SETTING TARGETS AND THE CHOICE OF POLICY INSTRUMENTS FOR LIMITING CO_2 EMISSIONS

by

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Abstract

Increasing concern in scientific and policy making circles about the possibility of global warming induced by the accumulation of CO_2 and other GHGs in the atmosphere has advanced for consideration of policies to limit emissions of these GHGs. This paper gives an overview of policy instruments that might be used to control CO_2 emissions, including command-and-control approach, energy taxes, carbon taxes, and tradeable carbon permits, with special attention paid to the economic instruments. It highlights the differences between energy taxes and carbon taxes in terms of target achievement. It presents some main findings arising from those studies on carbon taxes, with the emphasis placed on some aspects of domestic carbon tax design and incidence. The allocations of emission permits (or reimbursement of carbon tax revenues) are also discussed. Moreover, a comparison of carbon taxes with tradeable carbon permits is briefly made. This paper ends with some conclusions.

1. Introduction

The record high temperatures and drought in North America in the summer of 1988 sharply raised serious concern about global warming as a result of increased atmospheric concentrations of man-made greenhouse gases (GHGs) and the overall socio-economic impacts of any resulting climate changes caused by global warming. While there are still uncertainties regarding the magnitude, timing and regional patterns of climate change, there is a growing consensus in the scientific and policy making circles that climate change and instability, including a rise in global atmospheric temperatures, a change in the frequency and severity of storms, shifts in precipitation patterns, and a rise in sea level, are most likely over the next century.

The *so-called* GHGs are carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), tropospheric ozone (O_3) and nitrous oxide (N_2O). According to the World Resources Institute (1990), the CO_2 emissions alone contribute about half the present global warming -even more on some estimates, and thus form the major cause of the greenhouse effect. This dominance of CO_2 contribution in the global warming suggests that CO_2 must be the main target in any attempt to limit emissions of GHGs. For this reason, I limit myself to a discussion of the problems of control of CO_2 emissions.

Policy instruments targeted at the control of CO_2 emissions include command-and-control approach, energy taxes, carbon taxes, and tradeable carbon permits. These alternative instruments have been discussed in a number of studies.

This paper gives an overview of the recent studies in the field. The second section points out why the targets for emissions reductions need to be predefined. In the third section, the differences between energy taxes and carbon taxes are briefly discussed and some main findings arising from those studies on carbon taxes are presented. The fourth section focuses on some aspects of domestic carbon taxes design and incidence. The allocations of emission permits (or reimbursement of carbon tax revenues) are the subject of the fifth section. The sixth section gives a brief comparison of carbon taxes with tradeable permits. The seventh section contains some conclusions.

2. Setting target: a separate approach

Before dealing with policy instruments targeted at the control of CO_2 emissions, I pause briefly to consider why the targets for emissions reductions need to be predefined.

According to the conventional theory of environmental economics, there is no need to set the targets for emissions reductions beforehand when the associated externalities are internalized (cf. Baumol and Oates, 1988). The optimal emission level is achieved when the point is reached at which the marginal cost of reducing emissions is the same as the marginal cost of the damages. So long as the *so-called* Pigouvian tax is set equal to the marginal cost of the damages, its implementation automatically leads to the optimal situation. This means that the process of internalization itself co-determines the target. However, this principle works better for conventional environmental problems than those problems with international and intertemporal dimensions (e.g. acid rain, ozone layer depletion and climate change), an essential feature of which is the absence of an institution with the international jurisdiction to enforce policy (cf. Folmer *et al.*, 1993). This also has consequences for the formulation of policy, including the revelation of costs and benefits (cf. Barrett, 1990).

Given the characteristics of these problems, we need to re-consider a separate approach that was first proposed by Baumol and Oates (1971; also 1988): setting emission reduction targets first and then selecting instruments to achieve these targets at the least cost. Compared with the conventional approach where the optimal solution is sought, effectiveness is the goal for the Baumol-Oates case in which there is nothing to indicate that the level of emission reduction achieved by the separate approach is either the economic or even the environmental optimum (cf. Baumol and Oates, 1971 and 1988; Faucheux and Noel, 1991).

It has been observed that the two most important international agreements on limiting emissions of atmospheric pollutants - the Montreal Protocol on CFCs and European Community's Large Combustion Plant (LCP) Directive to limit acid emissions - have been formulated in this way. The Montreal Protocol calls for 50% reduction in CFC emissions by the signatory countries by 1999, with a grace periods of ten years for developing countries (cf. Enders and Porges, 1992). The LCP Directive incorporates a complex formulation of SO_2 and NO_x reduction levels for three target dates, with different elements of backdating for each member country (cf. Haigh, 1989).

With the conclusion of two important agreements based on percentage reduction targets for gaseous emissions, it is not surprising that calls for limiting CO_2 emissions have focused on a similar strategy. The Toronto Conference has recommended a 20% reduction by 2005 and a 50% reduction by 2025 in global CO_2 emissions relative to the 1988 levels, with an initial goal set for 20% cut by 2005 in the industrialized countries (UNEP, 1988).

The acceptable reduction targets can be set by scientific expertise or international agreement. Whatever the acceptable carbon reduction target that is eventually set, the remaining issue is how it is to be achieved. In this regard, there are four alternative policy instruments: command-and-control approach, including the widely-discussed uniform percentage reductions in emissions by all countries; energy taxes; carbon taxes; and tradeable permits.

With regard to the global warming problems, especially in the CO_2 context, a number of recent studies discusses market-based instruments or economic incentive instruments, namely energy taxes, carbon taxes and tradeable carbon emission permits. It is argued that these economic instruments to limit CO_2 emissions can achieve the same target at lower costs as compared with the conventional command-and-control approach. Moreover the economic instruments can act as a continuous incentive to search for ever clear technology, while, for the command-and-control approach, there is no incentive for the polluters to go beyond the standards unless the standards are continually revised and set slightly above the best available technologies. Therefore the economic instruments have a *technology-forcing* characteristic. Some evidence shows that this dynamic efficiency aspect of economic instruments is important (Tietenberg, 1990). In the CO_2 context, the dynamic efficiency takes on extra dimension because, unlikely sulphur, CO_2 is difficult to dispose of, even if it is removed from stack gases, and incentives to develop disposal technologies are therefore of particular relevance (Pearce, 1991).

In what follows, our attention is restricted to the economic instruments in the CO_2 context, namely energy taxes, carbon taxes and tradeable carbon emission permits.

3. Energy taxes versus carbon taxes

An energy tax is an excise tax, which is expressed as a fixed absolute amount of e.g. US$ per Terajoule. It is a tax placed on both fossil fuels and carbon free energy sources according to their energy (or heat) content, with renewables usually being exempt. By contrast, a carbon tax (an excise tax that is imposed according to the carbon content of fossil fuels) is restricted to carbon based fuels.

Given that oil and gas have greater heat content for a given amount of CO_2 emissions as compared with coal, an energy tax falls more heavily on oil and gas than a carbon tax. Moreover, an energy tax burdens nuclear energy, which, with the exception of hydropower, provides so far the only proven method for enormous potential for the large scale generation of electricity without parallel production of CO_2 emissions.

If the goal is to reduce CO_2 emissions, an energy tax (if introduced) will lead to poor target achievement or else to unnecessarily high costs as compared with carbon taxes, given that general tax on energy has no connection with the reduction of CO_2 emissions (cf. Kågeson, 1991; Cline, 1992; Manne and Richels, 1993; Jorgenson and Wilcoxen, 1993). This can be explained by two factors: first, price induced energy conservation; and secondly fuel switching (Manne and Richels, 1993). Carbon taxes reduce CO_2 emissions both through their effects of price mechanism on energy consumption and through fuel choice. By contrast, since the energy tax is imposed on both fossil fuels and nuclear, the incentive for fuel switching will be reduced, and the reductions in CO_2 emissions will be mainly achieved by price induced energy conservation. Thus a higher tax is required for achieving the same reduction target as compared with the carbon taxes. Put another way, for the economy in question it is more costly to reduce CO_2 emissions through an energy tax than through a carbon tax. This has been clearly showed in the study by Manne and Richels (1993), which evaluates the implications of the CEC proposal for a mixed carbon and energy taxes. Similar finding is also shown in the study by Jorgenson and Wilcoxen (1993), the results of which suggest that the US GNP loss in 2020 of an energy tax is 20% greater than that of a carbon tax in order to stabilize the US CO_2 emissions at 1990 levels in the year 2020.

Let us now turn to a carbon tax. So far, a number of studies has focused on the cost estimates for achieving a given reduction in CO_2 emissions. These studies usually incorporate a carbon tax as a method for achieving the target because of its good target achievement. The main findings arising from these studies (cf. Whalley, 1991; Whalley and Wigle, 1991a, 1991b; Martin *et al.*, 1992; Hoeller and Coppel, 1992; Piggott *et al.*, 1992; Pezzey, 1992; Walker and Birol, 1992; Manne and Richels, 1991a, 1993; Kverndokk, 1993; Jorgenson and Wilcoxen, 1993; Poterba, 1993; Rose and Stevens, 1994), among others, are:

• the carbon tax should escalate over time if it is to reflect the rising costs of damage from the accumulation of CO_2 in the atmosphere and if it is to give the markets the signal that CO_2 emissions will eventually be heavily taxed;

• there would be significant variation in the timing and size of the carbon taxes among countries and regions;

• the carbon tax could be production- or consumption-based, but the effects across options would be significantly different among countries. A national production-based carbon tax operates much like an export tax, if applied, oil-exporting countries such as OPEC would gain substantially, but in a national consumption-based tax case, they would become significant suffers;

• the carbon taxes imposed unilaterally or even regionally would be largely ineffective. This ineffectiveness is attributed partly to relatively small share of coalition (e.g. EC, OECD) emissions in the world total and partly to strong economic growth and the resulting increase in emissions taking place in non-coalition countries that offset the coalition's achievements;

• the autonomous (i.e. non-price-induced) energy efficiency improvement, the possibilities for fuel substitution, and the availability of backstop technologies are essential. Without non-fossil fuel options, the upper bound on the carbon tax required rises. Moreover, the autonomous energy efficiency improvement, and the cost and availability of low-carbon or carbon-free backstop technologies are crucial to limiting the tax level required and thus reducing the costs induced for compliance with the emission reduction targets; and

• the carbon tax itself would impose a deadweight loss to country where there are no distortions in the energy markets. But when existing distortions arising from energy subsidies are taken into account, the introduction of carbon tax that increases domestic energy prices up to the world market prices would not impose a cost.

I will not go further into these interesting topics. But instead I will focus on three aspects that are considered to be important when designing a domestic carbon tax.

4. Three aspects of domestic carbon tax design and incidence

The three aspects to be addressed below are: the treatment of the carbon tax revenues, the impacts on the distribution of income, and the effects on international competitiveness.

I begin with the treatment of the carbon tax revenues. A domestic carbon tax has important implications for the tax structure within the economies. If the objective of a carbon tax is to reduce consumption of carbon-based energy products through reallocating spending away from CO_2-emitting activities and thus slow down (or even stabilize) the build-up of atmosphere CO_2 rather than for macroeconomic management, the carbon tax is in essence an incentive tax rather than a revenue raising tax. In macroeconomic terms it seems therefore appropriate that revenues raised through an increase in one indirect tax (a carbon tax) could be offset by a reduction of another indirect tax e.g. value added tax (VAT) so as to minimize the effect on the general level of prices. Then the inflationary and indeed all the highly uncertain macroeconomic effects of the carbon tax are reduced to a minimum (Barker, 1992; Walker and Birol, 1992; Barker *et al.*, 1993). Another measure used to recycle all revenues from the carbon tax to the economy is by means of reduction in income tax. If it is adopted, inflation is then likely to increase, although the extent of acceleration depends on the attitude of wage negotiations to the increases in disposable income from the reduction in income tax. This higher inflationary response has been found in the modeling on the effects on the CEC tax (cf. DRI, 1991; Karadeloglou, 1992; Standaert, 1992; Barker *et al.*, 1993). Alternatively, if the carbon tax revenues are retained in treasury coffers to reduce public sector deficits, then this will depress the economy, certainly in the short term. If the revenues are all spent by the government, for example on non-fossil energy investment, this would imply a large investment programme which could lead to macroeconomic imbalance and rapid inflation (Barker *et al.*, 1993).

The second aspect is the impacts on the distribution of income. A carbon tax would have a regressive impact on the distribution of income since lower income households spend a larger proportion of their income on energy than do higher income households, although the extent of regressive effect depends on how strongly household spending on energy is related to income. Smith (1992) calculates the distributional effects of a mixed carbon and energy tax at $10 per barrel in the UK on different income groups. The results show that the poorest 20% of the population would have paid an additional £1.45 per week in tax, the richest 20% an additional £2.95 per week in tax, and the average household an additional £2.21 per week in tax. Translated into increases of tax paid as a percentage of total spending, these figures are equivalent to 2.4%, 0.8% and 1.4%, respectively. Clearly the relative burden of the additional tax would be higher for the poorest decile, and lower for the richest. This highlights that unless low income groups are to be made worse off by the carbon tax, a large part of the revenues from the tax will need to be used to compensate poorer households from suffering under the tax through the use of tax reductions and increases in social security benefits and pensions to provide roughly uniform amounts in compensation to each household. Unfortunately, the use of the carbon tax revenues in this way will reduce the scope for the revenues to be used to maximize the efficiency gains from reductions in other existing distortionary taxes e.g. VAT described above (cf. Smith, 1992; Barker, 1992; Pearce, 1991). There is thus a clear trade-off between efficiency and equity in the use of the revenues: the efficiency gains can only be achieved by sacrificing the distributional neutrality of the package (Smith, 1992).

The above findings are typically shown in the studies for the industrialized countries. Shah and Larsen (1992) argue that such findings nevertheless cannot be generalized to the developing countries, where the incidence of carbon taxes would be affected by institutional factors. Among some important factors that may have a bearing on the tax-shifting are market power, price controls, import quotas, rationed foreign exchange, the presence of black markets and tax evasion and urban-rural migration (see Shah and Larsen (1992) for a further discussion).

Now I consider the third and last aspect, namely the effects on international competitiveness. A domestic carbon tax has important implications for the international competitiveness of economies in relative terms. Although international competitiveness is not necessarily reduced over the long term by higher energy prices, however, in certain industries, the effects of introducing an unilateral carbon tax may be serious in the short term. The exemptions from the new taxes are therefore suggested to protect the price competitiveness of these industries in international trade. For example, the CEC proposals provide for exemptions for the six energy-intensive industries, such as iron and steel, non-ferrous metals, chemicals, cement, glass, and pulp and paper, at least until similar actions in competitor countries, especially in the United States and Japan, are taken (or some more general OECD-wide tax is adopted). As discussed above, a carbon tax is intended to fall most heavily on the products of carbon-intensive industries. Clearly the exclusion of these industries from coverage of the carbon tax on grounds of competitiveness reduces the effectiveness of the carbon tax in achieving its objective of reducing CO_2 emissions, while it does mean that the EC industries most vulnerable to competition are protected in their markets. The ineffectiveness of unilateral action suggests that carbon taxes need to be imposed regionally or globally for sufficient reductions of CO_2 emissions.

So far our discussion is restricted to domestic carbon tax. It has been argued that even if domestic emission reduction targets are achieved in cost-efficient ways, for example through a domestic carbon tax, global cost-efficient emissions reduction target is only be achieved if CO_2 emissions are distributed among countries in such a way that the marginal costs of abatement are equalized among countries (cf. Hoel, 1991, 1992). This global cost efficiency may be achieved through an international carbon tax or through a tradeable carbon emission permits regime. The remainder of this section will briefly deal with the former, while the latter will be left to be discussed in the next section.

Hoel (1991) has shown that a tax administered and collected by an international agency is too bureaucratic and would interfere with domestic sovereignty, while a tax implemented by each government would fall foul of free rider problem, since governments could easily offset a carbon tax by reducing other domestic taxes on fossil fuels. The way out has therefore to be one in which the carbon tax should be globally imposed on each country by some international agency but nationally administrated and collected through its central government (cf. Hoel, 1991). The carbon tax is set be the same for each country. The revenues from the tax are then reimbursed; handed back to the countries where the revenues are raised according to some agreed rule of allocation. Each country would then act to minimize the sum of its tax payments and abatement costs. Then how to reimburse the tax revenues? This is equivalent to determination of the initial permits under a regime of tradeable carbon emission permits. The issue is to be discussed in the next section.

5. Tradeable carbon emission permits

An alternative to an international carbon tax is a regime of tradeable carbon permits which allows the permit holders to trade or sell their entitlements to other countries (Pearce, 1990; Hoel, 1991). As long as marginal costs of reducing CO_2 emissions differ among countries, countries have an incentive to trade permits with the market price of CO_2 permits being equal to the marginal costs of abatement, and make net gains. The process is lasting until the marginal costs of reducing CO_2 emissions are just equalized across countries, thus inducing a cost-efficient distribution of CO_2 emissions.

Once an international emission budget is set, the question then arises how to allocate the initial permits to each participating country. The obvious rules are based on both the costs of reducing CO_2 emissions and the consequences of climate change. The rules could be applied if the costs of abatement and the consequences of climate change were common knowledge (Hoel, 1991). However, this is not the case. In practice, these costs cannot be measured objectively without any precision, and there are still uncertainties regarding the magnitude, timing and regional effects of climate change. For this reason, the allocation of permits would in practice have to be based on relatively straightforward rules. In the CO_2 context, the rules based on uniform percentage reduction, existing CO_2 emissions (a grandfathering approach), current GNP (or GDP), and population, among others, have been suggested (cf. Grubb, 1989; Pearce, 1990; Rose, 1990; Manne and Richels, 1991b; Hole, 1991; Simonis, 1992; Cline, 1992; Kverndokk, 1993; Welsch, 1993; Rose and Stevens, 1993, 1994). The diversity of these allocation rules, with each of them discussed below, reflects the lack of consensus on a 'best' equity principle.

An uniform percentage reduction offers the operational advantage that it focuses on easily observable physical burden-sharing (Welsch, 1993). It is for this reason that international environmental agreements often take the form of an uniform percentage reduction. An example is the Helsinki Protocol to reduce sulphur dioxide emissions by 30%, i.e. the *so-called* '30 percent club' (cf. Folmer, 1994). In the CO_2 context, the rule ignoring the past build-up and simply basing reduction requirements on current emissions would be equivalent to penalizing developing countries for their economic development when no such penalty was imposed on industrialized countries for their abusing the global commons in the course of their industrialization (Rose and Stevens, 1993). Therefore it at least seems conceivable that the rule would not be accepted by the developing countries. Moreover, it has been argued that the rule based on uniform percentage reductions are inefficient in the sense that the same goal could be achieved at lower costs through the rule that equalizes the marginal costs of abatement among all participating countries (cf. Hoel, 1992).

Using the grandfathering of permits or current GNP as a base would minimize the disruption of current production. However, using either rule as a base would favour the developed countries and does little or nothing to create incentives for the developing countries to co-operate. Moreover, there are some nasty wrinkles associated with adjusting the initial permits: Should an energy-efficient country such as Japan be rewarded with additional permits? Should a country that relies on nuclear power and therefore is also a small emitter - like France - get extra permits? Should Brazil, whose copious forests absorb carbon dioxide, be rewarded for that (Sun, 1990)? Also should countries that have unilaterally cut down their CO_2 emissions long before any CO_2 agreement be rewarded for that, which are otherwise punished?

Using population as a base is compatible with equal emission rights and could be accepted as fair by the developing countries. Given the great disparities in current per capital CO_2 emissions, however, this would probably imply the net payments transfers from the developed countries to the developing countries on a substantial scale and therefore would not be easy for political leaders to justify. The study by Kverndokk (1993) shows in the case that the transfers of 6% and 3% of their potential GDP in the year 2000 are required from USA and other OECD countries to the developing countries, respectively. The magnitude of these transfers is scarcely credible, when the United Nations's level of development assistance at 0.7% of GDP is not met by most of the industrialised countries yet. Moreover, the allocation rule would create an implicit incentive for countries to increase their population, whereas just the opposite is needed to address the greenhouse problem. Grubb (1989) suggests that only adults above a specific age should only be accounted in order to avoid the implicit reward for overpopulation (see Grubb (1989) for a further discussion).

The foregoing clearly indicates that the acceptability of tradeable permit regimes will depend on the allocation rules for permits. In view of the respective weaknesses of each rule discussed above, it follows that an acceptable allocation rule might take into account historical CO_2 emissions, GNP (or GDP) and population together, and that the emissions entitlements to each participating country should be adjusted over time in order to reduce the relative benefits of and relative excess costs of each country. Pearce (1990), for instance, argues that an allocation regime, based initially on grandfathering but with the emission permits be modified by altering the value of the permits over time, would be most appropriate. Thus, developed countries would have declining permits over time, while developing countries could have rising permits that less than offset the developed countries's reductions. This can be illustrated by, for example, the following formula (Cline, 1992):

$$Q_i = Q_g[w_H \Phi_{O,H,i} + w_Y \Phi_{O,Y,i} + w_P \Phi_{O,i,P}]$$

where i represents the country in question; Q is the emissions quota; subscript g is the global emissions target; subscripts H, Y, and P refer to historical CO_2 emissions, GDP, and population, respectively; w refers to the weight assigned to the rule, with the sum of w_H, w_Y and w_P being equal to one; Φ is the country's share in the relevant global total; and subscript O refers to the base year. This approach weights three alternative rules to determine an overall country permits. Cline argues that, if the three weights would shift over time toward the population rule and thus equity, the approach would seem to stand the best chance of support by both industrialized and developing countries: it would give heavy weight to the 'realism' concerns of industrialized countries at the beginning of the period, but also provide large scope for a shift over time toward the equity concerns of developing countries.

Along this line, there exist, though relatively few, quantitative analyses of the effects of changing CO_2 permits over time. In the study of Manne and Richels (1991b), for example, the carbon permits, though still benchmarked against 1990 baseyear, are distributed with grandfathering initially (the year 2000) but in proportion to the 1990 level of population at the end of the planning horizon (the year 2100). This allocation rule is designed to not only avoid an abrupt change in the status quo, but over the long run it leads to an egalitarian distribution of carbon permits. The results (Manne and Richels, 1991b) show that according to the allocation rule there are no dramatic gains from trade and each of the regions would *benefit modestly from trade*, since none of the five regions buys or sells more than 5% of the total global volume of tradeable carbon permits.

So far our discussion on the allocation rule is associated with a regime of tradeable carbon permits. These rules are also valid for determining how to reimburse carbon tax revenues if the international carbon tax is imposed across countries.

6. Carbon taxes or tradeable carbon permits?

As discussed above, both carbon taxes and tradeable permits minimize overall abatement costs by allocating the cutbacks to the countries where marginal costs of reducing CO_2 emissions are the lowest. Moreover, given both perfectly competitive markets and certainty, carbon taxes are equivalent to tradeable permits (cf. Hoel, 1991). In practice, however there are some differences between these two instruments.

By far, probably the most serious arguments in favour of tradeable permits rather than taxes are as follows:

Tradeable carbon permits, unlike carbon taxes, are a form of rationing and their great advantage is that in this way one can be sure of achieving the agreed target. By contrast, the actual achievements in reductions of CO_2 emissions for a proposed carbon tax remain uncertain because of imperfect knowledge of the price elasticities of demand and supply for fossil fuels, especially for the large price increases caused by carbon taxes for major emissions cutbacks (see e.g. Cline (1992) for further discussion). This implies that setting the initial tax will be a hit-and-miss affair, and could thus induce hostile reaction from countries, industries, and consumers although it is not clear how serious an objection this is (Pearce, 1990, 1991). Moreover, in the context of global warming, the delays in adjusting the insufficient carbon tax to the desired level will mean additional committed warming.

Another complication of the carbon tax is the initial differences in energy prices. As a consequence of existing distortions by price regulations, taxation, national monopolies, barriers to trade etc., there are initially wide differences in energy prices, both between fuels and across countries (cf. Hoeller and Coppel, 1992; Haugland *et al.*, 1992). If CO_2 emissions are then to be reduced by similar amounts in two countries, lower taxes are required for the country with low prices before the tax imposition than the country with the higher pre-tax prices provided everything else is equal in both two countries (cf. Hoeller and Coppel, 1992). Thus an eventual cost-efficient regime of international carbon tax would presumably need removing existing distortions in international energy markets. Otherwise, countries with the lower pre-tax prices will enjoy free-ride benefits (Cline, 1992).

However, a regime of tradeable carbon permits is also subject to important limitations. Although the regime might require less of an international bureaucracy than would be needed to administer and enforce an international carbon tax, some supra-national agency would be required to regulate and perhaps periodically intervene in the permit market in which some undesirable consequences of e.g. influences by big countries may occur (cf. Hoel, 1991; Shah and Larsen, 1992), to adjust the global target level and re-issue permits in response to changing conditions as discussed above, and to monitor transactions and enforce any penalties for abuse (cf. Pearce, 1990; Hoel, 1991; Pearce and Barbier, 1991). All the administrative and transaction costs associated with tradeable permits cannot be known in advance. They may turn out to be much higher than was imagined when the target was defined, thereby making tradeable permits less of an attractive instrument. This uncertainty regarding the costs of emission reductions is an important distinction between tradeable permits and carbon taxes. If there is great uncertainty about the costs of emission reductions, carbon taxes are preferred in order to avoid potentially large and unexpected costs (Shah and Larsen, 1992). However, if the overall impacts of climate change would believed to be unacceptably high or there would be a threshold effect caused by the stock of CO_2 emissions beyond which atmosphere temperatures would rise exponentially, the target would then have high political priority. In this case, the choice of economic instruments should not be swayed by uncertainty regarding the costs of emission reductions and tradeable permits would be preferred to carbon taxes (cf. Kågeson, 1991; Shah and Larsen, 1992).

Besides, so far there has been limited international experience with tradeable permits. While tradeable permits have enjoyed some considerable success in the various domestic contexts, by no means does that guarantee their success in the international context (Tietenberg, 1994). Thus such a regime is perhaps yet to be validated through more experience on a small rather than global scale. In this regard, it is worthwhile to putting into practice *joint implementation*, a derivative of the idea of permits trading that has been built into the UN Framework Convention on Climate Change to allow countries to invest in emission reduction projects in other countries where such projects would be more cost effective than trying to achieve an equivalent reduction within their own countries. The experiments may provide some experience for implementation of a global tradeable emissions permits regime (cf. IEA, 1992; Tietenberg, 1994).

7. Conclusions

This paper has evaluated policy instruments targeted at the control of CO_2 emissions. The following conclusions emerge from the analysis:

First, global warming problem has international and intertemporal dimensions, where its impacts cannot be confined to the country of origin, will last over generations, and are hard to quantify. In dealing with such a problem, achieving the predefined targets for emissions reductions at the least cost is the goal rather than seeking the optimal solution through internalization of the associated externalities.

Second, if the goal is to reduce CO_2 emissions, energy taxes (if introduced) will lead to poor target achievement or else to unnecessarily high costs as compared with carbon taxes. In the case of general taxation on energy, the reductions in CO_2 emissions will be mainly achieved by price induced energy conservation. By contrast, carbon taxes reduce CO_2 emissions both through their effects of price mechanism on energy consumption and through fuel choice.

Third, for the effectiveness of action, carbon taxes should escalate over time and imposed globally in order to reflect the rising costs of damage from the accumulation of CO_2 emissions in the atmosphere, to give the markets the signal that CO_2 emissions will eventually be heavily taxed, and to prevent carbon leakage that would otherwise take place in regions or countries without such taxes. But if this is not the case, special attention should be given to the treatment of the carbon tax revenues, the impacts on the distribution of income, and to the effects on international competitiveness when designing an unilateral carbon tax.

Fourth, the allocation of emission permits would in practice have to be based on relatively straightforward rules. If an allocation rule is likely to induce relatively large participation, account might be taken into historical CO_2 emissions, GNP (or GDP) and population together, and the emissions entitlements to each participating country should be adjusted over time in order to reduce the relative benefits of and relative excess costs of each country.

Finally, the actual achievements in reductions of CO_2 emissions for a proposed carbon tax remain uncertain, while, under a regime of tradeable carbon permits, there will be certainty about the magnitude of emissions reductions but great uncertainty about the costs of such reductions. If there would be a threshold effect of climate change, tradeable permits would be preferred to carbon taxes. Given our current lack of knowledge about the magnitude, timing and threshold effects of climate change, however, carbon taxes appear to be the superior and more flexible instrument that avoids potentially large and unexpected costs.

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