflected in market prices of the ERCs, thereby increasing sellers' incentives to meet the ERC requirements.

CHAPTER 8

CONCLUSIONS

This dissertation analyzed the applicability of marketable permits for managing natural common-pool resources (CPRs), especially the atmosphere as a sink for carbon dioxide (a global CPR). This chapter briefly discusses the major characteristics of CPRs to point out the importance of the presented research. Then, it presents this dissertation's theoretical approach and its major findings. Subsequently, it examines transferability of the findings to potential carbon dioxide markets. It concludes with some limitations of the presented study and suggests some areas of future research.

8.1. Why Is It More Difficult to Allocate CPRs Than Private Goods?

The difficulty in allocating CPRs lies in the combination of two characteristics: rivalry in consumption and high costs of excluding potential CPR users. The resource-use can be conceptualized in two ways. A CPR can be appropriated by withdrawing a flow from the CPR stocks, such as a gallon of water, a ton of fish, or a barrel of oil. However, a discharge of a flow of pollution into a common sink also constitutes resource-use: the discharge of the "bad" is just a mirror image of the withdrawal of the "good" from a CPR.[1] While the first case constitutes a subtraction of the good, the latter constitutes an addition of the bad. Once a unit of pollution is discharged, a small part of the medium's storage capacity is used up and it cannot, therefore, be used by any other polluter. The only difference is that the resource use in the former is embodied in units flowing out of the CPR, whereas in the latter, it is reflected as an increased concentration of the pollutant in the medium.

Rivalry in consumption is more difficult to notice when the resources are vast and any given user's contribution to resource deterioration is small. For example, when the fish stock is large and each fisherman has limited ability to catch them, the rivalry in appropriation among fishermen will not be noticed easily. Similarly, if a sink is vast,

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[1] For a contrary view, see Buck (1998).

such as the atmosphere, it is difficult to see the rivalry in emitting pollutants. In this case, the resource limits and, therefore, the rivalry in consumption, can be viewed in two ways. First, we can see them as the physical limits of the system. If one ton of air pollutant is emitted into the air, this increases its concentration in the atmosphere and reduces the atmosphere's ability to serve as a sink for pollution in the future. Second, as the CPR used for one purpose (a sink for air pollution) increases, this influences other uses of atmosphere. For example, an increased use of the atmosphere as a sink for CFCs decreases the ability of the atmosphere to shield the earth from the damaging radiation from space. As using the atmosphere in the second sense has aspects of a public good, scholars tend to attribute the character of a public good to all aspects of the atmosphere. This blurs the analysis and resulting policy recommendations.

Rivalry in consumption alone does not cause the allocation problems. These problems arise because the rivalry is combined with the difficulty to prevent others from appropriating the CPR. For example, if it were easy (not costly) for a user restraining her current resource use to prevent others from free-riding on her effort, she would have incentives to postpone her resource use. However, if it is technically difficult and, therefore, costly to prevent others from using the CPR, the benefits from current resource-use restraint may not occur in the future.

The question then is who can and should devise the resource-use rules that will prevent overconsumption of the CPR and what type of rules will work in which situation? The answer depends on multiple factors, such as the type of the resource, resources users, and the users' ability to devise, monitor, and enforce rules. There is a large variation in these aspects of resource use. We cannot, therefore, devise one type of rules that will work for all CPRs.

Crafting of an institutional arrangement requires development of boundary rules, i.e., rules regulating who is allowed to use the CPR, rules regulating the flows that individuals can appropriate, and regulating the obligations the resource users have. Conflicts can arise in this process. The more severe the resource-use limits, the more severe are these conflicts. If the resource use has to be stabilized at the current level, the division of rights could exhibit the characteristics of a zero-sum game and, therefore, require redistribution of existing resource flows.

The institutional arrangements to prevent CPR overuse and deterioration were devised by two groups of actors. In many cases, resource users themselves crafted institutional arrangements that regulated resource use.[2] In other cases, national governments devised the institutional arrangements. Given the variation in CPR characteristics, it is important that the devised rules regulating CPR use reflect characteristics of the specific CPR and its use. Regulating local CPRs by resource users who have the best information about the CPR stocks and about individual user's appropriation levels, allows for maximum flexibility. This flexibility is significantly reduced when national governments and their specialized environmental agencies devise the rules. This is because such rules are usually standardized for a wide range of CPRs, which does not account for local variations.

The national government in the U.S. and its specialized environmental agencies initially relied on rules that prescribe the inputs used in resource appropriation (technological standards such as the size of fishing boats or installation of filters on exhausts). The time and the duration of access to the CPR was also limited (for example, determining fishing seasons or prohibiting emissions during high-pollution periods). The evolution of rules from simple and easy to monitor (time limitation, installation of required equipment) to imposing limitation of the quantity of the appropriated resource seems to be related to the availability of information on resource stocks.[3] The third option, that is, privatization and using market instruments, was recommended to increase the flexibility given to users of CPRs. Instead of prescribing how the resource should be used, market instruments allow users of CPRs to choose the way that minimizes their costs of limiting their CPR use.

8. 2. An Analytical Framework for Analyzing Variation across CPRs

There are large variations across different CPRs in terms of their size, number of users, and the ways the resource use affects the resource stocks. These characteristics

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[2] For an overview of literature analyzing the application of this solution to allocation of local CPRs, see Ostrom (1990) and McCay and Acheson (1990). For the application of these lessons at the global level, see Keohane and Ostrom (1995).

[3] Ostrom (1990) indicates a similar process for self-organized resource governance systems.

affect how CPRs are managed. Given these variations, we cannot devise one ideal institutional arrangement that would prevent CPR overuse or deterioration. Some CPRs may be privatized while others will not be. Among those that are privatized, there is a large variation in terms of preventing the CPR deterioration and increasing market liquidity. If this is the case, would privatizing the global atmosphere prevent the overuse of the atmosphere? Would a global carbon dioxide permit market work? What are the lessons from the existing CPR markets that we can draw on? These are the broad research questions addressed in this dissertation.

This study focused on factors that affect performance of marketable permit systems for CPRs. Unlike the existing literature, which examines marketable permit systems by comparing them to a command-and-control approach or to a (theoretical) perfectly competitive market, this study analyzed multiple CPR markets and compared their performance. The performance of market permit systems was evaluated along two broad criteria: (a) the effectiveness of the system to reduce CPR overuse and (b) market liquidity (number of trades, proportion of resource users who trade, and price dispersion).

This dissertation employed the Institutional Analysis and Development (IAD) framework to examine the effects of the following factors on the performance of marketable permits: (1) CPR characteristics affecting resource "measurability", (2) users' characteristics, (3) external legal and regulatory environments, and (4) rules regulating CPR use and users.

I hypothesized that marketable permits are more effective in reducing CPR overuse when CPR stocks and flows are easily measured. Measurability was analyzed as a function of the following resource characteristics: (1) resource's spatial extent (the smaller the extent, the higher the measurability); (2) availability of reliable indicators of resource stocks and flows; and (3) relationship between resource flows and resource stocks (the more uniform the effect of resource flows on the resource stocks, the higher the measurability). Further, I hypothesized that marketable permits are more effective when the number of resource users was small and if the users were cost-minimizers. Marketable permits are more likely to prevent resource overuse when they regulate resource use of the largest resource users and they place limits on resource use that are stringent, monitored, and enforced.

Marketable permits' liquidity was hypothesized to depend on the ability of the rules regulating resource use and users to create secure permits with high value and to reduce exchange costs. The more secure the permits, the more likely that CPR users will invest in them and exchange or bank them. Resource users are most certain that the permits will continue in the future, if they themselves regulate their use. The external legal and regulatory environments can grant this authority to them or authorize a regulatory agency to regulate CPR use. In the latter case, the resource users cannot be certain about the future laws and regulations concerning the permits. Further, since permits are not treated as private property, they are rarely protected by the "takings" laws. Some regulations, for example, the Clean Air Act Amendments of 1990 regulating SO2 permits or the RECLAIM regulation, explicitly state that the permits are not private property and that they can be revoked. The security of the permits is, therefore, not certain and is only estimated by the permit holders, based on the information they have on the past policies of the regulators (Williams, Collins, and Lichbach, 1996).

A permit's value depends on its importance for CPR users. Regulations, drastically reducing CPR use, increase the value of CPR for its users. For example, if a user's unconstrained use was 10 units and if the allocated permits amount to only 5 units, the user has to reduce its use by one half. In this case, the value of the permits is much higher than if allocated permits covered the entire unrestrained CPR use for all users.

High exchange costs decrease the number of trades and the total traded volume, thereby diminishing the potential cost savings of the tradeable permits systems. Exchange costs are a function of permit characteristics: the number of issued permits, their denomination, the flexibility in their exchange (Hall and Walton, 1996), the availability of information, and existence of past trading between permit holders. Past trades in CPR markets can reduce current exchange costs if trades produce positive informational externalities.

High exchange costs, however, may not completely prevent trading. CPR resource users search for options that reduce these costs. These options include: trading within firms (if firms consist of smaller units that were allocated permits) rather than between firms (inter-firm trade), and trading a cluster of pollutants rather than trading each pollutant individually (Foster and Hahn, 1995).

8.3. Results of the Empirical Analysis of Past and Extant Marketable Permit Systems in the U.S.

This study examined CPR markets that vary across all independent variables. Table G1 (Appendix G) presents the variation in outcomes of these markets and in factors affecting the outcome. The examined CPRs varied from small and local (for example, using the atmosphere as a sink for pollutants that have local effects) to those with a global extent (emission of CFCs). They included CPRs with a very small number of users (CFCs) to large numbers (RECLAIM). Some markets were designed to ensure high homogeneity of regulated resource users whereas in other markets, the regulated users did not have much in common. For example, they had no prior trading experience and were, therefore, expected to face high exchange costs. The security and the exchangeability of permits varied from very limited in some markets (early EPA emission trading and Wetlands Mitigation Banking) to high for other CPRs (sulfur dioxide and Lead Phasedown Program in the second stage).

The empirical analysis helps us understand reasons for the variation in the performance of marketable permits. Before I analyze them, I want to stress that the relationships among the independent variables and between the independent variables and the dependent variables (environmental effectiveness and market liquidity) are complex and interactive. The effects are not easy to determine with the limited available data. We can, however, examine the variables that seem to have clear associations with the outcome variables.

Two markets exhibited high environmental performance and high market liquidity: sulfur dioxide allowance market and Lead Phasedown Program. High environmental performance was associated with high predictability of CPR stocks and flows, stringent environmental targets, and continuous monitoring. In both cases, the atmosphere is used as a sink for air pollutants. Sulfur dioxide travels across greater distances than emitted lead. In both cases, however, the effects are relatively easy to predict. Air modeling is used to estimate the effects of the CPR flows on the stocks. The estimates are reliable, as the effects that the flows have on the stocks are not impacted by highly variable factors that are out of control of policymakers (such as air temperature or the amount of sunlight). In both cases, the CPR use was concentrated in a relatively small number of users, which made it easier to monitor their resource use.

The empirical analysis does not support the hypothesis that markets for CPRs in which resource flow has uniform effect on resource stocks would perform better than markets for CPRs with non-uniform effects (when effect depends on the location of resource flow). CPRs with non-uniform effects of resource use require that exchange rules are devised that account for this variation. This sacrifices market liquidity to ensure environmental effectiveness. The flow of sulfur dioxide into the atmosphere has relatively uniform effects whereas the flow of lead into the atmosphere has distinctly non-uniform effects (most lead is deposited in a close proximity to the emission points). If my hypothesis were correct, the Lead Phasedown Program would have to exhibit lower market effectiveness than the sulfur dioxide market. The empirical analysis, however, does not confirm this.

The empirical analysis suggests the trade-off between environmental effectiveness and market liquidity resulting from a non-uniform effect of resource flows can be reduced by rules regulating resource users. Lead emissions have a strong non-uniform effect on the resource stocks. The Lead Phasedown Program regulated fuel suppliers (oil refineries adding lead into gasoline) rather than fuel users. This resulted in reduction of lead use in general, thereby reducing lead emissions. So-called hot-spots could have occurred, if gasoline from the lead-permit buyers (high lead-content gasoline) were concentrated in one market. However, as gasoline from overcomplying refineries is mixed in the pipeline system with large lead-users, the hot-spots did not occur.

High market liquidity in these two markets is associated with low exchange costs. These costs were low because CPR users were relatively homogeneous and had traded extensively with each other prior to the introduction of marketable permits. In the case of sulfur dioxide allowances, the EPA and private brokers who entered the market further reduced exchange costs. In both cases, permits were clearly defined and standardized. They were also fully exchangeable in time and space. Exchangeability in time was initially limited in the Lead Phasedown Program. Once banking was allowed, trading increased further and CPR users reduced their CPR use more than required. This is because users could bank the unused permits for the second period that imposed more stringent resource-use limitations.

Moderate environmental performance is associated with moderate predictability of resource stocks and resource flows in the rest of the markets. The more complex is the CPR, and the more difficult it is to estimate the resource stocks and the effects of resource flows, the less likely it is that any institutional arrangement can be devised to prevent CPR overuse. Moderate environmental effectiveness in these markets can also be attributed to a small proportion of resource users that are actually regulated (Wetlands Mitigation Banking) and to difficulties in enforcing resource-use limitations (numerous illegal trades in the CFC markets).

Variation in the market liquidity between moderate (RECLAIM and CFC production quota trading) and modest (early EPA Emission Trading and Wetlands Mitigation Banking) can be attributed to the clarity of permits and their exchangeability. In RECLAIM and CFC markets, the permits are clearly defined and standardized. Each CPR user is allocated a given amount of allowances at the beginning of the period. If the CPR user does not use all of the allocated permits, he/she can sell the excess permits. In the case of the early EPA Emission Trading and the Wetlands Mitigation Banking, permits have to be defined for each exchange and they are likely to be exchanged at a non-unit ratio (for a unit of resource use, the buyer must obtain permits for more than one unit). These non-unit exchange ratios are less problematic if they are known in advance. In this case, the seller and the buyer only have to negotiate who will bear the costs of additional permits that the buyer has to acquire due to non-unit exchange ratios. The exchange is further impeded if the exchange ratios are not known in advance, but are specified by environmental agencies for each exchange (this was the case for some trades in the early EPA emission trading and for all credits purchased from the Wetlands Mitigation Banks).

8.4. Policy Recommendations for Devising Domestic and International Carbon Dioxide Markets

Table G2 presents three alternative models of carbon dioxide permit trading scheme. Two of them have been proposed for the United States; the industrial and the fuel model (ELI, 1997a).

The industrial model, which moderately resembles the existing sulfur dioxide allowance trading, would regulate emissions of electricity generation, transportation, and most important industrial emitters. It would address about 86 percent of the total carbon dioxide emissions; if focused only on electricity generation and automobile manufacturers, it would address about 67 percent of emissions by regulating less than 2,100 entities (ELI, 1997a). This compares to the Acid Rain regulation that regulates approximately 2,000 entities and captures about 70 percent of the SO2 emissions. Regulating the key manufacturers (those with the highest energy consumption) such as cement, paper mills, petroleum refining, organic chemicals, and steel industries would capture an additional 11 percent of the emissions but would also increase the number of regulated entities to somewhere between 4,000 and 10,000 (ELI, 1997a).

The fuels model would apply to energy providers (coal and oil companies) and would capture 98 percent of all CO2 emissions by regulating only 3,000-6,000 entities. The trade-off between the proportion of the regulated emissions and the number of regulated entities is therefore more favorable in the case of the fuels model. If extraction of the fossil fuels were regulated, there would be 863,000 entities, whereas if the distribution were regulated, there would only be about 3,600 coal companies, 200 oil refineries or 2,000 oil companies, and 133 gas pipeline companies to regulate. The smaller number of regulated entities would impose lower monitoring costs. Regulation at the point of distribution would further allow for the non-combusting fuel use to be exempt from regulation. Regulation at the point of extraction, would, however, prevent leakage of emissions from the fuels distributed by larger to smaller distributors.

Findings on the past and extant CPR markets suggest that the carbon dioxide market should be based on the fuel suppliers. They are a homogeneous group with a long history of trading. In addition, many fuel suppliers are present in various fuel markets. For example, many oil suppliers also supply natural gas. In some cases, they are also the most important investors in alternative, non-fossil energy sources, such as solar energy. This would enable intra-firm trading, which was found in all markets to be even more important than inter-firm trading. Further, the fuels model would regulate a large proportion of the CPR use by regulating a smaller number of users. This would reduce monitoring costs, thereby increasing environmental effectiveness.

Findings from the past and extant markets that were based on clearly defined emission allowances (the best-case scenario) indicate that we cannot expect to be able to create a perfect market instantaneously. Policies are experiments that try to accomplish the goals given the existing knowledge of the resource stocks and flows (Ostrom, 1999). Even the sulfur dioxide market, one of the best performing CPR markets with standardized permits and publicly available price information, even now, six years after the beginning of trading, still experiences large variations in permit prices.

Creation of a marketable permit system is not free of political pressures from the industries. Current efforts of large fuel users, such as electric utilities, are focused on finding cheap alternatives for reducing emissions not in their own facilities, but in less-efficient electricity-generating plants abroad and in projects storing carbon in growing biomass. This suggests that these actors will only support the carbon dioxide market that will allow for opt-in by countries and sectors that are not a part of the countries and activities for which resource-use reduction targets exist. This will require high-cost definition of traded commodity on a case-by-case basis, or definition of exchange ratios on a case-by-case basis. Many U.S. CPR markets suggest that this may significantly reduce both environmental effectiveness and market liquidity.

When carbon sequestration is included in the carbon dioxide market, the major characteristics of the market would change (see Table G2). Resource flows will become more difficult to measure (at least the opt-in part). The provision of carbon storage services (sequestering carbon in growing biomass) has many aspects that are similar to prevention of wetland conversion (Chapter 6). Including sequestration into the carbon dioxide market will increase the variation in the resource-use patterns and users. This increased variation will require a large variation in devised rules (Ostrom, 1999). This will, however, impede trading. Differences in reliability of measurement of resource use by various users will require non-uniform exchange ratios. This market will therefore exhibit some characteristics of local air pollution markets (examined in Chapter 5). The exchange ratios will not be set in a market, but will require a political process.

The carbon dioxide market should allow for international trading. Currently, no truly international CPR market exists. The CFC production permit market operates only at a national level, with some international transfers, which are actually intra-firm transfers. Major challenges of an international carbon dioxide market are related to enforcement of permits across country borders. Review of the existing CPR markets suggests that marketable permits perform better when the use of the CPR is severely limited by an authorized agency and the limits are enforceable. Thus, marketable permits for global atmosphere will have to rely on national limits. Countries will need to have autonomy in devising their own ways of monitoring and enforcement. Internationally, compliance with national limits will be periodically reviewed and non-compliance at the country level sanctioned.

8.5. Augmenting Theory of Marketable Permits

This study suggested that there is too much variation among CPRs that we could devise a single market arrangement applicable to all of these resources. Multiple characteristics of the CPR and its users have to be explored as they affect the performance of this institutional arrangement.

Second, privatization was extremely limited in all examined markets, eliminating one of the most important advantages of marketable permits. The rights to a CPR consist of more than just the right to use the resource. The rights to access the resource and withdraw a flow from (or into) the resource were privatized in the analyzed markets. The CPR users were, however, not given the right to manage the resource, to decide the amount of resource use or who can get access to the resource. This suggests that complete privatization is not necessary for successful markets (as argued by Demsetz, 1964). These rights remained with the national government or its specialized environmental agency. However, resource users could have access to the processes of devising rules through which these amounts are determined. One of the markets examined in this dissertation (the SO2 allowance market) clearly indicates that the regulators were under pressure from the electric industry when devising the rules regulating the resource flows. Primary allocation of CPRs was not performed in the market. Marketable permits can only be employed once the primary allocation of the CPR is performed. This allocation, however, is still performed by a regulatory agency and therefore prone to the same regulatory failures as other governmental policy instruments. Marketable permits therefore do not solve the problems resulting from elected officials selecting the policies that get them re-elected rather than those that are in the public's interest.

Third, marketable permits have been considered to be more flexible than other policy instruments, as they allow for changing the aggregate level of the resource use when better information on resource stocks or resource flows becomes available. This dissertation supports this assertion. Any changes, however, reduce the security of permits, potentially reducing the motivation for trading. This uncertainty has been suggested to be a major impediment to trading (McCann, 1996; Dwyer, 1992; Hahn, 1989). The empirical analysis suggested, however, that the lack of property-rights status for permits did not impede trading significantly. For some markets, the effects of the expected future increase in demand for permits were much stronger than the uncertainty about the future status of permits (see the analysis of prices of futures for sulfur dioxide allowances in Chapter 4).

Fourth, tradeable permits were considered to have static and dynamic advantages over other policy instruments as they provide incentives for adoption of new technology (Milliman and Prince, 1989). The empirical results supported this also. However, we need to examine what types of technology innovation and adoption result from marketable permits. The sulfur dioxide market indicates that limiting use of the atmosphere as a sink did result in important technological innovations, such as new methods of coal blending and improved efficiency of scrubbers. Scrubbers, were, however, not widely adopted, in spite of receiving subsidies and preferential tax treatment. Most resource users did not opt to invest in scrubbers, but preferred coal switching and/or blending.

Fifth, the timing of enacting marketable permits system is important, if they are employed to regulate a resource that is already regulated. We should not expect high levels of trading activity when marketable permits are employed only after resource users have invested in expensive technology to meet the requirements of the previous policy.

8.6. Limitations of This Study and Areas of Future Research

The presented study faced four limitations that suggest areas of future research. First, all analyzed CPR markets entitled the resource users only to access the resource and to withdraw a flow from (or into) the resource, and not to manage the resource or determine who can access it (Ostrom and Schlager, 1996). There are markets in the U.S. in which resource users had a wider array of rights. For example, in southern California, groundwater users noticed problems of overdraft and filed suits in courts to adjudicate the water rights. Once the courts adjudicated water rights (often the solutions were suggested during the negotiation among users), water markets developed in four out of seven basins (Blomquist, 1992). In these 4 basins, pumping rights were quantified, individualized, and made transferable. Including these markets into analysis would allow for examination of the effect of the ability of resource users to devise the collective-choice level rules. I hypothesize that this would improve the outcome of marketable permit systems, everything else held constant.

Second, the presented research built an analytical framework to compare various CPR markets. It allowed us to see how various factors affect the outcome, when they are combined in the "real and messy" world of CPR markets. This research, however, did not analyze the partial effects of the independent variables. For example, CPR measurability is affected by predictability of the resource stocks and flows, spatial extent of the resource, and the type of effect resource flows have on the resource stocks (uniform versus non-uniform). Devising more precise indicators measuring the independent variables would allow for developing a model that could tease out these partial effects. A unit of analysis would be a CPR market in one year. These data would exhibit characteristics of a panel data set and would require carefully checking for heteroscedasticity (Green, 1993; Buttolph-Johanson and Joslyn, 1995). Further, even more precise indicators of independent and dependent variables would most likely not be continuous variables. This would require careful selection of a regression model (Long, 1997).

Third, the empirical results suggest the importance of banking, that is, exchangeability of permits in time. When banking is allowed, CPR users have incentives to overcomply to be able to store permits for future use. This results in quick environmental improvements. As banking is an alternative to trading, it may reduce the number of traded permits. CPR users may overcomply in the present period and keep the permits for future use. They may not necessarily trade them. Banking, therefore, increases flexibility in time whereas trading increases flexibility in space. The former may be equally important as the latter. With better data on banking, it will be possible to empirically estimate its importance for market performance over time.[4]

Fourth, the analysis was focused on natural CPRs. Developments in technology and institutional arrangements, however, result in creation of a number of man-made CPRs. These include the Internet, condominiums, and budgets of firms and organizations. Including these CPRs into the analysis would significantly improve the generalizability of the findings.

Last, the study indicated that international carbon dioxide markets would face important challenges in measuring, monitoring, and enforcing carbon storage services. In the future, I would like to focus on various market practices that have been used to increase trust, such as warranties, professional certificates, and share contracts. They will play an important role in reducing the exchange costs in this market.

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[4] Most permit transfers are recorded only when the buyer presents them to prove the compliance.

APPENDIX A

EMISSIONS OF SO2 AND TRANSACTIONS OF SO2 ALLOWANCES

Table A1: Emissions of SO2 (thousand metric tons)

	1970	1975	1980	1985	1987	1989	1990	1991	1992	1993	1994	1995	1996	1997
ENERGY	21,727	21,104	20,038	18,823	18,776	19,313	19,747	19,344	19,096	18,818	18,314	15,913	16,471	16,911
Electric utilities	15,783	16,573	15,848	14,762	14,244	14,710	14,433	14,319	13,985	13,779	13,507	10,959	11,460	11,868
Fuel combustion (I)	4,144	3,003	2,677	2,875	2,783	2,800	3,221	2,954	2,987	2,979	2,919	3,045	3,084	3,053
Fuel comb. (C,R)	1,352	982	881	525	601	566	754	685	711	700	708	719	709	738
On-road vehicles	373	456	473	472	488	517	492	517	524	469	273	276	287	290
Non-road engines	75	90	159	189	660	720	847	869	889	891	907	914	931	962
INDUSTRY	6,434	4,249	3,424	2,207	1,762	1,791	1,686	1,520	1,555	1,499	1,467	1,443	1,449	1,513
Chemical	536	333	254	414	386	399	269	254	252	244	249	259	260	273
Metals processes	4,332	2,585	1,671	945	588	630	659	555	558	547	510	481	481	501
Petroleum activities	799	660	666	458	404	389	390	343	377	347	344	335	334	349
Other industries	767	671	833	390	384	373	368	368	368	361	364	368	374	390
WASTE	7	42	30	31	32	33	38	40	40	64	54	42	43	45
OTHERS	100	18	10	10	12	10	11	10	9	8	14	8	12	12
TOTAL	28,268	25,413	23,502	21,071	20,582	21,147	21,482	20,914	20,700	20,390	19,849	17,406	17,975	18,481

Notes:

(1) Other categories encompass other combustion and fugitive dust.

(2) Other industrial categories encompass Agriculture, Food, & Kindred Products; Textiles, Leather, & Apparel P; Wood, Pulp & Paper P; Rubber and Miscellaneous Plastics, Mineral P; Machinery P, Electronic Equipment, Miscellaneous Industrial Processes; Solvent Utilization in various industries, and Storage and Transport for Industrial Activities.

(3) Emissions are converted to metric tons by multiplying the short ton values by 0.9072.

(4) I stands for Industrial-, C for Commercial-, and R for Residential- Sector.

Source: National Air Pollutant Emission Trends Update, 1970-1997, Table A-4.

Table A2: Emissions and Heat Input of the Title IV Units, 1980-1998

	1980	1985	1990	1995	1996	1997	1998
Phase I, Table 1 Units (263 units)							
Heat input (billion mmBtu)	4.28	4.39	4.39	4.70	4.90	5.05	
SO2 emissions **(million tons)**	9.38	9.27	8.66	4.45	4.76	4.77	
Phase I, Substitution and Compensation Units							
Heat input (billion mmBtu)	1.2	1.35	1.37	1.94	1.29	1.39	
SO2 emissions **(million tons)**	1.12	1.15	1.1	0.86	0.65	0.70	
Phase I, Opt-In Units (7)							
					0.04	0.08	
Phase II Units (1473 units)							
Heat input (billion mmBtu)	12.38	12.68	13.92	15.22	16.63	17.30	
SO2 emissions **(million tons)**	6.79	5.68	5.97	6.56	7.10	7.51	
TOTAL							
Heat input (billion mmBtu)	17.86	18.41	19.68	21.86	22.83	23.74	24.49*
SO2 emissions (million tons)	17.30	16.09	15.72	11.86	12.51	12.98	13.85*

Notes:

(1) Emissions (heat input) for the 263 Phase I (table I) units for the years 1991, 1992, 1993, 1994 are 8.4 (4.32), 8.14 (4.35), 7.58 (4.40) and 7.4, respectively.

(2) In years 1995, 1996, and 1997, there were 182, 161, and 153 substitution and compensation units, respectively.

* Preliminary data from the ATS system, not available broken down by Phase I and Phase II units.

Source: EPA Acid Rain Score 1996, Results of the Sulfur Dioxide Program, 1997; Preliminary Summary Emission Reports, all from www.epa.gov/acidrain/.

Table A3: Number of Transactions between Economically Distinct Actors in Private Markets and in the EPA Annual Auctions, by Sellers and by Buyers

	1993	1994	1995	1996	1997	1998	Jan-May 1999	TOTAL
PRIVATE MARKET								
Seller								
B	0	12	57	73	138	110	22	**412**
E	0	0	0	0	1	1	2	**4**
F	0	6	84	131	253	232	73	**779**
O	0	6	23	52	66	43	17	**207**
P1	0	28	66	62	126	55	15	**352**
P2	0	8	60	168	122	51	25	**434**
U	0	3	49	89	132	244	238	**755**
Total	**0**	**63**	**339**	**575**	**838**	**736**	**392**	**2,943**
Buyer								
B	0	20	77	111	174	165	29	**576**
E	0	0	0	0	5	4	4	**13**
F	0	9	65	198	275	235	108	**890**
O	0	14	39	45	48	48	20	**214**
P1	0	5	31	46	36	37	36	**191**
P2	0	2	14	33	53	16	35	**153**
U	0	13	113	142	247	231	160	**906**
Total	**0**	**63**	**339**	**575**	**838**	**736**	**392**	**2,943**
THE EPA ANNUAL AUCTIONS								
Buyer								
B	2	8	3	2	9	27	9	**60**
E	3	1	16	14	21	7	11	**73**
F	0	3	3	10	5	0	0	**21**
O	18	23	12	30	15	7	3	**108**
P1	8	7	2	0	4	0	0	**21**
P2	4	2	3	3	2	0	2	**16**
U	31	22	32	22	8	0	23	**138**
Total	**66**	**66**	**71**	**81**	**64**	**41**	**48**	**437**

Source: The EPA Annual Auctions and ATS Databases.

Table A4: Number of Allowances Traded between Economically Distinct Actors in Private Markets and in the EPA Annual Auctions, by Sellers and by Buyers

	1993	1994	1995	1996	1997	1998	Jan-May 1999	**TOTAL**
PRIVATE MARKET								
Seller								
B	0	49,597	270,766	611,406	1,223,422	1,675,501	145,801	3,976,493
E	0	0	0	0	4	1,163	768	1,935
F	0	24,439	97,342	896,338	2,391,813	2,897,238	443,041	6,750,211
O	0	225,884	148,675	303,768	877,949	333,204	120,138	2,009,618
P1	0	464,352	512,151	450,645	1,061,408	356,202	467,972	3,312,730
P2	0	89,033	1,115,555	985,247	1,074,637	312,096	853,991	4,430,559
U	0	5,067	522,362	1,146,615	1,789,721	2,592,753	2,010,666	8,067,184
Total	**0**	**858,372**	**2,666,851**	**4,394,019**	**8,418,954**	**8,168,157**	**4,042,377**	**2,854,8730**
Buyer								
B	0	65,507	260,439	991,499	1,597,000	1,329,503	287,947	**4,531,895**
E	0	0	0	0	20,004	6,667	778	**27,449**
F	0	37,713	337,961	1,424,369	3,020,046	2,481,467	627,652	**7,929,208**
O	0	367,429	257,641	374,149	584,260	378,669	58,250	**2,020,398**
P1	0	65,000	137,394	373,868	401,844	490,496	521,107	**1,989,709**
P2	0	2,100	264,952	227,941	683,312	159,373	888,359	**2,226,037**
U	0	320,623	1,408,464	1,002,193	2,112,488	3,321,982	1,658,284	**9824,034**
Total	**0**	**858,372**	**2,666,851**	**4,394,019**	**8,418,954**	**8,168,157**	**4,042,377**	**28,548,730**
THE EPA ANNUAL AUCTIONS								
Buyer								
B	2,672	3,301	8,001	9,725	35,650	235,005	24,251	**318,605**
E	3	1	164	434	211	8	64	**885**
F	0	1,524	4,512	142,307	95,315	0	0	**243,658**
O	112	124,198	31,625	460	20,049	39,987	15	**216,446**
P1	7,141	18,485	1,000	0	1,410	0	0	**28,036**
P2	5,439	725	2,350	5,074	10,890	0	9,271	**33,749**
U	134,633	26,766	127,348	117,000	136,475	0	241,399	**783,621**
Total	**150,000**	**175,000**	**175,000**	**275,000**	**300,000**	**275,000**	**275,000**	**1625,000**

Source: The EPA Annual Auctions and ATS Databases.

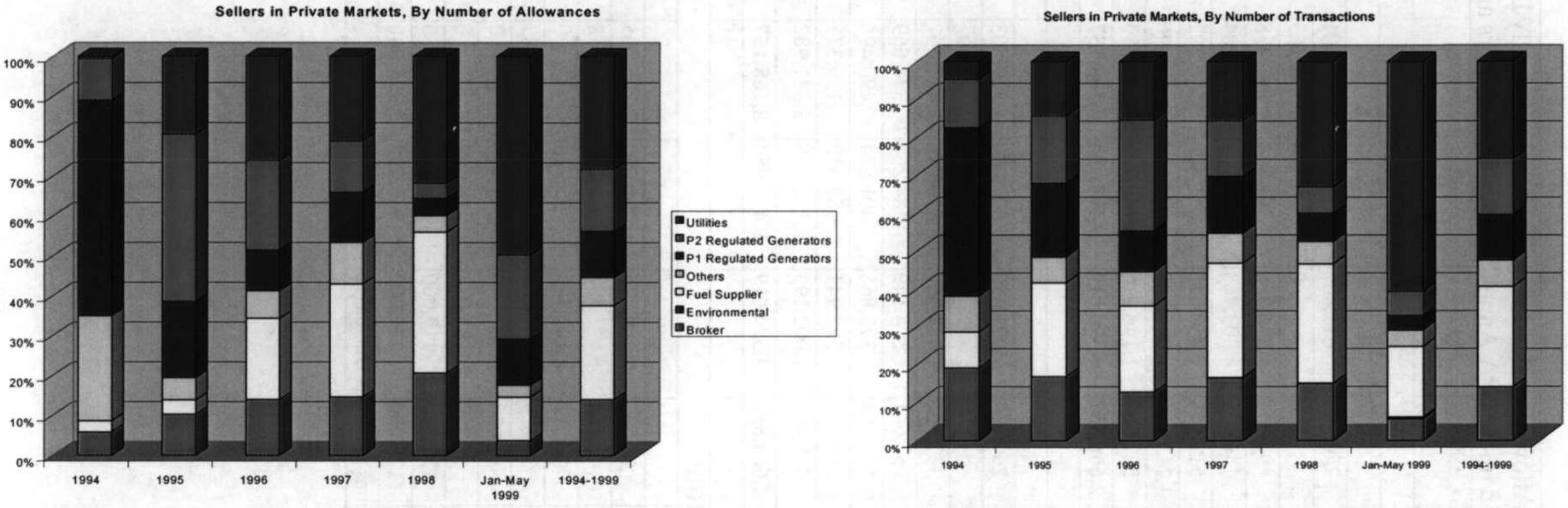
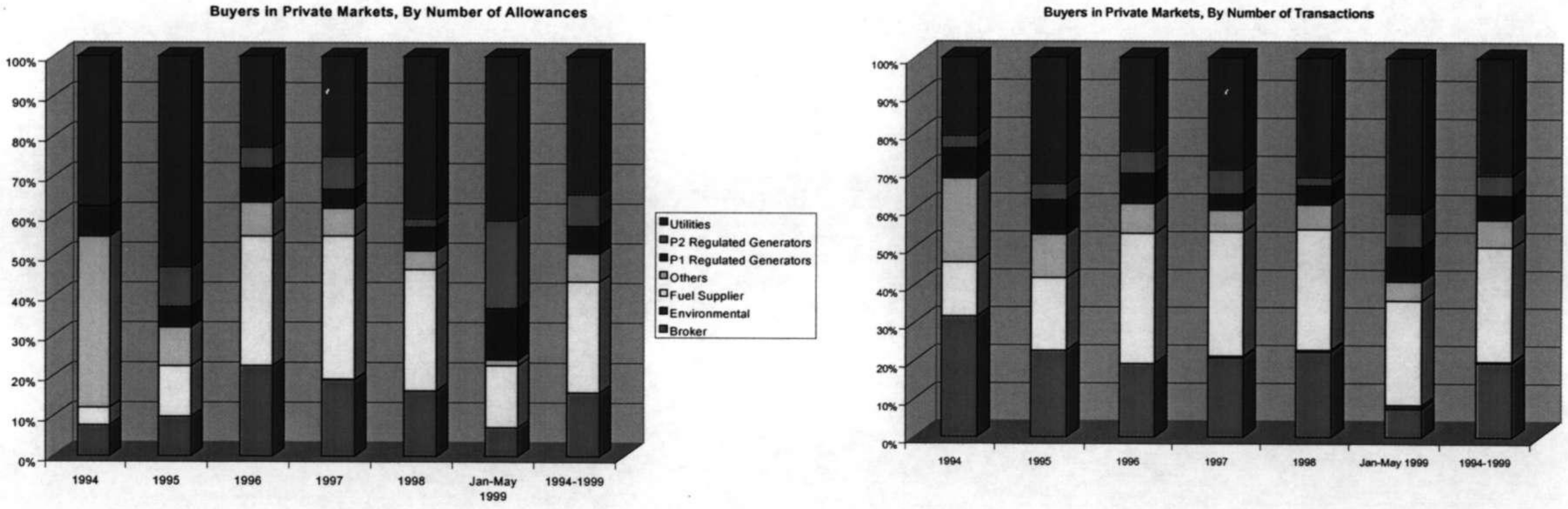


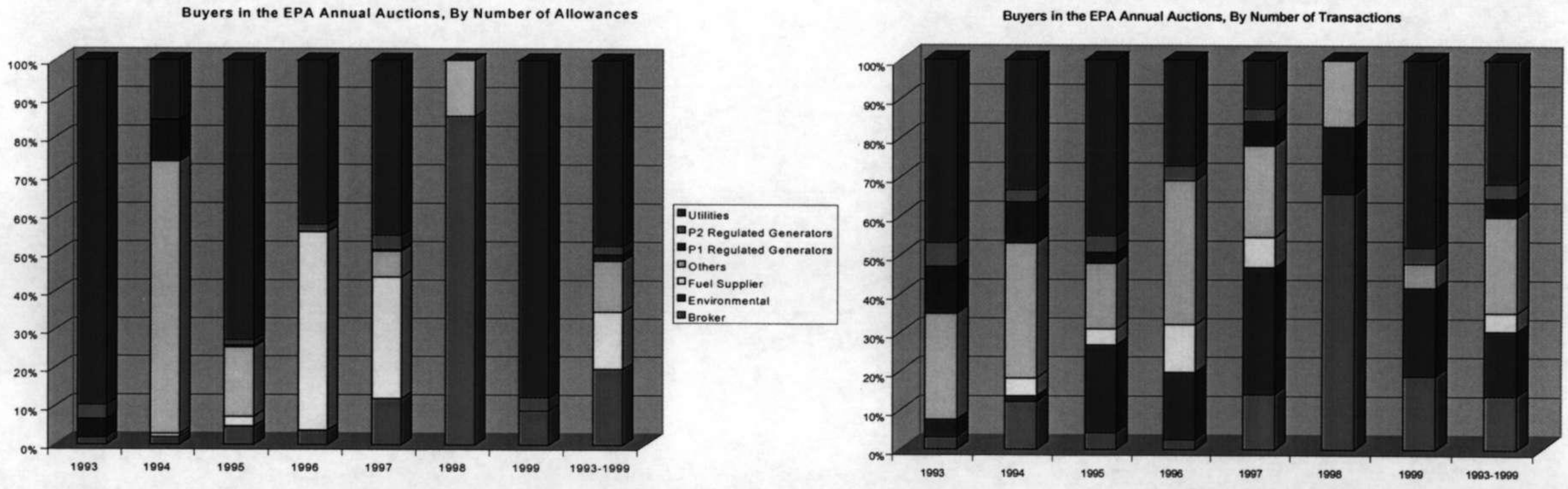
Figure A1: Sellers in Private Markets, by Number of Allowances and Number of Transactions



Buyers in Private Markets, By Number of Allowances

Buyers in Private Markets, By Number of Transactions

Figure A2: Buyers in Private Markets, by Number of Allowances and Number of Transactions


Buyers in the EPA Annual Auctions, By Number of Allowances

Buyers in the EPA Annual Auctions, By Number of Transactions

Figure A3: Buyers in the EPA Annual Auctions, by Number of Allowances and Number of Transactions

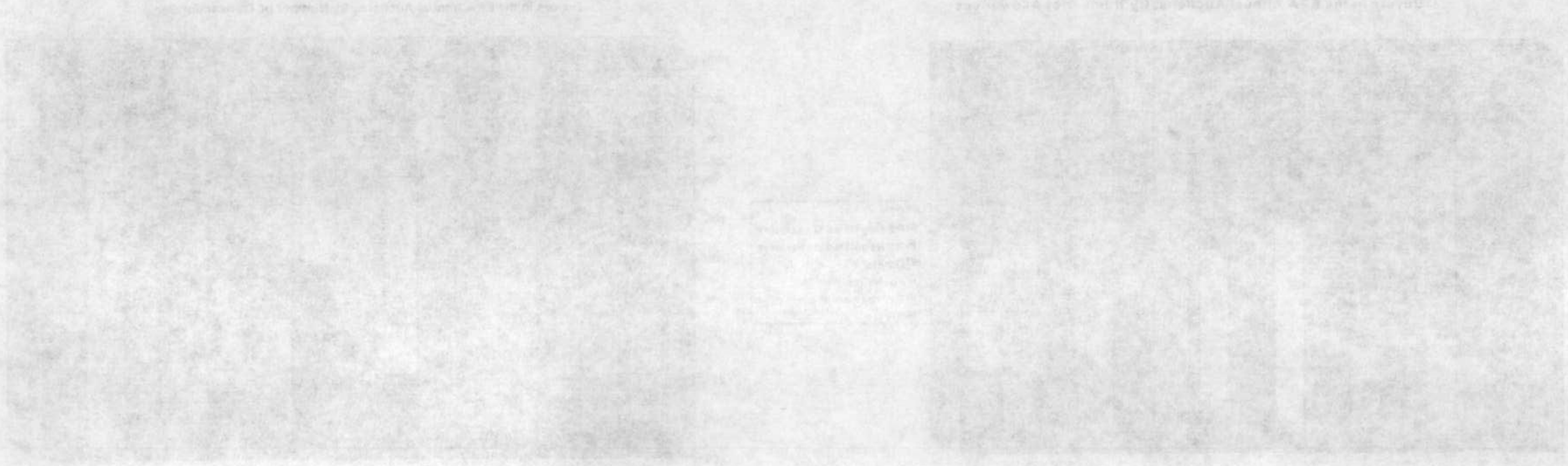


Figure A3: Buyers in the EPA Annual Auctions by Number of Allowances and Number of Transactions

Table A5: Number of Transactions between Economically Distinct Actors by Trading Pairs

Seller	**Buyer**	1993	1994	1995	1996	1997	1998	1/1999-5/999	Total
B	B	0	0	1	2	12	9	1	**25**
	E	0	0	0	0	0	1	2	**3**
	F	0	1	15	11	41	20	6	**94**
	O	0	2	9	13	14	13	2	**53**
	P1	0	4	7	6	8	25	1	**51**
	P2	0	2	0	14	10	5	0	**31**
	U	0	3	25	27	53	37	10	**155**
B Total		**0**	12	**57**	**73**	**138**	**110**	**22**	**412**
E	B	0	0	0	0	0	0	0	**0**
	E	0	0	0	0	1	1	2	**4**
	F	0	0	0	0	0	0	0	**0**
	O	0	0	0	0	0	0	0	**0**
	P1	0	0	0	0	0	0	0	**0**
	P2	0	0	0	0	0	0	0	**0**
	U	0	0	0	0	0	0	0	**0**
E Total		**0**	**0**	**0**	**0**	**1**	**1**	**2**	**4**
F	B	0	0	15	13	35	29	10	**102**
	E	0	0	0	0	0	0	0	**0**
	F	0	1	7	19	42	30	13	**112**
	O	0	1	4	13	13	7	7	**45**
	P1	0	0	10	21	20	10	0	**61**
	P2	0	0	0	4	7	8	6	**25**
	U	0	4	48	61	136	148	37	**434**
F Total		**0**	**6**	**84**	**131**	**253**	**232**	**73**	**779**
O	B	0	2	0	8	5	8	0	**23**
	E	0	0	0	0	0	0	0	**0**
	F	0	0	7	12	11	12	1	**43**
	O	0	1	4	5	1	0	0	**11**
	P1	0	0	6	7	2	2	6	**23**
	P2	0	0	1	1	19	1	5	**27**
	U	0	3	5	19	28	20	5	**80**
O Total		**0**	**6**	**23**	**52**	**66**	**43**	**17**	**207**

Table A5: Number of Transactions between Economically Distinct Actors by Trading Pairs (continued)

Seller	**Buyer**	1993	1994	1995	1996	1997	1998	Jan-May 1999	Total
P1	B	0	10	13	11	42	31	1	**108**
	E	0	0	0	0	4	1	0	**5**
	F	0	6	25	32	62	10	0	**135**
	O	0	8	10	3	11	13	2	**47**
	P1	0	1	2	3	1	0	3	**10**
	P2	0	0	6	4	3	0	2	**15**
	U	0	3	10	9	3	0	7	**32**
P1 Total		**0**	**28**	**66**	**62**	**126**	**55**	**15**	**352**
P2	B	0	6	33	49	39	26	0	**153**
	E	0	0	0	0	0	1	0	**1**
	F	0	0	0	100	63	18	2	**183**
	O	0	2	5	1	6	1	0	**15**
	P1	0	0	0	3	1	0	1	**5**
	P2	0	0	5	4	4	0	1	**14**
	U	0	0	17	11	9	5	21	**63**
P2 Total		**0**	**8**	**60**	**168**	**122**	**51**	**25**	**434**
U	B	0	2	15	28	41	62	17	**165**
	E	0	0	0	0	0	0	0	**0**
	F	0	1	11	24	56	145	86	**323**
	O	0	0	7	10	3	14	9	**43**
	P1	0	0	6	6	4	0	25	**41**
	P2	0	0	2	6	10	2	21	**41**
	U	0	0	8	15	18	21	80	**142**
U Total		**0**	**3**	**49**	**89**	**132**	**244**	**238**	**755**
EPA	B	2	8	3	2	9	27	9	**60**
	E	3	1	16	14	21	7	11	**73**
	F	0	3	3	10	5	0	0	**21**
	O	18	23	12	30	15	7	3	**108**
	P1	8	7	2	0	4	0	0	**21**
	P2	4	2	3	3	2	0	2	**16**
	U	31	22	32	22	8	0	23	**138**
EPA Total		**66**	**66**	**71**	**81**	**64**	**41**	**48**	**437**
EPA/O	U	0	0	0	0	0	0	1	**1**
EPA/P1	O	0	0	1	0	0	0	0	**1**
EPA/P1	P1	1	2	0	0	0	0	0	**3**
EPA/P1	U	0	1	3	0	0	0	0	**4**
Private EPA Total		**1**	**3**	**4**	**0**	**0**	**0**	**1**	**9**

Table A6: Number of Allowances Transacted by Economically Distinct Actors by Trading Pairs

Seller	**Buyer**	1993	1994	1995	1996	1997	1998	Jan.-May 1999
B	B	0	0	2,961	5,463	101,442	84,202	1,500
	E	0	0	0	0	0	4	10
	F	0	356	19,786	69,595	448,701	443,717	113,027
	O	0	341	122,982	147,429	183,712	197,006	3,100
	P1	0	45,000	8,238	74,010	61,732	277,321	88
	P2	0	2,100	0	51,603	37,623	63,379	0
	U	0	1,800	116,799	263,306	390,212	609,872	28,076
B Total		**0**	**49,597**	**270,766**	**611,406**	**1,223,422**	**1,675,501**	**145,801**
E	B	0	0	0	0	0	0	0
	E	0	0	0	0	4	1,163	768
	F	0	0	0	0	0	0	0
	O	0	0	0	0	0	0	0
	P1	0	0	0	0	0	0	0
	P2	0	0	0	0	0	0	0
	U	0	0	0	0	0	0	0
E Total		**0**	**0**	**0**	**0**	**4**	**1,163**	**768**
F	B	0	0	5,105	51,993	264,199	160,465	131,182
	E	0	0	0	0	0	0	0
	F	0	10,000	6,966	135,562	327,956	130,204	67,750
	O	0	5,000	16,120	86,410	119,413	32,257	43,568
	P1	0	0	10,021	193,968	287,299	194,958	0
	P2	0	0	0	5,164	29,667	93,994	56,165
	U	0	9,439	59,130	423,241	1363,279	2,285,360	144,376
F Total		**0**	**24,439**	**97,342**	**896,338**	**2,391,813**	**2,897,238**	**443,041**
O	B	0	797	0	57,475	192,626	120,099	0
	E	0	0	0	0	0	0	0
	F	0	0	17,162	28,400	27,807	76,378	5,000
	O	0	87	25,839	54,000	8,000	0	0
	P1	0	0	60,264	27,331	21,695	10,217	59,193
	P2	0	0	2,000	15,000	444,674	2,000	41,411
	U	0	225,000	43,410	121,562	183,147	124,510	14,534
O Total		**0**	**225,884**	**148,675**	**303,768**	**877,949**	**333,204**	**120,138**

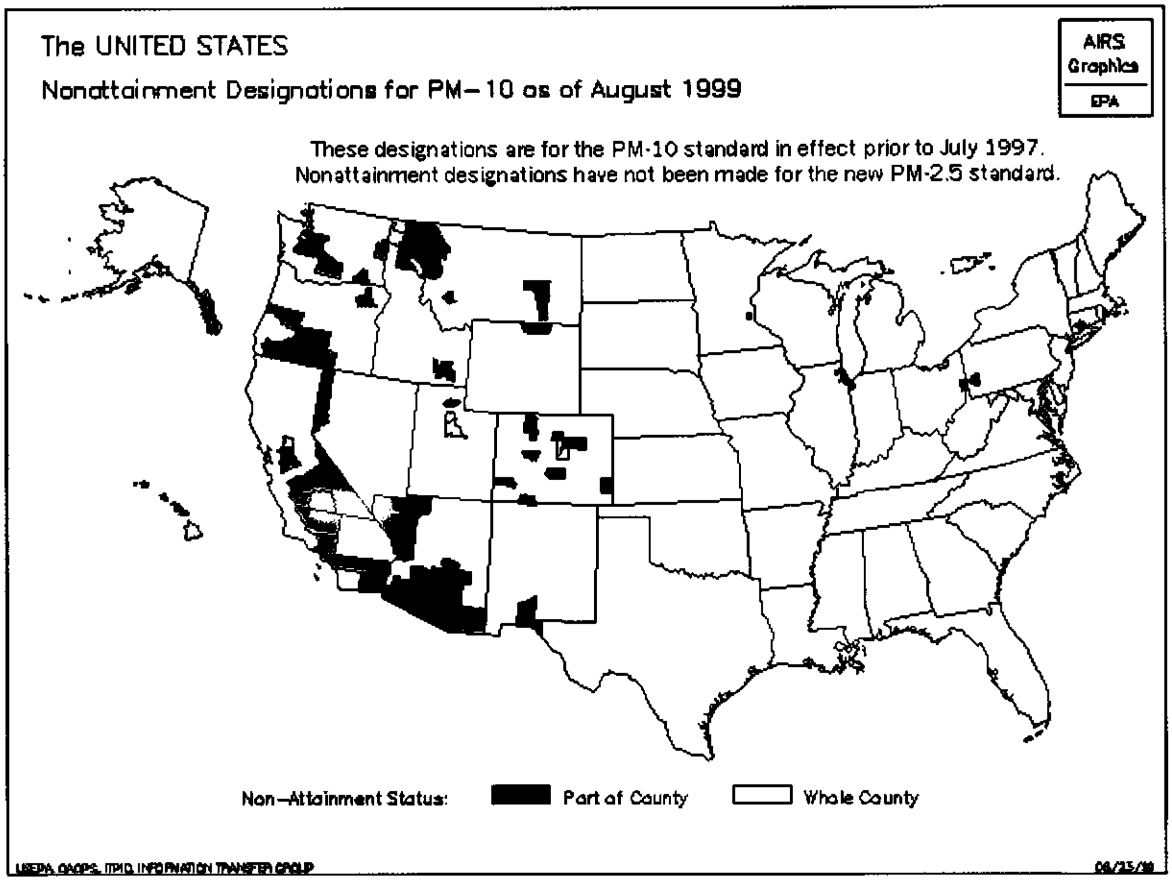
Table A6: Number of Allowances Transacted by Economically Distinct Actors by Trading Pairs (continued)

Seller	**Buyer**	1993	1994	1995	1996	1997	1998	Jan-May 1999
P1	**B**	0	46,967	5,113	40,888	282,438	199,514	200
	E	0	0	0	0	20,000	500	0
	F	0	26,000	152,101	274,402	667,739	137,350	0
	O	0	287,001	29,200	12,380	29,669	18,838	582
	P1	0	20,000	5,001	15,000	5,000	0	1,682
	P2	0	0	42,175	59,114	51,562	0	10,330
	U	0	84,384	278,561	48,861	5,000	0	455,178
P1 Total		**0**	**464,352**	**512,151**	**450,645**	**1,061,408**	**356,202**	**467,972**
P2	B	0	14,033	171,914	314,057	247,454	146,520	0
	E	0	0	0	0	0	5,000	0
	F	0	0	0	518,674	466,919	140,980	35,000
	O	0	75,000	6,500	4,500	216,466	8,900	0
	P1	0	0	0	40,468	100	0	3,054
	P2	0	0	179,777	51,001	31,000	0	16,000
	U	0	0	757,364	56,547	112,698	10,696	799,937
P2 Total		**0**	**89,033**	**1,115,555**	**985,247**	**1,074,637**	**312,096**	**853,991**
U	B	0	3,710	75,346	521,623	508,841	618,703	155,065
	E	0	0	0	0	0	0	0
	F	0	1,357	141,946	397,736	1,080,924	1,552,838	406,875
	O	0	0	57,000	69,430	27,000	121,668	11,000
	P1	0	0	53,870	23,091	26,018	8,000	457,090
	P2	0	0	41,000	46,059	88,786	0	764,453
	U	0	0	153,200	88,676	58,152	291,544	216,183
U Total		**0**	**5,067**	**522,362**	**1,146,615**	**1,789,721**	**2,592,753**	**2,010,666**
EPA	B	2,672	3,301	8,001	9,725	35,650	235,005	24,251
	E	3	1	164	434	211	8	64
	F	0	1,524	4,512	142,307	95,315	0	0
	O	112	124,198	31,625	460	20,049	39,987	15
	P1	7,141	18,485	1,000	0	1,410	0	0
	P2	5,439	725	2,350	5,074	10,890	0	9,271
	U	134,633	26,766	127,348	117,000	136,475	0	241,399
EPA Total		**150,000**	**175,000**	**175,000**	**275,000**	**300,000**	**275,000**	**275,000**
EPA/O	U	0	0	0	0	0	0	10
EPA/P1	O	0	0	600	0	0	0	0
EPA/P1	P1	10	800	0	0	0	0	0
EPA/P1	U	0	400	800	0	0	0	0
Private EPA total		**10**	**1,200**	**1,400**	**0**	**0**	**0**	**10**

Table A7: Number of Transactions, by Allowance Vintage Year and Purchase Year								
Vintage	1993	1994	1995	1996	1997	1998	Jan.-May 1999	Total
1995	37	69	248	167	156	39	36	752
1996	/	**8**	**40**	274	250	146	137	855
1997	/	/	**9**	**14**	244	129	50	446
1998	/	/	**4**	**3**	**15**	290	89	401
1999	/	**10**	**18**	**9**	**23**	**36**	78	174
2000	30	22	1	17	36	13	6	125
2001	/	22	12	1	23	5	1	64
2002	/	**2**	41	12	26	10	/	91
2003	/	/	**8**	43	23	8	1	83
2004	/	**2**	**7**	**25**	38	17	3	92
2005	/	/	/	**24**	**26**	61	/	111
2006	/	/	/	/	**9**	**3**	22	34
2007	/	/	/	**35**	**4**	**4**	/	43
2008	/	/	/	/	/	**3**	/	3
2009	/	/	**17**	**24**	**20**	**4**	**4**	69
2010	/	/	/	**6**	**5**	**1**	/	12
2011	/	/	/	**3**	**2**	/	/	5
2012	/	/	/	/	/	**1**	/	1
2013	/	/	/	/	/	**4**	/	4
2014	/	/	/	/	/	/	/	/
2015	/	/	/	/	/	/	/	/
2016	/	/	/	/	/	/	/	/
2017	/	/	**2**	/	/	/	/	/
2018	/	/	/	/	/	/	/	/
2019	/	/	/	/	/	/	/	/
2020	/	/	/	/	/	/	/	/
2021	/	/	/	/	/	/	/	/
2022	/	/	/	/	/	/	/	/
2023	/	/	/	/	/	/	/	/
2024	/	/	/	/	**2**	/	/	2
2025	/	/	**7**	/	/	/	/	7
2026	/	/	/	/	/	/	/	/
2027	/	/	/	/	/	**3**	/	3
2028	/	/	/	/	/	**2**	**15**	17
Total	67	135	414	657	902	779	442	3396
Futures (in %)	/	**16**	**27**	**22**	**12**	**8**	**4**	**9**
Notes: Futures are trades of allowances with vintages that are not issued yet.								

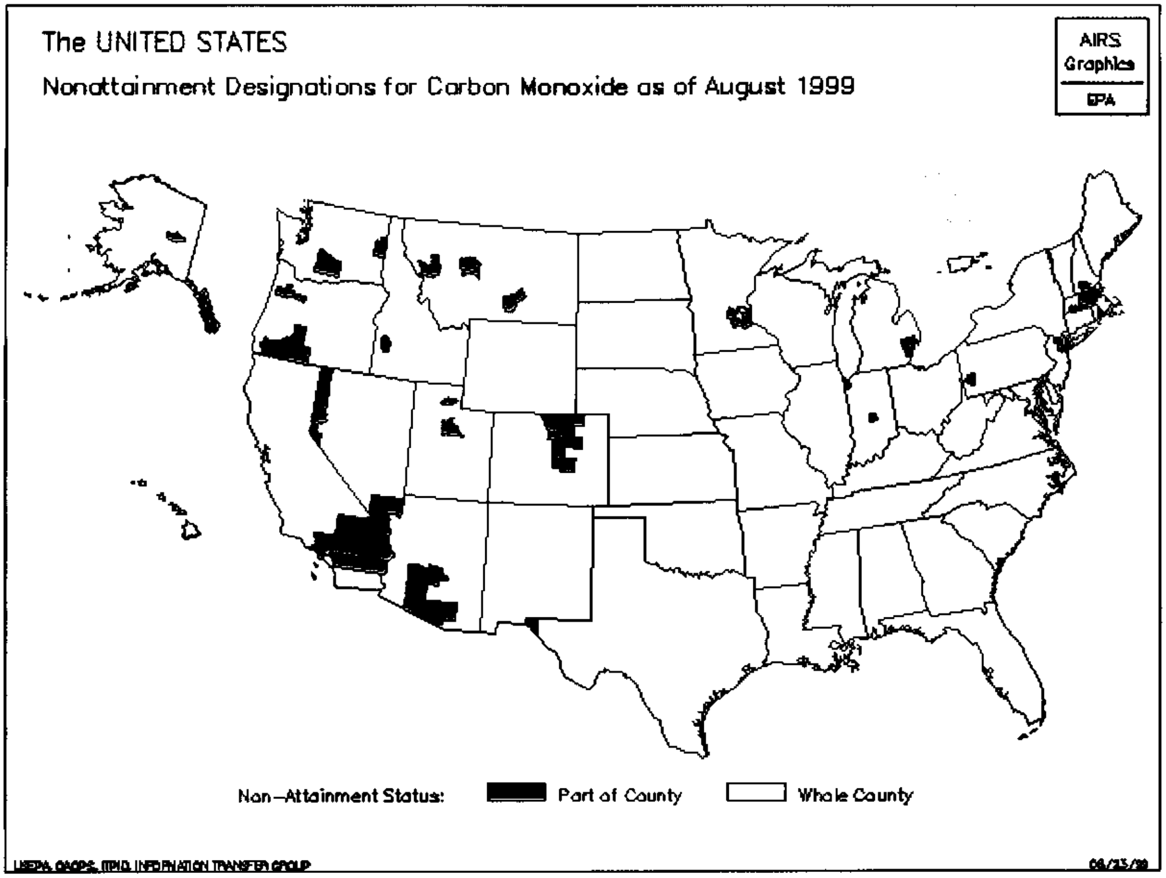
APPENDIX B

LOCAL AIR QUALITY IN THE U.S.



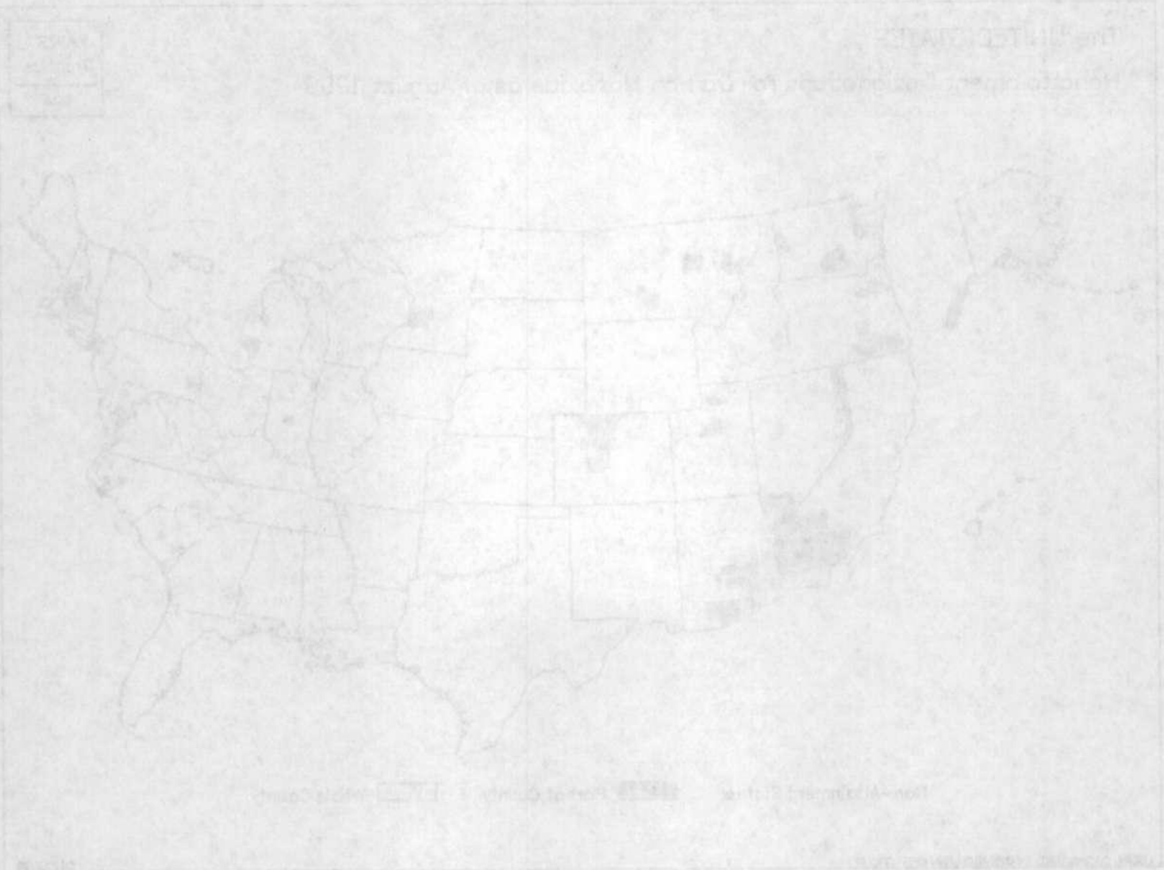
Source: The Greenbook, 1999: http://www.epa.gov/airs/rvnonpm1.gif, September 4, 1999.

Figure B1: Non-Attainment Areas for PM-10, August 1999



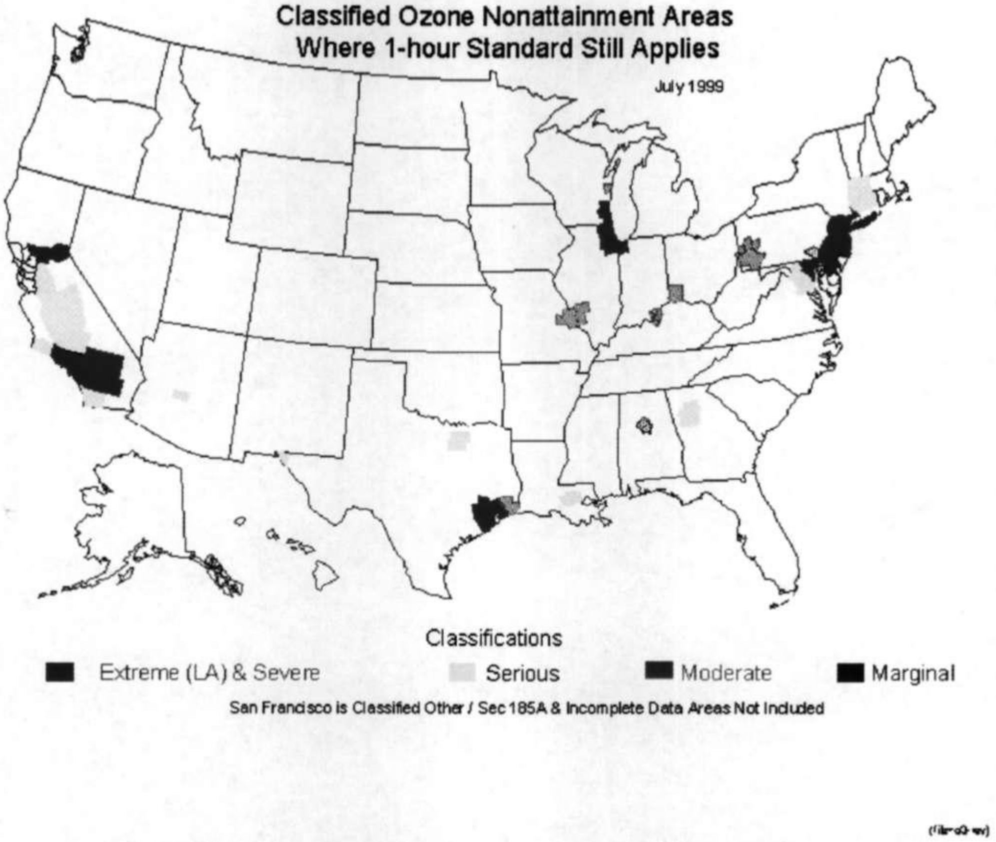
Source: The Greenbook, 1999.http://www.epa.gov/airs/rvnonco.gif, September 4, 1999.

Figure B2: Non-Attainment Areas for Carbon Monoxide, August 1999



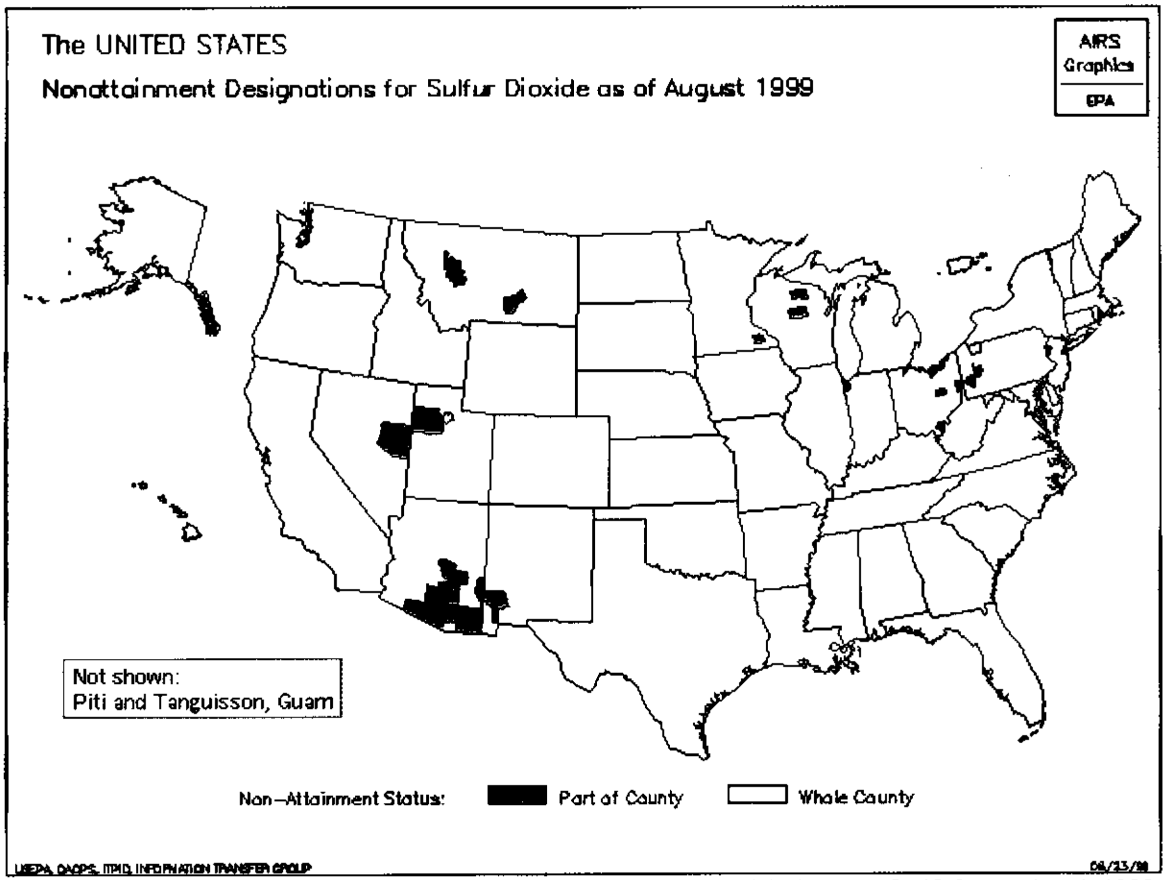
Source: The Greenbook, EPA, http://www.epa.gov/oar/oaqps/greenbk/, September 4, 1999

Figure B2: Non-Attainment Areas for Carbon Monoxide, August 1999



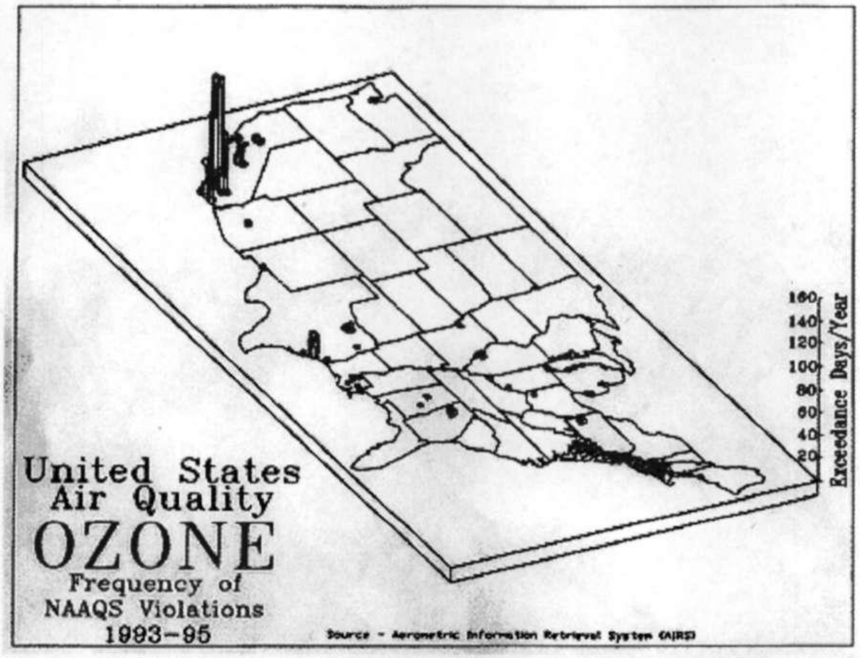
Source: The Greenbook. 1999. http://www.epa.gov/oar/oaqps/greenbk/onmapc.html, September 4, 1999.

Figure B3: Non-Attainment Areas for Ozone, August 1999



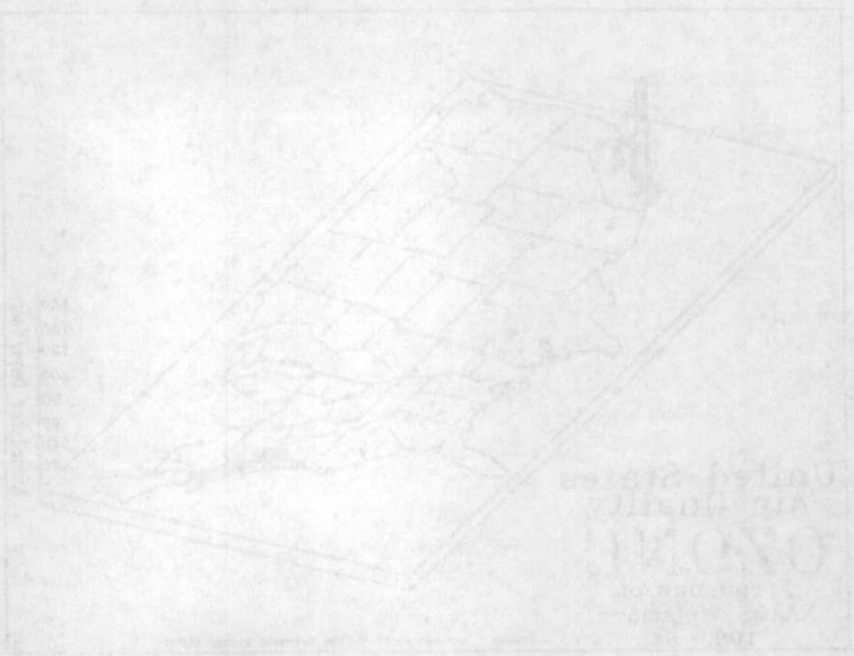
Source: The Greenbook, 1999. http://www.epa.gov/airs/rvnonso2.gif, September 4, 1999.

Figure B4: Non-Attainment Areas for Sulfur Dioxide, 1999



Source: 1995 Air Quality and Trends, http://www.aqmd.gov/smog/95o3us.html, September 4, 1999.

Figure B5: Frequency of Ozone National Ambient Air Quality Standard Violations (in days/year), 1993-1995



Source: 1993 Air Quality and Trends, http://www.[illegible], September 4, 1996.

Figure B5. Frequency of Ozone National Ambient Air Quality Standard Violations (in days/year), 1993–1995

APPENDIX C

WETLANDS LOSSES AND GAINS

Table C1: Average Annual Wetland Losses and Gains, 1982-1992, Compared with Restoration Activity, 1992-1996 (in acres)

Program	1982-1992 Average Annual Gross Wetland		Restoration Activity						Average Annual Restoration	
	Loss	Gain	1992	1993	1994	1995	1996	Total	1992-96	Adjusted[1]
WRP [2]	NA	NA	43,438	0	159,634		197,313	400,385	80,077	76,073
PWP [3]	NA	NA	38,000	34,528	54,739	54,146	51,407	232,820	46,564	2,328
NAWMP [4]	NA	NA	88,000	51,000	50,000			189,000	37,800	9,450
404 Permit	NA	NA	NA	NA	15,000	45,925	47,864	108,789	21,754	20,670
Mitigation banks [5]	NA	NA	1,144	1,144	1,144	1,144	1,144	5,720	1,144	1,087
TOTAL	156,000	77,000	170,582	86,672	280,517	101,215	297,728	936,714	187,343	109,608

Notes:

NA= not available

[1] Adjusted for the proportion of wetland versus upland acres, restoration versus enhancement, and for double counting

[2] Wetland Reserve and Emergency Wetlands Reserve Programs, assumes 95 percent is actual restoration

[3] Fish and wildlife Service-Partners for Wildlife Program, assumes 95 percent is actual restoration

[4] Fish and Wildlife Service-North American Waterfowl Management Plan, assumes 95 percent is actual restoration

[5] Forty-six banks existing in 1992, assumes 95 percent is restoration

Source: Heimlich et al. (1998: 54).

APPENDIX D

COUNTRIES' PRODUCTION AND CONSUMPTION OF OZONE-DEPLETING SUBSTANCES

Table D1: Production of CFCs (Annex A, Group I) (In ODP tons)

		base- 86	1989	g89-freeze	1994	g94-75%	1996	g96-100%	g89-ach	g94-ach	g96-ach
TOTAL		**1,072,295**	**1,044,218**		**339,731**		**160,006**				
Non-Article 5 Parties		**1,027,027**	**985,315**	**1,129,730**	**228,822**	**359,460**	**50,707**	**154,054**	**144,415**	**130,638**	**103,347**
Africa		**10,800**	**9,500**	**11,880**	**1,947**	**3,780**	**0**	**1,620**	**2,380**	**1,833**	**1,620**
	South Africa	10,800	9,500	11,880	1,947	3,780	0	1,620	2,380	1,833	1,620
Asia		**119,998**	**146,744**	**131,998**	**21,593**	**41,999**	**705**	**18,000**	**-14,746**	**20,406**	**17,295**
	Japan	119,998	146,744	131,998	21,593	41,999	705	18,000	-14,746	20,406	17,295
E. Europe		**107,274**	**106,308**	**118,001**	**42,757**	**37,546**	**16,777**	**16,091**	**11,693**	**-5,211**	**-686**
	Czech R.	1,978	2,122	2,176	231	692	7	297	54	461	290
	Russian F.	105,296	104,186	115,826	42,526	36,854	16,770	15,794	11,640	-5,672	-976
W. Europe and others		**788,955**	**722,763**	**867,851**	**162,525**	**276,134**	**33,225**	**118,343**	**145,088**	**113,609**	**85,118**
	Australia	15,385	17,613	16,924	4,452	5,385	0	2,308	-689	938	2,308
	Canada	19,104	17,895	21,014	0	6,686	0	2,866	3,119	6,686	2,866
	France	71,018	55,206	78,120	3,688	24,856	0	10,653	22,914	21,168	10,653
	Germany	123,653	104,096	136,018	15,997	43,279	0	18,548	31,922	27,282	18,548
	Greece	14,045	12,372	15,450	3,505	4,916	1,450	2,107	3,078	1,411	657
	Italy	56,656	48,840	62,322	9,842	19,830	8,475	8,498	13,482	9,988	23
	Netherlands	42,331	41,294	46,564	21,013	14,816	13,293	6,350	5,270	-6,197	-6,943
	Spain	33,728	30,833	37,101	18,729	11,805	5,424	5,059	6,268	-6,924	-365
	U.K.	102,014	74,178	112,215	7,091	35,705	3,907	15,302	38,037	28,614	11,395
	U.S.A	311,021	320,436	342,123	78,208	108,857	676	46,653	21,687	30,649	45,977
Article 5 Parties		**45,268**	**58,903**		**110,909**		**109,299**				
Asia		16,077	33,266		76,291		85,443				
E. Europe		0	/		191		0				
Latin America & Caribbean.		29,191	25,637		34,427		23,856				

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each Substance in the Group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D2: Consumption of CFCs (Annex A, Group I) (In ODP tons)											
		base- 86	1989	g89-freeze	1994	g94-75%	1996	g96-100%	g89-ach	g94-ach	g96-ach
TOTAL		**1,070,207**	**1,034,130**		**349,589**		**168,969**				
Non-Article 5 Parties		**946,356**	**893,618**	**1,040,992**	**183,367**	**331,225**	**24,548**	**127,347**	**147,374**	**147,858**	**102,799**
Africa		**12,449**	**10,656**	**13,694**	**2,417**	**4,357**	**0**	**1,867**	**3,038**	**1,940**	**1,867**
	South Africa	12,449	10,656	13,694	2,417	4,357	0	1,867	3,038	1,940	1,867
Asia		**122,276**	**151,169**	**134,504**	**20,610**	**42,797**	**37**	**3,735**	**-16,665**	**22,187**	**3,698**
	Israel	4,142	4,560	4,556	897	1,450	7	621	-4	552	614
	Japan	118,134	146,609	129,947	19,713	41,347	0	17,720	-16,662	21,634	17,720
	Turkmenistan	/	/	134,504	/		30				-30
E. Europe		**141,873**	**138,562**	**156,060**	**31,418**	**49,656**	**16,236**	**21,281**	**17,498**	**18,238**	**5,045**
	Azerbaijan	481	481	529	/	168	456	72	48	/	-384
	Belarus	2,511	1,680	2,762	900	879	524	377	1,082	-21	-147
	Bulgaria	2,940	2,612	3,234	684	1,029	4	441	622	345	437
	Czech R.	5,461	5,498	6,007	403	1,911	50	819	509	1,508	769
	Hungary	5,468	4,848	6,015	844	1,914	0	820	1,167	1,070	820
	Latvia	6,102	4,736	6,712	/	2,136	307	915	1,976	/	608
	Lithuania	5,462	5,528	6,008	596	1,912	289	819	480	1,316	530
	Moldova	/	/		/		51			/	-51
	Poland	4,986	4,986	5,485	1,678	1,745	549	748	499	67	199
	Russian F.	100,352	99,242	110,387	23,413	35,123	12,345	15,053	11,145	11,710	2,708
	Slovakia	1,706	1,979	1,877	229	597	0	256	-102	368	256
	Ukraine	4,625	4,518	5,088	2,421	1,619	1,401	694	570	-802	-707
	Uzbekistan	1,779	2,454	1,957	250	623	260	267	-497	373	7
W. Europe and others		**669,758**	**593,231**	**736,734**	**128,922**	**234,415**	**8,275**	**100,464**	**143,503**	**105,493**	**92,189**
	Australia	14,290	14,293	15,719	3,895	5,001	234	2,144	1,426	1,107	1,910
	Austria	7,760	5,860	8,536	922	2,716	/	1,164	2,676	1,794	/
	Canada	19,958	18,843	21,954	4,853	6,985	129	2,994	3,111	2,132	2,865
	EU	301,930	225,985	332,123	44,703	105,676	6,010	45,290	106,138	60,973	39,280
	Finland	3,301	1,886	3,631	508	1,155	/	495	1,745	647	/

Table D2: Consumption of CFCs (Annex A, Group I) (In ODP tons) (continued)

	Iceland	195	140	215	31	68	0	29	75	37	29
	Liechtenstein	37	13	41	4	13	0	6	28	9	6
	Monaco	0	0	0	5	0	0	0	0	-5	0
	New Zealand	2,088	1,185	2,297	338	731	2	313	1,112	393	311
	Norway	1,313	908	1,444	173	460	3	197	536	287	194
	Sweden	4,962	2,552	5,458	215	1,737	/	744	2,906	15,227	/
	Switzerland	7,960	4,023	8,756	741	2,786	0	1,194	4,733	2,045	1,194
	U.S.A	305,964	317,543	336,560	72,534	107,087	1,897	45,895	19,017	34,553	43,998
Article 5 Parties		**123,851**	**140,512**		**166,222**		**144,421**				
Africa		11,904	10,001		9,700		8,428				
Asia		69,309	92,190		120,430		102,401				
E. Europe		6,545	5,065		2097		1,485				
Latin America & Caribbean		35,806	32,890		33,934		32,037				
W. Europe		287	366		61		70				

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D3: Production of Halons (Annex A, Group II)

		base-86	1992	g92-frz	1994	g94-100%	1996	g92-ach	g94-ach
TOTAL		**197,458**	**104,995**		**26,466**		**45,896**		
Non-Article 5 Parties		**186,168**	**90,597**	**204,785**	**1,446**	**18,617**	**912**	**114,188**	**17,171**
Asia		**28,419**	**20,140**	**31,261**	**0**	**2,842**	**0**	**11,121**	**2,842**
	Japan	28,419	20,140	31,261	0	2,842	0	11,121	2,842
E. Europe		**27,800**	**8,996**	**30,580**	**1,446**	**2,780**	**912**	**21,584**	**1,334**
	Russian F.	27,800	8,996	30,580	1,446	2,780	912	21,584	1,334
W. Europe and others		**129,949**	**61,461**	**142,944**	**0**	**12,995**	**0**	**81,483**	**12,995**
	France	34,465	23,216	37,912	0	3,447	0	14,696	3,447
	Germany	18,134	0	19,947	0	1,813	0	19,947	1,813
	Italy	2,094	0	2,303	0	209	0	2,303	209
	U.K.	16,500	12,402	18,150	0	1,650	0	5,748	1,650
	U.S.A	58,756	25,843	64,632	0	5,876	0	38,789	5,876
Article 5 Parties		**11,290**	**14,398**		**25,020**		**44,984**		
Asia		11,290	14,398		25,020		44,984		

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D4: Consumption of Halons (Annex A, Group II)

		base-86	1992	g92-frz	1994	g94-100%	1996	g92-ach	g94-ach
TOTAL		**214,320**	**127,738**		**32,396**		**44,931**		
Non-Article 5 Parties		**177,993**	**88,411**	**195,792**	**1,527**	**17,799**	**1,518**	**107,381**	**16,272**
Africa		**6,222**	**5,372**	**6,844**	**0**	**622**	**0**	**1,472**	**622**
	South Africa	6,222	5,372	6,844	0	622	0	1,472	622
Asia		**19,360**	**16,742**	**21,296**	**0**	**1,936**	**0**	**4,554**	**1,936**
	Israel	2,405	1,956	2,646	0	241	0	690	241
	Japan	16,955	14,786	18,651	0	1,696	0	3,865	1,696
E. Europe		**38,710**	**9,880**	**42,581**	**1,479**	**3,871**	**1,518**	**32,701**	**2,392**
	Azerbaijan	3,279	/	3,607	/	328	501	/	/
	Belarus	278	221	306	92	28	24	85	-64
	Bulgaria	40	16	44	16	4	2	28	-12
	Czech R.	92	/	101	113	9	0	/	-104
	Hungary	1,883	507	2,071	0	188	0	1,564	188
	Latvia	61	/	67	/	6	0	/	/
	Lithuania	40	/	44	0	4	1	/	4
	Poland	3,900	100	4,290	0	390	0	4,190	390
	Russian F.	28,800	8,996	31,680	1,258	2,880	926	22,684	1,622
	Slovakia	47	22	52	0	5	0	30	5
	Ukraine	258	18	284	0	26	64	266	26
	Uzbekistan	32	/	35	0	3	0	/	3
W. Europe and others		**113,701**	**56,417**	**125,071**	**48**	**11,370**	**0**	**68,654**	**11,322**
	Australia	4,270	430	4,697	0	427	0	4,267	427
	Austria	1,650	5,315	1,815	0	165	0	-3,500	165
	Canada	3,218	1,642	3,540	0	322	0	1,898	322
	EU	40,993	23,900	45,092	0	4,099	0	21,192	4,099
	Finland	598	205	658	0	60	0	453	60
	Iceland	81	18	89	0	8	0	71	8
	Liechtenstein	6	0	7	0	1	0	7	1
	N. Zealand	490	3	539	0	49	0	536	49
	Norway	1,411	637	1,552	0	141	0	915	141
	Sweden	1,831	270	2,014	6	183	/	1,744	177
	Switzerland	1,350	17	1,485	42	135	0	1,468	93
	U.S.A	57,803	23,980	63,583	0	5,780	0	39,603	5,780
Article 5 Parties		**36,327**	**39,327**		**30,869**		**43,413**		
Africa		3,730	4,360		916		1,169		
Asia		30,851	32,428		28,145		41,634		
E. Europe		342	114		90		32		
Latin America & Caribbean		1,386	2,416		1,718		578		
W. Europe		18	9		0		0		

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D5: Production of Other Fully Halogenated CFCs (Annex B, Group I)

		base-89	1993	g93-20%	1994	g94-75%	1996	g96-100%	g93-ach	g94-ach	g96-ach
TOTAL		**3,318**	**966**		**276**		**20**				
Non-Article 5 Parties		**3,318**	**966**	**2,986**	**276**	**1,161**	**20**	**498**	**2,020**	**885**	**478**
Asia		**2,342**	**808**	**2,108**	**136**	**820**	**0**	**351**	**1,300**	**684**	**351**
	Japan	2,342	808	2,108	136	820	0	351	1,300	684	351
E. Europe		**300**	**1**	**270**	**25**	**105**	**20**	**45**	**269**	**80**	**25**
	Russian F.	300	1	270	25	105	20	45	269	80	25
W. Europe and others		**676**	**157**	**608**	**115**	**237**	**0**	**101**	**451**	**122**	**101**
	Germany	61	32	55	13	21	0	9	23	8	9
	Netherlands	23	19	21	1	8	0	3	2	7	3
	U.K.	15	0	14	0	5	0	2	14	5	2
	U.S.A	577	106	519	101	202	0	87	413	101	87
Article 5 Parties		**0**	**0**		**0**		**0**				
Latin America & Caribbean		0	0		0		0				

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D6: Consumption of Other Fully Halogenated CFCs (Annex B, Group I)											
		base-89	1993	g93-20%	1994	g94-75%	1996	g96-100%			
TOTAL		**4,050**	**1,337**		**1,776**		**123**				
Non-Article 5 Parties		**3,975**	**952**	**3,578**	**271**	**1,391**	**16**	**596**	**2,626**	**1,120**	**580**
Africa		**667**	**0**	**600**	**0**	**233**	**0**	**100**	**600**	**233**	**100**
	South Africa	667	0	600	0	233	0	100	600	233	100
Asia		**2,331**	**788**	**2,098**	**136**	**816**	**0**	**350**	**1,310**	**680**	**350**
	Japan	2,331	788	2,098	136	816	0	350	1,310	680	350
E. Europe		**343**	**10**	**309**	**28**	**120**	**16**	**51**	**299**	**92**	**35**
	Belarus	2	5	2	1	1	1	1	-3	-1	-1
	Bulgaria	20	/	18	0	7	0	3	/	7	3
	Czech R.	9	0	8	0	3	0	1	8	3	1
	Poland	2	1	2	/	1	0	1	1	/	1
	Russian F.	300	1	270	25	105	14	45	269	80	31
	Ukraine	10	3	9	2	4	1	2	6	2	1
W. Europe and others		**634**	**154**	**571**	**107**	**221**	**0**	**95**	**417**	**115**	**95**
	Australia	1	0	1	0	1	0	1	1	1	1
	Austria	0	37	0	3	0	0	0	-37	-3	0
	Canada	2	1	2	1	1	0	1	1	-1	1
	EU	58	40	52	8	20	0	9	12	12	9
	Norway	1	1	1	1	1	0	1	-1	-1	1
	Switzerland	1	0	1	0	1	0	1	1	1	1
	U.S.A	571	75	514	94	200	0	86	439	106	86
Article 5 Parties		**75**	**385**		**1,505**		**107**				
Africa		1	124		8		1				
Asia		62	207		1,290		79				
E. Europe		10	/		0		0				
Latin America & Caribbean		2	54		207		27				

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D7: Production of Carbon Tetrachloride (Annex B, Group II)

		base-89	1995	g95-85%	1996	g96-100%	g95-ach	g96-ach
TOTAL		**328,775**	**42,497**		**25,468**			
Non-Article 5 Parties		**230,166**	**22,598**	**57,542**	**1,808**	**34,525**	**34,944**	**32,717**
Africa		**12,697**	**4,931**	**3,174**	**0**	**1,905**	**-1,757**	**1,905**
	South Africa	12,697	4,931	3,174	0	1,905	-1,757	1,905
Asia		**19,602**	**2,463**	**4,901**	**539**	**2,940**	**2,438**	**2,401**
	Japan	19,602	2,463	4,901	539	2,940	2,438	2,401
E. Europe		**9,246**	**2,736**	**2,312**	**744**	**1,387**	**-425**	**643**
	Czech R.	5,286	1	1,322	0	793	1,321	793
	Poland	3,960	/	990	0	594	/	594
	Russian F.	0	2,735	0	744	0	-2,735	-744
W. Europe and others		**188,621**	**12,468**	**47,155**	**525**	**28,293**	**34,687**	**27,768**
	Belgium	26,592	0	6,648	0	3,989	6,648	3,989
	Canada	29,310	2,553	7,328	0	4,397	4,775	4,397
	France	5,119	983	1,280	506	768	297	262
	Germany	8,067	0	2,017	0	1,210	2,017	1,210
	Italy	8,769	0	2,192	0	1,315	2,192	1,315
	Spain	40,634	0	10,159	0	6,095	10,159	6,095
	U.K.	14,094	0	3,524	8	2,114	3,524	2,106
	U.S.A	56,036	8,932	14,009	11	8,405	5,077	8,394
Article 5 Parties		**98,609**	**19,899**		**23,660**			
Asia		34,568	3,772		5,135			
E. Europe		11,879	4,665		2,879			
Latin America & Caribbean		52,162	11,462		15,646			

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D8: Consumption of Carbon Tetrachloride (Annex B, Group II)

		base-89	1995	g95-85%	1996	g96-100%	g95-ach	g96-ach
TOTAL		**231,592**	**27,127**		**27,968**			
Non-Article 5 Parties		**158,611**	**397**	**39,653**	**1,132**	**23,792**	**39,256**	**22,660**
Africa		**8,919**	**0**	**2,230**	**0**	**1,338**	**2,230**	**1,338**
	South Africa	8,919	0	2,230	0	1,338	2,230	1,338
Asia		**75,352**	**327**	**18,838**	**68**	**11,303**	**18,511**	**11,235**
	Israel	473	72	118	68	71	46	3
	Japan	74,879	255	18,720	0	11,232	18,465	11,232
E. Europe		**5,422**	**70**	**1,356**	**586**	**813**	**1,286**	**227**
	Belarus	10	0	3	3	2	3	-2
	Bulgaria	275	22	69	6	41	47	35
	Czech R.	3,078	2	770	0	462	768	462
	Hungary	825	18	206	0	124	188	124
	Latvia	20	17	5	17	3	-12	-14
	Lithuania	76	10	19	6	11	9	5
	Poland	962	/	241	0	144	/	144
	Russian F.	0	0	0	542	0	0	-542
	Slovakia	100	1	25	0	15	24	15
	Ukraine	0	0	0	0	0	0	0
	Uzbekistan	76	/	19	12	11	/	-1
W. Europe and others		**68,918**	**0**	**17,230**	**478**	**10,338**	**17,230**	**9,860**
	Australia	6	0	2	0	1	2	1
	Austria	139	/	35	/	21		
	Canada	6,168	0	1,542	0	925	1,542	925
	EU	50,406	0	12,602	463	7,561	12,602	7,098
	Finland	88	/	22	/	13	/	/
	New Zealand	3	0	1	0	1	1	1
	Norway	3	0	1	0	1	1	1
	Sweden	176	/	44	/	26	/	/
	Switzerland	5	0	1	4	1	1	-3
	U.S.A	11,924	0	2,981	11	1,789	2,981	1,778
Article 5 Parties		**72,981**	**26,730**		**26,836**			
Africa		880	900		386			
Asia		46,065	20,857		25,896			
E. Europe		2,610	177		540			
Latin America & Caribbean		23,426	4,796		14			

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D9: Production of Methyl Chloroform (Annex B, Group III)

		base-89	1993	g1993-frz	1994	g94-50%	1996	g96-100%	g93-ach	g94-ach	g96-ach
TOTAL		**65,880**	**38,777**		**14,864**		**1,540**				
Non-Article 5 Parties		**64,676**	**38,682**	**71,144**	**14,817**	**38,806**	**1,387**	**9,701**	**32,462**	**23,989**	**8,314**
Asia		**15,636**	**7,146**	**17,200**	**464**	**9,382**	**868**	**2,345**	**10,054**	**8,918**	**1,477**
	Japan	15,636	7,146	17,200	464	9,382	868	2,345	10,054	8,918	1,477
E. Europe		**310**	**100**	**341**	**197**	**186**	**0**	**47**	**241**	**-11**	**47**
	Russian Federation	310	100	341	197	186	0	47	241	-11	47
W. Europe and others		**48,730**	**31,436**	**53,603**	**14,156**	**29,238**	**519**	**7,310**	**22,167**	**15,082**	**6,791**
	Canada	1,132	0	1,245	0	679	0	170	1,245	679	170
	France	6,170	2,422	6,787	1,705	3,702	71	926	4,365	1,997	855
	Germany	7,895	3,006	8,685	1,136	4,737	0	1,184	5,679	3,601	1,184
	U.K.	7,810	5,371	8,591	5,520	4,686	0	1,172	3,220	-834	1,172
	U.S.A	25,723	20,637	28,295	5,795	15,434	448	3,859	7,658	9,639	3,410
ARTICLE 5 Parties		**1,204**	**95**		**47**		**153**				
Asia		47	85		0		140				
E. Europe		27	10		8		13				
Latin America & Caribbean		1,130	0		39		0				

Note: Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each substance in the group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D10: Consumption of Methyl Chloroform (Annex B, Group III)

		base-89	1993	g1993-frz	1994	g94-50%	1996	g96-100%	g93-ach	g94-ach	G96-ach
TOTAL		**65628**	**37312**		**14226**		**2509**				
Non-Article 5 Parties		**60899**	**33132**	**66989**	**10754**	**36539**	**133**	**6488**	**33857**	**25785**	**6355**
Africa		**450**	**362**	**495**	**114**	**270**	**0**	**68**	**133**	**156**	**68**
	South Africa	450	362	495	114	270	0	68	133	156	68
Asia		**17649**	**7798**	**19414**	**580**	**10589**	**121**		**11616**	**10009**	**-121**
	Israel	370	252	407	183	222	121		155	39	-121
	Japan	17279	7546	19007	397	10367	0		11461	9970	0
	E. Europe	498	118	548	110	299	11	75	430	189	64
	Belarus	11	11	12	9	7	6	2	1	-2	-4
	Bulgaria	15	5	17	5	9	0	2	12	4	2
	Czech R.	15	4	17	2	9	0	2	13	7	2
	Hungary	78	23	86	19	47	0	12	63	28	12
	Lithuania	18	/	20	2	11	0	3	/	9	3
	Poland	30	7	33	2	18	0	5	26	16	5
	Russian F.	310	50	341	39	186	0	47	291	147	47
	Slovakia	20	18	22	14	12	0	3	4	-2	3
	Ukraine	0	0	0	5	0	5	0	0	-5	-5
	Uzbekistan	1	0	1	13	1	0	1	1	-12	1
W. Europe and others		**42302**	**24854**	**46532**	**9950**	**25381**	**1**	**6345**	**21678**	**15431**	**6344**
	Australia	854	359	939	227	512	0	128	580	285	128
	Austria	198	35	218	37	119	/	30	183	82	/
	Canada	1292	458	1421	490	775	0	194	963	285	194
	EU	13598	6528	14958	4591	8159	0	2040	8430	3568	2040
	Finland	89	46	98	34	53	/	13	52	19	/
	Iceland	1	0	1	1	1	0	1	1	-1	1
	Lichen stein	5	4	6	1	3	0	1	2	2	1
	New Zealand	98	27	108	10	59	0	15	81	49	15

Table D10: Consumption of Methyl Chloroform (Annex B, Group III) (continued)

		base-89	1993	g1993-frz	1994	g94-50%	1996	g96-100%	g93-ach	g94-ach	G96-ach
	Norway	88	61	97	35	53	0	13	36	18	13
	Sweden	134	65	147	73	80	/	20	82	7	/
	Switzerland	348	142	383	75	209	0	52	241	134	52
	U.S.A	25597	17129	28157	4376	15358	1	3840	11028	10982	3839
ARTICLE 5 Parties		**4729**	**4180**		**3472**		**2376**				
Africa		110	60		70		66				
Asia		3064	2924		2308		1995				
E. Europe		213	172		137		23				
Latin America and the Caribbean		1339	1021		955		292				
W. Europe		3	3		2		0				

Note:
Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each Substance in the Group.

Source: : Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D11: Production of HCFCs (Annex C, Group I)

		base-89	1996
TOTAL		**13,779**	**29,621**
Non-Article 5 Parties		**12,409**	**27,285**
Africa		**0**	**0**
	South Africa	0	0
Asia		**1,639**	**4,428**
	Japan	1,639	4,428
E. Europe		**437**	**74**
	Russian F.	437	74
W. Europe and others		**10,333**	**22,783**
	Australia	132	0
	Canada	246	65
	France	792	5,673
	Germany	511	794
	Greece	75	440
	Italy	337	799
	Netherlands	514	975
	Spain	482	249
	U.K.	679	1,245
	U.S.A	6,565	12,543
Article 5 Parties		**1,370**	**2,336**
Asia		871	1,831
Latin America & the Caribbean		499	505

Notes:
Montreal Protocol limits only on consumption.
Ozone Depleting Potential tons are calculated by multiplying actual tons with the Ozone Depleting Potential of each Substance in the Group.

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) - 1986-1996.

Table D12: Consumption of HCFCs (Annex C, Group I)

		1989	1996	Base-89	g96-frz	g96-ach
TOTAL		**13518**	**29387**			
Non-Article 5 Parties		**11357**	**24594**	**36378**	**36378**	**11784**
Africa		89	195	387	388	192
	South Africa	89	195	387	388	192
Asia		**1660**	**4294**	**5893**	**5893**	**1599**
	Israel	201	129	329	329	200
	Japan	1459	4164	5564	5564	1400
	Turkmenistan	/	1			/
E. Europe		**610**	**195**	**4490**	**4490**	**4295**
	Azerbaijan	1	5	14	14	9
	Belarus	3	5	50	50	45
	Bulgaria	9	6	82	82	76
	Czech R.	2	6	156	156	150
	Hungary	0	68	136	136	68
	Latvia	5	4	138	138	134
	Lithuania	1	3	156	156	153
	Poland	5	/	145	145	/
	Russian F.	537	73	3316	3316	3243
	Slovakia	3	2	58	58	56
	Ukraine	38	21	165	165	144
	Uzbekistan	6	2	75	75	73
W. Europe and others		**8998**	**19910**	**25608**	**25608**	**5698**
	Australia	148	216	548	548	332
	Austria	18	/	182	182	/
	Canada	365	744	893	893	149
	EU	1901	7431	8229	8229	798
	Finland	20	/	73	73	/
	Iceland	5	8	9	9	1
	Monaco	0	0	0	0	0
	New Zealand	23	39	56	56	17
	Norway	51	62	76	76	14
	Sweden	86	/	157	157	/
	Switzerland	18	40	131	131	91
	U.S.A	6363	11370	15254	15254	3884
Article 5 Parties		**2161**	**4793**			
Africa		43	158			
Asia		1574	3620			
E. Europe		37	23			
L. America & the Caribbean		506	987			
W. Europe		1	5			

Note: ODP tons are calculated by multiplying actual tons with the ODP of each substance.

Source: Report of the Secretariat on Data: Production and Consumption of ODSs - 1986-96.

Table D13: Production of Methyl Bromide (Annex E, Group I)

		base-91	1995	g95-frz	1996	g95-ach
TOTAL		**37,575**	**35,064**		**36,747**	
Non-Article 5 Parties		**37,501**	**34,872**	**41,251**	**36,076**	**6,379**
Asia		**18,076**	**17,690**	**19,884**	**17,216**	**2,194**
	Israel	14,700	14,528	16,170	14,207	1,642
	Japan	3,376	3,162	3,714	3,009	552
E. Europe		**0**	**841**	**0**	**0**	**-841**
	Ukraine	0	841	0	0	-841
W. Europe and others		**19,425**	**16,341**	**21,368**	**18,860**	**5,027**
	France	2,517	1,976	2,769	2,740	793
	U.S.A	16,908	14,365	18,599	16,120	4,234
Article 5 Parties		**74**	**192**		**671**	
Asia		74	171		660	
E. Europe		/	21		11	

Note: ODP tons are calculated by multiplying actual tons with the ODP of each substance.

Source: Report of the Secretariat on Data: Production and Consumption of ODSs - 1986-96.

Table D14: Consumption of Methyl Bromide (Annex E, Group I)

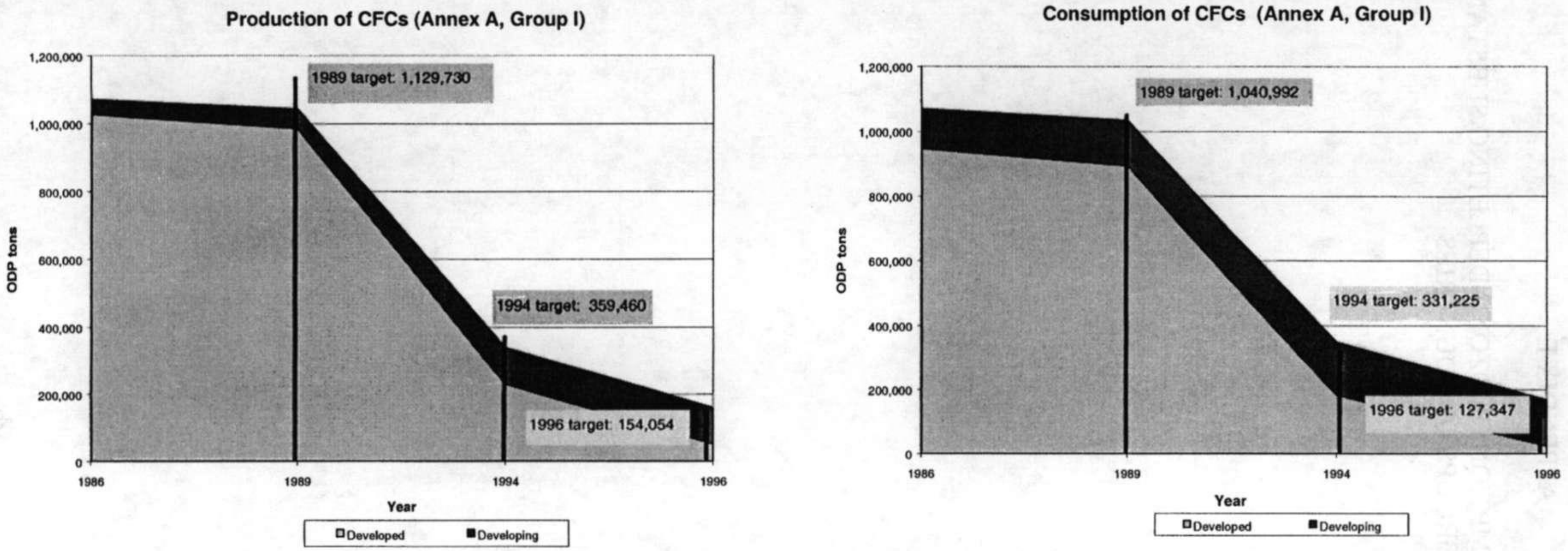
		base-91	1995	g95-frz	1996	g95-ach
TOTAL		**35,664**	**37,177**		**35,513**	
Non-Article 5 Parties		**32,191**	**29,625**	**35,410**	**28,331**	**5,785**
Africa		**759**	**604**	**835**	**604**	**231**
	South Africa	759	604	835	604	231
Asia		**3,664**	**3,583**	**4,030**	**3,157**	**447**
	Israel	0	0	0	0	0
	Japan	3,664	3,583	4,030	3,157	447
E. Europe		**215**	**1,928**	**237**	**207**	**-1,692**
	Azerbaijan	3	/	3	0	/
	Belarus	0	15	0	37	-15
	Bulgaria	0	7	0	0	-7
	Czech R.	6	11	7	0	-4
	Hungary	32	32	35	32	3
	Latvia	15	12	17	15	5
	Lithuania	33	31	36	27	5
	Poland	120	/	132	/	/
	Russian F.	0	1,430	0	96	-1,430
	Slovakia	6	0	7	/	7
	Ukraine	0	390	0	0	-390
W. Europe and others		**27,553**	**23,510**	**30,308**	**24,363**	**6,798**
	Australia	422	298	464	379	166
	Austria	2	/	2	/	/
	Canada	148	75	163	80	88
	EU	11,530	10,557	12,683	10,907	2,126
	Finland	5	/	6	/	/
	New Zealand	81	77	89	58	12
	Norway	6	5	7	6	2
	Sweden	16	/	18	/	/
	Switzerland	26	14	29	13	15
	U.S.A	15,317	12,484	16,849	12,920	4,365
Article 5 Parties		**3,473**	**7,552**		**7,182**	
Africa		1,037	1,975		1,657	
Asia		710	2,063		2,166	
E. Europe		126	50		61	
L. America & the Caribbean		1,576	3,427		3,275	
W. Europe		24	37		23	

Note: ODP tons are calculated by multiplying actual tons with the ODP of each Substance.

Source: Report of the Secretariat on Data: Production and Consumption of ODSs - 1986-96.

APPENDIX E

PRODUCTION AND CONSUMPTION OF OZONE-DEPLETING SUBSTANCES, BY GROUPS OF COUNTRIES

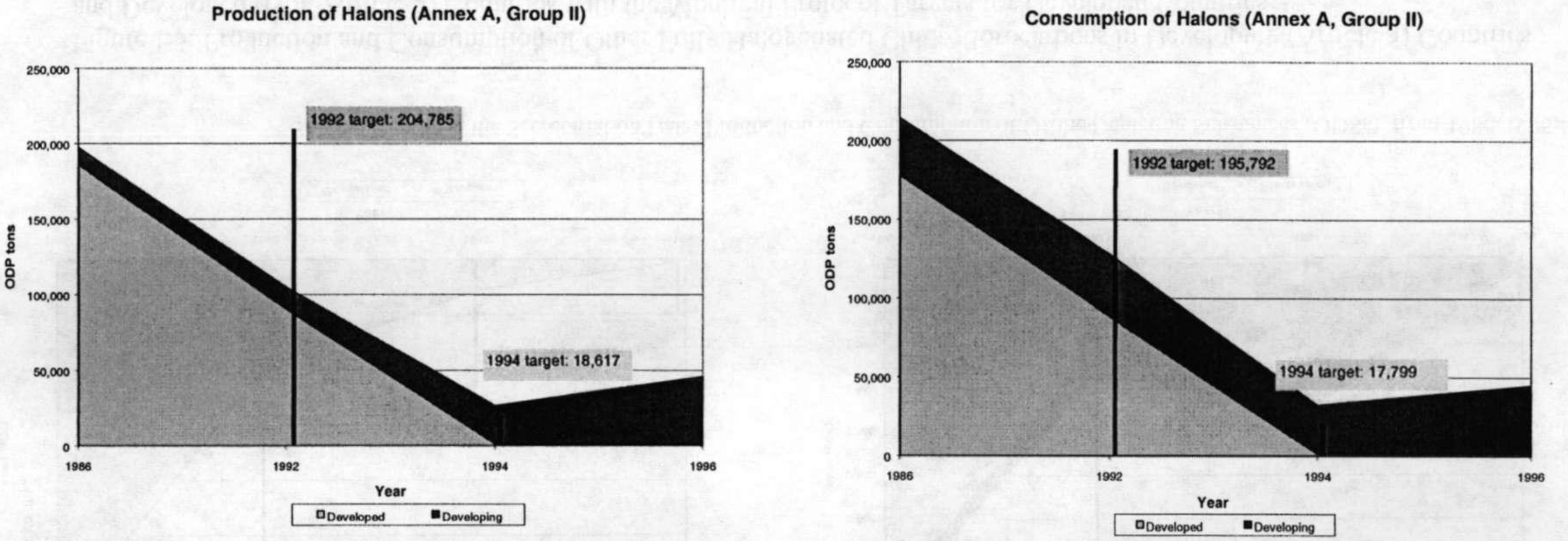


Production of CFCs (Annex A, Group I)

Consumption of CFCs (Annex A, Group I)

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E1: Production and Consumption of Chloroflorocarbons in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries

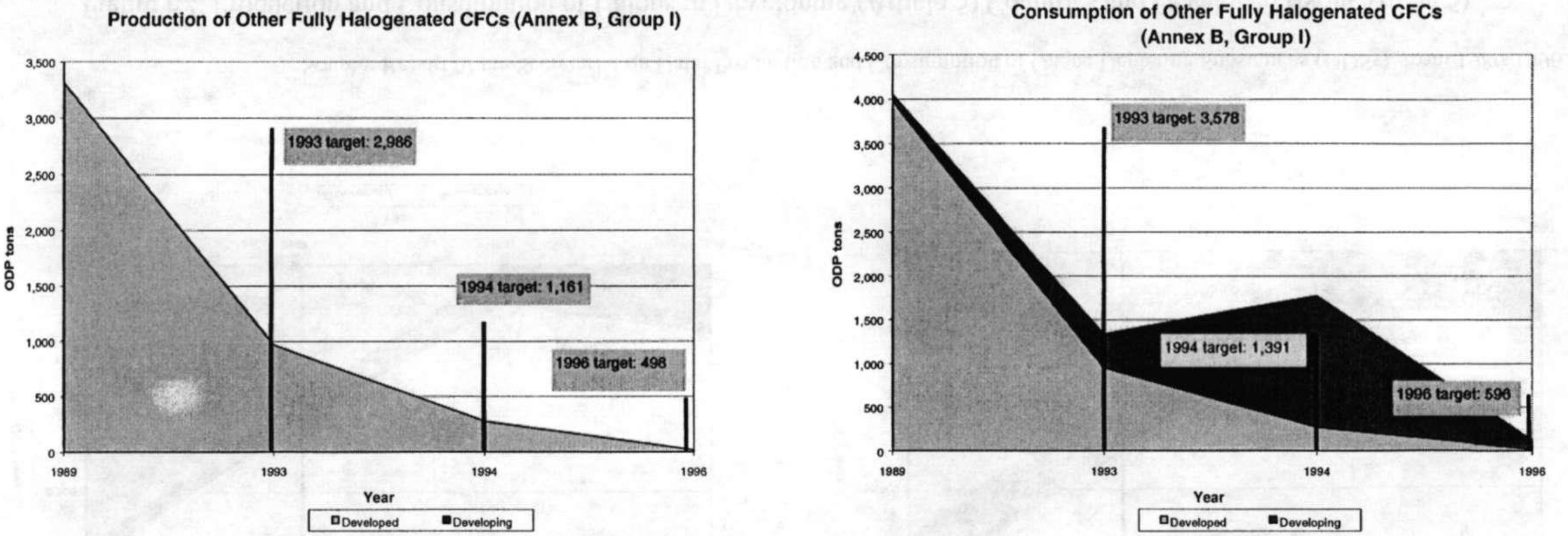


Production of Halons (Annex A, Group II)

Consumption of Halons (Annex A, Group II)

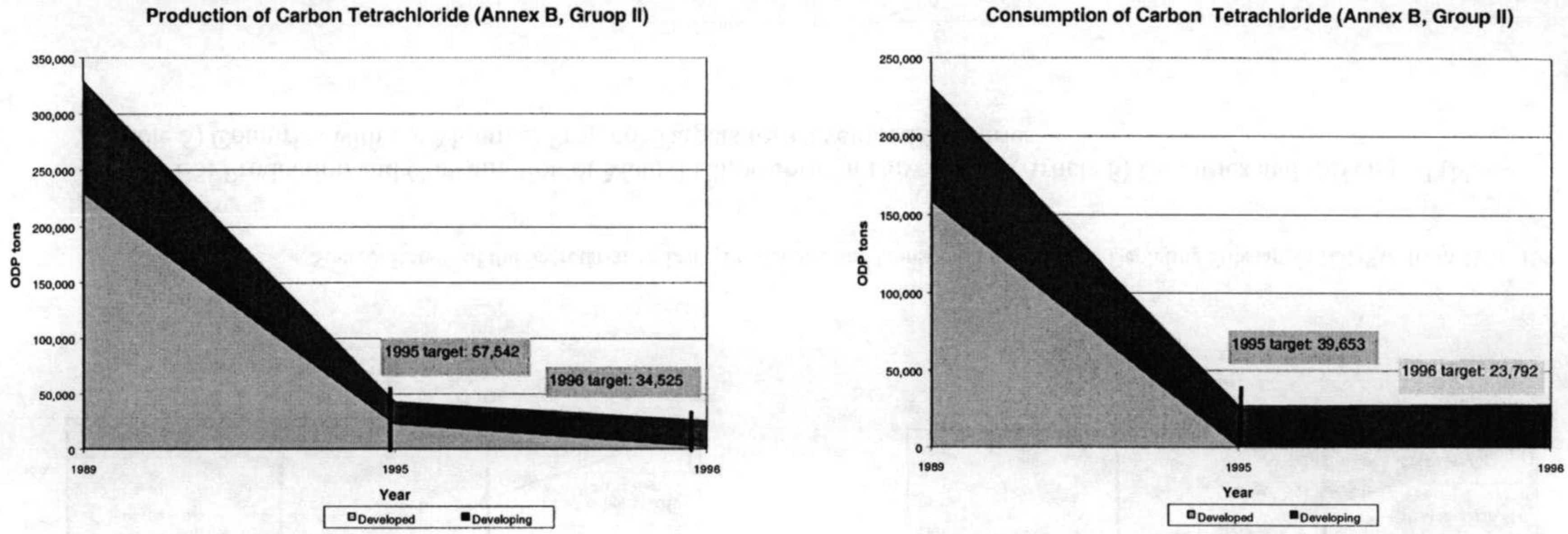
Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E2: Production and Consumption of Halons in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries



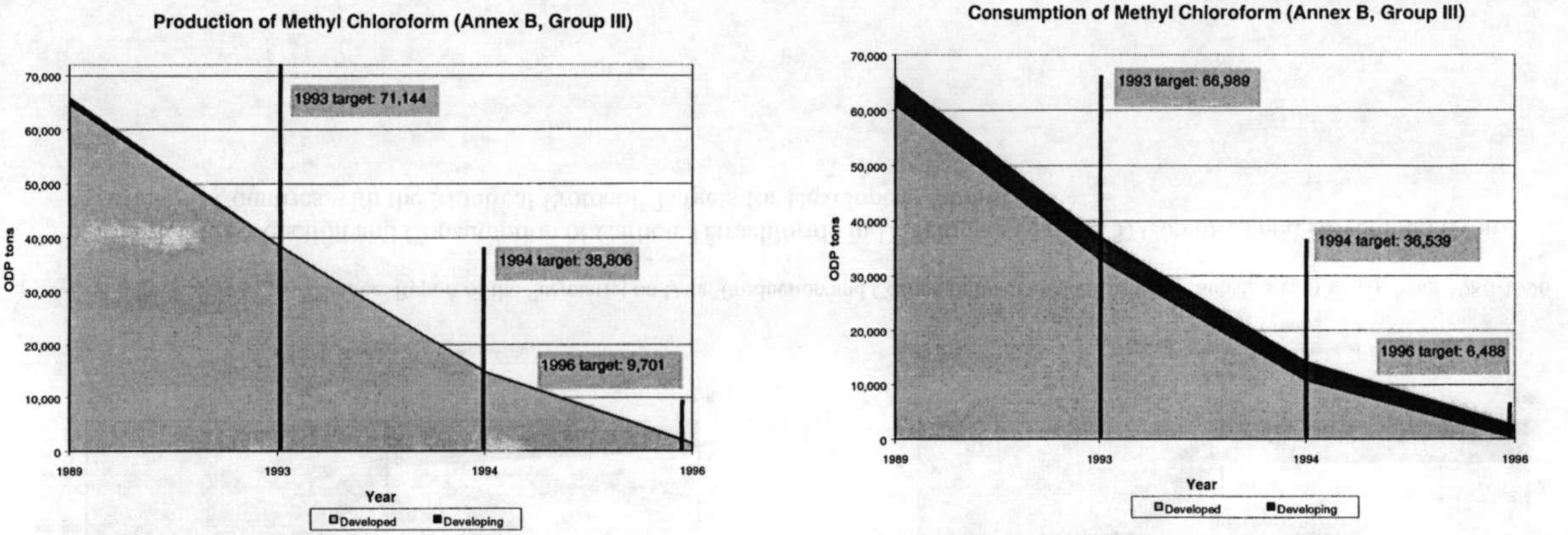
Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E3: Production and Consumption of Other Fully Halogenated Chloroflorocarbons in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries



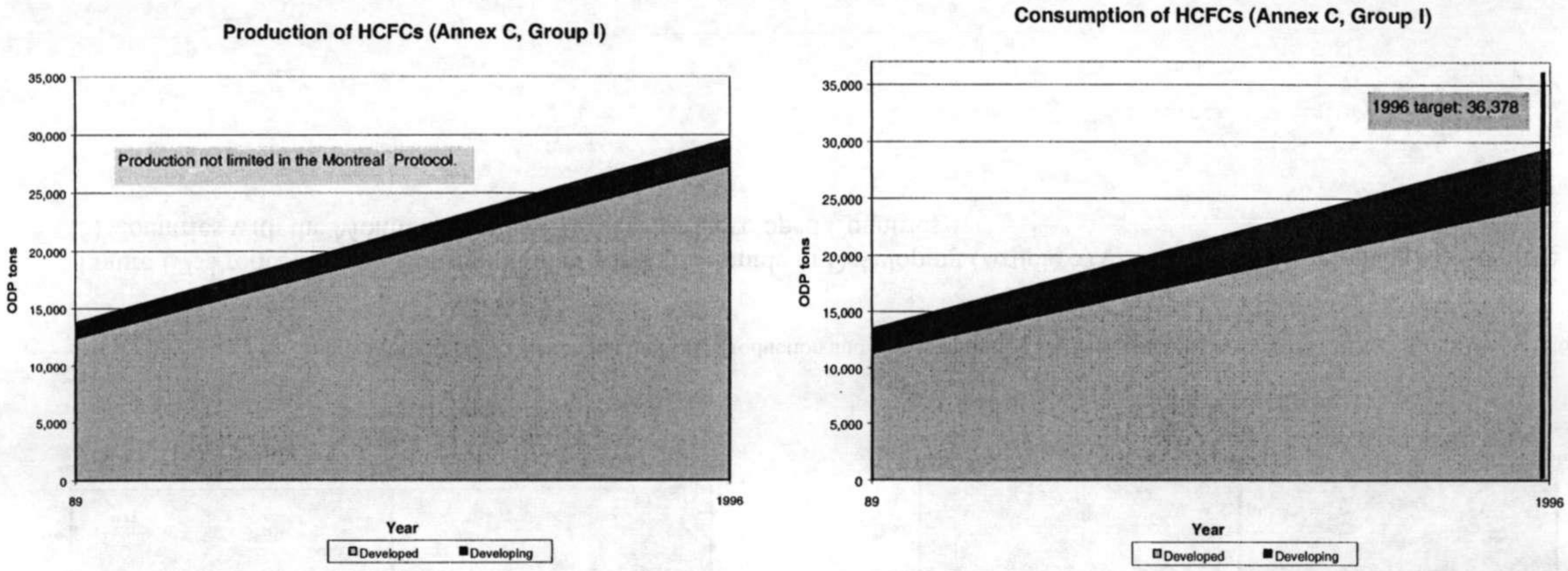
Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996

Figure E4: Production and Consumption of Carbon Tetrachloride in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries



Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E5: Production and Consumption of Methyl Chloroform in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries


Production of HCFCs (Annex C, Group I)

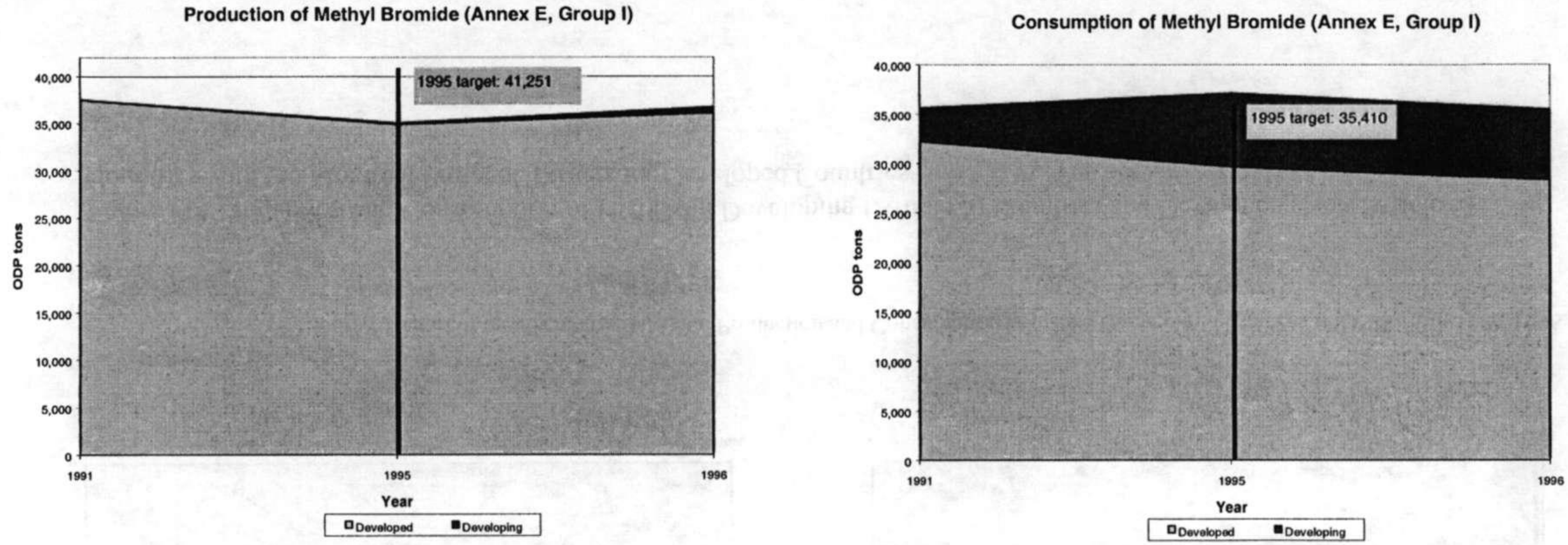
Production not limited in the Montreal Protocol.

Consumption of HCFCs (Annex C, Group I)

1996 target: 36,378

Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E6: Production and Consumption of HCFCs in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries

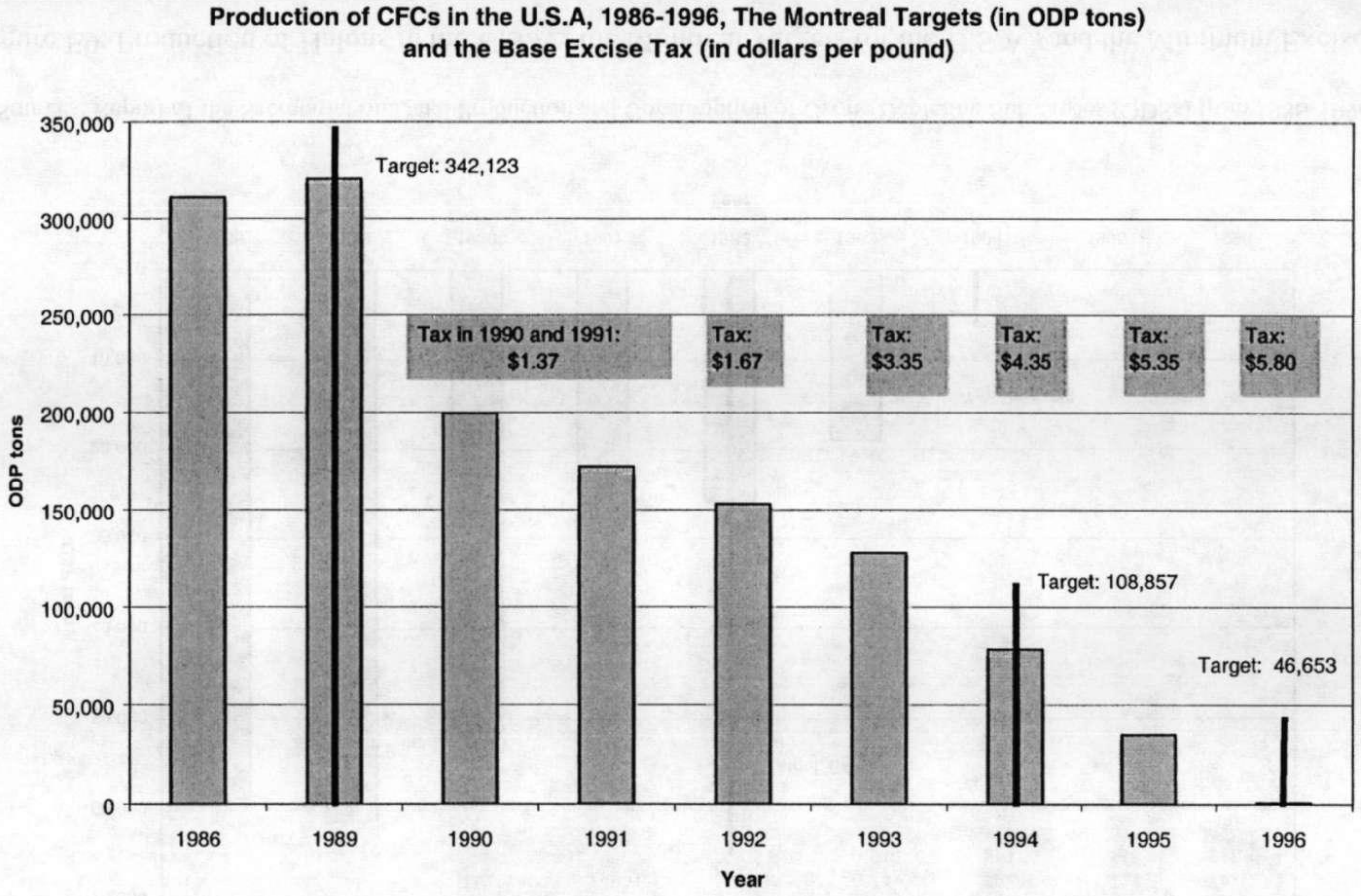


Production of Methyl Bromide (Annex E, Group I)

Consumption of Methyl Bromide (Annex E, Group I)

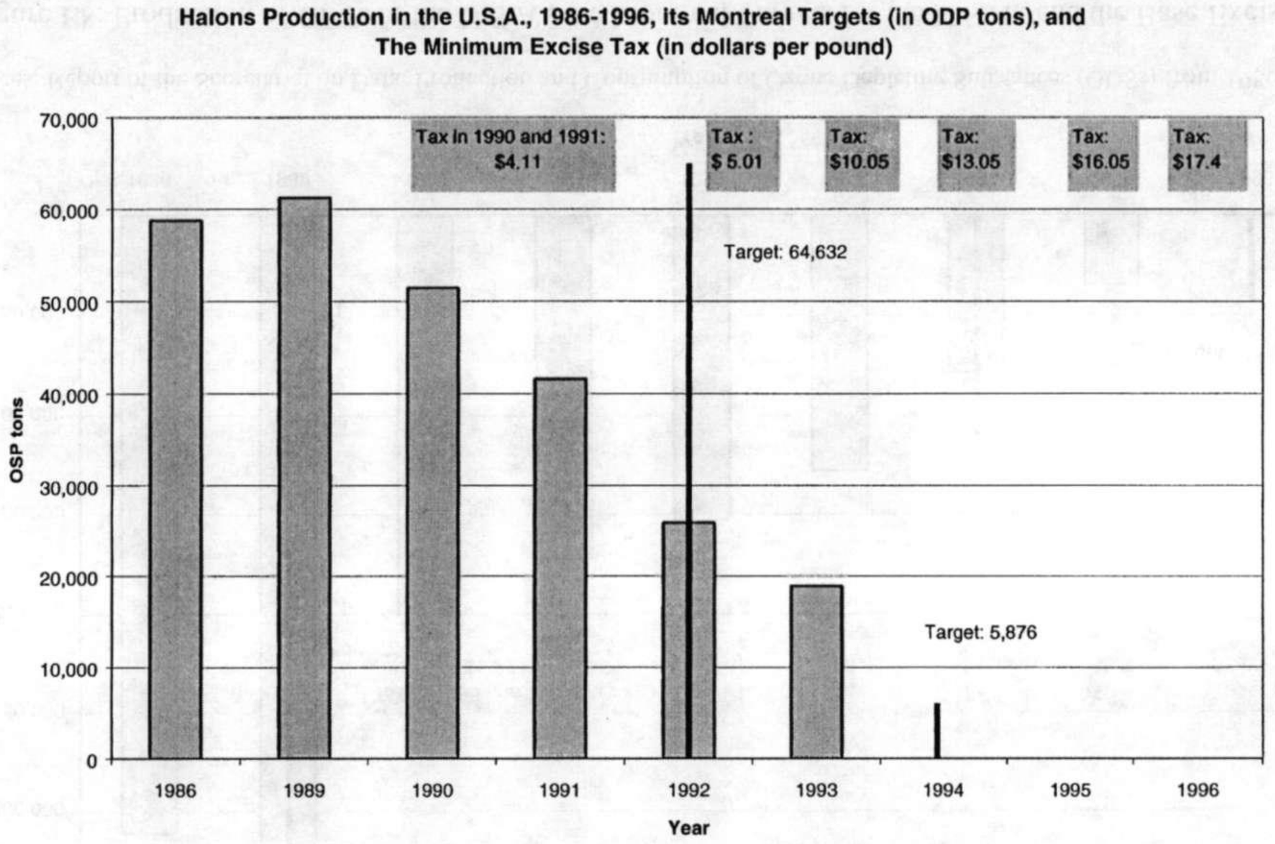
Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E7: Production and Consumption of Methyl Bromide in Developing (Article 5) Countries and Developed (Non-Article 5) Countries with the Montreal Protocol Targets for Developed Countries



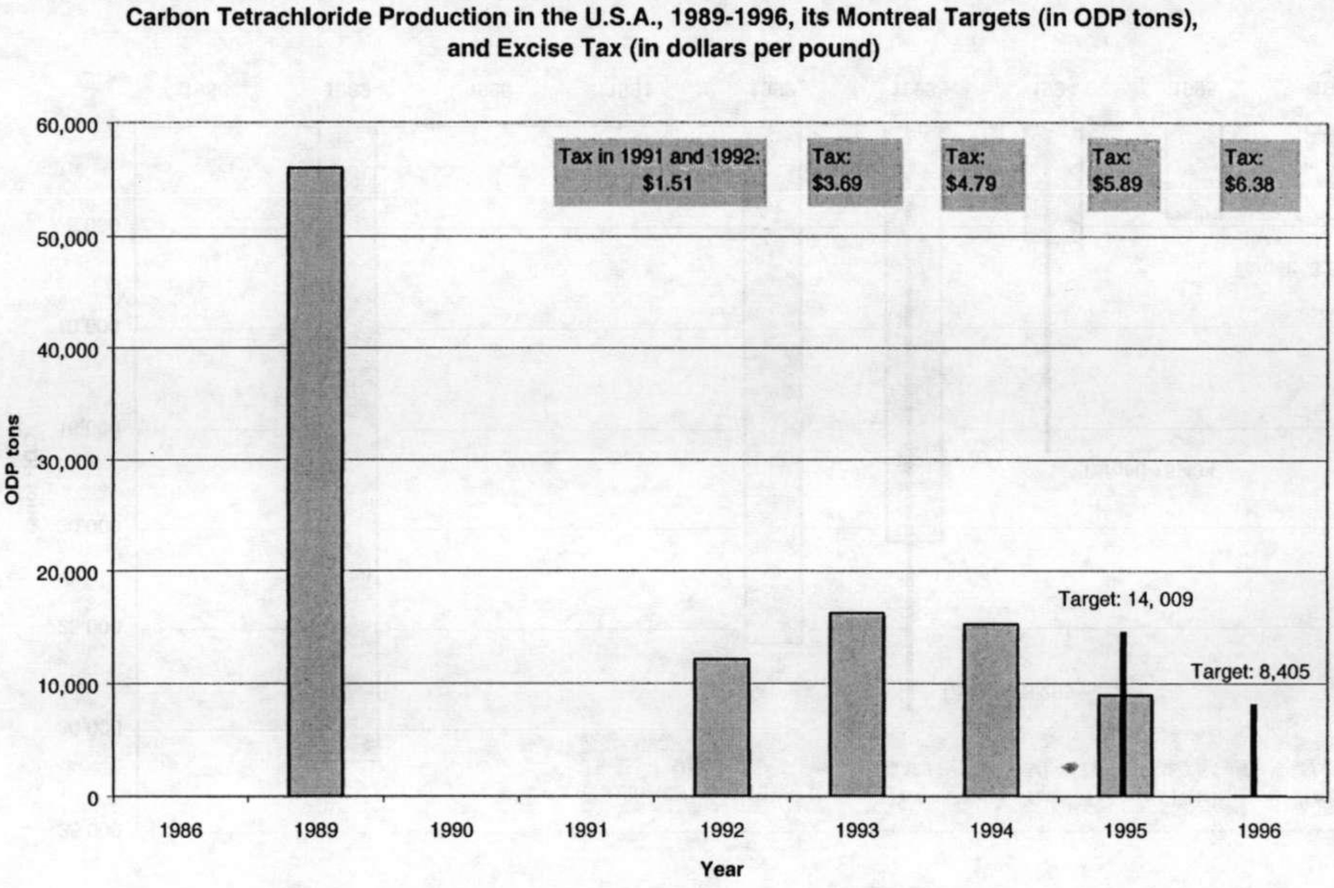
Sources: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996; Hoerner (1996).

Figure E8: Production of CFCs in the U.S.A., the Montreal Targets for the U.S.A., and the Base Excise Tax



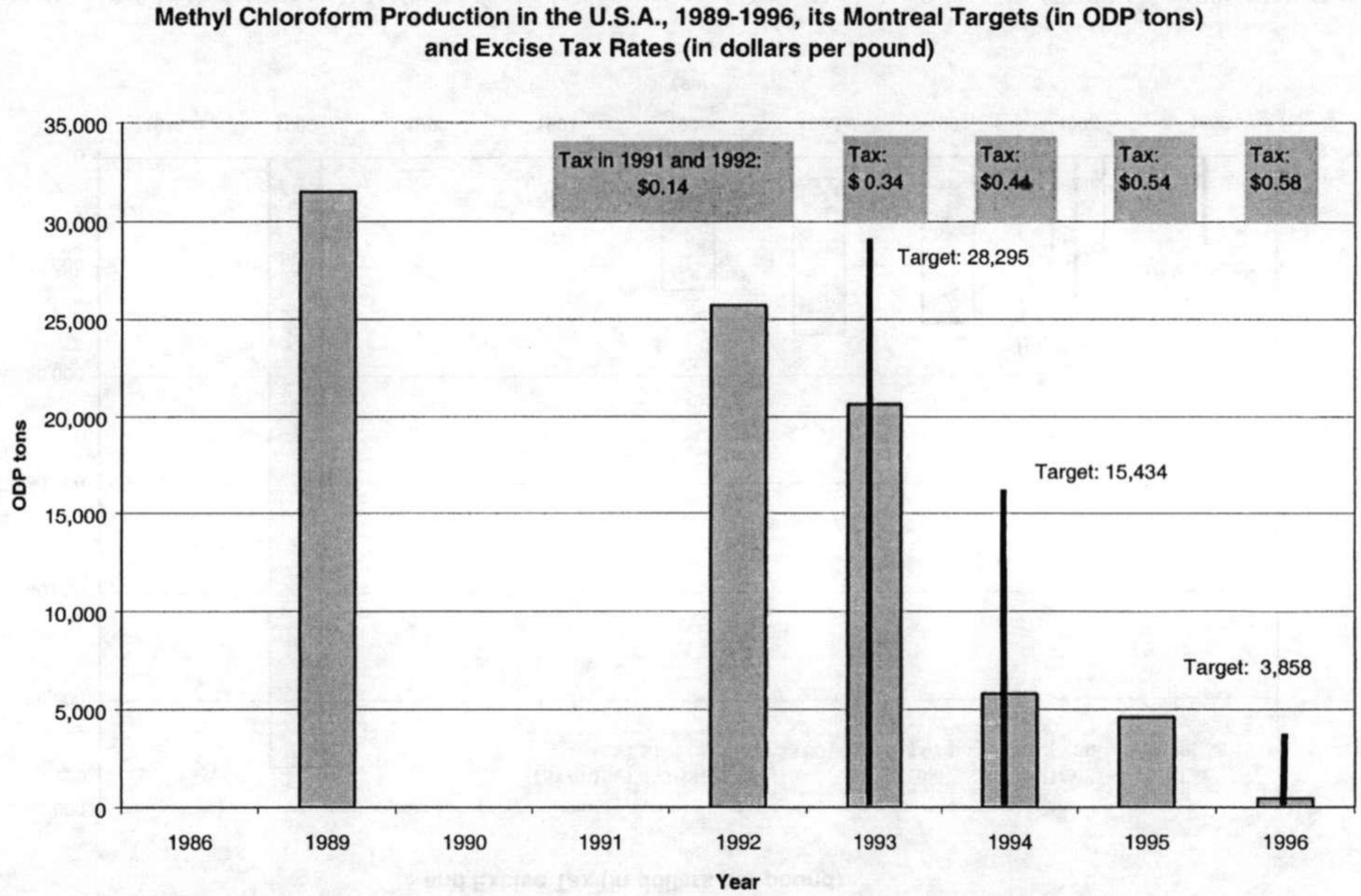
Sources: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996; Hoerner (1996).

Figure E9: Production of Halons in the U.S.A., the Montreal Targets for the U.S.A., and the Minimum Excise Tax



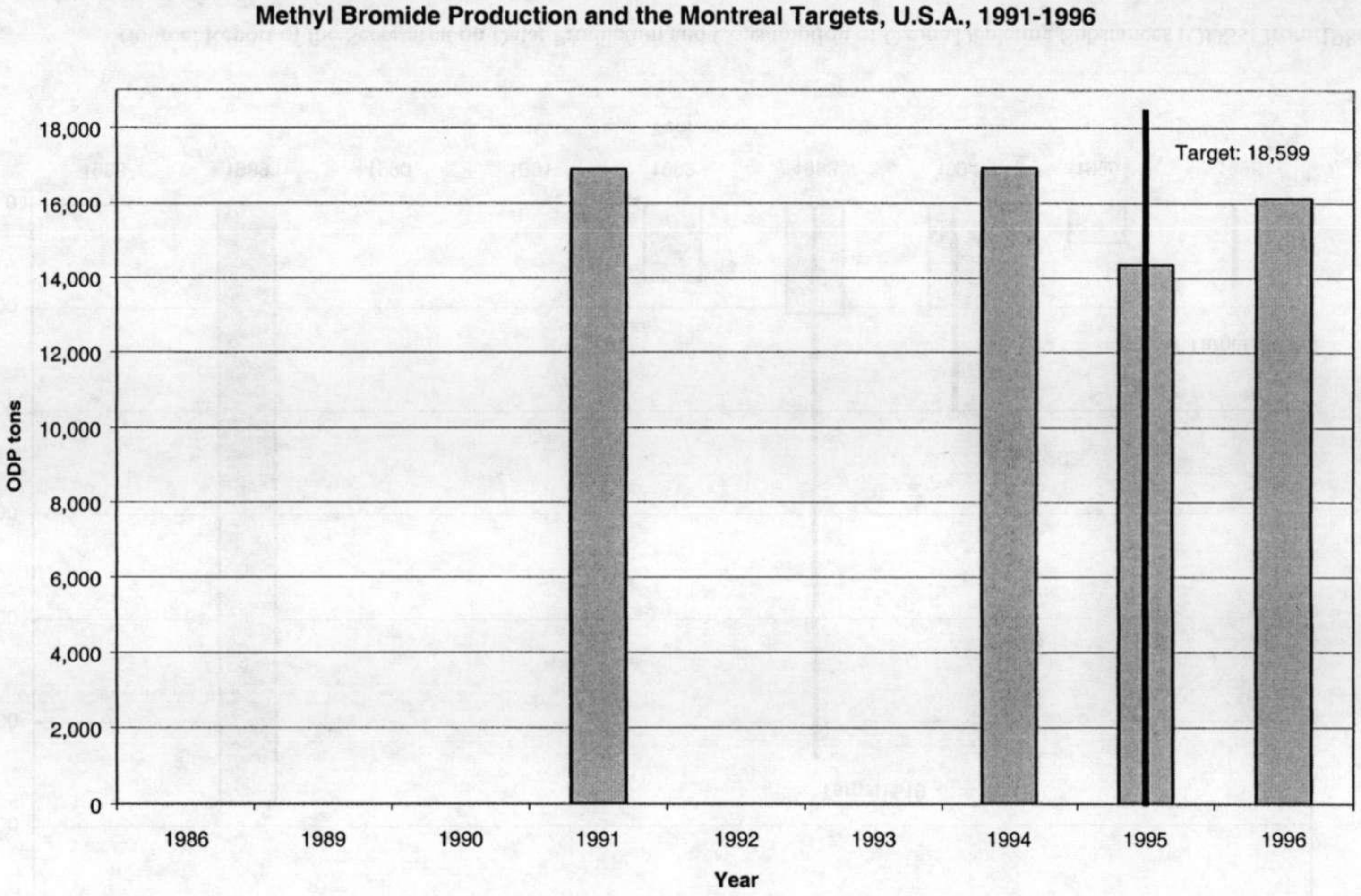
Sources: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996; Hoerner (1996).

Figure E10: Production of Carbon Tetrachloride in the U.S.A., the Montreal Targets for the U.S.A., and the Excise Tax



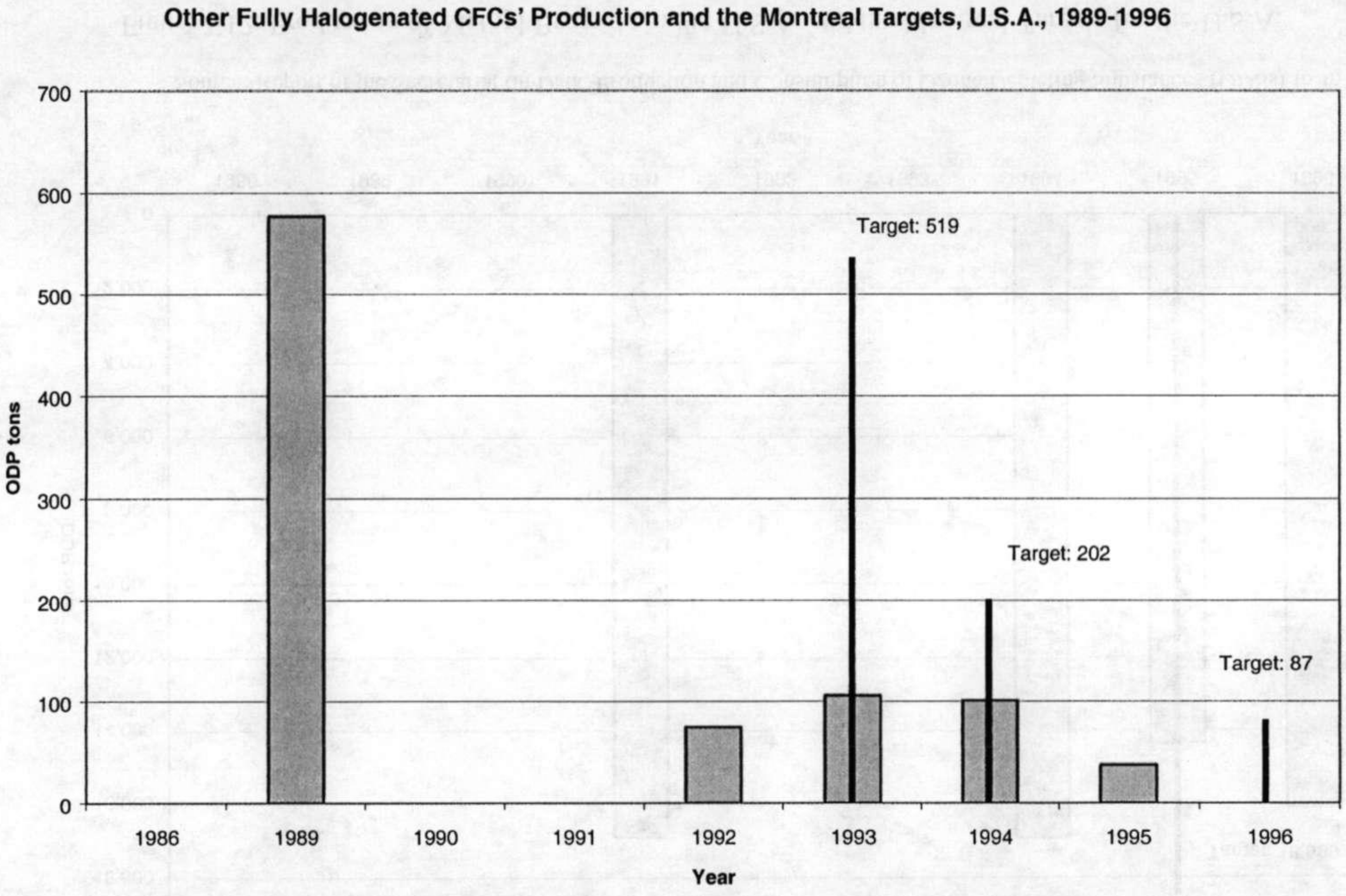
Sources: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996; Hoerner (1996).

Figure E11: Production of Methyl Chloroform in the U.S.A., the Montreal Targets for the U.S.A., and the Excise Tax



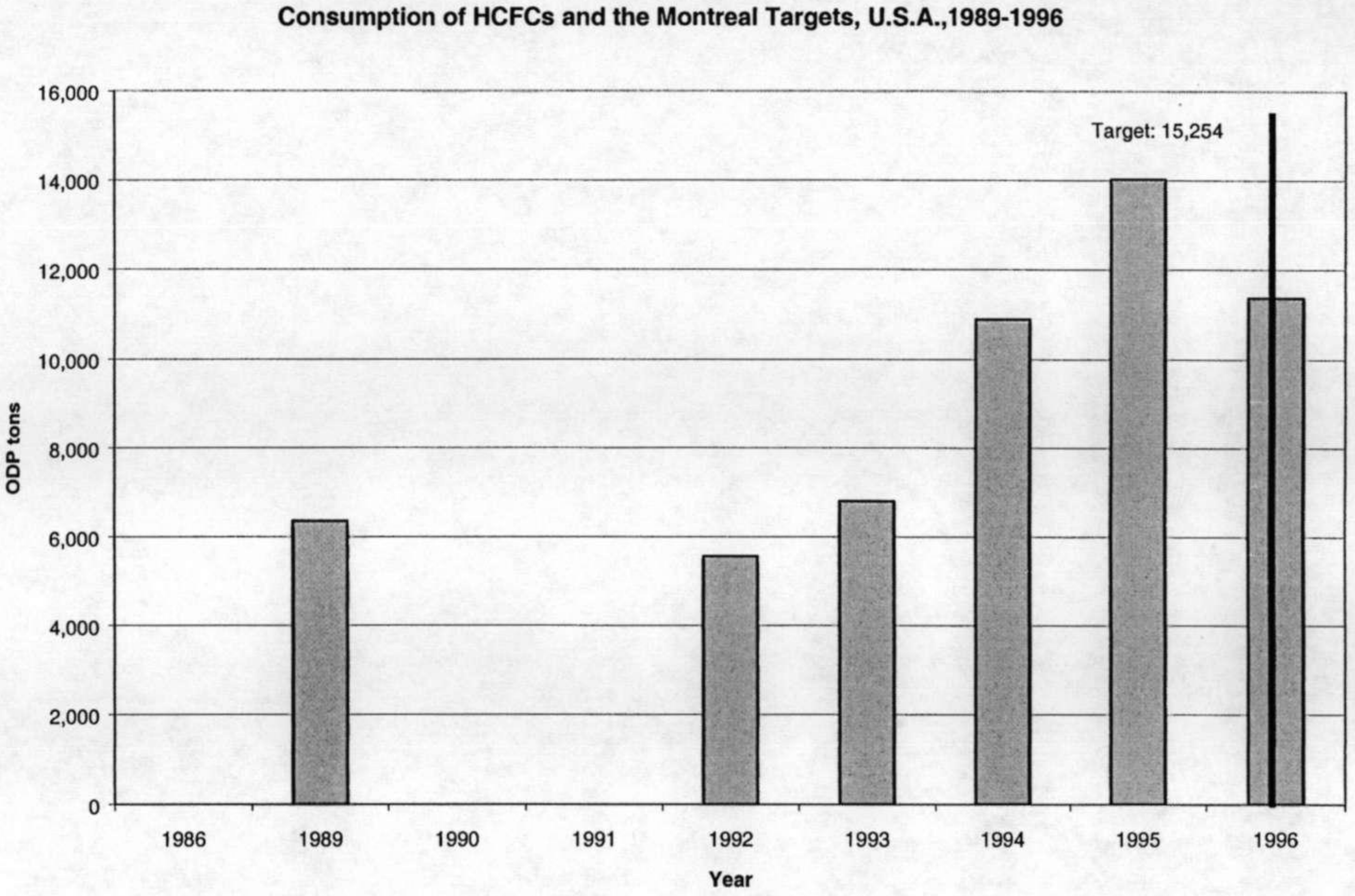
Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E12: Production of Methyl Bromide in the U.S.A. and the Montreal Targets for the U.S.A.



Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E13: Production of Other Fully Halogenated CFCs in the U.S.A. and the Montreal Targets for the U.S.A.



Source: Report of the Secretariat on Data: Production and Consumption of Ozone Depleting Substances (ODSs) from 1986-1996.

Figure E14: Consumption of HCFCs in the U.S.A. and the Montreal Targets for the U.S.A.

APPENDIX F

COUNTRIES' EMISSIONS OF CARBON DIOXIDE AND THEIR EMISSION-REDUCTION TARGETS

Table F1: Key Energy and CO2 Emissions Data for OECD Countries (1992)

	PES (10^6 tons of oil equivalent)	TPES/cap (toe/cap)	TPES/GDP (toe/1985 us$1000)	TFC (10^6 toe)	Energy related CO2 emissions (10^6 tons of CO2)	Energy related CO2/cap (tCO2/cap)	Energy related CO2/GDP (tCO2/1985 us$1000)
Australia	88.76	5.06	0.463	59.59	272.6	15.55	1.42
Austria	25.89	3.29	0.328	22.35	56.8	7.21	0.72
Belgium	51.90	5.17	0.542	36.97	118.6	11.82	1.24
Canada	216.25	7.88	0.545	163.40	443.3	16.16	1.12
Denmark	19.38	3.75	0.302	14.79	56.7	10.97	0.88
Finland	28.03	5.56	0.496	23.08	50.3	9.98	0.89
France	231.20	4.03	0.373	154.33	378.0	6.59	0.61
Germany	340.27	4.22	0.408	242.41	913.3	11.34	1.10
Greece	22.90	2.22	0.607	15.33	74.8	7.26	1.98
Iceland	1.30	4.99	0.397	1.08	2.2	8.42	0.67
Ireland	10.22	2.88	0.399	7.75	31.7	8.93	1.24
Italy	159.15	2.75	0.316	122.76	416.7	7.20	0.83
Japan	451.08	3.63	0.256	319.38	1099.3	8.84	0.62
Luxemburg	3.81	9.78	0.838	3.63	11.3	28.97	2.48
Netherlands	68.78	4.53	0.446	54.65	165.7	10.92	1.07
New Zealand	14.71	4.31	0.628	10.40	27.7	8.12	1.18
Norway	22.74	5.30	0.345	17.84	32.1	7.48	0.49
Portugal	17.84	1.81	0.668	13.39	46.6	4.73	1.75
Spain	94.17	2.41	0.443	64.83	235.8	6.03	1.11
Sweden	46.72	5.38	0.427	32.79	52.5	6.05	0.48
Switzerland	25.30	3.66	0.238	20.68	44.8	6.48	0.42
Turkey	55.53	0.94	0.730	43.69	143.9	2.45	1.89
UK	216.23	3.74	0.413	152.09	577.2	9.98	1.10
US	1984.12	7.78	0.427	1399.38	4917.1	19.28	1.06
OECD	4196.27	4.84	0.395	2996.57	10169.0	11.73	0.96
EU	1235.85	3.56	0.399	882.92	3026.4	8.72	0.98

Source: Climate Change Policy Initiatives, v. I, 1994: 26.

Table F2: Annex I Countries and Their Emission Reduction Commitments

Party	Emission Limits (percentage of base year or period)	Actual 1996 Emissions (percentage of base year or period)	Party	Emission Limits (percentage of base year or period)	Actual 1996 Emissions (percentage of base year or period)
Australia	108	115	Liechtenstein	92	/
Austria	92	103	Lithuania*	92	65
Belgium	92	109	Luxemburg	92	86
Bulgaria*	92	106	Monaco	92	/
Canada	94	100	Netherlands	92	112
Croatia*	95	110	New Zealand	100	126
Czech Republic*	92	89	Norway	101	141
Denmark	92	112	Poland*	94	105
Estonia*	92	77	Portugal	92	113
European Community	92	/	Romania*	92	98
Finland	92	116	Russian Federation*	100	81
France**	92	102	Slovakia*	92	92
Germany	92	88	Slovenia*	92	129
Greece	92	112	Spain	92	110
Hungary*	94	103	Sweden	92	112
Iceland	110	109	Switzerland	92	104
Ireland	92	117	Ukraine*	100	63
Italy	92	101	United Kingdom	92	99
Japan	94	109	United States	93	110
Latvia*	92	71			

Notes:* Estimated with 1992 as a base year.
** Percentage for Actual Emission Reductions Includes Monaco.

Sources: UN (1997), Annex B; Marland et al., (1999).

APPENDIX G

AN OVERVIEW OF MARKETABLE PERMIT SYSTEMS AND THEIR PERFORMANCE

Table G1: Overview of Marketable Permits Systems for CPRs and Their Performance

	Independent Variables					Outcome	
Marketable Permit System	CPR	Users	Regulated Users	Permits	Exchange Costs	Prevention of Resource Overuse	Market Liquidity
SO2 Allowances	High predictability stocks and flows, Regional extent Uniform effect	Moderate number Not cost-minimizers	Homogeneous group Opt-in Continuous monitoring Phased	Clearly defined, Fully exchangeable Not property rights Continuous monitoring Modest severity	Moderate	High	High
Lead Phasedown Program	High predictability Local once emitted Non-uniform	Moderate number Cost-minimizers	Homogeneous group Trading experience No-opt in Samples monitored	Clearly defined Not property right Severe limits Exchangeable in space, not in time	Low	High	High
RECLAIM	Moderate predictability Local extent Non-uniform	Large number Cost- minimizers	Not very homogeneous Opt-in Partially continuous monitoring	Clearly defined Exchange ratios (space) Exchangeable in time Modest severity	Moderate	Moderate	Moderate
CFC Production Quota Trading	Moderate predictability Global extent Uniform effect	Very small number Cost minimizers	Very small number Homogenous group No opt-in Phased Self-reporting	Clearly defined Substance specific Exchange ratios High value Severe limits of resource use	Low	Moderate	Moderate
Early EPA Emission Trading	Moderate predictability Local Extent Non-uniform	Large number Cost-minimizers	Large number Not very homogeneous Opt-in	Case-by-case definition Exchange ratios High severity	High	Moderate	Modest
Wetlands Mitigation Banking	Moderate predictability Watershed extent Non-uniform	Large number Cost-minimizers	Heterogeneous group No trading experience Many exceptions Opt-in is the only source of supply	Case-by-case definition Case-by-case exchange Property .rights status	High	Moderate	Modest

Table G2: Overview of Potential Carbon Dioxide Marketable Permits Systems and Their Estimated Performance

Potential Market Designs	Independent Variables				Outcome		
	CPR	Users	Regulated Users	Permits	Exchange Costs	Prevention of Resource Overuse	Market Liquidity
Industry Model National level No Sequestration	High measurability High predictability Global extent Uniform effect	Large number Some cost-minimizer	Moderate number Some trading experience	Clearly defined Fully exchangeable Moderate severity Opt in within industry Monitoring difficult	Moderate	Moderate	Moderate
Fuel Model National Level No sequestration	High measurability High predictability Global extent Uniform effect	Large number Cost-minimizers	Small number Previous trading experience	Clearly defined Fully exchangeable Moderate severity Opt-in within industry Monitoring easy	Low	High	High
Fuel Model Sequestration as Opt-in	Low measurability Low predictability Global extent Uniform effect	Large number Cost-minimizers (not public owners)	Large number No trading experience	Clearly defined Opt-in on case-by case basis Exchange ratios for opt-in projects Opt-in difficult to monitor	High	Moderate	Moderate

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