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Tradable Permits in Developing Countries

Evidence from Air Pollution in Santiago, Chile

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Tradable Permits in Developing Countries: Evidence from Air Pollution in Santiago, Chile

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Abstract

Santiago was one of the first cities outside the OECD to implement a tradable permit program to control air pollution. This paper looks closely at the program's performance over the past ten years, stressing its similarities and discrepancies with trading programs implemented in developed countries, and analyzing how it has reacted to regulatory adjustments and market shocks. Studying Santiago's experience allows us to discuss the drawbacks and advantages of applying tradable permits in less developed countries.

Key Words: Air pollution, environmental policy, tradable permits, developing countries

JEL Classification: Q53, Q58

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Introduction

Policymakers have paid increasing attention to market-based policy instruments over the last decades. Tradable emission permits have been at the center of this discussion due to the theoretical promise of cost-effectiveness and because they have been used successfully in the United States to reduce sulphur dioxide (SO_2) and nitrogen oxides (NOx). However, it remains an open question whether tradable permits are appropriate for use in transition and developing economies when they lack institutions and expertise with market-based policies. There are also many crucial design issues for the permit schemes as well as several competing instruments, such as environmental taxes.

Those arguing in favor of market-based instruments emphasize that they are efficient instruments that relax the trade-off between economic growth and improved environmental quality, and that they can be achieved without specific knowledge of the technology or pollution-reduction costs of polluting sources. On the other hand, those opposed to the use of tradable permit programs in developing countries emphasize the lack of transparency and monitoring possibilities, the inadequate legal systems, and, foremost, the difficulties involved in creating a functioning market observed in less developed countries (see Bell and Russell 2002; Bell 2004). However, pervasive constraints would affect the performance of *any instrument*, including both economic policies and command-and-control policies (Ellerman 2002), although the implementation of more sophisticated policy instruments, as tradable emission permits, might require the decision maker to implement some particular institutional changes. For that reason, some market advocates argue that emissions taxes would be more appropriate, since they imply a change to an

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effective economic incentive system and raise revenue for environmental projects and programs (see Eskeland et al. 1992; Krupnick 1997; and Blackman and Harrington 2000). Finally, advocates of trading approaches argue that, as countries develop and as economies and political systems become more willing to impose real environmental requirements, trading programs will become more adequate. Thus, the important point is to start developing the institutions to build over the coming years now (see Krueger 2003).

Many donors and advisors have promoted the use of market-based instruments as the key to more effective environmental protection in the developing world (see O'Connor 1998). However, there has been rather limited experimentation with tradable permits in less developed countries, although efforts have been made in some transitional countries, such as Poland, Kazakhstan, the Czech Republic, and the Slovak Republic, to implement emission trading programs during the 1990s (see Zylicz 1995; Farrow 1999; Hauff and Missfeldt 2000; and Bell 2004) and raise academic and governmental interest in implementing emissions trading in China (see Ellerman 2002). In all of these cases, the main concern has been related to the transition from pre-existing environmental regulations to tradable emissions permits and the monitoring and enforcement capabilities that would be required in order to ensure compliance.

Santiago was one of the first cities outside the Organization for Economic Cooperation and Development (OECD) to implement a tradable permit program. The program launched in 1997 to control emissions coming from stationary sources of pollution has been characterized by a combination of failures affecting the attractiveness of trading: over-allocation of permits, high transaction costs, lack of clear penalties for sources in violation, and several regulatory changes affecting the tenure over emission permits and hampering trade. The total amount of emission permits initially granted to incumbent sources has been decreased twice; the rate of offsetting has been raised twice while the program's rules have led many sources to lose their emission permits because trade is only allowed within a specified period of time and banking permits are not possible.

How has the emissions market reacted to these new regulations and conditions? Currently 46.3 percent of the initial allocation of permits are void and 38 percent of these voided permits have been lost because incumbent sources did not trade before the legal deadline.

Why did sources not trade before the legal deadline? For this paper, we analyzed the design and implementation issues limiting the development of the tradable permit market in

Santiago, as well as the challenges and advantages of applying tradable permits in less developed countries.

Previous studies evaluating the performance of the Santiago's trading program were done at early stages of its implementation. Montero et al. (2002) found that the grandfathering used to allocate emissions permits initially created economic incentives for incumbent sources to more readily declare their historic emissions in order to claim permits. O'Ryan et al. (2002) examined the impact of the introduction of natural gas in the applicability of the tradable permit program, concluding that this fuel increased the range of emissions potentially abated at a lower cost and reduced the efficiency gains from using a market-based instrument. Finally, Palacios and Chavez (2005) evaluated the performance of the program in terms of enforcement, concluding that the aggregate level of over-compliance coexisted with frequent violations of regulations by some of the sources. This paper goes more deeply into these issues using an updated database in order to analyze whether the program has improved over time and how it has reacted to regulatory adjustments and market shocks.

The paper is organized as follows. The next section reviews the main lessons from the international experience with tradable permit programs. The second section describes the tradable permit program applied in Santiago. Then, the design and implementation issues limiting the development of the market are analyzed. The fourth and final section reviews the lessons that can be learned from Santiago' experience and concludes.

1. The Use of Tradable Permit Programs in Developed Countries

Although the efficiency properties of tradable permit programs were discussed by some economists in the early 1970s (Dales 1968; and Montgomery 1972), it was not until the early 1980s that they started to be promoted in academia. The rise of interest occurred at the same time as when many of the basic environmental laws were being written in the United States. They were used to provide greater flexibility to firms charged with controlling air pollutant emissions (U.S. Environmental Protection Agency's [EPA] Emission Trading Programs), to phase out leaded gasoline and ozone-depleting chlorofluorocarbons (CFC) from the market and to reduce sulphur dioxides (SO_2) and nitrogen oxides (NOx) in the Los Angeles basin (RECLAIM). There was a gradual learning process concerning design issues that led to the launching of the successful U.S. tradable permit program to control acid rain by cutting nationwide emissions of SO_2.

Apart from the European Union's Emission Trading Scheme (EU ETS), the world's first large-scale CO_2 emissions trading program, few applications of tradable permits existed previously in Europe, since taxes and other instruments were used more frequently**.** The most important programs include the U.K. Emissions Trading Scheme (UK ETS), the Danish CO_2 trading program, the Dutch offset programs, and BP's internal experiment. On the other hand, very few applications have been implemented in transition or developing countries. Chile and Singapore were pioneers in this area, while some pilot programs were introduced in Poland during the 1990s.[1]

The experience with emissions trading over the past 27 years offers some lessons concerning the use of tradable permits in controlling pollution (see Hahn and Hester 1989; Hahn 1989; Rico 1995; Stavins 1998; Schmalensee et al. 1998; Salomon 1999; Tietenberg 1999; Ellerman 2000; Stavins 2001; Boemare and Quirion 2002; Burtraw and Palmer 2003; Ellerman 2005; Victor and House 2006; Ellerman and Buchner 2007; and Convery and Redmont 2007). The first lesson concerns the functionality of emission trading as a regulatory instrument, while the second lesson concerns the features that make trading programs more efficient.

Regarding the first lesson, the overall experience with emissions trading is that it can work. To date, targeted emissions-reductions have been achieved and exceeded. Total abatement costs have been significantly less than what they would have been in the absence of trading. Recent studies indicate that benefits exceed costs by a significant margin (see Burtraw and Palmer 2003; and Chestnut et al. 2005), while trading volume has increased over time with a significant fraction of allowance transfers among economically unrelated parties.

As regards the second lesson, there are several features that are important for emissions trading to work. The most fundamental is that the rights to the environmental service or resource in question be allocated in a manner that creates some permanence and confidence. Additional features are realistic incentives to trade, spatial and temporal flexibility, inclusion of the private sector to fulfill brokerage needs, monitoring and

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[1] In 1991, the first pilot project of emissions trading was carried out in Chorzow as an experiment following an agreement between the minister of environment and regional authorities. The project let several polluters in one of the most contaminated neighborhoods jointly comply with individual emissions standards. Despite profound legal problems and a turbulent political environment against the policy, it led to a radical decrease of pollution and significant savings (see Zylicz 1995). There are also a large number of programs in various countries with tradable fishing quotas that have quite a few similarities to the programs we discuss here.

enforcement, and the allocation of allowances. (See appendix 1 for a comparison of selected features of emissions trading programs implemented to date.)

The right to trade must be clearly defined and not subject to case-by-case approval. Ellerman (2005) distinguished between the incentives to trade provided by the three types of emissions trading: credit-based, allowance-based, and averaging-based trading. In credit-based trading, credits can be created by reducing one source's emissions more than required by some pre-specified standard and transferring the credit to another source, which is thereby allowed to increase emissions above the standard. Although sources can propose trades, the final decision to create the credits and make the transfers rests with the regulator. On the other hand, in allowance-based trading, rights to emit are created initially and distributed to sources, and there is no presumption that individual sources will limit emissions to the number of allowances they receive. They are free to trade allowances and the only requirement is that allowances equal emissions at the end of every compliance period. Averaging-based trading presumes a pre-specified standard of which emissions are traded, but subsequent trades between sources are not confined by regulatory approval.

In practice, credit-based trading has not worked well because of the high transaction costs associated with the creation and transfer of credits. The process of getting regulatory approval limited trading in the early EPA programs because of the uncertainty involved in getting individual trades. Quite the opposite, trading observed in allowance-based (such as RECLAIM and the Acid Rain Program) and averaging-based programs (such as the Lead Phase-Out) has been much greater.

If environmental damages do not depend on localization of emissions and monitoring costs are not disproportionate, trading program should include as many sources as possible. First, the larger the number of participants, then the larger the abatement cost differences among firms and the larger the benefits of trading. Second, a greater number of sources reduces the risk of market power in the permit market. Flexibility allows for a broader set of compliance alternatives to be considered in terms of timing and spatial coverage. All of the U.S. emissions trading programs, except RECLAIM, have included inter-temporal trading or "banking." Banking provides important flexibility for sources to undertake early reductions to accumulate allowances that can be used to ease compliance in the future, dampening the volatility of permit prices since it accommodates dynamic market changes and allows for shifts in industry structure with constant total emissions. According to Ellerman (2005), the Acid Rain Program, which has the greatest flexibility since it allows nationwide spatial trading and unlimited banking, has experienced price fluctuations of no more than 3:1 when measured as the ratio of the highest observed price to the lowest.

By contrast, RECLAIM is the most restricted program in the scope of spatial trading: it does not allow for banking and has experienced price fluctuations of 60:1.

It is clear that high transaction costs lower the effectiveness of tradable permits significantly. Transaction costs include the costs of finding an appropriate trading partner, establishing the terms of trade, and completing the arrangements. The inclusion of the private sector to fulfill brokerage needs reduces these costs, which increases the economic incentives to trade. According to Tietenberg (1999), most observers of the early EPA emissions trading programs agree that fewer trades took place than necessary to achieve full cost-effectiveness and that high transactions costs played a role in explaining this shortcoming. Anecdotal evidence can be found in the predominance of intra-firm (within firms) transactions over inter-firm (between firms) transactions. Further evidence is suggested by the role played by some states in developing programs to assist firms in finding partners and minimizing administrative costs (see Harrison 1999).

Kerr et al. (1998) found evidence that transaction costs prevented trading in lead phase-out programs because of under-developed brokerage and trading mechanisms. They estimated that the loss of cost effectiveness from these costs was 10–20 percent and quite dependent on the characteristics of traders and the market (which increased when potential traders were small, unsophisticated, and poorly integrated). Gangadharan (2000) also found evidence for the existence of transaction costs during the initial years of the RECLAIM program. According to her, the absence of brokers increased the costs of finding a trading partner—in addition to the high information costs of entering the market—and reduced the probability of trading by about 32 percent. The author also found specific “learning by doing” effects in the permits market. The results suggested that increasing the number of times a facility enters the market reduces information costs until a certain point (15 trades) is reached. After that point, further increases in the number of trades seems to have no effect in reducing information costs further.

The Acid Rain Program was consciously designed to minimize transaction costs. Rights were allocated according to principles that were quite transparent and remained constant for a long period. The auction market established as part of the sulfur allowance program reduced transaction costs by providing an easy means for buyers and sellers to transact, but also by providing systematic public information on prices. This allowed private firms to offer a variety of trading services, such as private brokerages, electronic bid/ask bulletin boards, and permit-price forecasts. With this available data, researchers were also able to isolate the effects on transaction costs. Conrad et al. (1996) confirmed that transaction costs did not significantly affect the trading and price of the SO_2 program.

Monitoring and enforcement are important design issues to be considered. Without them, trading programs do not provide enough incentives for a high degree of compliance. Compliance requires matching emissions and permits and needs specific technology to measure and account for allowances permanently. On the other hand, enforcement of the programs depends not only on the technical ability to detect violations but also on the legal ability to deal with them, once detected, via effective sanctions.

Direct continuous monitoring of emissions has been an important factor in the success of the Acid Rain Program. Rigorous checks and balances ensure compliance, system credibility, and integrity. Every allowance is assigned a serial number; EPA records transfers make sure that a unit's emissions do not exceed the number of allowances it holds and makes this information available to the public.

Stranlund et al. (2002) analyzed the compliance incentives faced by firms under the Acid Rain Program and RECLAIM, stressing the importance of implementing fixed and automatic monetary penalties for emissions violations. While SO_2 abatement apparently achieved a perfect compliance record, compliance rates in the RECLAIM program have ranged between 85 percent and 95 percent. Non-compliance seems related to the uncertain value of monetary penalties, since under RECLAIM the stated monetary penalties are maximum administrative penalties and actual sanctions are decided on a case-by-case basis.

A key issue in any tradable permit program is the initial allocation of permits. Despite a common preference for auctioned permits among economists, grandfathering of incumbent emitters has been applied in virtually all applications to date to gain political consensus for implementing the program. Only in the Acid Rain Program, Singapore's CFC program, and EU ETS program have auctioning schemes been introduced. In the Acid Rain Program, a small portion of the permits are auctioned out to make up for market imperfections and/or to accommodate newcomers to the market. Singapore's CFC auction of half its permits enables the government to appropriate a sizeable share of the scarcity rents, which is used to subsidize recycling services and the diffusion of information on alternative technologies. Finally, in the EU ETS program, member states are allowed to auction up to 5 percent of their allowance in the first trading period and up to 10 percent in the second period, but few countries make much use of this option.

However, as shown by Sterner and Müller (2008), the incentives provided by free allocation schemes depend very much on the permit allocation rules, and any rule where the firms can affect allocation (even indirectly in the future) will distort incentives and program efficiency. This was the case in the lead program, for example, where each refinery was allowed to average concentrations across the gallons it produced. The refineries and other agents thus gained more rights by selling more gasoline.

2. Santiago's Tradable Permit Program

In 1992, the Chilean environmental authority established a tradable permit program PROCEFF (Program for the Control of Fixed Substances)[2] for total suspended particles (TSP), trying to control the adverse effects produced by the excessive level of this pollutant in Santiago. Due to their easy identification and relative importance, the system focused on large boilers, which at the time accounted for more than 40 percent of total point-source emissions. Although the program became mandatory in 1994, it became active in 1997, giving the environmental authority two years to collect information on sources' emissions.

The environmental law regarding the tradable permit program rests mainly on two pieces of legislation: Supreme Decree 4 (passed in 1992) and Supreme Decree 16 (passed in 1998). SD 4 established an individual cap for the emissions of industrial and residential boilers discharging emissions through a duct or stack at flow rates higher than 1000 m^3/hour (large boilers) and a tradable permit program that let this type of source exceed the cap through offsets from other large boilers. For that purpose, it distinguished between existing and new large boilers. Existing boilers—those installed or approved before 1992—were endowed with emission permits called "initial daily emissions" (IDE). Each unit of IDE allows the holder to emit one kilogram of TSP daily. New large boilers—installed or approved after 1992—are required to fully offset their emissions through abatement in existing large boilers. Emissions parameters for new large boilers are known as "daily permitted emissions" (DPE) and have the same characteristics as IDE.

Since regulated sources were relatively small for the purpose of implementing sophisticated monitoring processes, the program was not designed on the basis of actual emissions but rather on a proxy variable equal to the maximum emissions that a source could emit in a given period of time. Thus, the daily cap on emissions of existing large boilers was calculated according to a formula that allowed them to emit a maximum given by the product of the maximum flow rate (m^3/hr) of the gas exiting the stack times 24 hours of operation times a target on emissions concentration equal to $56*10^{-6}(kg/m^3)$.

[2] PROCEFF is the government office responsible for implementing and enforcing the environmental regulations intended to control fixed sources emissions.

Table 1. Syntheses of PROCEFF's Main Regulatory Adjustments and Program Features

Affected sources	Industrial and residential boilers discharging emissions through a duct or stack at a flow rate higher than 1000 m^3/hour in Santiago
Covered pollutants	Suspended particulates (kg/day)
Permits allocation	Grandfathering: Existing large boilers installed or approved before 1992 were granted emission permits called "initial daily emissions" (IDE), according to the following formulas: $IDE^{1997–1999}$(kg/day): flow $rate_{1997}$ (m^3/hr) * 24(hr/day)* 0.000056 (kg/m^3) $IDE^{2000–2004}$(kg/day): flow $rate_{1997}$ (m^3/hr) * 24(hr/day)* 0.000050 (kg/m^3) $IDE^{2005–}$ (kg/day): flow $rate_{1997}$ (m^3/hr) * 24(hr/day)* 0.000032 (kg/m^3) Permits above the adjusted cap were taken away. Existing large boilers not using their IDE had two years to sell their permits before they became void. Existing large boilers exiting the market have three years to sell their permits before they became void.
Offsetting rate	1997–1998: 1.0 1998–2000: 1.2 2000– : 1.5
Emissions trading	Credit-based: All trades require approval by the regulatory agency, even those trades among large boilers that share common ownership.
Flexibility	Banking: No Borrowing: No
Administration of emissions inventories and permits accounts	System is maintained by a regulatory agency. Under-developed brokerage
Monitoring and reporting	Annual report Self-reporting
Penalties	Penalty fee ranges from US $4.50 to $90,000.
Automatic monetary penalties	Monetary penalties are maximum administrative penalties and actual sanctions are decided on a case-by-case basis.

As the program progressed, PROCEFF realized that its initial emissions cap was too generous. SD 16 modified the quantity of allowed emissions for existing large boilers.[3] In

[3] SD 16 also established a compensation program for industrial processes, intending to reduce the emission of particulate matter and NO_2. The program began May 1, 2007. For large boilers, large processes were classified between existing and new ones. In the case of particulate matter, existing processes were granted

2000 the targeted emission concentration was decreased to $50*10^{-6}(kg/m^3)$ and was reduced again to $32*10^{-6}(kg/m^3)$ in 2005. The offsetting rate was also modified. Initially, it was set at 100 percent, but in 1998, it was increased to 120 percent, and in 2000 to 150 percent.

Santiago's tradable permit program is a credit-based program. All trades require approval by the regulatory agency, even those trades among large boilers that share common ownership. Sources trying to offset their emissions must request the offset and find a partner, signing an offsetting agreement specifying the emissions to be compensated and the sources involved in the transaction (in the case of unrelated sources, both steps must be legalized by a public notary), and, finally, certifying the level of emissions of each source in the transaction through formal monitoring procedures. After all this paperwork, PROCEFF accepts or rejects the transaction or asks for additional information. If the transaction is accepted, a resolution grants the buyer a level of allowable daily emissions.

Permits are given in perpetuity and large boilers are restricted to trading permits on a permanent basis. This feature of the program makes banking (and borrowing) of permits virtually impossible. It is an important restriction in the structure of the property rights that differentiates this scheme from the U.S. SO_2 program or the carbon rights in the European ETS, where permits are distributed on an annual basis and used to cover emissions in a particular year. As pointed out by Montero et al. (2002), a consequence of this feature of the program is to create an illiquid market where sources are uncertain about the availability of permits in the future and where buyers pay prices close to their top prices, even if in the aggregate there is an over-supply of permits.

SD 16 established that existing large boilers not using their IDE or wanting to exit the market had two and three years, respectively, to sell their permits before they became void. Therefore, IDEs have an expiration date, and sources are not allowed to save credits for future use or sale for a long period.

Occasionally brokers have provided information about trading partners and about the trading process. However, most sources have relied on the environmental authority to

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emissions permits equal to 50% of their actual emissions in 1997. In the case of NO_2, they were granted 67% of their actual emissions in 1997. New processes would offset 120% of their NO_2 emissions and 150% of their emissions of particulate matter.

deliver such information, which is supposed to provide an annually updated record of the IDEs and DPEs in force.

The program relies on self-reporting by regulated sources. Existing and new large boilers report emissions once a year to the program authorities. To comply with reporting requirements, sources must contact an independent and certified laboratory to monitor the flow and the concentration of emissions discharged through their stacks. Dual sources, which burn more than one fuel, are compelled to declare and offset their emissions as if they were using the dirtiest fuel. Thus, there is no incentive for firms that use two fuels to use as much as possible of the cleaner fuel, which is an unfortunate design detail.

Sources that do not comply with the reporting requirement face sanctions that can be imposed through an administrative procedure. Palacios and Chavez (2005) highlighted two important features of the sanctions in Santiago's program. First, sanctions are not clearly specified. Second, they are not automatically imposed. In fact, according to the authors, sanctions might include a note of violation as well as a wide range of lump-sum monetary sanctions ranging from US$ 4.50 to $90,000. The level of the sanction actually imposed depends, in an unclear way, on each particular case, considering the extent of the emissions capacity violation and backsliding of the source, among other things. In addition, a prohibition on a source's operation is also possible, although infrequent.

The comparison between the features of the relatively successful SO_2 programs and Santiago's program suggests two outcomes. First, transaction costs are expected to be significant because of the requirement for regulatory approval and the under-developed brokerage component. Second, a significant rate of non-compliance should be expected, since monetary penalties are not clearly defined and actual sanctions are decided on a case-by-case basis.

3. Performance of Santiago's Tradable Permit Program

Table 2 summarizes some statistics about affected sources and shows the evolution of the stock of aggregate emission permits from 1997 to 2007. The summary was prepared using PROCEFF databases and contains information about the number of sources in the program, initial allocation of permits, aggregate emissions, offsetting of permits, sources' flow rates, emissions concentrations, and number of firms using cleaner fuels.

At the beginning of 1997, 4045.40 kilograms[4] of particulate matter emissions were allocated among 430 existing sources. Currently, only 53.7 percent of the initial allocation of permits remains in force and 60 percent are in hands of new large boilers.

Notice that although the aggregate cap on emissions has been respected from the beginning, new sources did not offset their emissions during the first years of the program. Montero et al. (2002) argued that one of the reasons behind this outcome was the lack of institutional capability to regulate stationary sources. Before permits could be distributed, it was necessary to develop a comprehensive inventory of sources and their historical emissions. Because of limited resources, the regulator concentrated all its regulatory activity on the completion of the inventory and the allocation of permits. The process lasted five years, and during that period the regulator did not track trading activity, so there was no reconciliation of permits and emissions until the market began to take off at the end of 1998.

Table 2 also shows that the permits in force have exceeded actual emissions since the beginning of the program. Two reasons explain this. First, since the environmental authority had a poor historic record of sources' emissions at the time the program was implemented, they overestimated the maximum amount of emissions that sources could potentially emit. Second, the fuel switching process made compliance more feasible.

Regarding the first point, the environmental authority granted emission permits assuming a standard 24 hours of activity. However, large boilers work, on average, 18 hours per day. Additionally, 128 sources that did not exist in 1997 received emission permits because they were operating at the time SD 4 was passed. These factors produced an immediate excess of permits in the hands of the initial holders.

The difference between permits in force and aggregate emissions has remained because the switch to cleaner fuels[5] has led to a decrease in the aggregate emissions.

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[4] According to Montero et al. (2002), this amount was estimated to be 64% of the aggregate emissions prior to the program.

[5] Sources began to switch to light oil, liquidified gas, kerosene, and natural gas. All of them produce a lower emissions concentration than the most demanding threshold imposed by the tradable permit program, which is $32*10^{-6}$(kg/m^3). For example, light oil and kerosene have an emission concentration equal to $30*10^{-6}$(kg/m^3), and this value decreases to $15*10^{-6}$(kg/m^3) in the case of liquefied and natural gas. Thus, the switch allowed sources to over-comply with the emissions' cap.

Table 2. Summary Statistics for Affected Sources

Variable	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of sources	593	583	516	534	495	513	521	526	519	526	511
Existing sources	430	402	332	324	286	277	273	264	251	235	217
New sources	163	181	184	210	209	236	248	262	268	291	294
Permits in force (kg/day)	4045.40	4044.40	4054.56	3710.37	3680.43	3087.34	2944.86	2856.05	2315.87	2204.17	2171.70
Initial daily emissions (IDE)	4045.40	3963.36	3672.76	3195.08	2981.53	2162.52	1897.75	1746.98	1123.49	929.75	851.59
Daily permitted emissions (DPE)	0	81.04	381.80	515.29	698.90	924.82	1047.11	1109.07	1192.38	1274.42	1320.11
Aggregate emissions (kg/day)	2544.79	1804.60	865.75	824.55	650.21	603.59	649.76	624.33	688.51	848.59	791.73
Existing sources	1684.27	1214.04	622.29	599.92	465.75	439.43	404.40	445.87	498.61	422.17	467.87
New sources	860.52	590.56	243.46	224.63	184.46	164.16	245.37	178.46	189.91	426.42	323.86
Excess of Permits [(a)]	1500.60	2239.80	3188.80	2885.81	3030.22	2483.75	2295.10	2231.72	1627.35	1355.59	1379.97
Existing sources	2361.13	2749.32	3050.47	2595.15	2515.78	1723.08	1493.36	1301.11	624.88	507.59	383.72
New sources	-860.52	-509.52	138.34	290.66	514.44	760.66	801.74	930.61	1002.47	848.00	996.25
Flow rate (m^3/hour)											
Average	4642.66	5131.59	4444.37	4444.98	5525.67	5415.96	5427.57	5349.46	5437.55	5947.64	6542.28
Standard deviation	3892.18	4790.80	3733.36	3746.09	5799.30	5661.77	5595.13	5458.10	5583.59	5968.65	6843.83
Maximum	182843.0	261304.7	182843.0	265122.3	610563.3	610563.3	610563.3	610563.3	610563.3	631607.2	773137.1
Minimum	381.7	440.0	385.4	381.7	276.0	276.0	276.0	303.6	303.6	305.0	305.0
Concentration (mg/m^3)											
Average	87.58	83.62	49.72	35.81	21.17	16.53	13.36	11.57	10.63	10.30	11.32
Standard deviation	47.46	49.98	23.84	21.61	12.79	9.57	7.48	6.98	6.38	6.65	8.30
Maximum	629.50	915.00	111.20	110.70	110.10	97.80	92.50	91.80	94.60	98.40	352.40
Minimum	8.80	8.80	2.60	2.70	2.70	1.30	1.50	0.50	0.90	0.10	0.30
Hours of operation											
Average	16.5	16.9	18.4	17.8	18.5	17.8	18.1	17.9	17.8	19.4	19.2
Standard deviation	6.99	6.92	6.34	6.74	6.46	6.63	6.65	6.71	6.86	5.93	6.04
Maximum	24	24	24	24	24	24	24	24	24	24	24
Minimum	1	1	1.5	1.5	2	1	1.5	1.5	1	1	1
Number of sources using cleaner fuels											
Using cleaner- non natural gas fuels	214	265	246	239	210	186	189	171	160	176	215
Existing sources	108	138	137	123	103	85	82	72	66	69	73
New sources	106	127	109	116	107	101	107	99	94	107	142
Using natural gas	0	54	131	162	204	231	228	234	222	277	221
Existing sources	0	36	77	90	110	120	116	119	105	105	83
New sources	0	18	54	72	94	111	112	115	117	172	138

Source: Elaborated from PROCEFF databases

(a) Excess of permits corresponds to the difference between the permits in force and the aggregate emissions

Regarding this process, sources began to switch to cleaner fuels from 1995, in response to several environmental regulations. The most popular cleaner fuel was natural gas, which was imported from Argentina in 1997. After its arrival, it became the cheapest and cleanest fuel readily available. A switching process quickly started and currently about 50 percent of large boilers have declared their intent to use natural gas (although many of them are dual sources and also burn light oil).

Unfortunately, from 2004 on, Chile has faced severe restrictions over the amount of natural gas that can be imported, giving rise to its so-called “natural gas crisis.” Since then, large boilers have faced more and more severe restrictions over the quantity of natural gas available and have again started to burn light oil, which has led to an increase in the aggregate emissions. In fact, aggregate emissions in 2007 were almost 27 percent larger than aggregate emissions in 2004.

To better understand the impact that the lack of reliable data about sources’ activity and the process of switching fuel has had on the excess of permits, we divided the excess into these two components. Thus, we calculated the excess of permits in force that would have been produced had the environmental authority allocated the initial cap based on the actual activity level of existing sources. This excess corresponds, then, to the difference between the aggregate permits granted that would have been based on actual activity less the actual aggregate emissions.

Second, we calculated the excess of permits in force that would have been produced if existing sources had met the legal emissions’ concentration target[6] and without over-compliance. Thus, this excess corresponds to the difference between the actual aggregate amount of permits granted and the aggregate emissions that would have been produced if existing sources had precisely accomplished the legal emissions’ concentration target

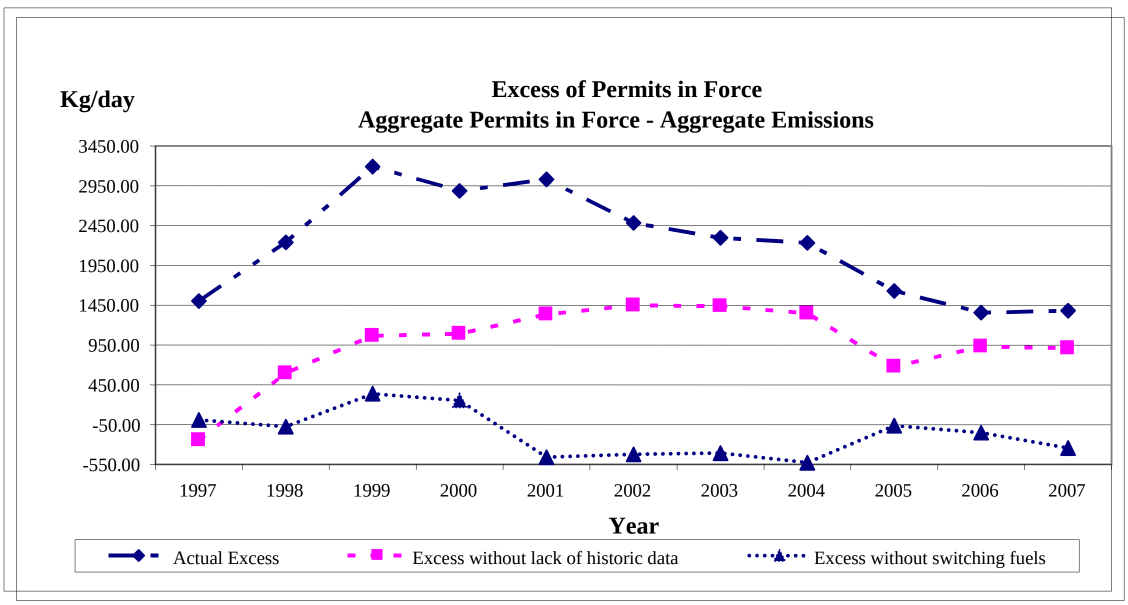
The first counterfactual allows us to identify the effect of the overestimation of the maximum amount of emissions that sources emitted, while the second counterfactual identifies the effect of the switching process on the emissions’ cap over-compliance.

[6] The legal emissions’ concentration target was 0.000056(kg/m^3) from 1997 to 1999, 0.000050 (kg/m^3) from 2000 to 2004, and 0.000032 (kg/m^3) from 2005 onward.

Figure 1 shows the actual excess of permits beside both counterfactuals. Although the overestimation of the maximum amount of emissions emitted has some role explaining the excess of permits in force, the switching process seems to explain most of the excess over time. In fact, if the affected sources had not switched to cleaner fuels, aggregate emissions would have exceeded the aggregate permits for most of the period.

Notice that the initial overestimation of the required permits allowed an accommodation of the aggregate level of non-compliance from new large boilers. If permits had not been granted in excess, the lack of offsetting would not have accomplished the target cap on emissions.

Figure 1. Excess of Permits



Source: Elaborated from data provided by PROCEFF

But as suggested by Palacios and Chavez (2005), aggregate over-compliance has coexisted with usual violations by some of the sources. Table 3 summarizes information about the incidence of individual violations of the emissions cap from 1997 to 2007. Two types of violations are considered: those produced when existing sources exceed the assigned IDE, plus any net transfer, and those produced when new sources do not cover their daily emissions with permits.

As expected, the enforcement design used in Santiago has not induced a high level of compliance, particularly with new sources. On average, almost 30 percent of large boilers in the sample did not meet their obligations regarding the cap on emissions at some point, with almost 80 percent of these sources being new sources. Both the number and magnitude of violations has decreased over time, although the natural gas crisis broke this trend slightly. Before the switch to cleaner fuel, large boilers burned dirtier fuels, such as coal, firewood, and heavy oil. Since 2005, in response to the lack of sufficient natural gas, the number of non-compliant existing sources has increased, as have additional violations; large boilers have begun to burn dirty fuels again, exceed their emissions' caps, and commit other violations.

Tradable permits are believed to promote "dynamic efficiency" because firms can expect to keep some or all of the gains from innovation through reduced abatement costs plus reduced payments for permits. Considering that the switch to natural gas was quite important for compliance with the emissions cap, it is worth asking whether or not the tradable program had some role in encouraging sources to switch to cleaner fuels.[7] Empirical evidence, however, does not support such a hypothesis. According to Coria (2006), the lower price of natural gas seems to have been the main driver behind the switch, while the tradable permit program had little or no effect. This result seems related to the features of the Santiago program. In fact, the aggregate excess of supply must have produced a very low permit price, making the benefits from saved emission permits irrelevant. Second, since dual sources were compelled to declare and offset their emissions as if they were using the dirtiest fuel, they had no expected gains from reduced payments for permits. Finally, the expected gains from reduced payments could also have been irrelevant, since the lack of clearly defined monetary penalties and sanctions did not provide enough incentive for firms to care about good compliance or to invest in technologies to reduce emissions.

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[7] Burtraw (2000) analyzed the innovation incentives under the Acid Rain Program. He found that innovation accounted for a large portion of the fall in compliance costs over the last decade. However, innovation was already in the works prior to, and independent of, the program. Nonetheless, the allowance trading program deserves significant credit for providing the incentives and flexibility to accelerate and fully realize these exogenous changes that were occurring in the industry.

Table 3. Compliance in the Santiago Tradable Permit Program

Variable	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AccumulatedViolation (Kg*/day)	1255.19	811.03	289.11	246.55	156.07	112.32	198.18	153.84	**175.05**	**197.93**	**221.26**
Existing sources	505.88	255.58	88.80	48.29	12.49	6.86	15.16	58.82	**92.55**	**114.78**	**124.89**
New sources	749.31	555.45	200.31	198.26	143.57	105.47	183.02	95.01	82.50	83.15	96.37
Average Violation (Kg/day)	4.61	3.41	1.50	1.27	1.11	0.90	1.62	1.27	**1.58**	**1.66**	**1.80**
Existing sources	3.28	1.59	0.59	0.32	0.10	0.06	0.14	0.56	**0.94**	**1.20**	**1.30**
New sources	4.87	3.45	1.34	1.30	1.21	0.94	1.71	0.90	0.84	0.87	1.00
Maximum Violation (Kg/day)	89.19	89.19	28.3	25.63	21.60	9.12	92.8	40.74	45.09	56.96	45.09
Existing sources	89.19	89.19	28.3	25.63	2.78	3.14	9.16	40.74	45.09	56.96	45.09
New sources	65.60	45.14	18.48	21.60	21.60	9.12	92.8	7.0	23.76	14.16	15.49
Minimum Violation (Kg/day)	0.008	0.008	0.010	0.006	0.006	0.002	0.036	0.030	0.018	0.005	0.030
Existing sources	0.08	0.012	0.248	0.58	0.42	0.19	0.19	0.16	0.06	0.03	0.06
New sources	0.008	0.008	0.010	0.006	0.006	0.002	0.036	0.030	0.018	0.005	0.003
Number of non complying sources	272	238	193	194	140	125	122	121	**111**	**119**	**123**
Existing sources	118	77	43	41	21	13	15	16	**13**	**23**	**27**
New sources	154	161	150	153	119	112	107	105	98	96	96
% of non complying sources	46%	41%	37%	36%	28%	24%	23%	23%	21%	23%	24%
Existing sources	20%	13%	8%	8%	4%	3%	3%	3%	3%	4%	5%
New sources	26%	28%	29%	29%	24%	22%	21%	20%	19%	18%	19%

* Sources violate the program when their emissions exceed their permits. Added violation corresponds to the addition of sources's violations.

Source: Taken from PROCEFF databases.

3.1 Trading Activity and Transaction Costs

Table 4 shows the trading activity to date. So far, 240 transactions have been approved, involving 445 sources and 39 percent of the initial allocation of emissions permits.[8] As expected, evidence suggests the important role played by transaction costs in the pattern of transactions. Around 76 percent of the transactions correspond to intra-firm trading, while 24 percent correspond to inter-firm trade transactions. Further evidence is suggested by the larger amount of emissions traded in inter-firm transactions and by the nearly 25 percent of sources which offset emissions and also traded more than once (learning effect).[9]

Table 4. Trading Activity

Total Trading Activity				
	# sources	# of transactions	Total kg/day	Average kg/day [(a)]
Aproved transactions	445	240	1579.02	6.58
Intrafirm	313	182	996.37	5.47
Interfirm	132	58	582.65	10.05
Sources trading more than once	114			
N° of Sellers	221			
Existing Sources	204			
New Sources	17			
N° of Buyers	224			
Existing Sources	13			
New Sources	211			
Sources that lost emission permits	153		798.95	

Source: Elaborated from data provided by PROCEFF

(a) It corresponds to the ratio between the total Kg/day traded and the number of transactions

Table 5 below shows some statistics about the length of time required to complete the transaction process. The average period required for a transaction to be approved is about 20.5 months. However, since the beginning of the program, there has been quite significant

[8] In 1997, 15.2 million allowances were traded in the Acid Rain Program, a program characterized by low transaction costs. This amount represents approximately 15% of the total allocation of allowances that year.

[9] Unfortunately, price information is not easy to obtain, since sources do not have to inform the environmental authority of the price agreed for their transactions and since intra-firm transactions do not have an explicit price. However, information from the few brokers suggests that prices ranged from US$ 10.741 (kg/day) in November 1997 to $5.555 (kg/day) in March 1998, and from $3704 (kg/day) in October 2000 to $2144 (kg/day) in 2005.

improvement. In fact, those transactions requested before 1998 needed more than 39 months to be approved.[10] Fortunately, the number of months in the transaction process has been trending downwards over time.

Surprisingly, intra-firm transactions took longer time to be approved, suggesting that regulatory efforts were focused on reconciliation of permits and emissions between firms.

Table 5. Transaction Process Period

	Trading Process Period	
	% of Total Aproved Transactions	Average Period (in months)
Aproved Transactions	**100%**	**20.49**
Intrafirm	76%	22.38
Interfirm	24%	17.03
Transactions Required Before 1998	**14%**	**39.21**
Intrafirm	76%	39.23
Interfirm	24%	39.13
Transactions Required 1998-2003	**64%**	**20.38**
Intrafirm	72%	21.60
Interfirm	28%	17.98
Transactions Required From 2004	**22%**	**8.55**
Intrafirm	50%	9.27
Interfirm	50%	7.80

Source: Elaborated from data provided by PROCEFF

Apart from the transaction costs and the uncertainty involved in the trading activity, the lengthy period it takes to the environmental authority to reconcile permits and emissions is also related to the high level of non-compliance by new large boilers. In fact, as is shown in table 5, it took several months for new large boilers requesting offsets to legally comply with the regulation. Thus, non-compliance is not just related to the lack of clear and automatic penalties but also to institutional failures making the compliance process uncertain and troublesome.

Since many large boilers are dual sources (light oil and natural gas) and compelled to offset their emissions as the dirtiest fuel, there is no reason to expect a significant increase in

[10] As a matter of fact, the first transaction was approved in August 1998.

trading activity due to the lack of natural gas. However, it could be possible to expect an increase in the trading activity by single fuel large boilers. Therefore, we divided the sample period into 1998–2003 and 2004 onward. There is no evidence of an increase in the number of transactions approved from 2004. During the former period, the average number of transactions per year was 26. Since 2004, it has been 13, although the rate of inter-firm transactions has increased.

3.2 Policy Adjustments

Table 6 shows the effects of the policy adjustments described previously on the stock of emission permits. The increase in the rate of offsetting has reduced the total allocation of permits by about 6.3 percent. On the other hand, the decrease in the concentration target level accounts for another 20.2 percent decrease in these permits. Finally, 17.3 percent has been lost because existing boilers did not trade or use their permits before the legal deadline.

Table 6. Decrease in the Emission Permits in Force

Decrease In Emission Permits In Force		
	Total Kg per day	%
Total emissions allocated at 1997	4045,40	100,0%
Emissions reduced due to the increase in the rate of offsetting in 1998 (1.2)	126,92	3,1%
Emissions reduced due to the increase in the rate of offsetting in 2000 (1.5)	130,97	3,2%
Emissions reduced due to the decrease in concentration target in 2000 (0.000050 Kg/m^3)	331,10	8,2%
Emissions reduced due to the decrease in concentration target in 2005 (0.000032 Kg/m^3)	646,50	16,0%
Emissions lost due to non-trading	638,20	17,3%
Total emission permits in force at 2007	2171,70	53,7%

Source: Elaborated from data provided by PROCEFF

Notice that the decrease in the number of emissions permits granted and the increase in the rate of offsetting have opposite effects on the attractiveness of trading. While the decrease in permits should have induced existing sources to trade before the decrease became binding, the increase in the rate of offsetting should have induced existing sources to retain permits if they were not sure of being able to buy permits back in case they were needed. This second effect should increase over time, since every time a new offsetting is produced, there is a net loss of permits in the market.

Considering that 35 percent of the sources originally granted IDEs lost their emission permits, it is worth analyzing the reasons behind this outcome. Table 7 shows some statistics.

More than 50 percent of the sources which lost permits are no longer operating, and 25 percent of them stopped operations before the implementation of the program in 1997. This evidence is consistent with the rent-seeking behavior suggested by Montero et. al. (2002), who found that grandfathering the permits instead of auctioning them off created economic incentives for incumbent sources (some of which were nonexistent at the time SD 4 was passed) to more readily declare their emissions and claim the corresponding permits.

Did sources lose their permits because of transaction costs? If true, the incidence of smaller, older, and poorly integrated sources losing emissions permits should be higher, since the costs of engaging in the trading process are greater. Data supports this hypothesis. There were clear differences in the level of aggregate emissions, size (flow rate), and level of integration between sources that lost their IDEs and those that did not. In fact, the incidence of poorly integrated sources losing emissions permits is quite significant. Just 9.2 percent of these sources had related sources to trade. On the other side, 78.3 percent of those which did not lose their permits had related partners. Thus, as expected, poorly integrated sources traded much less than integrated sources.

Table 7. Sources Granted with IDE

Description of Sources Granted with IDE				
	Sources that lost IDE		Sources that did not loose IDE	
Number Sources	153	100.0%	277	100.0%
Not operating	78	51.0%	47	17.0%
Not trading ever	97	63.4%	89	32.1%
Had related sources in operation	14	9.2%	217	78.3%
IDE (kg/day)	7.31		10.26	
Aggregate emissions in 1997 (kg/day)	1.25		5.23	
Flow rate in 1997 (m^3/hour)	3503.17		5516.16	

Source: Elaborated from data provided by PROCEFF

4. What Can We Learn from Santiago’s Tradable Permit Program?

There is no doubt that despite of their theoretical advantages, tradable permit programs have been used far less frequently than command-and-control policies. Perhaps one of the most significant barriers to implementing this policy is finding a political process that favors the introduction of market regulations in environmental management. This has been the case in

Poland, where the main obstacle to the introduction of emissions trading during the 1990s was the low priority of the environmental issues combined with political controversies regarding the use of this market approach. But, according to Stavins (1998), the political process has gradually become more receptive to this policy instrument over the last decade. Currently, many donors and advisors are promoting the use of market-based instruments, such as tradable permit programs, as the key to more effective environmental protection in economies in transition as well as in developing countries. However, financial and institutional constraints have turned out to be significant barriers, which may make the use of this environmental policy more problematic than in developed countries.

Before promoting the implementation of emission trading on economies in transition and in the developing world, we should review how developed countries have managed these issues to succeed. What have we learned about the requirements for tradable programs to work? Can less developed countries accomplish these requirements? In this paper, we studied the performance of the tradable permit program implemented in Santiago, emphasizing the design and implementation issues that have limited the development of the emissions' market.

The review of a successfully implemented trading program offers some lessons on the importance of realistic incentives to trade and spatial and temporal flexibility, including allowing the private sector to fulfill brokerage needs as well as monitoring and enforcement. Have these elements affected the performance of the Santiago's tradable program? They have. Requirements for prior regulatory approval and the under-developed brokerage component have increased transaction costs, while there is a significant rate of non-compliance because monetary penalties are not clearly defined and actual sanctions are decided on a case-by-case basis. Additionally, the program is not temporally flexible. Permits must be traded on a permanent basis rather than an annual basis, they have an expiration date, and the banking option is not contemplated, so sources are not allowed to save credits for future use or sale for a long period.

Beside the lengthy amount of time required to complete the transaction, the fact that a significant group of smaller, older, and poorly integrated sources lost emission permits because they did not trade before the legal deadline represents further evidence of the significance of transaction costs preventing trading. On the other hand, the increase in the rate of non-compliance as the sources' optimal response to the natural gas crisis reveals the important role played by the lack of enforcement.

But in spite of the above-described weaknesses, the aggregate cap on emissions has been met and the trading activity has increased over time. However, is it likely that the high transaction costs has decreased trading, with the result that full cost-effectiveness has not been achieved?

A number of design modifications would have substantially improved the efficiency of the Santiago system:

- Better measurement of emissions at the time the program was implemented
- More certain tenure over the permits
- Avoidance of rules that hamper trade, for instance, the offset rules that provide a bias against trade
- Allow banking in some form

Thus, Santiago's experience shows us that the challenges of designing successful environmental programs in less developed countries should not be underestimated. If the Chilean environmental authorities do not work out the current weaknesses in design, the success of the trading program will remain quite limited. Obvious additional recommendations to improve the performance of the market seek ways to reduce transaction costs and to improve monitoring and enforcement. Improving data system and public access to data can help with the first task. In fact, although the environmental authority is supposed to annually provide an updated record of emission permits in force, information about actual emissions, violations, and trades is not publicly available. Enhancing public access to this information can build the credibility of the environmental program, allow brokers to enter into the market to provide information about trading partners and the trading process, and, finally, allow society to exercise pressure over firms to improve their environmental performance.

From the Chilean experience, we can also learn that there are no clear reasons to believe that developing countries *cannot* benefit from the additional flexibility that tradable permits confer over more inflexible regulations. In fact, it took the United States some three or four decades of experimentation to learn how to design the institutions for a trading scheme. The Chilean scheme compares quite favorably with all the early U.S. programs and to the European ETS scheme, which, (despite being launched long after the Chilean scheme) has roughly the same number of flaws related to over-allocation and lack of clear rules for penalties. Thus, one might say that Chile's experience demonstrates that a middle-income country is quite capable of implementing this type of scheme, even if much work remains before the design is really satisfactory.

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Appendix 1. Comparison of Emission Trading Programs

Program and objective	Affected sources	Covered pollutants	Permits allocation	Emissions trading	Flexibility	Monitoring and reporting	Penalties	Automatic monetary penalties
EPA EmissionTrad-ing Program Cut nation-wide emission of several pollutants	Firms emitting controlled air pollutants	Volatile organic compounds, carbon monoxide, sulfur dioxide, particulates, and nitrogen oxides	Grandfathering	Credit-based: Netting is subject to approval at the state level, offsets and bubbles are subject to approval at the federal level	Banking Netting only allows intra-firm trading Offsets and bubbles allow intra- and inter-firm trading	No additional monitoring requirements beyond those incorporated into existing air quality regulations Enforcement is implemented through periodic facility inspec-tions to ensure that pollution con-trol equipment is installed, operat-ing and meeting the regulatory requirements		
EU ETS Cut emissions of member states during the Kyoto period	Energy-intensive industries: iron and steel, certain mineral Industries, energy production, and pulp and paper	Carbon dioxide	Member states freely allocate CO_2 emissions to incumbents and new entrants on the basis of the National Alloca-tion Plan Member states are allowed to auction up to 5 percent of their total allowance allocation	Cap and trade: Overall cap on total emissions from all 25 mem-ber countries equal to the EU com-mitment under the Kyoto Protocol. National cap equal to national allowances under the Kyoto	Banking and borrowing are allowed within each phase (2005–2007; 2008–2012).	Continuous emissions Monitoring is optional Most installations are expected to use emission factors coupled with fuel use or production data to calculate their emissions	€40 per ton of CO_2 in the first phase €100 per ton of CO_2 in the second phase Additional administrative and criminal penalties are left to the member states	Yes

				Protocol				
Lead Phase-Out Phase out leaded gasoline from 1979-1987	Petroleum refineries, national system	Leaded gasoline	Permits allo-cated quarterly, based on leaded gasoline produc-tion in that quarter	Averaging-based	Banking was allowed for the latter portion of the program	Self monitoring: each quarter refineries must submit a report on their gasoline usage and lead usage	Most disputes administratively settled, with few court actions.	Yes
Phase-Out of Ozone Depleting **Substances (ODS)** Phase out CFC and halons from 1989-1995	28 CFC and halon produ-cers and importers	Five major chlorofluorocar-bons (CFC) and halons	Grandfathering	Credit-based: Trades require approval by the regulatory agency	Banking Intra-firm and inter-firm, inter-pollutant, and between nations that signed the Montreal Protocol	Self reporting of production levels, imports, exports, and “recycled” ODS	US$ 25,000 per kilogram Possible illegal labeling of imported and exported ODS as “recycled”	Yes
US Acid Rain Program Cut nation-wide emission 50% below 1980 levels by 2010.	Electricity generating units (2000 U) National system	Sulfur dioxide	Grandfathering and auctions	Allowance-based	Unrestricted	Continuous emissions monitoring is obligatory for all sources	US$ 2000 per ton	Yes
RECLAIM Cut local emission 80% below 1990 levels by 2003.	Point sources emitting more than 4 tons per year (elec-tric generating units are excluded from	Sulfur dioxide and nitrogen oxide	Grandfathering	Allowance-based	No banking or borrowing	Continuous emissions monitoring obligatory for 2/3 of sources, others have less strict methods	Up to US$ 500 per violation	No

	the SO_2 pro-gram); local system, south coast of California							
Denmark Cut CO_2 nation wide emissions 70% below 1998 levels by 2003	Electricity producers and asso-ciations of electricity producers which have CO_2 emis-sions above 100,000 tons per year; national system	Carbon dioxide	Grandfathering, a portion of quotas is withheld by the minister for environment for new entrants		Banking	Self monitoring, annual reports	U$ 6 per ton of CO_2	
The Netherlands **NOx emission permits** Cut NOx nation wide emissions 50% below 1995 levels by 2010	Stationary sources larger than 20 MW; about 250 firms	NOx	Free yearly allocation of NOx emissions on the basis of performance standards per facility	Averaging based	banking and borrowing is restricted to 5% of one year's allowances	Self monitoring, annually reports	To be worked out	
UK emission trading scheme Cut CO_2 nation wide emissions	Voluntary scheme through financial incentives	CO_2	Grandfathering, based on output				Negotiated agreement, sources lose 80% tax reduction	
BP's emissions trading Cut BP's emissions 10% below 1990	BP's business units (BU)	CO_2	Grandfathering based on emissions; for new BUs, permits were allocated based on a forecast	Bilateral trades through a central broker	BUs could bank up to 5% of their allocation for future use		Emissions goals were written into the performance contracts of the business unit leaders	No

levels								
Singapore Phase out CFC from 1980	CFC producers and importers	CFC	Grandfathering and auctions, quarterly allocation of quotas		No banking no bilateral trading			

Source: Based on Hahn and Hester (1989); Hahn (1989); Rico (1995); Stavins (1998); Schmalensee et al. (1998); Salomon (1999); Harrison (1999); Tietenberg (1999); Ellerman (2000); Stavins (2001); Boemare and Quirion (2002); Ellerman (2005); David and House(2006); and Ellerman and Buchner (2007).