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Tradable Permits in Developing Countries: Evidence From Air Pollution in 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 article looks closely at the program's performance over the past 10 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 say that a middle-income country such as Chile is capable of implementing this type of scheme even if much work remains before the design is really satisfactory. Considering the urgency of improving the environment in many of these countries, it is important to use the whole range of potential instruments.

Keywords

air pollution, environmental policy, tradable permits, developing countries

Introduction

The most threatening environmental problems are often found in the major metropolis of developing countries. It is a matter of considerable urgency to find good policy instruments to deal with such problems. Policy makers in richer countries 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 fact that they have been used successfully in the United States to reduce sulfur dioxide (SO_2) and nitrogen oxides (NOx) and more recently in various regions including Europe for

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carbon trading. However, it remains an open question whether tradable permits are appropriate for use in transition and developing economies due to special social and cultural circumstances such as the lack of 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. However, those opposed to the use of tradable permits programs in developing countries emphasize the lack of transparency and monitoring possibilities, the inadequate legal systems, and the risk that less privileged groups will be dispossessed or disadvantaged in some way (see Bell, 2003; Bell & Russell, 2002). However, pervasive constraints would affect the performance of *any instrument* including both economic policies and command, 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. Some market advocates argue that emissions taxes would be more appropriate; once a tax is in place, regulators may be able to raise taxes and strengthen enforcement over time while raising revenue to finance regulatory activity and direct investment in environmental projects (see Blackman & Harrington, 2000; Krupnick, 2003). Finally, advocates of trading approaches argue that as countries develop, there will eventually be sufficient political will to impose real environmental requirements. Therefore, the important point is to start developing the institutions to build over the coming years (see Krueger, Grover, & Schreifels, 2003).

Many donors and advisors have promoted the use of market-based instrument 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 like Poland, Kazakhstan, the Czech Republic, and the Slovak Republic to implement emission trading programs during the 1990s (see Bell, 2003; Farrow, 1999; Hauff & Missfeldt, 2000; Toman, Cofala, & Bates, 1994; Zylicz, 1995) and the academic and governmental interest in implementing emissions trading in China (see Ellerman, 2002). In all these cases, the main concern have been related to the transition from preexisting environmental regulations to tradable emissions permits and the monitoring and enforcement capabilities that would be required to ensure compliance.

Santiago was one of the first cities outside the OECD to implement a tradable permit program. The program launched in the early 1990s to control emissions coming from stationary sources of pollution is sometimes considered a success; but it has actually been characterized by a combination of failures affecting the attractiveness of trading—over allocation of permits, high transaction costs, lack of clear penalties to 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 is not possible.

How has the emissions market reacted to these new regulations and conditions? Currently 46.3% of the initial mass of permits has become expired, and 34% of this expired mass has been lost because incumbent sources did not trade before the legal deadline.

Why did sources not trade before the legal deadline? In this article, we analyze the design and implementation issues limiting the development of the tradable permit market in Santiago and try to use this as a case study to illustrate the general challenges and advantages of applying tradable permits to industrial air pollution problems in less developed countries.

Previous studies evaluating the performance of the Santiago's trading program were done at early stages of its implementation. Montero, Sanchez, and Katz (2002) found that the grandfathering used to allocate emissions initially created economic incentives for incumbent sources to more readily declare their historic emissions to claim permits. O'Ryan (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 overcompliance coexists with frequent violations of regulations by some of the sources. This article goes more deeply into these issues using an updated database to analyze whether the program has improved through time and how it has reacted to regulatory adjustments and market shocks.

The article is organized as follows. The next section reviews the main lessons from the international experience with tradable permit programs. The Santiago's Tradable Permit Program section describes the tradable permit program applied in Santiago. Then, the design and implementation issues limiting the development of the market are analyzed. The last section reviews the lessons that can be learnt from Santiago's experience and concludes.

The Use of Tradable Permit Programs to Control Industrial Air Pollution in Developed Countries

Although the efficiency properties of tradable permit programs were discussed by some economists in the early 1970s (Dales, 1968; 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 many of the basic environmental laws were being written in the United States (Bell, 2003). They were used to provide greater flexibility to firms charged with controlling air pollutant emissions (EPA's Emission Trading Programs), to phase out leaded gasoline and ozone-depleting chlorofluorocarbons (CFC) from the market and to reduce sulfur dioxides (SO_2) and nitrogen oxides (NOx) in the Los Angeles basin (RECLAIM). There was a gradual learning process concerning design issues that led up 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 Emissions Trading System (EU ETS) program, 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 have been 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. However, very few applications have been implemented in transition or the developing countries. Chile and Singapore were pioneers in this matter whereas 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 air pollution (see Boemare & Quirion, 2002; Burtraw & Palmer, 2003; Convery & Redmont, 2007; Ellerman, 2000, 2005; Ellerman & Buchner, 2007; Ellerman & Montero, 1998; Hahn, 1989; Hahn & Hester, 1989; Montero, 2000; Rico, 1995; Salomon, 1999; Schmalensee, Joskow, Ellerman, & Montero, 1998; Shabman, Stephenson, & Shobe, 2002; Stavins, 1998, 2003; Tietenberg, 1999, 2002; Victor & House, 2006). The first lesson concerns the functionality of emission trading as a regulatory instrument, whereas 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. 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, and recent studies indicate that benefits exceed costs by a very significant margin (see Burtraw & Palmer, 2003; Chestnut & Mills, 2005) whereas the trading volume has increased over time with a significant fraction of allowance transfers among economically unrelated parties.

As regards to the second lesson, there are several features that are important for emission trading to work. The most fundamental of these is that the rights to the environmental service or resource in question are allocated in a manner that creates some permanence and confidence. Additional features are realistic incentives to trade, spatial, and temporal flexibility, the inclusion of the private sector fulfilling brokerage needs, monitoring and enforcement, and the allocation of allowances. In what follows, we discuss these features.

Realistic Incentives to Trade

Emissions trading can be classified in three types: credit-based, allowance-based, and averaging-based trading (that is also known as relative target-based trading).[2] In credit-based trading, credits can be created by reducing one source's emissions more than required by some prespecified 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. However, 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 prespecified standard of which emissions are traded, but subsequent trade between sources is not confined by regulatory approval.

In practice, credit-based trading has not worked very well because of the high transaction costs associated with the creation and transfer of credits. The process of regulatory approval limited trading in the early EPA trading programs because of the uncertainty involved in getting individual trades. Quite the opposite, trading observed in allowance-based (RECLAIM and Acid Rain Program) and averaging-based programs (such as the Lead Phase-out), where the right to trade is clearly defined and not subject to case-by-case approval, has been much greater (see Ellerman, 2005).

Spatial and Temporal Flexibility

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, because the larger the number of participants, the larger the abatement cost differences among firms and the larger the benefits of trading. Second, because the risk of market power in the permit market is reduced. However, banking encourages firms to undertake early emissions reductions to accumulate allowances that can be used to ease compliance in the future; therefore, it dampens the volatility of permit prices as it accommodates dynamic market changes and allow for shifts in industry structure with constant total emissions. Thus, for example, the Acid Rain Program—the program with the greatest flexibility as 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. In contrast, RECLAIM—the most restricted program in the scope of spatial trading and that does not allow for banking—has experienced price fluctuations of 60:1 (see Ellerman, 2005).

Inclusion of the Private Sector and Reduction of Transaction Costs

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—including the costs of finding a trading partner, establishing the terms of trade, and completing the arrangements—played a role in explaining this shortcoming. Anecdotal evidence can be found in the predominance of intrafirm (within firms) transactions over interfirm (between firms) transactions and in the existence of a "learning by trading" effect (see Gangadharan, 2000). Further evidence is suggested by the role played by some states developing programs to assist firms in finding partners and minimizing administrative costs (see Harrison, 1999; Tietenberg, 1999).[3]

However, the Acid Rain Program was consciously designed to minimize transaction costs (see Conrad & Kohn, 1996). Rights were allocated according to principles that are quite transparent and remain constant for a long period. The auction market established as part of the sulfur allowance program reduced transaction costs by providing not only an easy means for buyers and sellers to transact but also systematic public information on prices that allowed private firms to provide a variety of trading services, such as private brokerage and electronic bid/ask bulletin boards, and permit price forecasts.

Monitoring and Enforcement

Monitoring and enforcement are important design issues to be considered. If not, trading programs do not provide enough incentives for a high degree of compliance. Compliance requires a matching of emissions and permits and for the technology to measure and to account allowances permanently.[4] However, the 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 setting effective sanctions; penalties for noncompliance must be fixed and automatically implemented. Thus, for example, Stranlund, Chavez, and Field (2002) compare the compliance incentives faced by firms under the Acid Rain Program and RECLAIM. Whereas the Acid Rain Program apparently achieved a perfect compliance record, compliance rates in the RECLAIM program have ranged between 85% and 95%; noncompliance seems quite related to the uncertain value of monetary penalties, as under RECLAIM stated monetary penalties are maximum administrative penalties and actual sanctions are decided on a case-by-case basis.

Allocation of Permits

Despite a common preference for auctioned permits among economists, free allocation to 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 has an auctioning scheme been introduced.[5] Nevertheless, 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, for example, the case in the lead program where each refinery was allowed to average concentrations across the gallons it sold. Then, refineries—or other agents—gained more rights by selling more gasoline.

Santiago's Tradable Permit Program

The history of environmental policy in Chile is interesting. In spite of the fact that when pollution became an issue, there were no environmental institutions; the free market environment of the Chilean economy, the strong support for all forms of property rights (including those for air pollution by polluters), and a great interest in the use of trading from the government led the environmental authority to implement the first trading program in 1992 to control total suspended particles (TSP) coming from large boilers, which at that time accounted for more than 40% of total point source emissions.[6]

A new governmental office was created to take care of the management of this program. The Program of Control of Emissions Coming from Stationary Sources (PROCEFF), under the Department of Health (currently Secretaría Regional Ministerial de Salud—henceforth SEREMI), was given the responsibility of allocating and keeping an updated record of permits as well as monitoring and enforcing emissions. Some years later, the first general environmental laws were passed, and in 1994 the National Environmental Commission (CONAMA) was created to coordinate all governmental offices with environmental jurisdiction (for example, the departments of transport, economy, and fisheries).

The fact that institutions and actual regulation evolved so fast and in some cases simultaneously or even superseding legal bases, may have complicated implementation. Trading is officially "recognized" as a policy instrument with the law that created CONAMA. Moreover, the law did not specify the allocation mechanisms, duration, and other characteristics of the permits schemes. Before that, there was just Supreme Decree 4—rather than a law—allowing the implementation of the large boilers program. Although the large boilers decree was passed in 1992, it was not until 1997 that the firms were given permits and transactions started to be recorded, giving the environmental authority some years to collect information on sources' emissions.

In terms of the design of the program, 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 1,000 m^3/hr (large boilers) and a tradable permit program that let this type of source exceed this cap through offsets from other large boilers. For that purpose, it distinguished between existing and new large boilers. Existing boilers are those installed or approved before 1992 that were endowed with emission permits called *initial daily emissions* (IDE). Each unit of IDE allows the holder to emit 1 kg of TSP daily. New large boilers are those installed or approved after that and were required to fully offset their emissions through abatement in existing large boilers. In other words, new large boilers need to buy emission permits from old ones; the emission permits in hands of new large boilers (due to the trading activity) are known as *daily permitted emissions* (DPE).

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. 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 hr of operation times a target on emissions concentration equal to 56×10^{-6} kg/m^3.

As the program progressed, SEREMI came to realize that its initial allocation was too generous. They modified the quantity of allowed emissions to existing large boilers.[7] In Year 2000, the targeted emission concentration was decreased to 50×10^{-6} kg/m^3, and it was reduced again to 32×10^{-6} kg/m^3 in 2005. The offsetting rate—that is, the number of permits sources need to buy to emit 1 kg of particulate matter—was also modified. Initially, it was set at 1, but in 1998 it was increased to 1.2 and in 2000 to 1.5.[8]

Santiago's tradable permit program is a credit-based program.[9] 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, SEREMI accepts or rejects the transaction or ask for additional information. If the transaction is accepted, a resolution grants the buyer a quantity of daily emission allowed.

Permits are given in perpetuity and large boilers are restricted to trade permits on a permanent basis. That is, permits imply the right to emit a number of kilograms of particulate matter forever. This feature of the program makes banking (and borrowing) of permits virtually impossible, and it is an important restriction in the structure of the property rights that differentiates this scheme from the SO_2 program in the United States or the carbon rights in the European ETS, where permits are distributed on an annual basis, used to cover emissions in a particular year and cancelled out every time 1 kg or tone is emitted. 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 that are higher than competitive and closer to their reservation prices even though there is an aggregate oversupply of permits.

In 1998, it was established that those large existing boilers that were not using their IDE or those that wanted to exit the market had 2 and 3 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.

Occasional brokers have provided information about trading partners and about the trading process. However, most sources have relied on the environmental authority to deliver such information, which is supposed to yearly provide an updated record of the IDEs and DPEs in force.

The program relies on self-reporting by regulated sources. The 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 conduct monitoring of the flow and the concentration of emissions discharged through the stack. Dual sources, burning 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) highlight 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 them, sanctions for exceeding the individual cap on emissions might include a note of violation as well as a wide range of lump sum monetary sanctions (from US$4.50 to US$90,000; Palacios & Chavez, 2005, p. 459). The level of the sanction actually imposed depends on each particular case in an unclear way, considering the extent of the emissions capacity permits violation and backsliding of the source, among other things. In addition, a prohibition on a source's operation is also possible, although quite 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 underdeveloped brokerage. Second, a significant rate of noncompliance should be expected as monetary penalties are not clearly defined and actual sanctions are decided on a case-by-case basis.

Performance of the Santiago's Tradable Permit Program

Table 1 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 SEREMI databases and contains information about the number of sources in the program, the initial allocation of permits, the aggregate emissions, the offsetting of permits, the sources' flow rate, the emissions concentrations, and the number of firms using cleaner fuels.

At the beginning of 1997, 4,045 kg of particulate matter emissions were allocated among 430 existing sources; this amount was estimated to be 64% of the aggregate emissions prior to the program (see Montero et al., 2002). In 2007, only 53.7% of this initial mass of permits remained in force (i.e., 2,172 kg), and 60% 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 1st year of the program. Montero et al. (2002) argues that one of the reasons behind this outcome was the lack of institutional capability to regulate stationary sources. Before permits could be allocated, it was necessary to develop a comprehensive inventory of sources and their historical emissions. Because of limited resources, the regulator concentrated all its

Table 1. 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)	4045.4	4044.4	4054.6	3710.4	3680.4	3087.3	2944.9	2856.1	2315.9	2204.2	2171.7
Initial daily emissions (IDE)	4045.4	3963.4	3672.8	3195.1	2981.5	2162.5	1897.8	1747	1123.5	929.75	851.59
Daily permitted emissions (DPE)	0	81.04	381.8	515.29	698.9	924.82	1047.1	1109.1	1192.4	1274.4	1320.1
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	245.36	178.46	189.90	426.42	323.86
Excess of permits[a]	1500.61	2239.80	3188.81	2885.82	3030.22	2483.75	2295.10	2231.72	1627.36	1355.58	1379.97
Existing sources	2361.13	2749.32	3050.47	2595.16	2515.78	1723.09	1493.35	1301.11	624.88	507.58	383.72
New sources	–860.52	509.52	138.34	290.66	514.44	760.66	801.75	930.61	1002.48	848.00	996.25
Flow rate (m^3/hr)											
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
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
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

(continued)

Table 1. (continued)

Variable	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of sources using cleaner fuels											
Using cleaner, nonnatural 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	224
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	141

Source: Elaborated from data provided by SEREMI.

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

regulatory activity on the completion of the inventory and the allocation of permits. The process lasted 5 years, and during that period, the regulator did not track trading activity, and so there was no reconciliation of permits and emissions until the market began to take off at the end of 1998.

Table 1 also shows that permits in force have exceeded actual emissions from the beginning of the program. Two reasons explain this outcome. First, as the environmental authority had a poor historic record of sources' emissions at the time of implementation of the program, they overestimated the maximum amount of emissions that sources could potentially emit. Second, the fuel-switching process made compliance more feasible.

About the first point, the environmental authority granted emission permits assuming a 24-hr level of activity. However, during 1997-2007 large boilers work on average 17.5 hr per day. In addition, 128 sources that did not exist in 1997 received emission permits because they were operating at the time SD 4 was promulgated. 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 through time because the switching to cleaner fuels has led to a decrease in the aggregate emissions.

Regarding this process, sources started to switch to cleaner fuels[10] from 1995 onward, in response to several environmental regulations. The most popular cleaner fuel was natural gas, which started to be imported from Argentina in 1997. After its arrival, it became the cheapest and cleanest fuel readily available. Thereby, a quick switching process started and currently about 50% of large boilers declare to use natural gas, although many of them correspond to dual sources, burning light oil too.

Unfortunately, from 2004 onward, Chile has faced severe restrictions over the amount of natural gas that can be imported, giving rise to the so called *natural gas crisis*. Since then, large boilers have faced more and more severe restrictions over the quantity of natural gas available, and they 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% larger than aggregate emissions in 2004.

To better understand the impact that the lack of reliable data about sources' activity and the fuel-switching process have had over the excess of permits, we can divide the excess into these two components. Thus, we calculate the excess of permits as it would have been if the environmental authority would have allocated the initial cap based on the actual level of activity of existing sources. This excess corresponds then to the difference between the aggregate permits granted that would have been granted based on actual activity less the actual aggregate emissions.

Second, we calculate the excess of permits in force that would have occurred if existing sources would have accomplished the legal emissions' concentration target[11] tightly and without overcompliance. Thus, this excess corresponds to the difference between the actual aggregate amount of permits granted and the hypothetical aggregate if existing sources would precisely have met the legal emissions' concentration target.

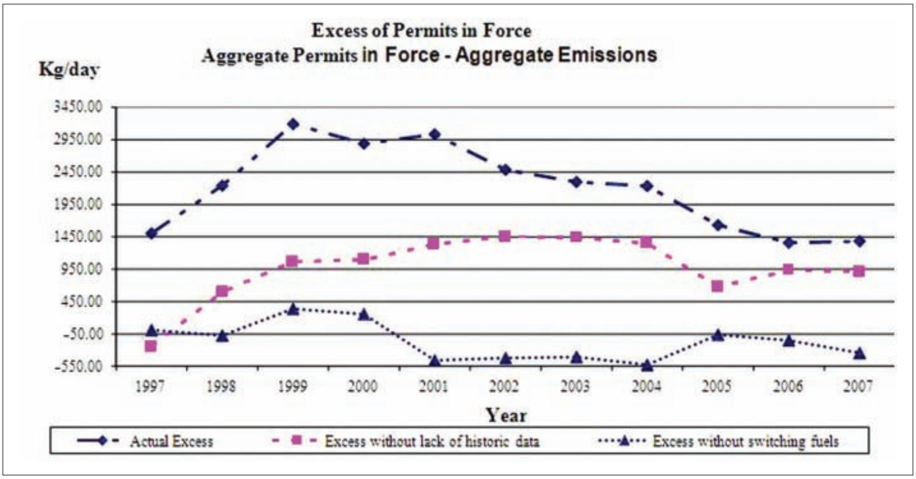

Figure 1. Excess of permits

The first counterfactual allows us to identify the effect of the overestimation of the maximum amount of emissions that sources emitted, whereas the second counterfactual allows identifying the effect of the switching process over the emissions' cap overcompliance.

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 throughout time. In fact, if affected sources would not have 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 accommodating the aggregate level of noncompliance from new large boilers. If permits would not have granted in excess, the lack of offsetting would not have allowed accomplishing the cap on emissions.

Nevertheless, as suggested by Palacios and Chavez (2005), aggregate overcompliance has coexisted with usual violations by some of the sources. Table 2 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 in the case of new sources. On average, almost 30% of large boilers has not met their obligations with regard to the cap on emissions at some point in the sample, with most of these sources being new sources. The incidence of violations in both number and magnitude has decreased trough time, although the natural gas crisis broke this trend slightly. Since 2005, the number of noncomplying

Table 2. Compliance in the Santiago's Tradable Permit Program

Variable	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Added violation (kg/day)[a]	1255.19	829.49	289.11	246.55	156.07	113.56	199.73	163.38	183.48	197.93	249.94
Existing sources	505.88	274.04	88.80	48.29	12.50	8.09	16.71	68.37	100.98	114.78	153.57
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	0.89	1.55	1.29	1.60	1.66	1.82
Existing sources	3.28	1.70	0.59	0.32	0.11	0.07	0.16	0.65	1.03	1.20	1.60
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 noncomplying sources	272	243	193	194	140	127	129	127	115	119	137
Existing sources	118	82	43	41	21	15	22	22	17	23	41
New sources	154	161	150	153	119	112	107	105	98	96	96
% of noncomplying sources	46%	42%	37%	37%	28%	25%	25%	24%	22%	23%	27%
Existing sources	20%	14%	8%	8%	4%	3%	4%	4%	3%	4%	8%
New sources	27%	28%	29%	29%	24%	22%	21%	20%	19%	19%	19%

Source: Elaborated from data provided by SEREMI.

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

existing sources has increased and so did the added violation. Before the switching, they were burning dirtier fuels like coal, firewood, and heavy oil. Their optimal response to the lack of natural gas has been starting to burn dirty fuels again, exceeding their emissions' cap and increasing the added violation.

Tradable permits are believed to promote "static" and "dynamic" efficiency; the market allocates emission permits among firms in such a way that the total costs of emission control are minimized whereas firms keep some or all of the gains from innovation through reduced abatement costs plus reduced payments for permits. O'Ryan (1996) uses a linear programming model to estimate the total costs of using market-based versus CAC policies to control TSP emissions from fixed point sources in Santiago; although he finds that a spatially undifferentiated emission trading program performs substantially worse than a system of ambient permit trading, the former policy is still much more cost effective than CAC policies.

When it comes to "dynamic" efficiency, as the switch to natural gas was quite important for compliance with the emissions cap, it is worth asking whether the tradable program had some role in encouraging sources to switch to cleaner fuels. Empirical evidence does not support such a hypothesis. According to Coria (2009), the lower price of natural gas seems to have been the main driver behind the switch although the tradable permit program had little or no effect. This result seems quite related to the features of the program. In fact, the aggregate excess of supply might have produced a very low "competitive" permit price, making the benefits from saved emission permits irrelevant. Unfortunately, price information is not easy to obtain as sources do not have to inform to the environmental authority the price agreed for their transactions and because intrafirm transactions do not have an explicit price. Besides, as discussed before, as permits constitute a permanent permission to emit, the prices of isolated transaction reflect the reservation price of the sources involved in the transaction instead of providing an idea of the price that clears the emissions market. Anyway, information from occasional brokers suggests that prices have ranged from US$10.741 (kg/day) in November 1997 to US$5.555 (kg/day) in March 1998 and from US$3,704 (kg/day) in October 2000 to US$2,144 (kg/day) in 2005. This downward trend seems to reflect the wide availability of cleaner fuels. Second, as 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 have also been irrelevant as the lack of clearly defined monetary penalties and sanctions did not provide enough incentives for firms to take a high degree of compliance or to invest in technologies to reduce emissions.

Trading Activity and Transaction Costs

Table 3 shows the trading activity to date. So far, 240 transactions have been approved, involving 445 sources and a 39% of the initial mass of emission permits.[12] As expected, evidence suggests the important role played by transaction costs in the pattern of

Table 3. Trading Activity

Approved transactions	Intrafirm	Interfirm	Total
No. of sources	313	132	445
No. of transactions	182	58	240
Total (kg/day)	996.37	582.65	1579.02
Average (kg/day)[a]	5.47	10.05	6.58
Sellers	**Existing**	**New**	**Total**
No. of sources	204	7	221
Buyers	**Existing**	**New**	**Total**
No. of sources	13	211	224
Length of the trading process (in months)	**Intrafirm**	**Interfirm**	**Total**
Total	22.38	17.03	20.49
Transactions requested before 1998	39.23	39.13	39.21
Transactions requested before 1998-2003	21.60	17.98	20.38
Transactions requested 2004-2007	9.27	7.80	8.55

Source: Elaborated from data provided by SEREMI.
a. It corresponds to the ratio between the total kg/day traded and the number of transactions.

transactions. Around 76% of the transactions correspond to intrafirm (within firms) whereas 24% correspond to interfirm trading (between firms) transactions. Further evidence is suggested by the larger amount of emissions traded in interfirm transactions and because about 26% of the sources offsetting emissions (114 sources) have traded more than once (learning effect).

Table 3 also 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 improvement. In fact, those transactions requested before 1998 needed more than 39 months to be approved.[13] Fortunately, the number of months the transaction process last has been trending downward over time.

Surprisingly, intrafirm transactions required a longer period to be approved, suggesting that regulatory efforts were focused on reconciliation of permits and emissions between firms.

Apart from the transaction costs and the uncertainty involved in the trading activity, the long period it takes to the environmental authority to reconcile permits and emissions is also related to the high level of noncompliance from new large boilers. In fact, as it is shown in the table, it took several months for new large boilers requesting offsets to legally comply with the regulation. Thereby, noncompliance is not just related

Table 4. Decrease in the Emission Permits in Force

	kg/day	%
Total emission permits allocated in 1997	4045.4	100
Emissions reduced due to the increase in the rate of offsetting in 1998 (1.2)	126.93	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 the concentration target in 2000 (50×10^{-6} kg/m^3)	331.1	8.2
Emissions reduced due to the decrease in the concentration target in 2005 (32×10^{-6} kg/m^3)	646.5	16.0
Emissions lost due to nontrading	638.21	5.8
Total emission permits in force in 2007	2171.7	53.7

Source: Elaborated from data provided by SEREMI.

to the lack of clear and automatic penalties but also related to institutional failures making the compliance process uncertain and troublesome.

Since many large boilers are dual sources (light oil and natural gas) compelled to offset their emissions according to the dirtiest fuel, there is no reason to expect a significant increase in the trading activity because of the lack of natural gas. However, it could be possible to expect an increase on the trading activity from single-fuel large boilers. Therefore, we have divided the sample period from 1998 to 2003 and from 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 equal to 26. Since 2004, it was equal to 13, although it has increased the rate of interfirm transactions.

Policy Adjustments

Table 4 shows the effects of the policy adjustments described previously over the stock of emission permits. The increase in the rate of offsetting has reduced the total mass of permits by about 6.3%. However, the decrease in the concentration target accounts for another 24.2% decrease on this mass. Finally, 15.8% of the mass has been lost because existing boilers did not trade or use their permits before the legal deadline.

Notice that the decrease in the amount of emission permits granted and the increase in the rate of offsetting have opposite effects on the attractiveness of trading. Whereas 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 needed them. This second effect should increase over time since there is a net loss of permits in the market every time a new offset is produced.

Table 5. Description of Sources Granted With IDE

	Lost IDE		Did not loose IDE	
	No.	%	No.	%
Number of sources	153	100	277	100
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/hr)	3503.2		5516.2	

Source: Elaborated from data provided by SEREMI.

Considering that 36% (153 out of 430) of the sources originally granted IDEs lost their emission permits, it is worth analyzing the reasons behind this outcome. Table 5 shows some statistics. More than 50% of the sources loosing permits are no longer operating, and 25% 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 find that grandfathering the permits instead of auctioning off created economic incentives for incumbent sources (some of which were nonexistent at the time SD 4 was promulgated) 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 (that do not have other sources to trade within their firms) loosing emission permits should be higher since the costs of engaging in the trading process are larger. Data support this hypothesis. There are clear differences in the level of aggregate emissions, size (flow rate), and level of integration between sources that lost IDE and those that did not. In fact, the incidence of poorly integrated sources loosing emission permits is quite significant. Just 9.2% of the sources loosing permits had related sources to trade. On the other side, 78.3% of those that did not lose permits have related partners. Thus, as expected, poorly integrated sources traded much less than integrated sources.

What Can We Learn From Santiago's Tradable Permit Program?

There is no doubt that despite their theoretical advantages, tradable permit programs have been used far less frequently than command and control policies. Perhaps, one of the most significant barriers for this policy to be implemented is finding a political process that favors the introduction of market regulations in environmental management. This has been the case of 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. However, 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 instrument like tradable permit programs as the key to more effective environmental protection in economies in transition as well as in the developing countries. Nevertheless, financial and institutional constraints have turned out to be main barriers, which may make the use of this environmental policy more problematic than in developed countries.

Before promoting the implementation of emission trading in economies in transition and in the developing world, we should review how developed countries have managed these issues. What have we learned about the requirements for tradable programs to work? Can less developed countries fulfill these requirements? In this article, we study 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 successfully implemented trading program offers some lessons pointing out the importance of realistic incentives to trade, spatial, and temporal flexibility, including private companies fulfilling brokerage needs and monitoring and enforcement. Have these elements affected the performance of the Santiago's tradable program? They have.

Requirements for prior regulatory approval and the underdeveloped brokerage have increased transaction costs. Besides the long period required to complete the transaction, the incidence of a significant group of smaller, older, and poorly integrated sources loosing emission permits because they did not trade before the legal deadline represents further evidence of the important role played by transaction costs preventing trading.

There is a significant rate of noncompliance because monetary penalties are not clearly defined and actual sanctions are decided on a case-by-case basis. The increase in the rate of noncompliance as the sources' optimal response to the natural gas crisis reveals the important role played by the lack of enforcement.

The program is not temporally flexible. Permits must be traded on a permanent basis rather than 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.

Finally, although so far changes in the offset rate have helped to remedy the exacerbated overallocation of permits, such rules might discourage trading in the long run as permits are depreciated progressively.

In spite of the above-described weaknesses, the aggregate cap on emissions has been met and the trading activity has increased through time. However, is it likely that the high transaction costs have decreased trading, so 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
- More certain tenure over the permits
- Clear penalties
- Avoiding rules that hamper trade, as for instance, the offset rules that provide a bias against trade
- Allowing 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 are looking for 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 provide an updated record of emission permits in force annually and contrarily to successful trading programs as the U.S. SO_2, information about actual emissions, violations, and trading is not publicly available. Enhancing public access to this information can build credibility in the environmental program, allowing brokers to enter into the market to provide information about trading partners and about the trading process and, most important, allowing society to exercise pressure over firms to improve their environmental performance (Dasgupta, Hong, Laplante, & Mamingi, 2006; Garcia, Sterner, & Afsah, 2007).

Conversely, from the Chilean' experience, we can also learn that 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 two decades of experimentation to learn how to design the institutions for a trading scheme. On the other hand, in a recent report by Tirole (2009), the author criticizes the European ETS on similar grounds, for insufficiently clear property rights and rules concerning banking, free allocation to new projects, loss of permits in plant closure, excessive subsidiarity, and penalties that are not sufficiently credible. Therefore, the Chilean scheme compares quite favorably with all the early U.S. programs and to the European ETS that in spite of being launched long after the Chilean scheme has many of the same flaws. Thus, one might thus say that this experience demonstrates that countries with similar income levels and institutional maturity as Chile should be able to develop well-functioning permit trading schemes. This should apply to most of the middle-income or "emerging" countries of Latin America or Asia as well as countries at comparable levels of development in Africa, such as South Africa.

One should also remember that many of the other policy options to permit trading, such as taxation, also imply a need for sophisticated monitoring and institutions and reliable data on historic emissions and technological options to reduce pollution. Indeed, it is not clear that taxes would outperform tradable permits in this case; the lack of base information would have made difficult to set the tax at a sufficiently high level such that it would have induced a significant reduction of emissions. The precautionary principle favors then the choice of tradable permits over taxes since ex-post aggregate emissions are known with certainty. Besides, it is the issue that in many developing countries the money that goes to the central treasury is often perceived as "lost" while the free allocation of permits increases the political feasibility of the trading instrument. Finally, there is a wide-ranging literature on the advantages of taxes vis-à-vis permits when it comes to incentives for encouragement of lobbyism or rent seeking. This literature takes us somewhat outside the realm of the current article but suffice it to say that it is far from obvious that tax systems, regulation, subsidies, or any realistic alternative would be prone to less problems of this sort than permit trading.

In synthesis, it is neither clear that trading schemes require significantly more "maturity" nor certain that institutional maturity should be a definitive criterion when judging which countries can and should develop trading schemes. More practical experience is needed here. However, considering the urgency of improving the environment in many of these countries, it is important to have a broad range of potential instruments available.

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Notes

1. In 1991, the first pilot project of emissions trading was carried out in Chorzow, Poland 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 to 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 with the programs we discuss here.
2. For instance, the Lead Phase-out program in the United States is an averaging-based trading program. Refineries were not allowed to produce gasoline averaging more than 1.1 glpg; however, interrefinery averaging of lead rights was permitted. See Hahn and Hester (1989) for an overview of the lead trading program.

3. Kerr and Maré (1998) find also evidence for the existence of transaction costs preventing trading in the lead phase out program because of underdeveloped brokerage and trading mechanisms. They estimate that the loss of cost effectiveness from these costs was around 10% to 20% and quite dependent on the characteristics of traders and the market, increasing when potential traders were small, unsophisticated, and poorly integrated. Gangadharan (2000) finds 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 and the information costs of entering the market, reducing the probability of trading by about 32%. The author finds specific "learning by trading" effects in the permits market. The results suggest 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 seem to have no effect in reducing information costs further.
4. 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 and EPA records transfers to make sure that a unit's emissions do not exceed the number of allowances it holds and makes this information available to the public.
5. In the Acid Rain Program, a very 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 a half of the 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% of their allowance in the first trading period and up to 10% in the second period, but few countries have made use of this option.
6. Stationary sources of emissions give account of approximately 20% of total suspended particles in Santiago whereas vehicles give account of approximately 28%.
7. There are currently other trading programs implemented in Santiago. These programs are intended to reduce particulate matter's and nitrogen oxides emissions coming from industrial processes. They were launched the 1st of May, 2007. As large boilers, large processes were classified between existing and new ones. In the case of particulate matter, existing processes were granted emission permits equal to 50% of their historic emissions in 1997. In the case of nitrogen oxides, they were granted as permits 67% of their historic emissions in 1997. The performance of these new programs do not differ much from the case analyzed in this article; although the level of noncompliance in the NOx program is higher due to the lack of technological options to abate this pollutant.
8. Therefore, the "initial daily emissions" (kg/day) were calculated according to the following formulas:

$$IDE^{1997–1999} = \text{Flow Rate 1997 } (m^3 / hr) \times 24 \text{ } (hr / day) \times 56 \times 10^{-6} \text{ } (Kg / m^3)$$
$$IDE^{2000–2004} = \text{Flow Rate 1997 } (m^3 / hr) \times 24 \text{ } (hr / day) \times 50 \times 10^{-6} \text{ } (Kg / m^3)$$
$$IDE^{2005–} = \text{Flow Rate 1997 } (m^3 / hr) \times 24 \text{ } (hr / day) \times 32 \times 10^{-6} \text{ } (Kg / m^3)$$

Permits above the adjusted cap were taken away.

9. This feature of the program is mainly explained by the fact that SD 4 was inspired in the early U.S. experience with tradable permit programs. Most early EPA's Emission Trading Programs were credit based.
10. Sources started to switch to light oil, liquidified gas, kerosene, and natural gas. All of them produce a lower emission concentration that 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, whereas this value decreases to 15×10^{-6} kg/m^3 in the case of liquefied and natural gas. Thereby, the switching allowed sources to overcomply with the emissions' cap.
11. Where the legal emissions' concentration target is 56 x 10^{-6} kg/m^3 from 1997 to 1999, 50 x 10^{-6} kg/m^3 from 2000 to 2004 and 32 x 10^{-6} kg/m^3 from 2005 onward.
12. In 1997, 15.2 millions of allowances were traded in the Acid Rain Program, a program characterized by low transaction costs. This amount represents approximately 15% of the total mass of allowances that year.
13. As a matter of fact, the first transaction was approved in August 1998.

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Bios

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