Market-based Approaches in Air Pollution Control: Theory and Practice

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Contents

Abstract

Emissions Trading, a market-based instrument used for environmental protection, has been adopted as one of the primary tools for emissions control in developed countries, and is being implemented in developing countries, in the context of increasing international cooperation to reduce greenhouse gas emissions (and other pollutant emissions) under the Kyoto Protocol. Emission trading is in theory both cost effective and environment effective, but implementation of such programs has never been trivial or easy. It took the U.S. more than three decades to implement what is now the world's most sophisticated, full-blown and successful functioning emissions trading program, and it will take more to duplicate the success of the U.S. programs in other developed countries, and much more in developing countries. Valuable lessons have been learned for designing and implementing efficient and effective emissions trading programs from the U.S. and other developed countries' success, and great challenges and obstacles have been revealed from the developing countries' failure. This paper examines two successful examples of emissions trading programs: the U.S. programs and the EU programs, as well as two representative unsuccessful programs in China and Chili. The examination attributes the success of the U.S. and EU programs to an efficient combination of trading options, such as banking and auctioning, and reveals the most common challenges and obstacles hampering success in developing countries, such as inefficient institutional arrangements, insufficient market information and inadequate regulatory intervention. By raising awareness and caution of the pros and cons of emissions trading schemes and their feasibility and practicality, this paper will hopefully contribute to a better understanding of the public policy challenges that lie ahead for countries that are new at working with such programs.

1. Introduction

To date, air pollution has been the source of serious environmental and health concerns. Pollutants include many different kinds of harmful chemicals and gaseous emissions generated by human activities. Electricity, transportation and industrial processes are the main sources of significant levels of anthropogenic emission of air pollutants such as nitrogen oxides (NOx), sulfur dioxide (SO2), particles and greenhouse gases that have major harmful effects on human's respiratory system, usually causing serious inflammatory symptoms, making the young, the newborns, and the elderly most vulnerable. This has been seen in increased hospital admissions, emergency room visits and medical treatments, and the soaring health care expense has become a heavy burden for the economy (Health Canada, 2006).

Besides its detrimental effect on human health, air pollution has a variety of harmful environmental effects (IPCC, 2007). The most prominent is acid rain, caused by emission of NO_x and SO_2, from the use of fossil fuels. Heavy reliance on fossil fuels has given rise to significant amounts of NO_x and SO_2 emissions worldwide. Carried by wind and travelling for thousands of miles before dropping to ground with precipitations, they can cause great damage, not only to man-made buildings, but also to the ecosystem by disrupting the acidity of water and soil, therefore, destroying the habitats of fish and other wild life.

The second harmful environment effect of air pollution is the global climate change, stemming from greenhouse gas. Known as the major cause of global warming, greenhouse gas is a family name for carbon dioxide (CO_2), methane, and chlorofluorocarbons (CFCs), etc. basically any gas that can absorb and store energy from sunlight, thereby raising the overall atmospheric temperature. CO_2, among all the others, is the most responsible pollutant for global warming, and the amount of its emission is monstrous, thanks to the substantial fossil fuel combustion. Global warming can lead to serious consequences, such as glacial melting, sea levels increase, floods and drought (Ellerman et al., 2003).

The ever-increasing international consensus on global control of air pollutant gases (including greenhouse gases) emission lead to eager demand for efficient and cost-effective design of emissions control policies. The traditional approach of emissions control in practice has been a command-and-control system that traces back to the 60s. The traditional approach was effective in enabling governments to accurately control the amount of emissions, but it has shortcomings that outweigh its merits, due to its environmental and cost ineffectiveness. Because of these disadvantages, the traditional emissions control system gradually gave way to the long-praised market-based system which has won popularity and achieved success in multiple countries during the ratification and implementation of the Kyoto Protocol (U.S. EPA, 2003).

To provide a broad and clear idea of the on-going debate and practice of emissions control systems for future guidance of better system design, this paper is devoted to reviewing the pros and cons of the traditional approach and highlights the merits and demerits of the market-based approach from theory to practice. The second section illustrates the traditional approach and its shortcomings. The next section elaborates on the evolution of the market-based approach, its variety of design and its economic and environmental virtues and advantages. The following section summarizes and comments international practice of the market-based system in emissions control, highlighting prominent examples of successful countries in the implementation and administration of emissions trading markets and countries whose experience provides valuable reference for future success. Problems with implementation in some countries are also discussed. The last section provides concluding remarks.

2. The traditional approach and its shortcomings

The command-and-control approach has been the most popular and most widely used policy used by environmental regulators before the market-based approach (such as emissions trading program) was proposed.

The command-and-control approach is a system which allows regulators to set up strict emission standards to regulate the sources of emission. Regulations range from controlling the location of polluting activities to the specification of emissions ceiling. Regulators "command" by how much emission must be reduced and what pollution control technology must be used by manufacturers. Under the command-and-control regime, all the emissions sources are treated equally. Because of this, they usually lack incentives to look for more efficient ways to control emissions and to reduce them by more than the standard. As a result, this "one-size-fits-all" command approach is costly, and it is impossible for the regulators to collect all the necessary information under different circumstances. Thus, under a command-and-control regime, all the sources are treated equally and have disincentives to go beyond the environmental goal that is commanded.[1]

In addition, the command-and-control approach seems less cost-effective in meeting the same environmental goals as other pollution control programs would be. This is demonstrated in the following numerical example.[2] Suppose there are two plants: plant 1 (clean) and plant 2 (dirty). The marginal cost of pollution control for plant 1 and plant 2 is $100/ton and $500/ton respectively. The environmental goal is to reduce the pollution by 2 tons. Under the command-and-control approach, plant 1 will spend $100, and plant 2 $500, on pollution control. The total cost of control is $600. However, if plant 2 could simply pay plant 1 to reduce 2 tons of pollution because plant 1 is far more efficient than plant 2 in pollution control, the costs for plant 1 and plant 2 would be $200 and $0. The total cost of control is then $200, much less than the $600 in the command-and-control system (Ellerman et al., 2003).

In conclusion, the command-and-control approach gives less flexibility (hence incentives) of pollution control to the sources, and it is less cost-effective as well. However, due to historical reasons, the command-and-control approach to air pollution control is still in effect in many countries, including the U.S. Even long after the merits of emissions trading system (the market approach) have been discovered, debated, and recognized, the command-and-control regulation remains partially intact worldwide.[3]

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[1] Driesen (1998).

[2] A similar demonstration can be found in Cole and Grossman (1999).

[3] In fact, command-and-control environmental regulations are “nominally” efficient in the sense that they produce social benefits that exceed their costs; they are even the most efficient approach, if the historical, technological and institutional contexts were to be taken into consideration that could affect comparative efficiency of alternative policy options. See Cole and Grossman (1999) for a more detailed discussion.

3. Emissions trading: the market approach

3.1 The evolution of the concept

Emission trading is a market-based approach which the government can use to control pollution. The purpose of emissions trading is to design a system of property allowance which can achieve environmental goals with the lowest possible compliance cost. The initial idea comes from Coase (1960) arguing that the market could play a substantial role not only in evaluating property rights, once made explicit and transferable, but also in assuring their best use on the whole societal scope. This idea was imbedded in practical programs for pollution control after its applicability pointed out by several economists, in particular, Crocker (1966) for air pollution control and Dales (1968) for water pollution control.

In an emissions trading system, every regulated pollution source receives a fixed amount of allowance which is added up to meet an aggregate standard. Each tradable allowance is defined as 1 unit of pollutant emission. Once the allowances are issued, the regulated sources cannot exceed the emission levels which are determined by the number of allowances they hold. Under ideal conditions, the emissions trading system is not only able to achieve a pre-specified target, but also achieve the target at minimum cost, even in the absence of any regulatory knowledge on the cost of such control.[4] No doubt this gives the system its first appeal to policy makers. The regulators can be freed from the burden of obtaining almost impossible-to-get information about the detailed compliance cost of different sources. The emissions trading approach achieves the goal cost-effectively simply through the market mechanism (Drayton, 1978).

Moreover, under the emissions trading regime, the sources have great flexibility, as they can trade their emission allowances at the market price. Each source will have detailed information on their compliance cost. Thus, they can decide whether to trade or not in the allowance market when considering the profit maximizing problem based on their own interest. So long as there are differences in marginal abatement costs, there exist incentives, large or small, for emission trading. Firms with high marginal abatement cost will do well to buy permits from firms with low marginal abatement cost, and the social marginal abatement

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[4] See Tietenberg (2010).

cost can be equalized in this way when the permit market clears and permit demand equals the fixed (and regulator-controlled) supply. This was first proved formally by Baumol and Oates (1971), in a special case which is interestingly most relevant with air pollutant emissions control.[5] Later the existence of cost-effective permit market equilibrium was proved by Montgomery (1972) in a more complicated case.

Theory shows that the market approach is typically more cost-effective than the command-and-control approach. Moreover, empirical work demonstrates an indeed large degree of difference in the efficiency between the two regimes, which suggests that the gains from regulation reform (from command-and-control to emissions trading) would be large enough to outweigh any costs associated with the transition.[6] A variety of programs based on emissions trading have been designed, developed and evolved, and their success has been assessed under the guidance of economic principles. In addition, emissions trading may affect pollutants that are not covered by the program, but are related to the pollutants that are covered. This may trigger external environmental effects, most of which are desirable.[7]

3.2 The varieties of emissions trading schemes

Ever since the discovery that the emissions trading approach can achieve environmental goals in the most cost-effective way, two major types of emissions trading approaches have been developed. They all have the tradable feature, though they are different in many ways.

3.2.1 Emission reduction credit

An emission reduction credit (ERC) program (also known as credit-based approach) presumes the existence of facility-specific baselines, which are provided by previously determined standards, and decided by the regulator. The baseline will vary with output since it is defined by the emission rates (e.g. kg (emissions)/unit (output)). The emissions sources need to earn credits before they start trading through cutting emissions under the baseline. The ERCs are issued at the end of a given period. Once the credits are created, the sources are

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[5] The Baumol and Oates results apply in the special case when all emissions from all emitters have the same impact on the environmental target (Tietenberg, 1973), which is indeed the case in air pollution, where all greenhouse gases have the same impact on the global climate regardless of the location of their emitters.

[6] Tietenberg (2006); Carlson et al. (2000); Ellerman et al. (2000).

[7] Tietenberg (2006).

able to trade them with other sources whose emissions may exceed the determined baseline. Those ERCs are considered to be permanent, just like property rights.[8]

The ERCs have to be certified on a case-by-case basis before they can be traded. The regulated sources must provide detailed information about how to achieve the requirements, whereas the regulator with enforcement power has to verify, approve and inspect every transaction. This procedure also implies high transaction costs. The ERC program has been used in several states in the US to control air pollution, such as lead in gasoline and heavy-duty engine emission standards programs.[9]

3.2.2 Cap-and-Trade

In a cap-and-trade system, the total number of emissions of the regulated sources is capped for a given period by the regulator (government) through the political process. The emission cap should be set based on the historical emissions level (must be lower than historical emissions). The time period of emissions control has to be defined clearly. During the defined period (also referred to as "true up" period), the sources are required to cover their emissions by the allowances they hold (obtained by either initial allocation or trading) and report at the beginning of each period, and the amount must be lower or equal to the emission cap.[10]

In contrast to the ERC program, a cap-and-trade program does not require pre-certified credits. The allowances are traded freely in the market; therefore, the cap-and-trade scheme has lower administrative cost. The regulators can concentrate on setting an appropriate emission cap. The difference in emission control cost among regulated sources is the main reason that favours emissions trading. The sources can simply control their emissions to meet their initial allocations. The sources with lower emission control cost (also called cleaner sources) can overcut their emissions and make profits by selling or banking them for future use. The sources with higher emission control cost will be better off by under-controlling their emissions and buying the allowances from the cleaner sources.[11]

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[8] Farrell and Lave (2004).

[9] U.S. EPA (2001).

[10] U.S. EPA (2003).

[11] Two exceptions are noteworthy: electric utilities operating in a price-regulated market and facilities that

The initial allocation of allowance is a key issue in a cap-and-trade system. Free allocation and auction are the two main types. We will discuss this issue in detail in the next session.

In conclusion, cap-and-trade is the most widely used trading scheme, having achieved substantial cost savings for the participants. Examples of cap and trade programs include U.S. Acid Rain Trading Program, California RECLAIM (the Regional Clean Air Incentives Market) and the Regional NO_x Trading Program.

Nonetheless, it is worth noting that a cap doesn't provide assurance of stable prices like an alternative program such as environmental taxation will do. When "shocks" occur, a cap can trigger permit price increases that may not be acceptable politically. An example is the greater Los Angeles area RECLAIM program, which aimed to control air pollutants emitted by electricity utilities.[12] During this program, the market experienced a very large and unexpected increase in demand for electricity that lead to increasing output that can only be accommodated by bringing back on line plants that are much older, hence more polluting. Since the supply of permits is fixed, the reopened "dirtier" plants caused permit prices to spike in a never anticipated pattern. To avoid such volatility in prices, the concept of a "safety valve" is proposed. The idea is to predefine a price threshold and impose a penalty on all emissions over the cap whenever prices rise above the threshold. In the case of RECLAIM, a substantial fee per ton of pollutants was imposed when permit prices soared above a threshold and the revenue was used to subsidize sources not covered by the cap to achieve additional emission reductions.[13]

3.2.3 Banking

Banking can bring great inter-temporal flexibility to the sources, which have a surplus of allowances in the current year, and bank and use them in future expansion. As shown in Figure 1, in a command and control program where banking is absent, the emissions are dropped suddenly from the baseline to the new regulated amount, since all the sources have to act the same and follow the "command". However, banking makes this process smoother.

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receive allowances based on an output-based distribution system. See Stavins (2007).

[12] Jacoby and Ellerman (2004).

[13] Harrison (2002).

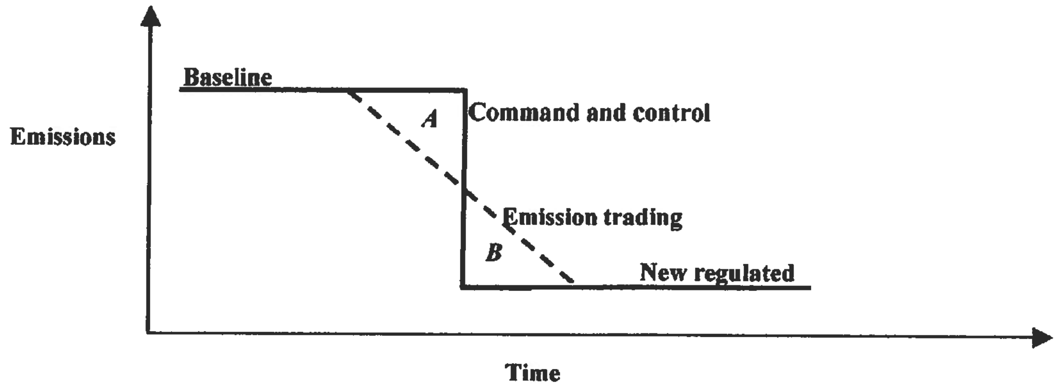

Figure 1: The Effect of Banking

Source: Farrell and Lave (2004)

Some sources can reduce earlier, some latter, as long as the deposited amount (represented by triangle A) is greater than or equal to the withdrawn amount (represented by triangle B) (Ferrell and Lave, 2004). According to Burtraw et al. (2005), companies can treat banked allowances as a financial asset, whose value can increase the feasibility and longevity of the program, because it is more likely for allowance-banks holding firms to be interested in the long run success of the program in order to realize the value of the allowances in their bank.

Banking has been successfully applied in most of emissions trading programs, such as the U.S. Lead Trading Program, Acid Rain Program, ABT program and North-eastern NO_x Budget Program. It brings important improvement in both the economic and environmental performance of emissions trading programs. For example, it has been estimated that almost half of the overall lead rights were traded annually, and this significant banking activity has generated additional economic gains. The importance of banking in improving environmental performance of both the Lead Trading Program and the Acid Rain Program has also been acknowledged. In fact, banking (and averaging) has been more heavily used than trading, as in the case of the U.S. ABT program (Nichols, 1997).

Banking has proved to be advantageous in generating environmental and cost-saving gains; its greatest advantage, though, may come from its flexibility in dealing with uncertainties and avoiding price fluctuation which would be the result of a fixed cap when uncertain demand for allowances rises in the case of non-instantaneous abatement responses, and hence dampen potential allowance price volatility.[14]

[14] Banking does not eliminate vulnerability to unexpected shifts in demand, and it is not the only means of

3.2.4 Initial allocation

Since the allowances have monetary value which can be transferred between sources, in designing an emissions trading program, the key issue that policymakers may face is how to distribute the allowances in the most effective manner. There are generally three choices that are most commonly applied: (1) auctioning; (2) free allocation; (3) a mix of the two.

3.2.4.1 Auctioning

Among the methods of allowance allocation, auctioning is considered to be more efficient and transparent.[15] The allowances - as mentioned above - have monetary value. The auctioning of allowances, therefore, generates revenue for the government who is the direct receiver. Under the auction scheme, the market is simply in charge of the process. The emission sources that value the allowances the most and provide the highest price will get them. The prices reflect the marginal emission control cost closely. The whole process of auction is available and fair to all the emission sources that take part in it. New entrants have the same opportunities as incumbents.

While designing the auction system, the policymaker should avoid market manipulation which can cause inefficient outcomes. As Ramseur (2008) puts it, the policymaker should discourage collusion among bidders, which may artificially lower the allowance price to the bidders' advantage. Also the policy maker should prevent bidders from hoarding allowance by making speculatively high bids, usually far above the competitive price, so as to obtain and store a disproportionately large portion of the allowance for future use.

In general, there are three main types of auctions: discriminatory price, one round, sealed bid auctions; uniform price, one round auctions; and uniform price, multiple round auctions. (Hahn, 2008; Holt, 2007).[16] Their processes are illustrated below.

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avoiding price spikes, but it does work as a good "safety valve" (see, e.g., Pizer 1999). In this mechanism, sources that are subject to a cap-and-trade program are allowed to purchase additional allowances at the "safety valve" price. This can avoid an "excessive" allowance price which would otherwise happen when demand for allowances is greater than expected. However, the safety valve will increase emissions to above the set cap, thus it should be used in parallel to some other mechanism which would offset the increased emissions so that overall emissions do not exceed the cap. See Jacoby and Ellerman (2004) for further discussion.

[15] Smith and Ross (2002).

[16] More information on EPA's SO_2 emission trading auction is available at: www.epa.gov/airmarkets/trading/factsheetauction.html#how.

Discriminatory price, one round auction: In this type, the auction is only one round (sealed bid). The bidders offer the prices for certain amount of allowances they would like to get. The regulator starts distributing the allowances to the bidder who offers the highest price, then the one that offers the second highest price, and so on, until the allowances are used up. For example, suppose there are 100 units of allowance to be auctioned. The highest bid is $120 per unit for 60 units, and the second highest bid is $110 per unit for 50 units. The result will be that the highest bidder gets 60 units of allowances at the price of $120 per unit, and the second highest bidder 40 units of allowances at the price of $110 per unit.

Uniform price, one round auction: In contrast, "uniform price, one round auction" requires all bidders to pay the second highest bid price. For the same example above, the result will be different: the highest bidder ($120 per unit) gets 60 units of allowances at the price of $110 per unit (the second highest bid), and the second highest bidder ($110 per unit) gets 40 units of allowances at the price of $110 per unit.

Uniform price, multiple round auctions: The regulator using this type of auction sets up a price for all allowances. The original price would be so low that demand would be higher than supply. The posted price would then be raised little by little until demand is equal to or a little less than supply. The price that equalizes demand and supply will be the final price that bidders pay for the allowance they would actually purchase.

3.2.4.2 Free allocation

Permits can also be allocated free-of-charge to the emitters by some criterion (such as historic authorized emissions, grandfathering, etc.). There are certain advantages to free allocation. The biggest advantage is that free allocation increases the relative attractiveness of an environmental protection policy. To the extent that stakeholders can influence policy choice, distributing allowances free-of-charge has made it more feasible to implement emissions trading programs (Svendsen, 1999). Still, even when political feasibility is taken into consideration in the design of programs, free allocation is not inevitable in principle, since the amount of revenue needed to hold stakeholders harmless during the implementation of the program is only a fraction of the total revenue that auctioning would generate, as suggested by empirical evidence (Bovenberg and Goulder, 2000).

Another argument for allocating allowances free of charge is that charging firms for emission rights will impair their competence.[17] For example, the chemical, aluminum, and cement industries are often considered to be vulnerable to international competition, and additional costs resulting from charges on allowances may give these industries incentive to move their factories to another region where environmental policy is less stringent and add to local pollution problems.

The disadvantages of free allocation are the lost revenues from permit sales that could have been used to alleviate the distortions of some pre-existing distortional tax system. For example, the permit sales revenues could be used to reduce income tax rates, thus reducing the distortions associated with marginal tax on income. Recent work indicates such "revenue recycling" can in principle enhance the efficiency of the system by a large amount.[18] This of course favours the use of revenue-raising instruments such as auctioning to allocate permits, rather than free distribution. In addition, free allocation can also cause inefficient strategic behavior. Since free allocation is usually based upon historic use, emitters will have an incentive to emit more pollutants prior to the implementation date to qualify for a larger initial allocation. Therefore, to minimize such effect, initial allocation should be based on a combination of historical emission activity levels and emissions rates that are in accordance with standard norms.[19]

3.3 Effectiveness assessment

Several studies have shown solid evidence of cost savings from trading in the Acid Rain Trading program. The gains stem from both spatial and temporal trading under the cap-and-trade component of the program and are measured in comparison to estimates of the costs that would have been incurred to obtain the same emission reductions using a non-market approach. Ellerman et al. (2000) and Carlson et al. (2000) estimate that cost savings can be achieved with as much as 50% reduction in compliance costs relative to the

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[17] Ramseur (2008).

[18] See e.g. Goulder et al. (1999), Parry et al. (1999), Parry et al. (2006).

[19] In response to evidence on both the efficiency and distributional advantages of auctioning, several states in a new emissions trading program to control carbon emissions in the Northeast (The Regional Greenhouse Gas Initiative) are currently planning to auction off the allowances. See National Commission on Energy Policy (2007).

costs of a command-and-control alternative. In the Los Angeles Air Basin RECLAIM program, in which there has been substantial trading activity, the cost saving is estimated to be 40%, and more cost saving is still yet to come in the future implementation of the program.

Moreover, researchers have argued that emissions trading system has helped to enhance environmental goals for three reasons. First, where the firms can bank emissions reductions when emission reduction requirements are phased in, as in the case of the Lead Trading, Acid Rain, ABT (Averaging, Banking and Trading programs), and Northeast NO_x Budget Programs in the U.S., the required emission reduction has been achieved in an accelerating pattern, since as long as emission reductions are associated with benefits that are discounted at a positive rate (which is certainly the case), the cumulative, required emission reductions will accelerate in time, even though the achievement of future emissions control may be deferred by the use of banked credits from early reductions (Goulder et al., 1999; Tietenberg, 2010).

Second, when firms that face high marginal costs of abatement or technical infeasibility are allowed to buy allowances and hence comply with environmental requirements by effectively paying others to reduce emissions on their behalf, economic hardship or technical barriers can be dealt with without relaxing the emissions standard and diminishing environmental effectiveness of an emission control program. The result is a decentralized mechanism for offsetting emissions that does not detract from achievement of the environmental goal (Harrison, 1996).

Third, an emissions trading system has greater ability to gain consensus on the environmental goal. When flexibility is present, an even more demanding goal can be adopted, because the mechanism can ease the burden of those who might otherwise stand to lose the most from tighter regulations and be therefore the biggest opponents. For example, the inclusion of emissions trading in Title IV of the Clean Air Act Amendment of 1990 in the U.S. enabled acid rain legislation to move on from a decade-long stalemate. In a similar way, the northeastern NO_x trading program also helped state officials and regulators to attain the National Ambient Air Quality Standards for ozone in these states, where such a goal has long been beyond attainment, and emissions trading in both SO_2 and NO_x enabled regulators in southern California to achieve the required emission reduction requirements (Harrison and Nichols, 1992).

Furthermore, emission trading programs will bring ancillary benefits that would lead to improved environmental quality, such as creating greater incentives for innovation in emission-reducing technologies than command-and-control regulations,[20] more significant improvement in the quality of environmental data resulting from the monitoring requirements of emissions trading programs, which should contribute to better understanding of and solutions to remaining environmental problems.[21]

To sum up, in general emissions trading has improved substantially the effectiveness of environmental goals, though in some programs emissions trading may not take all credits for these improvements. Some complementary policies or exogenous factors may also be contributing. Evidence from laboratory experiments suggests that proper design of the trading market is also vital for the program's effectiveness (e.g. Cason, 1995; Cason and Plott, 1996; Cason and Gangadharan, 1998). Some programs with adequate market instruments work just fine and to the expectation, whereas others don't, leaving potential improvement to the market functioning rules.[22]

Also noteworthy is that not all emissions trading mechanisms are equivalent. Laboratory experiment evidence seems to favour the cap-and-trade mechanism, among all market

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[20] There is indeed a disincentive to go beyond the requirement of a command-and-control system because the more efficient abatement technology, the tighter the standard will be. In contrast, the incentive to abate in cap-and-trade programs is continuous when any improvements in abatement technology will result in allowance savings and increase the financial value of the firm (Swift, 2001). Kerr and Newell (2003) provide empirical evidence that the Lead Trading Program led to more efficient adoption of lead-reducing technologies by refiners. As confidence is gained in the effect of these incentives on innovation, it should be feasible to reduce emissions more than would otherwise be the case.

[21] Although emissions monitoring could be, and sometimes is, required of command-and-control regulation, more typically emissions are not monitored since compliance is determined by inspection to ensure that the mandated equipment is installed and working or that the mandated practices are being followed (Ellerman et al., 2003).

[22] For example, Cason and Plott (1996) find that the uniform price call auction is more efficient, induces more truthful revelation of underlying values and costs, provides more accurate price information, and is more responsive to changes in underlying market conditions, relative to non-uniform price call auction. On the contrary, Cason and Gangadharan (1998) conclude that the tradable emission permit program implemented in the Los Angeles area featuring a new electronic bulletin board trading institution performs well and the prices reflect market conditions quite accurately.

mechanisms under scrutiny, in terms of cost effectiveness (Buckley, 2004; Buckley et al., 2005). For example, Buckley (2004) finds that the ERC programs exhibit higher average emission rate, compared to an optimal cap-and-trade program with the same emissions target. Following the same argument, the Buckley et al. (2005) experiment shows that aggregate output and emissions are inefficiently high under ERC programs (also known as baseline-and-credit trading plan) compared to a corresponding cap-and-trade program at the optimum.

Nevertheless, it is worth noting that in the real world, some other economic factors may also come into play and affect the effectiveness of emission trading mechanisms. One example is the presence of transaction costs (Stavins, 1995). Another is market power. It has been argued that when the emissions-controlling program is based on tradable pollution permits, the least cost solution is not reached and the post-trading equilibrium relies on the initial allocation, if there is a dominant strategic firm in the pollution permit market that seeks to minimize its environmental conformity cost (Hahn, 1984). In this case of "simple manipulation", the initial allocation of tradable rights to emission is no longer indifferent.

Moreover, the structure of some industries may exhibit "exclusionary manipulation". Dominant firms may manipulate the emission rights trading market to influence the behavior of rivals in the same industry, driving up rivals' costs to obtain an advantage in the product market. This strategy will sometimes worsen, and other times alleviate, the abatement inefficiency, depending on the initial distribution of permits (Misiolek and Elder, 1989)[23]. In this case, interaction between firms in an industry will become an important issue (Newbery, 1990; Vickers and Yarrow, 1991). An expanding literature has thus been devoted to studying the implications of strategic behavior on the efficiency of market-based policies, trade in environmental rights, and the equilibrium in related markets (Misiolek and Elder, 1989; von de Fehr, 1993; Fershtman and de Zeeuw, 1995; Sartzetakis 1997; Joskow and Tirole, 2000; Mansur, 2004). Although in these studies the crucial assumptions about the realization of

[23] It is shown that strategic considerations typically drive the aggressiveness of firms in the market for emissions rights and lead to under-investment in abatement technology in order to keep new entrants from entering. Typically such an industry structure is detrimental to consumer welfare, and indeed overall industry welfare, under certain conditions (von de Fehr, 1993).

market power differ and seem to be restrictive, the importance of exclusionary manipulation has been generally recognized and invoked as part of the explanation of the inefficiency in an emitting industry's product market. For example, Kolstad and Wolak (2003) blame exclusionary manipulation behavior for the California electricity crisis in 2000. In the international context, such strategic behavior will provide government incentives to distort its pollution cap from the first best target so as to achieve trade-related policy objectives by deterring the foreign rivals' production. Such strategic behaviour can increase (or decrease, depending on specific circumstances) global emissions, resulting in the so-called "carbon leakage" (Bueb and Schwartz, 2011).

Along the same line, later studies have illuminated the advantages and disadvantages of permits allocation to market-dominating firms (Malueg, 1990; Joskow and Tirole, 2000; Brueckner, 2002; Eshel, 2005; Resende and Sanin, 2007). Brueckner (2002) studies the case of the air transportation industry and finds that in the case where a handful of airlines dominate the market, the success of a market-based approach to trading exclusionary permits depends largely on the initial distribution of rights among airlines.[24] Yet the permits market can still increase efficiency by allowing the firm with market power to operate in the market for emissions rights as a buyer or seller, compared with the case where there is no emission trading market or where the market is regulated through emission quotas (Eshel, 2005)[25], despite the inevitable real effects of strategic behaviour of firms in non-competitive markets on equilibrium permit prices and permit demand, and therefore actual emissions (Resende and Sanin, 2007).

Besides the market-disturbing forces such as anti-competitive behaviour and strategic interaction between firms, laboratory experimental studies also point to other market imperfections that hamper the effectiveness of an emission trading market, among which are

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[24] The same concerns have also been voiced in the early study about the use of emission rights to control water pollution in Scotland's Fourth Estuary (Hanley and Moffat, 1993). They show that market power may become a serious obstacle for least-cost pollution control based on tradable permits.

[25] According to Eshel (2005), the dominant firm should be given a relatively smaller share of initial rights if the increase in shares is accompanied by an increase of the product price, and a relatively larger share of initial rights if the increase in shares leads to a decrease in the product price, assuming that the firm optimizes and enhances its monopoly power in the market for rights.

industrial heterogeneity and market uncertainty. Researchers are yet to integrate the separate frameworks for comprehensive evaluation of the implication of market imperfection on the effectiveness of emissions trading programs, but existing studies already uncover some of the negative effects. Ben-David et al. (1999) suggest that higher degrees of abatement cost heterogeneity may lead to decreased efficiency in the operation of the permit market. In another study, Ben-David et al. (2000) show that uncertainty dulls incentives to achieve cost savings through permit trading and inhibits efficient allocation of abatement efforts by firms.

Also could institutional idiosyncrasy have an effect in the market operation. Bureaucratic inefficiency may be another problem that hampers the effectiveness of emissions trading. Excessive cautious bureaucracy may impose constraints on emissions trading that would impede the system from working to its full capacity to achieve environmental goals and save costs as much as expected. Fortunately, over time and with increasing bureaucratic comfort with the idea of emissions trading, both the number and intensity of these constraints have shown a tendency to diminish.[26]

4. Emissions trading practice around the world

4.1 Experiences in U.S.

(1) EPA ET programs

The U.S. is the birthplace of the idea of a market approach in environmental protection. It also has the most successful version of emissions trading to date. The earliest of U.S. emissions trading programs is the EPA ET (Environment Protection Agency Emissions Trading) program, which started in the mid 1970s, under the Clean Air Act. The program included four parts:[27]

Part one was netting, which allows an existing facility to increase emissions amounts from new sources or major modifications of existing sources if the same facility can reduce emissions amounts from its other sources sufficiently.

Part two, offsets, allows a major new source to locate in a non-attainment area (where a

[26] Parry et al. (2006).

[27] U.S. EPA (2001).

given National Ambient Air Quality Standard was not attained) if an existing source has reduced its emission by at least as much as the new source would emit.[28]

Part three allows a firm to comply with an aggregate limit which combines the limits for several different sources instead of with all the limit for each source individually; because this policy allows firms to combine limits into an aggregate limit like combining small bubbles into a big one, it gets its name: bubble.[29]

Part four is banking, which gives firms credits for reducing emissions below the relevant standard, and the credits can be accumulated for future use or sale.

These early programs are cumbersome to implement, and incapable of distinguishing whether firms' reduction of emissions was beyond what was required from them; as a result, their applicability was restricted, and relatively fewer trades and lower cost savings had been achieved than supposed, since the resulting transactions costs from the pre-approval requirements and construction of customized arrangements often exceed the market value of the credits and have indeed been the major obstacle to more widespread participation in these programs[30] (Hahn and Hester, 1989).

Still, the early EPA ET programs provide a good precedence of official recognition of the potential value of emissions trading, and they precede the more successful emissions trading programs, which encourage to embody the concept of emissions trading into practice on a larger scope.

(2) Lead trading program

The early EPA ET programs are the predecessor of a much more successful trading

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[28] Conditions apply, however. Offsets can only be used in certain geographic areas and any "trades" using them are not one-for-one.

[29] These "bubbles" are difficult to combine, however, since it initially involved approval of revisions to an applicable standard, and it was such a lengthy administrative process as to discourage the use of bubbles (Ellerman et al., 2003).

[30] For example, Foster and Hahn (1995) estimate that in the Los Angeles region, broker fees (fees that are charged when brokers and other intermediaries are involved in putting buyers and sellers of credits together) vary between 4% and 25% of the value of the trade, depending on the complexity of the transaction to comply with EPA's administrative and regulatory requirements, and the administrative fees to government agencies in Los Angeles can total about $25,000 per trade, with the approval process taking from five to twelve months. Moreover, only about 20% of proposed trades are fully approved as proposed.

program during the mid-1980s: the averaging program for regulating lead in gasoline, which enforced lead limits on refineries throughout 1982.

In this program, each refinery was allowed to average lead concentration across its total gasoline production, and if the lead in its gasoline was below the average, it was rewarded with permits which could be sold to other refineries that use lead in their gasoline above the limit. The program was implemented nationwide and during the implementation, the lead limit was reduced more than ten-fold in two phases. As part of the rule, refineries could bank their lead reductions during the first phase and use or sell it during the second phase. The biggest success of the program was the establishment of a vigorous market in lead rights. In a typical quarter, more than half of all refineries participated in the market to trade as many as one fifth of total lead rights. The fraction of lead rights in trade was even larger after the tightening of lead restrictions (Nussbaum, 1992).

Particularly successful was the banking components of the program. The banking of 10600 tons of lead had lead to savings of more than $226 million (in 1985 dollars and discounted at 10% real rate) over two years and half. This counted for around 20% of the estimâted cost and led to a faster reduction in lead emissions than might otherwise have been achieved. Another marked innovation in this program is the use of averaged refinery-specific limit as baseline without worrying about whether a specific refinery would have reduced the lead content of gasoline to a lower level, hence avoiding annoying case-by-case review for tradable credits certification and additional costs for monitoring of calculation of credits and debits (differences between the refinery's average lead content and its average limits, which are easy to calculate). In effect, credits were automatically issued to refineries that successfully reduced lead content below the average and could be used at other facilities.[31]

More credits were given to the Lead Trading Program for two reasons. First, according to Kerr and Newell (2003), more efficient lead-reducing technologies were adopted thanks to the Lead Trading Program. Second, according to the U.S. EPA (2001), the banking component of the program has introduced useful flexibility that accelerated the phase-out of lead in gasoline during the last half of 1985.

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[31] U.S. EPA (2001).

(3) Acid rain program

Yet the success of the Lead Trading Program was dwarfed by the 1990's sulfur dioxide cap-and-trade program (the Acid Rain Program), which was a creation of Title IV of the 1990 Clean Air Act Amendments and so far the largest, best-known and most successful experience with emissions trading. Under this innovative approach targeted at controlling the emission of acid rain gases from electric utility, allowances, which provide a limited authorization to emit sulfur oxides, were allocated to individual plants which would reduce by the year 2010 about 10 million tons of emissions from 1980 levels by reducing the number of emissions allowed in two phases. The allocation of allowances is based on an allocation formula. In the formula, each allowance is defined annually, but emitters are allowed to bank unused allowances for future use, or transfer them in full to other emitters (McLean, 1997).

One of the many innovations this program features is an auction market institution, which assures that allowances are always available and prices are transparent so that transactions costs were lower and emission trading is more effective than would otherwise be in a private sale where information was confidential and knowledge about potential buyers and sellers was absent. This auction market was instituted by the EPA and run by the Chicago Board of Trade. In face of opposition of utilities which had to buy at the full market price the allowances that would be given to them free of charge under the traditional distribution system, EPA established the so-known "zero revenue auction" to ease the potentially significant additional financial burden on these utilities.[32] In this auction, EPA withholds somewhat less than three percent of the allocations of allowance to utilities, and auctions them off to the highest bidders. Successful buyers will pay their actual bid price, instead of a common market-clearing price, and the proceeds will be refunded to the utilities from which the allowances were withheld on a proportional basis, so that the degree of inefficiency of the auction design is held to a minimum (Ellerman et al., 2000).[33]

(4) RECLAIM program

At about the same time as the Acid Rain Program, another prominent cap-and-trade

[32] Hahn and Noll (1982).

[33] The auction design is not efficient, because it provides incentives for inefficient strategic behavior; see Huasker (1992) and Cason (1993).

program was developed by regulators in the Los Angeles air basin. This program, RECLAIM (the Regional Clean Air Incentives Market), was the first significant example of a tradable permit program developed by a local jurisdiction, in contrast to the previous federal-authority-developed programs (Foster and Hahn, 1995).

Unlike the Acid Rain and Lead Trading programs, RECLAIM covers a heterogeneous group of participants, ranging from power plants, refineries, cement factories and other industrial sources and divides emissions into two geographic regions.[34] Another distinctive feature of the RECLAIM program is that banking is not allowed in the concern of delayed compliance with ambient air quality standards that might occur when banked emissions were used to justify possibly substantial increases in future actual emissions. Instead, the program provided limited temporal flexibility by grouping sources into two 12-month reporting periods (one from January through December and the other from July through June) and allowing trading in overlapping periods (Harrison and Nichols, 1992).

(5) ABT program

Another program, similar to the Lead Trading program, the federal mobile source averaging, banking and trading (ABT) program, provided the manufacturers of certain mobile sources of emissions the flexibility to trade differences around a pre-specified emission rate standard (usually expressed as emissions per horsepower-hour) without expensive pre-approval, by allowing the manufactures to average emissions over engine families produced by the manufacturer in the same model year, bank credits to offset emissions from the same or other engine families the manufacturer produces in future years, and trade these credits from or to another manufacturer, instead of requiring all manufacturers to meet the same emission standard for all of their engine families within a particular category. The calculation of emissions credits (and debits) is based upon clearly established factors that

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[34] Since emissions in the Los Angeles basin generally drift inland from the coast, the program issues two types of trading credits, one that can only be used by sources located in the coastal zone, and one that can be used by both sources located in the coastal zone and sources located in the inland zone. As was the case with the Acid Rain program, the RECLAIM trading credits was allocated free of charge. The initial allocation of credits was the most contentious subject, but eventually an allocation plan was developed and accepted by the wide range of affected facilities, and the final result, though departed from the original and simple proposal considerably, was administratively feasible and politically viable (Harrison, 1999a).

differ somewhat by mobile source category and the monitoring of emission rates is the same as that required to implement a traditional command-and-control program, hence imposing no major additional monitoring costs and allowing more ambitious environmental targets to be adopted (Rubin and Kling, 1993).

(6) The northeast NOx budget trading program

The Northeast NO_x Budget Trading Program was implemented among the District of Columbia and twelve states in the Northeastern United States. The program is a cap-and-trade program targeted at regional tropospheric ozone or otherwise known as "smog", which is a result of NO_x emissions from electricity-generating facilities (National Resource Council 1991).

One feature of this program is a novel banking provision. A mechanism called Progressive Flow Control was devised to allow unused permits to be banked for limited use in the future, so that banking does not give much incentive for sources to increase emissions in the future.[35]

Though the NO_x Budget Program has not been in operation for very long, early review suggests that the program is effective, and the NO_x trade market has developed with notable speed. Moreover, derivative products like options were used more in the NO_x market than in the SO_2 market developed in the Acid Rain program.[36]

(7) Discussion

Although emissions trading originated and has seen its most successful use in the U.S., trading does not dominate the U.S. politicians' toolbox for environmental protection. Most regulatory programs still use traditional methods even in a fully developed market system like the U.S., because to do otherwise proves technically difficult and politically controversial. The inconsistency among the approaches embedded in the various U.S. environmental statutes reflects the variation in political and bureaucratic interests of stakeholders involved in drafting and ratifying legislation and the conflict in firms' objectives that are not exclusively driven by efficiency. Moreover, extension of the current functioning U.S. emissions trading

[35] See Nichols (1997) for an analysis of issues related to banking and the development of the concept of flow control in the context of the NO_x Budget program.

[36] Farrell (2000).

program for air pollution to water pollution encounters challenges that many consider to be different to overcome, such as high degree of disparity among sources (including non-point), and difficulties from hydrology and monitoring, to name a few.[37]

Nevertheless, some emissions trading programs have also achieved success beyond the U.S. territory. The Kyoto Protocol, in its international agreement to control emissions of carbon dioxide and other greenhouse gases, provides the opportunity for the international use of various emissions trading mechanism. In some countries, emissions trading programs are being developed during ratification of the Protocol, and in other countries, already existing emissions trading programs are pushed further forward. For example, both the U.K. and Denmark have instituted greenhouse gas emissions trading programs.[38] In December 2002, the European environment ministers reached agreement on the ground rules for a European Union trading program. The program began in 2005, first for controlling carbon dioxide emissions, and later for other greenhouse gases, and has been considered successful in many aspects.[39]

4.2 Experiences in the European Union

Since 2005, the European Union has developed maybe the largest emission trading program for greenhouse gases to facilitate implementation of the Kyoto Protocol. The European Union Emissions Trade Scheme (EU ETS) is the world's first large-scale CO_2 emissions trading program operating in a region that accounts for about 20 percent of global GDP and 17 percent of the world's energy-related CO_2 emissions.[40]

The EU ETS closely follows the emissions trading programs in the U.S., in particular, the sulfur dioxide cap-and-trade program (the Acid Rain program), but significant differences exist. The EU ETS is much larger.[41] Its coverage of sources is approximately more than three times that of the U.S. program.[42] It deals with more serious pollution problem than the U.S.

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[37] Boyd (2000).

[38] See Kruger and Pizer (2004).

[39] European Commission (2007).

[40] European Environment Agency (2007).

[41] It covers 25 countries, including the 10 "accession" countries, most of which are former members of the Soviet bloc (European Environment Agency, 2007).

[42] The program covers initially only carbon dioxide emissions from four broad sectors: iron and steel, minerals,

program does, and it distributed more allowances in terms of money value than the U.S. program. More importantly, the EU ETS is highly decentralized due to the multinational nature of the EU system. Also different is the EU ETS from the U.S. program in the pollutant to control: EU ETS aims at limiting CO_2 whereas the U.S. Acid Rain program targets SO_2 emissions. These two types of pollutant gases, though seeming similar, can have so much practical and political difference as to affect implementation, such as the allocation of allowances, and so on. Still, it's a pioneer in its allocation of CO_2 allowances to individual emitters (with maybe the earlier Danish CO_2 trading program being the only exception).[43]

The biggest problem encountering the EU ETS, surprisingly, is the lack of readily available installation-level data for allocating allowances. Harrison and Radov (2002) note that "no single EU database currently provides plant-level information that could be used as a solid foundation for plant-level allocations across the member states" (p.10). The consequence of this is the disproportional absorption of resources and attention to collect and reconstruct these data, which makes the scheme appear too ambitious to implement. Nevertheless, the problem has now largely been overcome (Oko-Institut, 2005).

Some of the other problems come from the decentralized, parallel decision making processes of the European Union.[44] In general, member states propose their number of allowances to the European Commission for review, and distribute the allowances, if approved, to their local firms. The allocation process is an iterated negotiation between government and industry until a solution is reached to make both the government and the affected firms happy. If claims of firms compete and no agreements can be reached, the government will act as the final arbiter (Kettner et al., 2005).

Unlike the U.S. Acid Rain program, which uses historical production shares as a

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energy, and pulp and paper, and includes all European installations in these sectors that are larger than established thresholds, which totaled more than 12,000 in all (European Environment Agency 2007).

[43] There's a detailed discussion in Ellerman and Buchner (2007).

[44] Some studies pronounced caveat for potential exclusionary market manipulation behavior. Market power may emerge in the market during the multi-national negotiation and coordination. There may be manipulated permit prices to meet both interests of the regulator and the dominant firm in the attempt to gain international product market advantage and increase domestic welfare. Attempt to limit such market power will increase pollution cap and harm the environment. See Bueb and Schwartz (2011) for detailed discussion.

benchmark to allocate allowances,[45] the EU ETS allocates allowances according to individual installations' shares of emission within the sector, because the production processes and conditions at existing installations are too heterogeneous for benchmarking.[46] Once allowances are initially allocated, a proportion of them are open to trade in an auction. Member states are allowed to auction as many as five percent of their total allowance in the first trading period, up to ten percent in the second period, and thereafter maybe more than ten percent, though the amount is unspecified. Allowances, however, are expected to be in shortage due to a binding constraint on CO_2 emissions, so in order not to put member states that install new investments at a disadvantage, new entrants are given allowances free of charge.[47]

Though the EU ETS has several problems,[48] it has succeeded in imposing a price on CO_2 emissions, making it by far the most significant accomplishment in climate policy to date. From a global perspective, the most significant aspect of the EU ETS is its multinational nature, which may provide a good example for the global cooperation of emissions control, yet it does raise the issue of whether to involve a broader principle in the allocation of allowances. Still, it is too early to assess definitely the economic effect of the EU ETS, but what is accomplished in establishing the system, deciding caps and allocating allowances is surely a valuable guidance of future actions.[49]

Besides the U.S. and Europe, emissions trading programs are also gaining popularity and interest in the developing world. The next two sections examine two most prominent cases in two developing countries: China and Chili. The example in China was chosen not because of its success, but the challenges it reveals which are quite common in the developing world. The example in Chili was chosen because as one of the first countries outside the OECD to

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[45] Stavins (1998).

[46] There were additional factors working against benchmarks. Emissions data is usually simply and more readily available than output or input data when deadlines are pressing. It takes a lot of time to agree upon the benchmarks in industry and sub-industry level even given appropriate data on output or input. There also lacks any preexisting standard with legal or institutional precedent and force. This is another factor complicating the use of benchmarks (Ellerman and Buchner, 2007).

[47] Hepburn et al. (2006).

[48] Such as the accused "over-allocation" of allowances; see Ellerman and Buchner (2007).

[49] Kruger et al. (2007).

implement environmental trading schemes, Chili has over 15 years of emissions trading experience which allows in-depth and thorough analysis of the consequence of improper fulfilment of the basic conditions for an efficient emissions trade market.

4.3 Experiences in China

In China, environmental issues have been very severe, and more so recently. Ambient concentrations of acid rain pollutant gases (sulfur dioxide in particular) are several times higher than the international air quality standards. Its detrimental impacts on health, ecosystems, cultural resources and the economy have been significant enough to draw political attention and push controlling acid rain and sulphur dioxide pollution on a national agenda.[50] Emission trading is one, among others, instrument under consideration and investigation for its potential to complement and maybe even replace current command-and-control regulations,[51] which have been rendered ineffective by the rapid growth of energy demand, hence consumption of coal which is the biggest emitter of sulphur dioxide.

The situation in China is particularly suitable for emission trading, because marginal abatement costs vary significantly among pollution sources, which are highly regional, and a numerical cap on total emissions already exists. Yang et al. (2004) summarize five necessary conditions for the success of emissions trading programs from the U.S. experience: (1) marginal abatement costs differ among emission sources; (2) the problem is regional or global in scope; (3) accurate and consistent emission measurement is possible; (4) the emission allowance market is legitimate; and (5) administrative institutions are capable of administering the program. It seems that these five conditions have more or less been developed in China.

First, a Chinese Research Academy of Environmental Sciences survey confirms major differences in marginal sulphur dioxide abatement costs among emission sources.[52] Emission

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[50] An early estimate of the economic toll of air pollution is around two percent of GDP annually (Xie, 1998).

[51] These regulations include requiring cities to comply with national ambient standards for SO_2 concentrations, adjusting the composition of the power sector, and encouraging desulphurization (Qu, 2003).

[52] Estimates of marginal abatement cost variance are as great as 30-50% between regions and 40% between sectors (Wang et al., 2002).

trading has thus enormous potential to reduce overall abatement costs.

Second, according to the Chinese State Council (2001), the emissions are highly regional because most emissions are from high-stack sources that are regional.

Third, because emissions are regional, local government, the Environmental Protection Bureau (EPB) in particular, is able to stipulate sources to complete a form of emission reporting and provide all data necessary for measuring emissions.[53]

Fourth, the EPB's issue of emission permits is also legitimate according to the new amendment to the Air Pollution and Control Law which further clarifies the total emission control policy and the legal basis for local governments within the "two control zones"[54] to approve total emissions from sources by permits, and defines with necessary clarity emission rights for sources.

Last but not least, the Chinese State Environmental Protection Administration (SEPA) is engaged with project partners and enhances the administration capacity of emission trading programs, and will set up a special division within the administration once a national program is in place, which ensures effective oversight, management and enforcement of the program for it to be on track and transparent to every stakeholder involved.[55]

All these conditions together had accelerated progress in piloting emissions trading in China, which was already in discussion early in the 1980s. In 1994, experiments in air pollutant emission trading were conducted in six cities (Baotou, Kaiyuan, Liuzhou, Taiyuan, Pingdingshan and Guiyang) on the basis of air pollutant emission permit pilots in sixteen cities. The pilot trades included allowance transfers within an enterprise, environmental compensation fees to obtain additional emission rights,[56] investments in non-point source

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[53] The measurement, however, is not yet accurate as desired, because emission data is based on consumption of coal and its sulfur content, and the fuel inputs and production processes are not stable, and monitoring of the data is only periodic (Yang et al., 2004).

[54] Key acid rain control and SO_2 pollution control zones which are identified based on areas affected by acid rain and high SO_2 concentrations in 1998 and given priority for investment and management to control emissions.

[55] Wang et al. (2003).

[56] This is a variant of the already existing SO_2 emission charges piloted in 1992, which is still in effect and currently values about 3 cents per kilogram of SO_2. This charge is, however, way less than the average marginal abatement cost of SO_2 and therefore insufficient to effectively stimulate pollution abatement to necessary levels (China Environment Yearbook, 2002).

pollution control to obtain additional emission rights,[57] and allowance transfers from sources with surplus allowances to new or existing sources with insufficient allowances.

Though the system has not been adopted nationwide, Taiyuan, one of the six pilot cities, has successfully established a rather comprehensive and complete SO_2 emission trading program in 2001 to achieve their SO_2 total emissions control limit at least cost, with financial assistance from the Asian Development Bank, technical assistance from the U.S. think tank Resources for the Future and the Chinese Academy for Environmental Planning, after an international cooperation between SEPA and the U.S. EPA in a feasibility assess study on introducing SO_2 emission trading in China in 1999. In 2002, more pilots were organized in seven other provinces. For instance, after one year of preparatory work, two power plants in Jiangsu Province have reached an agreement to trade SO_2 allowances to meet total emissions control limits.[58]

In Jiangsu Province, the focus for the pilot experiment is on the power sector. There are 196 power plants in the province and they make the largest contribution to provincial SO_2 emissions. In the program, total allowable SO_2 emissions from the power sector are controlled by the provincial environmental protection bureau, which allocates allowances based on an emission performance standard, or generation performance standard, breaks down the emission cap to individual power plants and gives green light to emission permits trade. Though the volume of trade is not significant since the installation of the pilot program, the success of the trade between the two power plants mentioned earlier is remarkable, since it is the first inter-city allowance trade in China.[59]

In Taiyuan city, after the promulgation of the Administrative Regulation for SO_2 Emissions Trading, twenty-three major sources were identified to participate in the first phase of the emission trading program. Allowances were allocated based on historic emissions or performance agreements, and new sources must obtain allowances through purchases from the bureau of other sources. Surplus allowances from the current year can be banked for use in the future or sold to other sources, and the price of surplus allowances, if sold, will be

[57] Non-point sources are primarily diffuse residential stoves.

[58] Chinese State Council (2001).

[59] Jiangsu Provincial EPB (2003).

determined by the trading parties. As a prerequisite, the bureau tracks the emissions data of sources, and the allowance transactions, and imposes financial penalties for non-compliance of legal liability.[60]

In summary, it has become a political consensus that total emissions control should be combined and administered with a national emissions trading system. Although current conditions in China are far from perfect for an efficient emission trading program to be implemented nationwide, the pilot programs create foundations for further progress. To name a few, emission trading has become a widely accepted concept and its economic and environmental advantages are now well understood; there has been evidence in pilot cities of achievement of emissions control at a lower cost; experimentation with pilot programs has provided valuable experience and data which would facilitate and guide nationwide expansion of emission trading programs.[61]

Yet there are still some issues and barriers to overcome, including legal authority, policy coordination, allocation issues, emission measurement and verification, and supervision and management systems. Some pilot provinces and cities have local regulations that require corresponding national legislation for a nationwide program to be pursued. The allocation of current total emissions targets to administrative districts and then further to emission sources by local governments are subject to bureaucratic discretion and hence vulnerable to provincialism. Measurement inaccuracy is still endemic since few sources have installed CEMs (Continuous Emission Monitors), which are usually relied on as the U.S. experience shows and penalties on non-compliance are largely inadequate.[62]

To help nationwide adoption of the emission trading program, national emissions control targets should complement each other and prove attainable with appropriate design of emission trading program. The introduction of an emissions trading program should be coordinated and compatible with existing regulatory policies so that current policies on environmental protection do not diminish and trade of allowances will not increase emissions

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[60] Cao et al. (2002).

[61] Yang (2002).

[62] Bell (2004).

and deteriorate local air quality even further.[63] Moreover, measurement and verification of emissions should be strengthened to improve accuracy, and measurement capabilities should be considered as a priority, especially so when large scale of installation of CEMs in numerous sources is reasonably and understandably expensive. Environmental enforcement should be strengthened and current inadequate penalties should be corrected. Finally, more equitable allocation methods should be designed to provide proper incentives for sources to take initiative and innovative actions to reduce emissions.[64]

4.4 Experiences in Chile

The Chilean program PROCEFF (the Program of Control of Emissions Coming from Stationary Sources) was designed to control sulfur dioxide emission and later extended to control also other stationary sources and pollutants such as NO_x (nitrous oxides). Before it started in practice in 1997, a cap-and-trade program was already established by the Chilean Supreme Decree 4 and implemented in Santiago in March 1992 and became mandatory in 1994. PROCEFF was initially under the supervision of the Department of Health and given the responsibility of allocation and up-to-date record-keeping of permits, monitoring and enforcement of the set emissions caps, and shortly after was coordinated by the newly created National Environmental Commission, which is in charge of not only environmental jurisdiction arbitration, but also new policies design (Del Fávero, 1994; Pizarro, 2007), though the Department of Health remained the actual implementer and manager of these programs. Sources installed or approved before 1992 were endowed with emissions permits and new sources after 1992 were required to buy permits from the incumbents. Credits were awarded when existing sources reduced their emissions by more than the requirement of the cap and could be transferred to another source, be it incumbents or new entrants. Besides the procedural specifics, the Chilean program is rather standard, bearing no major difference with its counterparts in the U.S. or other countries (Bell and Russel, 2002).

The Chilean experience is interesting because despite the fact that the Chilean economy exhibits a free market environment, property rights of all forms (including air pollution rights)

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[63] Compatibility is theoretically feasible. For example, Ellerman (2001) shows that the low charges for the emission charge system should not impede the effectiveness of an emission trading program.

[64] Yang et al. (2002).

are strongly supported, and the government has a strong interest in the use of emissions trading and has implemented the first trading program as early as 1997, the Chilean programs have not been operating with the expected efficiency, as evident in the coexisting high noncompliance rates and over-compliance (Montero et al., 2002; Palacios and Chavez, 2005; Coria and Sterner, 2010). Examination of the underlying reasons would shed light on the general challenges and obstacles encountering developing countries in their effort of implementing emissions trading programs.

Generally, researchers attribute the inefficiency of Chilean programs to the following reasons: lack of information about permit prices; lack of information about penalties for violation; regulatory uncertainty introduced by changes in the rules; and incoherent institutional arrangements (Coria et al., 2010; Calfucura et al., 2009; Gangadharan, 2000; Centro, 2008).

To start, insufficient information about partners, prices and technological options is a result of complications involved in trading. In practice, each trade takes months to resolve, and the actual price of a transaction, if any, is not required to be officially reported to the authorities; further, the price may not even be explicit if the transaction takes place between various sources of the same firm.[65] The result is the absence of marketplace and systematic record of firms' transactions history, which prevents further trading activities among firms. Inability to give estimates of the actual trade prices is common among Chilean firms. Coria et al. (2010) find that the fraction of firms that can provide any price data for either selling or buying is less than one fourth, and much of the data reported was not of much use or analytical interest. More than 30% of the firms could not give any estimates, and among the firms that could, there is high uncertainty in terms of the more than eight-fold disparity between the highest estimate and the lowest estimate of current permit prices. On average, firms seem to underestimate permit price for particulate matters and overestimate permit price for NO_x, and empirical results show no systematic improvement of estimates for firms that made more trades. For this reason, a data management system is in drastic need, where firms would have access to information about potential sellers, buyers and prices of permits.

[65] Coria and Sterner (2010) show that the rate of "infra-firm" trading is around 76% and inter-firm trading accounts for the rest.

Second, absence of information on noncompliance penalties reduced compliance incentives of firms. High uncertainty concerning the penalties of noncompliance was reported by Calfucura et al. (2009). It is estimated that about four firms in five find the noncompliance penalties unclear. Most firms believe other firms do not comply and about half of respondents believe they can find ways to escape penalties or just prefer to pay the penalties than comply with the emission cap set by the program in face of increasing compliance costs. Also seven firms in ten believe the authority's monitoring of sources is far from enough.

Also, as shown in Gangadharan (2000), in the Chilean program, regulators intervene to affect the tenure and value of emission permits rather arbitrarily. Aware of changes in the rules such as offsetting rate, expiration date, and so on, firms find such arbitrary intervention has dampened nearly one fourth of their willingness to trade, because firms are concerned about the possible fluctuation in permit price due to changing permits supply (mostly believed to be decreasing).

Last, Centro (2008) concludes the existence of agency problems arising from the intricate institutional arrangement in Chile's environmental protection agency. The program is coordinated between two authorities, the Department of Health and the National Environmental Commission. The former bases its performance on health indices, while the latter is more concerned about policy efficiency and effectiveness. As a result, the National Environmental Commission is more popular among firms because it is more cooperative than the Department of Health on trading procedures and others. It is not agreed whether the environmental authorities are helping or understanding the trading schemes or not, but firms seem to be more negative toward the Department of Health than the National Environmental Commission.

In general however, neither authority is considered as helpful by most firms. National firms seem to be more negative on both authorities than international firms. More than half of the firms express their concern that the program has negatively affected industry growth and competitiveness in Santiago. Most firms would rather deal with one single regulatory authority than the two separate authorities they are currently dealing with, though they do want separate enforcement and appeal. Finally, almost all firms prefer the authority to be more diligent, efficient and timely (Centro, 2008).

It is still unclear which factor contributes most to the failure of the trading programs. Nevertheless, most concern is on the absence of information. The second most common complaint is the lack of diligence of the environmental authority, followed by unclearness of rules and inconsistency in policy. More than half of the firms blame the program for the failure and would prefer the authority to use a different emissions control policy, such as emissions standards, technology regulations and emissions taxes. National firms seem to dislike permits trading the most.[66]

Interestingly, firms are less reluctant than generally expected to deal with environmental regulation. Some firms even demand more frequent monitoring, which is unusual in old-fashioned regulation. This atypicality may be the result of the economic value of permits endowed by the trading program. However, current policies and their implementation are found to be dissatisfying. Greater clarity and access to market information is direly demanded, and frequent and discretionary modification of rules should definitely be avoided. Noncompliance should be penalized heavily to build credibility of the program, and trading procedures should be more expedient and transparent. Otherwise, there is a danger that the program will not be taken seriously and will set back to the old-fashioned and inefficient regulations.[67]

Also regulators are strongly recommended not to give firms the expectation of progressively depreciating permits, because it is a significant disincentive to trading. On the other hand, emission permits should not become a barrier to new entrants whose investment usually embeds new technology. Encouraging new firms hence is a way to have a certain turnover in the industry. For this sake, some discouraging policies such as offsetting should be avoided or replaced.[68]

Finally, it is clear that great care should be given to the institutional setting. No matter how many authorities are in charge, they should share the same objective, and any jurisdiction fight between them should be kept within them, and not affect the policy. In

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[66] Gamma (2007).

[67] Palacios and Chavez (2005).

[68] This is because offsetting may provide existing sources with perverse incentives to continue to operate while "taxing" newer and cleaner entrants by selling them emission permits (Coria et al., 2010) .

particular, the objective of the enforcement authority should be more related to the program.[69]

Although the programs in Chile are not very successful, neither are the programs in other developing countries due to some common challenges and obstacles that are the biggest hindrance to successful adoption of market instruments for environmental policy as previously discussed: institutional inadequacies such as poorly functioning legal systems, historical experience or inexperience with markets, distorting and often institutionalized corruption and inadequate public acceptance. Together, these barriers would make effective emissions trading impossible (Bell, 2002).

Admittedly some flaws observable in the developing countries' emissions trading programs are also present in the developed countries' programs, such as the EU ETS, and the U.S. EPA ET. It is too early to conclude about the potential success of emissions trading programs in developing countries. A fully-fledged emission trading system is not built overnight. It took the U.S. several decades of error and trial before the current relatively better functioning programs could be reached. Most developing countries are only starting experimentation with such programs. Given the major reforms needed and the limited time, the current performance of the emissions trading programs in developing countries is still remarkable and the future is promising.

Still, much fundamental change must take place before a successful adoption of a market instruments for environmental policy. In the meantime, traditional approaches might generate incremental improvements and achieve pragmatic goals that lead step by step to the ultimate goal. A mixed or tiered approach might be more suitable for countries with a low level of institutional capability and environmental protection experience, starting with simple discharge control technology requirement and progressing to technology-based discharge limitations similar to those found in the U.S. Clean Water Act, such as easily monitored discharge standards, or deposit-refund systems (which pay people for dropping recyclable material at a designated place), until they become fully capable of issuing tradable discharge permits or charging per unit of pollutant discharged.[70]

[69] Coria et al. (2010).

[70] See Bell (2004).

5. Concluding remarks

In the early 1970s, emission trading was still considered an academic game and ultimately impractical. Politicians would not bother to bring it on the national agenda and reformers had little luck for successes. All this changed with the success of the sulfur allowance program, which confirmed the economic analysis, demonstrating not only the feasibility of this market-based approach, but also its effectiveness both environmentally and economically, creating expectations and enthusiasm, and emboldening nationwide practice of design and implementation of emissions trading programs. Since then, emissions trading has come a long way from a theoretical insight to a practical policy instrument, and has expanded steadily and gained significant experience worldwide. Though not dominating the toolbox for pollution control in the U.S. or elsewhere, emissions trading programs are now firmly established as a highly valued policy and have seen their use increase in many countries, mostly in the developing world.[71]

However, emission trading is not without its weaknesses. First, the idea that emissions trading can achieve environmental goals with minimum cost may tempt policy makers to set overly ambitious goals that would in fact challenge the effectiveness of any environmental tool. Second, the success of emissions trading programs relies on strong enforcement and accurate measurement of emissions by all relevant parties. The enforcement and measurement problem is a very common problem that not only afflicts developing countries, but also haunts even the world's (once) largest and most transparent market economy, the U.S., where straightforward monitoring of emissions is still somewhat a naive and unduly overoptimistic expectation.[72] This problem is of course more serious in developing countries and countries in transition from the former Soviet regime and has to a large degree impeded more potential success of emission trading programs in these countries.

Also noteworthy is that not all emissions trading programs are equal. Some designs are no doubt better than others, but also more impractical, especially for countries that are only beginning the process of integrating market instruments with environmental protection.

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[71] Tietenberg (2010).

[72] See, e.g. Nordhaus (2006) with respect to CO_2 emission trading.

Furthermore, it has been proved that one size cannot fit all, and it is wiser to tailor emissions trading programs to each specific application. Besides, emission trading is only one of the many market-based instruments for environmental control and protection. Alternative policies include deposit-refund systems, taxes on fertiliser, gasoline and other polluting agents, emissions charges, etc., which might be more practical for countries lacking the necessary institutional foundation for a successful emissions trading program.

Emission trading is by no means a cure-it-all, no matter how much evidence has suggested that well-designed programs are efficient in targeting pollution problems. A market instrument cannot be installed in a country as easily as machines are installed in a factory. No alternative policy option to emissions trading is easy to implement in any absolute sense; for example, taxation also implies a need for sophisticated monitoring and institutional complements. Nothing could be said on the required "maturity" to guarantee success of emissions trading programs, or any political program. Strategies for pollution control and environmental protection are admittedly a reflection of traditions of government intervention that roots deeply in the national context which makes the tone for the choice and implementation of specific policy instruments. No country is exception to the political partiality embedded in the relationship between the government and the industry. Hence it requires comprehensive knowledge from case-by-case study of a country's unique political heritage (the constitution, administration, history and institutional culture, etc.) to design a functioning program that accommodates the opportunities and limitations arising from a particular policy style and takes full advantage of the theoretical and somewhat empirically confirmed benefits of market-based approach to environmental protection.[73]

[73] Kruger et al. (2004).

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