Determining optimal air quality standards: Quantities or prices?

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Abstract

In this study, a basic comparison between the Pigouvian and the Coasean approaches is carried out in order to discuss and comment on the mechanisms by which externalities are resolved. Environmental control approaches are examined and compared in terms of minimization of abatement costs, development of new technologies, revenue-generating capacity, complexity, popularity, incentives to cheat and inflation and adjustment costs. It seems that economic instruments have several advantages over regulations: they are less rigid and static, they are cost-effective, provide a source of finance and encourage innovation. However, market mechanisms do not invalidate regulatory approaches; they are, and must be, an adjunct to them.

Keywords: Pollution; Economic instruments; Abatement costs; International cooperation.

JEL Classifications: H23; Q50; Q52; Q53.

Introduction

The industrial age brought economic, social and technological advance. But it also created a number of environmental problems. The vastly increased burning of fossil fuels to generate heat and electricity and a growing reliance on motor vehicles are principally to blame. When fuels (such as coal, oil, petroleum and gas) are burned, different chemicals are released into the atmosphere as waste products.

Once emitted some of the oxides fall directly onto surfaces of plants, trees, soils, lakes and buildings and this phenomenon is known as **dry deposition**. Oxygen in the atmosphere transforms the remaining oxides into sulphuric and nitric acids (H_2SO_4 and HNO_3) and these are deposited as rain, snow, hail and dew, known as **wet deposition**. Dry deposition generally occurs close to the point of emission. Wet deposition often occurs thousand of kilometres downwind of emission sources. In other words, pollutants can be 'exported' by one country and 'imported' by another. Hence, emissions from one country may be deposited in neighbouring countries, thus limiting the ability of individual countries to reduce environmental damage by their own actions.

This implies that environmental quality in any one European country is significantly affected by the actions of others. It is thus a classic case of externality: the user-country may have little reason to concern itself with the pollutant content of the fuels it uses, except to the extent that legislation or 'moral' incentives force it to take account of pollutant emissions. In terms of sulphur emissions, it has been estimated that about two thirds of the sulphur deposited in Sweden originates in other countries, mainly continental Europe and U.K. On the other hand, a substantial part of the sulphur emitted in Sweden is deposited in Finland and in the northern Soviet Union (OECD 1986). In this sense, the acidification problem is truly international, as there are external diseconomy problems between countries.

The concept of external diseconomies is one of the most elusive in economic literature. The meaning of external diseconomies is essentially synonymous with externality or external effects in the sphere of production and consumption. That is, external diseconomies in production are unpaid side effects of one producer's output or inputs on other producers. A producer's pollution, which increases the costs of other producers, is perhaps one of the most well known cases of externality. At an earlier stage, external diseconomies in the meaning now given were called technological external diseconomies, reflecting the fact that the effects were transmitted outside the market mechanism and altered the technological relationship between the recipient firms output and the inputs under its control.

Externalities can take either of two forms: a public (undepletable) form or a private (depletable or rival) form. Freeman (1982) illustrates the phenomenon of depletable (private) externalities with the case of acid rain. In this instance, sulphur emissions from a particular source are distributed in the form of acid-rain. The word 'depletable' means that "each pound of sulphur emitted to the atmosphere must land somewhere and if the quantity falling on A's land increases, there is less to fall elsewhere". Acid rain is clearly a global problem in that pollution emissions may be deposited anywhere in the world, including the country of origin.

For practical purposes acid rain may be viewed as a regional reciprocal externality where a group of countries is both the source and the victim of the problem. An important characteristic of this is that transfers of pollution between countries may be very unequal in quantity because of the existence of prevailing winds. There are two problems associated with regional reciprocal externalities, which must be addressed in modelling the cost of acid rain abatement. The first is the need to achieve optimal economic efficiency across countries in pollution abatement. If this condition is not met scarce economic resources will be wasted. The second is the classic economic problem of the free riding: countries will benefit from pollution abatement in other countries at no cost.

2. Conventional economic approaches: Pigouvian or Coasean?

The standard economic approach to externalities is typically credited to Pigou (1920) who devised a system of taxes and subsidies to allow for the social costs, which are not included in private decision-making. In this caser a tax is imposed on the source of pollution in order to bring the cost function in the level of the true social cost imposed to the society by the production of the externality. The polluter pays for the damage imposed to the society and as a consequence it reduces his/her output to the socially optimal level of pollution. In the Pigouvian approach, the decision maker internalizes the externality by forcing the polluter to pay the full (true) costs of his/her activities.

On the other hand, a subsidy can be paid to the pollutee in order to compensate for the damage created by the activities of the polluter. In this case, the compensatory payment of subsidies does not reduce the pollution level. The Pigouvian tax may or may not be exactly offset by the subsidy. This is a function of the demand and supply elasticities as well as whether the tax revenue is transferred to the victim or not. The most significant insight in the Pigouvian approach is that the damage imposed in the environment has a cost which is reflected by the right price to the participants in any economic decision (Dieter and Pearce, 1990).

This approach to externalities has been challenged by pro-market theorists such as Coase (1960). According to the free-market approach, the problem of externalities is caused due to the absence of markets and property rights. The argument is that an economy with well established property rights may internalise all externalities. In the original model of Coase, there are only two participants: a polluter and a pollutee. These participants bargain with each other and as result an equilibrium is established irrespective of the allocation of property rights between the participants. Property rights may be determined through the market or through the legal system. The efficiency of the outcome is not influenced if the polluter compensates the victim for the damage imposed or if the victim(s) bribes the polluter to reduce its emissions and the associated damage. The only implications are distributional.

The simple Coase's model suffers from several deficiencies (Dieter and Pearce, 1990):

i. The Coasean approach assumes that markets are in place. In reality, the major global environmental problems arise in cases where property rights are impossible to be defined;

ii. Similarly, in the Pigouvian tax approach, well-functioning markets are hypothesized;

iii. At the same time, when there are many participants involved, we may face significant incentives to free-ride.

iv. Additionally, significant bureaucratic costs are associated with the allocation of costs between the participants, which may reduce the efficiency of the bargaining process.

A basic comparison between the two approaches is related to the mechanism by which externalities are resolved. In practice, the only difference between the two approaches lies in the relative cost of governmental versus legal intervention. That is, in the Pigouvian approach officials identify the participants and try to calculate the marginal costs and benefits for each participant and the optimal taxation is then imposed. On the other hand, the Coasean approach expects the market to assist bargaining between the participants involved. If they cannot agree then the dispute is solved in courts, where lawyers and judges estimate the costs and benefits of the externality to the participants involved (Dieter and Pearce, 1990).

Another fundamental difference between the two approaches concerns the fact that in the Pigouvian approach it is assumed that the polluter pays, while in the Coasean approach the possibility that the victim pays is allowed. That is, in the Coasean bargaining approach the Polluter Pays Principle (PPP) is seen simply as an equity judgement without any justification in economic efficiency terms. In this way, the PPP may be sub-optimal as the participants involved may have little incentives to minimize their exposition to pollution. The assignment of property rights to non-marketed goods, like air and water, offers a background to the participants involved to come to a decision on the problem of negative externalities instead of doing nothing.

3. Promotion of International Cooperation

The lack of freely available and reliable information represents one of the major limits to bargaining activity and to the achievement of co-operative solutions. A country's willingness to pursue international strategies of environmental control is affected to a large extent by the balance between its shares of benefits and costs of such a policy. If a country has to support a large share of the costs but also receives a large proportion of benefits associated with emissions abatement, the probability of co-operative solutions increases in line. On the other hand, an uneven distribution of costs and benefits makes collaboration more difficult.

Costs and benefits from acid rain abatement are not fully reflected in potential or actual exchanges. They represent incomplete or missing markets. Mäler (1990, p. 94) argues, "The net benefits from co-operation will in general be very unevenly distributed among the countries in a region with reciprocal environmental externalities. This implies that there is a need for a compensation system in order to redistribute the gains from co-operation in a way that is fair and gives countries incentives to co-operate; in the short run countries will have strong incentives to be "free-riders".

Global or regional environmental problems are a game in which, those who gain by co-operation must devise incentives to make those who lose play the game. A 'game theoretic' approach seems to be a proper methodology to analyse the system of incentives and constraints of countries to cooperate in the area of environmental control strategies. The contradiction between the maximization of country's gains and the maximization of the collective good (common property, i.e. atmosphere) is the essence of the 'Prisoners Dilemma'. Each player in the game stands to gain by not cooperating with other players, but all players would be better off if they did co-operate.

Non co-operative equilibria are inefficient because each country does not take into account the effects of its action on the welfare of other countries when it seeks to minimize the costs of pollution abatement. In a co-operative solution the costs are minimized for all countries together but co-operative solutions require binding agreements. Agreements not fully binding may face individual defection by free riding. Binding agreements require incentive systems in the form of side payments, cash or technology transfers, to potential defectors. In such side-payments the victims pay polluters not to pollute.

However, there may be solutions intermediate between the co-operative and the fully non co-operative ones. There may be coalitions of a subset of countries, which would benefit from co-operation to reduce emissions. This is particularly likely if countries interact repeatedly and therefore have reputations to preserve. Furthermore, some countries may offer co-operation in the environmental field in exchange for co-operation in other fields (e.g. trade or political relationships). On the basis of some very crude cost and benefit estimates, Halkos (1993a, 1994a) and Mäler (1989, 1990) have compared non-cooperative equilibria with full co-operative solutions. They both claim that the potential aggregate gains from co-operation are significant. However, the potential gains are very unevenly distributed.

Moreover, a deposition target in a given country may be achievable at a lower cost by emissions' reductions in neighbouring countries. However, countries required to make large expenditures may be unwilling to pay, especially if the corresponding benefits are likely to be gained in other countries. A number of alternative available economic instruments may be thought of which, if applied internationally, could encourage implementation of the desired abatement strategies by countries, at least in the sense of pushing the countries to minimize abatement costs within them, if they are not always willing to minimize such costs across them (Halkos, 1993b, 1994b).

Economists have for many years proposed that decentralized-based policies are more efficient than centralized command-and-control approaches as the solution to the problem of how to regulate air pollution cost-effectively (Schultze, 1977). There is a wide body of literature addressing issues of the economics of regulation and public choice reviewed in, for example, Stigler (1971), Mueller (1989) and Eskeland and Jimenez (1991). Environmental control approaches include actions to protect the environment using policy instruments, such as regulations, or economic instruments like charges, taxes and marketable emission permits (or licences). These are examined and compared next.

4. Policy or economic instruments

The first instrument, which is regulation, can vary from the extreme case of prohibition and/or the imposition of production quotas on producers to the setting of "standards" for protecting selected target populations. In the air pollution field, the use of standards is based on notions governing the relationship between emissions at the source level and concentrations in specific air sheds. Direct regulatory instruments, also known as "command and control" mechanisms, are regulations on activities affecting the environment, such as environmental quality regulations and enforcement mechanisms.

Environmental quality standards protect human health or ecosystems. Indicators of "quality" are precisely defined as allowable average concentrations over a specific time period for a given pollutant in a particular region. The standards are usually based on scientific dose-response relationships that are the expected health response resulting from a given dose of pollutant. Critical loads are used in some countries as a basis for the definition of environmental quality standards.

In practice, environmental quality standards take many forms like emissions restrictions, restrictions on pollution per unit of an input and restrictions on the use of a polluting input. The control of sulphur emissions by emission standards is widely used in air and water pollution (Vernon, 1990). They set a maximum allowable rate of pollution output for each generic type of source (electricity generating, industry, petroleum refineries and transport) by type of pollutant. Furthermore, fuel quality regulations are structured around the types of fuels in use (e.g. coal, oil etc) and are limited by the technical possibilities and the costs of cleaning process for the different fuels. At present, varying types of fuel-quality standards are in use in nearly all OECD countries. Control of fuel use has been applied as a strategy for air pollution reduction on a permanent or temporary basis to satisfy general environmental and health concerns. In some heavily polluted areas such as Ankara, coal is restricted in winter (Vernon, 1990). Finally, enforcement policies rely on a variety of legal instruments, ranging from licence withdrawal to criminal prosecution.

The second way of implementing optimal abatement strategies for pollution control is by the use of emissions' charges or taxes to encourage abatement. Pollution taxes or charges are based on Pigou's concept of increasing the costs of polluter's activities so that they reflect the true social cost to society of those activities through environmental damage. The essence of charges approach is for a tax to be imposed on each unit of pollutant emitted. This implies revenues that can go to a Central Authority for the creation of a European fund for air pollution control (Bergman, 1986; Hettelingh and Hordijk, 1986; and Mäler, 1990). In this case this International Authority would impose a charge on uncontrolled emissions. The Authority could then distribute any tax revenue received to subsidize further emissions' abatements. However, the Authority would need to know the shape of the corresponding abatement cost functions to be able to set the appropriate emissions' charge.

Economic theory indicates that the optimum rate of pollution charges is at the level where the marginal abatement cost is equal to the marginal damage cost of the pollution it is intended to abate. In a "first-best policy" one should differentiate the tax rate between different exporters according to the size of their damage costs. In the case of limited available information a "second best" but still cost effective solution is to set a level of uniform charge high enough to ensure that polluters will abate pollution to a target level of pollution. Such a level of charges is often too high to be acceptable or enforceable for political or other reasons. A feasible form of tax in the case of most pollutant emissions is one related to the sulphur content of fuels burnt. For instance, any given tax on the sulphur content of fossil fuels will lead to desulphurisation up to the point where the marginal desulphurisation cost per unit of sulphur abated equals the tax.

Market incentives such as taxes, charges and permits can lead to solutions superior to that of a regulation instrument, provided, however, that the prices or quantities designed to achieve a given air quality objective reflect accurately the social costs of pollution. In any case, even if this assumption is relaxed such market approaches can still be considered superior to regulatory ones, since they afford polluters the opportunity to avoid paying penalties by striving for a greater abatement cost effectiveness (whereas regulated standards would just be "imposed" on them). It would be efficient for each country to arrange for implementation of emissions' abatements up to the point where the marginal cost of abatement is less than or equal to the emissions' charge; and to pay the charge on emissions which are relatively more expensive to abate.

Under a system of emission charges, regulators set prices for emission levels that are designed to achieve a given air quality objective. With the third class of instruments, i.e. marketable emission licences, regulators establish the quantity of emissions that would achieve a given air objective, issue permits to pollute this amount and leave it to the market to decide the value of these permits. In theory, both approaches are equivalent in a perfect world of zero cost information; administration and legal enforcement insofar as they both minimize the cost of achieving a given level of air quality but in practice the two approaches are different.

With marketable emission permits, the problem of the Authority having to know the shape of abatement cost functions is avoided, because in this case countries would be allocated a specific number of licences defining the amount of pollutants they would be allowed to emit in any given period. The initial number of licences issued in each country would depend on their contribution to depositions in sensitive receptor areas and on their required depositions' reduction. In countries upwind of sensitive areas a greater number of licences would be required to emit one unit of pollutant than in countries downwind. Crubb (1989), Hoel (1990, 1991) and Pearce (1990) suggested a number of approaches to the initial allocation of permits once the total limit on emissions has been agreed. Such an approach should rely on the current pollutant's emissions or the current gross national product as far as energy use is linked to economic activity.

However, both approaches reward polluting countries and restrict developing countries. Crubb (1989) suggests that population should be the most equitable basis for allocation, but under the condition that only adult population counts, to prevent giving an incentive to increase population and to reduce the relative benefit to developing countries, which have much higher proportion of children in their populations. Finally, another approach is by using the land area. This approach has the advantage that can be measured easily and would discourage high population densities, but the lack of a link to human activity makes it impracticable.

In order to determine whether the market will be sufficiently competitive to produce an efficient result with enough participants and transactions, one needs to be able to forecast the final distribution of permits. Whether the market for permits has monopolistic features that undermine its efficiency depends on whether one, two or more countries account for a large share of either sales or purchases (Hahn and Noll, 1983). To predict the concentration in permits transactions also requires solving the cost-minimizing problem for participants in the market. From this, one can predict a final distribution of permits. This can be compared to the initial distribution to generate an estimate of net sales (or purchases) by each country (through the central authority), which then can be used to calculate expected market shares. The main feature of emissions' licences is that they are tradable, so that countries in which abatement is relatively expensive would be able to buy extra permits rather than pollution control equipment.

The role of the Authority would essentially be to determine the initial allocation of licences and to supervise the buying and selling of licences between the countries. Separate bodies could be set up to supervise swapping of licences within Western and Eastern Europe, with an overall co-ordinating body to arrange such swaps. The initial allocation of permits (q_{ji}^{o}) depends on each country's contribution to depositions in sensitive receptor areas and on its required depositions' reduction, being the constrained depositions i. It would be then convenient for countries to buy permits rather than further reduce emissions, whenever $q_{ji}^{o} < MAC_i$, where MAC_i is the marginal abatement cost of country i.

It is worth mentioning that a permanent allocation of permits and trading on a permanent basis, creates the problem of powerful parties hoarding rights for future use rather than trading. Instead the periodic "re-issuing" of permits according to the initial allocation would amount to a system in which permits were leased rather than sold and hoarding would not be possible. Finally, the trading requires some sort of enforcement procedure, with penalties for countries exceeding their permitted emissions. Hahn and Hester (1989) show that excessively bureaucratic monitoring systems in the USA impede trading. Let us next compare such instruments with each other to see where the differences are, when they are used for implementing optimal abatement strategies.

5. Political, economic and technical considerations

Some of the main aspects of the available instruments are now considered aiming to highlight the political, economic and technical aspects (Halkos, 1992).

1. **Minimization of abatement costs:** For optimal economic efficiency, a regulatory system that considers each specific source of emissions assumes that regulators know enough about the production process they are inspecting, and the abatement opportunities applicable to it, to be able to determine the optimal emissions reduction for it. Countries are likely to be reluctant to provide accurate information to regulators, because some abatement strategies may involve changes in the production process which, if revealed as a result of regulation would give away commercial secrets. Consequently, standards are unlikely to provide the most cost-effective method of air pollution abatement.

If countries are cost-minimizers, emissions taxes can lead to the cost-minimizing solution (Burrows, 1980; Dick, 1974; Baumol and Oates, 1989; Kneeze and Shultze, 1975; Pearce and Turner, 1990). On the contrary, a policy of regulation could achieve this least-cost allocation only if the individual polluters' abatement costs were revealed to the policy maker. Moreover, marketable permits and emissions charges allow polluters with low abatement costs to benefit from reducing pollution to a low level. Polluters with high control costs can pay rather than spending on controls. In this way market mechanisms allow greater reduction in pollution for the same cost, or the same reduction for a lower cost, compared with regulations and standards (Vernon, 1990). By giving the polluters a chance to trade, the total cost of pollution abatement is minimized compared to the more direct regulatory approach of setting standards (Pearce and Turner, 1990).

When economists refer to pollution standards, they mean uniform reduction on pollution emissions (Baumol and Oates, 1989; Besanko, 1987). Emission standards and regulations, which require uniform reduction in pollution, are inefficient, because the costs of reduction are not uniform for all polluters. Under uniform emission standards, some polluters will be reducing emissions less than it would be cost-effective to do so, while others will be reducing emissions by more than is cost-effective. The regulatory approach of differentiated individual standards, selected on the basis of environmental impact without any consideration of abatement costs, is an expensive means of achieving an emission target.

To reach the same emission target by implementing a uniform charge means that this target will generate more damage than under regulated individual standards, because the market allocation of pollution shares ignores the difference in environmental impact between different locations. On the other hand, implementing differentiated rates of charge, which take into account the differences in environmental impact of various polluters' effluent, have an advantage over differential individual standards when abatement costs differ between polluters (Halkos, 1993b).

Tietenberg (1990) has estimated the relative costs of regulations compared to market mechanisms in eleven cases. In four of these, regulations were 1 to 2 times as expensive as market mechanisms, in 5 cases regulations were 2 to 10 times more expensive, and in two cases more than 10 times more costly than market mechanisms.

2. Encouragement of the development of new technologies: Standards provide little incentive for innovation in pollution abatement technology. It is the economic interest of companies that are the objects of regulations, to resist the adoption of efficient but expensive abatement technologies. On the other hand, one of the general advantages of charges and permit systems is the greater encouragement to develop new abatement technologies.

Conversely, regulations limiting the pollutant's content would raise the cost of using fossil fuels because low, say, sulphur fossil fuels can only be obtained by paying the sulphur premium or by incurring the cost of desulphurisation. With source specific regulation, every new abatement technology and every new source must obtain specific regulatory approval. This requirement imposes costs of delay and process that not only inhibit the adoption of more efficient technologies, but also restrict structural change in the economy by making new production facilities less attractive to investors. By contrast, a tradable permits system makes emissions more like other inputs to a production process as emissions permits like other inputs must be acquired through a market. To the extent that a permits market is characterized by easily arranged transactions at predictable prices, the problem of acquiring new permits (or selling old ones) would not differ materially from the problems of participating in markets for labour, raw materials, land or other inputs (Vernon, 1990; Hahn and Noll, 1982; Jaffe *et al.,* 1999).

3. **Revenue-generating capacity:** Regulation does not have the same revenue-generating capability as a pollution charge, at least if there are no violations of the limits set under regulations. This is due to the absence of a charge for the pollution units below the limits regulated. Once violations are allowed for, even regulation generates revenue from fines. On the contrary, a charge has the extra source revenue from intramarginal units of pollution, which is lacking under regulation. The tax proposal will generate revenues that are needed to compensate the losers and to finance other abatement measures.

A permit system may be designed to raise the same amount of money, if the permits are valid only for a limited time, and if they are auctioned off regularly. Then, the permit system will be identical to a tax system under full information. However, the permit system may be designed differently. If the initial distribution of rights is determined as a proportion to the initial sulphur export, no revenue will be raised. In this case, the compensation to the losers must be made through the distribution of initial rights. One possibility would be that countries that are expected to have negative expected net benefits would be given a number of permits equal to their initial exports, while the other countries would be given permits as a fixed uniform proportion of the initial exports (grandfathering).

4. **Complexity, administering costs and cost of enforcement:** Administrative costs of an instrument may include the monitoring of pollution levels and the running of the facilities for making the payments. In fact, regulation requires only the former, while a charge requires both because it involves a transfer of funds. The imposition of standards is costly and time consuming. Regulatory standards may inhibit the entry of new firms into an area. Emission standards for new plants tend to be substantially more strict and expensive to implement than standards for established plants in the same industry using the same production technology.

Charges systems may become very complex. If we are to set taxes according to damage done, it is necessary to vary the taxes by sources since different receptor points will have different assimilative capacities for pollution. This raises the spectre of a highly complex and administratively burdensome system (Pearce and Turner, 1990). To assess how much tax the polluter should pay, the total emissions during the "tax-year" must be known; whereas with typical regulations, which specify some maximum limit, which must not be exceeded, any arrangement, which ensures that the limit is not breached, is sufficient.

Continuous monitoring of emissions is likely to be expensive for many pollutants. Since there are a large number of small emitters of sulphur emissions in every European country it would be extremely expensive to insist on installing continuous monitoring devices on all chimneys. Marketable permits avoid some of the costs of the regulatory process itself. Regulators would not need to devote resources to identifying specific technical fixes for a long list of emissions sources and to undertaking a protracted procedure for charging standards for any particular source.

Finally, it is notable that in many administrations economists play a minor role; authorities are more familiar with the command-and-control approach. Regarding the cost of enforcement regulation involves the punishment of firms (countries) through a set of automatic penalties imposed by the governments (or the central authority) or through litigation in the courts. It is expected that these costs will be high but will not be lower with a charge.

5. **Popularity:** The imposition of taxes may be politically unpopular with industry. The main argument against pollution taxes is that recipient countries may fear that it has little effect on pollution levels, while the polluting companies see the tax as harming profits. The extent to which industries pay taxes out of profits depends on whether the increase in taxes can be passed along to consumers. Permits can overcome organized resistance from the industry affected, since firms can be allocated licences in accordance with current

emission levels. However, they are susceptible to anti-competitive strategic behaviour by firms pre-empting licences to raise "rivals" costs by forcing them to abate their emissions. If international agreements merely defined the status quo for bargaining, then recipient countries could establish a market price for licences, and might, if they overcame their co-ordination problems, be able to act as a quasi-competitive force. If damage per tonne is relatively independent of both pollution levels and the year in which it occurs recipient countries could arbitrage the price over time. Relative stability of the price would reduce the ability of dominant polluters to manipulate the price of licences. The seriousness of this limitation depends on how competitive the permit markets are (Newbery, 1990).

Finally, it is notable that firms (countries) often assume they have more influence on regulations via negotiations. Negotiations make the implementation of new regulations to take a long-time. On the other hand, licences can meet international agreements on emission levels. Other countries or environmental groups can negotiate further reductions by buying licences, providing that the issuing authority recognizes their property rights in such licences. If the market in permits is free, an environmental pressure group could enter the market and buy the permits, holding them out of the market or destroying them (Pearce and Turner, 1990).

6. **Incentives to cheat:** with a tax system, countries will probably try to make gains by giving biased reports. With a tradeable permit system countries still have incentives to cheat. If cheating becomes pervasive, however, the demand for permits will go down and so the equilibrium price on permits, thereby reducing the incentives to cheat (Andreasson, 1989). Thus, the tradable permit system has a self-regulating mechanism that makes cheating less profitable than in a system with a tax as a regulatory instrument.

7. **Inflation and adjustment costs:** If there is inflation in the economy, the real value of pollution taxes will change, possibly eroding their effectiveness. Because permits respond to supply and demand, inflation is already taken care of. This is as the permits themselves are issued in quantities equal to the required standard and it is prices that adjust.

6. Concluding remarks and policy implications

The selection of the appropriate strategies to reach and implement pollution control objectives is of crucial importance to planners. Because of the existing differences between countries in energy-use patterns, emissions, source locations and other economic factors, it is unlikely that a single, uniform program of abatement will be appropriate in all countries. Appropriateness is defined in terms of cost effectiveness compatible with specific pollution control goal attainment, but also in terms of political and social acceptability as well as administrative feasibility.

Regulations will generally effect internalisation indirectly, by requiring countries to change behaviour in a given way to reduce pollution. Economic instruments tend to operate more directly. In general, they have several advantages over regulations: they are less rigid and static, they are cost-effective, provide a source of finance and encourage innovation (Oates *et al.,* 1989). However, market mechanisms do not invalidate regulatory approaches; they are, and must be, an adjunct to them.

Price- and quantity-based approaches differ in cases where we have incomplete information (Cropper and Oates, 1992). When the abatement cost curves are unknown, taxes provide a certain level of control over the cost of methods to be used. If we place a ceiling on the marginal abatement cost then the price-based approach introduces a limit on the appropriate abatement methods to be used by excluding options, which are more expensive. But it will provide at a-priori neither an indication of the level of pollution avoided nor the overall abatement cost of the methods used to achieve the specific target.

On the other hand, in the case of a quantity-based approach the total abatement cost will not be estimated as the marginal abatement cost of the methods used is unknown. But at least in this case, we may ensure a direct monitoring over the predetermined amounts of pollution. Additionally limitation of the number of permits in circulation and adjustment of the permit prices accordingly is affordable. In the price-based cases continuous adjustments can be made on the tax level in order to manage the targeted pollution reductions.

We may conclude that the symmetry between price- and quantity-based approaches is not total (Menanteau *et al.*, 2002). The choice depends on the abatement cost curve as well as the damage cost curve. As known, when pollutant's abatement cost curve is flat, quantity regulations work better than price regulations. In contrast, when a pollutant's abatement cost curve is steep, price regulations probably work better (UK, CEED, 1986; Weitzman, 1974). In order to adopt the proper policy, Table 1 presents the maximum achievable level of sulphur dioxide abatement and the countries where the abatement cost curve are flat or steep (Halkos, 1993c).

The obvious advantage of permits over charges systems is that the former avoids the problem of the authority's uncertainty about abatement costs. The consequence of an underestimate of abatement costs in the presence of permits is simply that the price of permits is forced-up, whereas the environmental standard is maintained. The charge approach also risks underestimating abatement costs. If the authority is wrong about the abatement costs, the charge could be set too low in the sense that polluters will prefer to pay it than to invest in abatement equipment, thus sacrificing the desired standard.

Table 1: Comments on $S0_2$ abatement cost curves

Countries	Maximum Abatement	Steep cost Curve (SO_2)	Flat cost curve (SO_2)
Albania	60%	Yes	
Austria	76%		Till almost 55%
Belgium	82%		Till almost 45%
Bulgaria	72%		Till almost 65%
Former CSSR	64%		Yes
Denmark	86%		Till almost 55%
Finland	72%		Till almost 50%
France	82%		Till almost 55%
Germany	76%		Yes
Greece	88%		Till almost 45%
Hungary	61%		Yes
Ireland	73%	Yes	
Italy	75%		Till almost 60%
Luxembourg	61%	Yes	
Netherlands	80%	Yes	
Norway	76%	Yes	
Poland	66%		Yes
Portugal	77%		Till almost 60%
Romania	76%		Yes
Spain	93%		Yes
Sweden	74%		Yes
Switzerland	78%	Yes	
Turkey	57%	Yes	
UK	79%		Till almost 65%
Former USSR	60%		Yes
Former Yugoslavia	70%		Till almost 60%

Source: Own calculations

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