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Working Paper

Trade implications of environmental taxes

Kiel Working Papers, No. 628

Kieler Arbeitspapiere
Kiel Working Papers

Working Paper No. 628

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April 1994

Institut für Weltwirtschaft an der Universität Kiel
The Kiel Institute of World Economics

ISSN 0342 - 0787

The Kiel Institute of World Economics
P. O. Box 4309
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1. INTRODUCTION

There is little disagreement about the need for tighter policy measures to avoid a further environmental dagradation. It is also widely accepted that economic instruments will achieve this objective in a wide range of circumstances more efficiently than other policy measures. Still, there is concern over side effects of such environmental policies, because they might negatively affect employment in the economy, they might create undesirable distributive impacts, and they might disturb international trade relations by changing the competitiveness of export industries. The aim of this paper is to review the potential impact of environmental taxes on trade flows on a conceptual as well as on an empirical level.

Trade policy and environmental policy have been distinct subjects for a long time - in policy as well as in a theoretical analysis. In the past few years, the debate about the rounding up of the Ururguay-Round on trade liberalization in connection with the increasing awareness about the deterioration of local as well as global environmental media has united the two policy arenas. A major effort in empirically investigating the impact of trade liberalization on environmental quality has been undertaken by the World Bank (Low 1992). The reverse relationship, i.e. the impact of environmental policy on the international division of labor, has not been paid as much attention although the topic has become a research subject much earlier.

The early empirical research on the impact of environmental policy on trade has generally found little evidence for a measurable relationship such that this topic has not been followed on a wider scale. Only the recently emerging global problem of controlling emissions of greenhouse gases has led economists to focus again on the interaction of international trade issues and environmental policies. Although the main reason for this interest came from the presence of transfrontier externalities requiring coordinated policy approaches, it became clear that even coordinated climate policies may result in drastic changes in the international division of labor and that these effects depend on the particular form in which these policies were implemented.

The positive analysis of the effects of environmental policies on trade are in fact independent of whether the emissions are trans-frontier or local externalities. It is therefore of interest in itself to analyse these trade effects for all types of environmental policies. In a first best world of policy choice the environmental policy should always be introduced at the source of the externality, i.e. charges or taxes should be imposed directly upon the emissions or the environmental services. Yet, in reality many factors can prevent the imposition of first best policies and environmental taxes are supplemented by command and control measures or the taxes are imosed upon products or processes related to the emissions in a more or less direct way.[1] These types of second-best environmental policies may have quite different impacts upon trade than the emission taxes.

[1] See OECD (1989, 1991, 1993)

One of the major problems of measuring the relationship between environmental taxes and trade has been in the past and presently still is the fact that environmental taxes are generally low - in most cases quite below their optimal level - thus making it impossible to deduct with statistical methods the impact of optimally set environmental taxes on trade volumes and trade structure. At best one can find the impact of the observable low taxes, but extrapolating these effects to higher - and presumably optimal tax levels - would only be sensible if taxes and trade effects had a linear relationship. Many studies have therefore concentrated on simulation models in order to assess not yet implemented taxes at or near their optimal levels.

This paper first develops a very simple analytical framework in which the impact of different environmental taxes on the international division of labor can be illustrated. It consists of a simple 2x2x2 Heckscher-Ohlin trade model in which the positive analysis of environmental taxes is assessed. Even in this simple framework numerous different configurations can be distinguished. The technical details are given in the Appendix where the results of the model are also illustrated graphically. The positive analysis in this simple model is followed by a number of possible extensions. The second part is devoted to a discussion of empirical studies on environmental policies from which conclusions about the specific topic of this paper can be deducted. Empirical studies which are directly address the questions raised in this paper do not seem to exist.

The paper continuous with a short discussion of issues which dominate the policy debate as far as trade effects of environmental taxes are concerned.
Global environmental problems will - at least in the beginning - not become addressed in a global coordinated framework. Instead, unilateral action of a small group of countries will probably be necessary to get international action started. The environmental effectiveness is then reduced because economic forces will lead to a relocation of environmentally harmful activities towards unregulated economies. The likely extent of this leakage of emissions is discussed. International rules laid down in the GATT have controlled traditional trade policy interventions through tariffs bat have also induced a proliferation of non-tariff barriers. Environmental taxes might also be considered a candidate for discriminating against foreign suppliers. Another policy issue concerns the fact that economies adjust to policy interventions differently in the short- and in the long-run. Finally, the problem of the distributional effectsof introducing environmental taxes is taken up. This debate centers aroung the question how - especially in an international context - tax revenues should be redistributed. The income effect of these tax revenues can have an important impact on the resource allocation as well as on the regional distribution of gains and losses of environmental policies.

The final chapter discusses the possibilities for mitigating the impact of environmental taxes on the international competitiveness of industrial sectors and assesses their likely environmental consequences. The paper ends with some conclusions.

2. Analytical Framework

2.1. Trade and the Environmental Taxes - The Basic Relationship

The impact of environmental policy in general - and of environmental taxes in particular - on the international division of labor depends even in a relatively simple framework on a large number of factors. Disentangling these different aspects requires an analysis on a relatively abstract level before the more practical issues can be discussed. This part therefore develops a theoretical framework in which the impact of environmental taxes on trade can be assessed. The results of trade models incorporating environmental issues vary with the exact specification of the situation under consideration. Without an explicit recognition of these different subgroups of possible situations the allocative effects as well as the welfare and distributional impacts of environmental policy can not be assessed. Therefore, some important cases will be discussed here before the impact of different environmental taxes on trade will be analysed.

It is, of course, necessary to define precisely, what is meant by the "environment". The environment is a resource which can be used in the production or consumption process either by dicharging emissions into it or by using the resource directly as an input in these processes, thus in both cases diminishing the size or the quality of the resource. The environment could - in addition to being a by-product in production or consumption processes - have positive welfare through its mere existence. In the latter case the choice of an environmental tax needs to recognize not only the scarcity of the resource extracted from the stock as an productive input but also the utility of the stock itself. A further factor might be that the stock of the environment may have some positive external effect on the production process. The environmental tax should therefore be seen as an instrument which determines the amount of resource use and the quality and size of the resource stock in an optimal way, i.e. by internalizing all the just mentioned externalities. In this paper the stock effects are ignored since taking account of them would be beyond the scope of this paper.

At least in a simple model, the environmental tax set by the government to achieve a desired resource use is no different from a command and control approach where the resource itself is allocated by the government, except for the possible income effect of the tax revenue. It is implicitly assumed in most models that the use of the environmental resource creates some spillover effects, i.e. the use of the environment produces externalities, thus rendering government intervention necessary. Without such externalities the environment as a resource reduces to a "normal" resource extraction problem which could be allocated under private ownership without efficiency problems.

It is well known from trade theory that there is a difference whether the country under consideration is a relatively small country, i.e. it can not influence world market prices, or a large one, i.e. its actions influence the terms of trade. Another dichotomy of equal importance comes from the nature of the environmental effect to be investigated. If the use of the environmental resource affects the utility functions of the individuals of the domestic country only, then there are no spillovers of pollution or resource use. On the other hand, if such transborder effects are present, then the optimal policy choice will be different. In addition, it will differ depending on whether the country follows an egoistic policy of maximizing national welfare or whether it maximizes global welfare.

Another issue related to the use of the environment concerns the question whether the environmental effect occurs during the production or the consumption of a particular commodity and where the environmental tax is levied. Internal efficiency would require to locate the economic instrument, i.e. the tax, as close to the source as possible.[2] Hence, emissions in the production process should be taxed directly at the emitting source, and environmental impacts during consumption should be taxed at the emitting household. In many cases a direct taxing of emissions is impossible or too costly due to monitoring, control, or other problems. In these cases taxes can be imposed upon the product either at the domestic producer level, at the retail level which is already quite close to the consumer, or at the point of consumption. This makes an important difference since the environmental tax on externalities in the production process would be levied only on domestic production, whereas an environmental tax for correcting consumption externalities would need to be levied on domestic consumption, i.e. domestic production minus exports plus imports. Consequently, the impact of these two different taxes on the international division of labor can vary considerably.

A final distinction common in trade models is the one determining comparative advantage in Heckscher-Ohlin models, i.e. the relative endowment with the different factors of production, one of which being the environment. A permutation of all these cases produces a considerable number of combinations which need to be investigated. In order to facilitate the presentation, they are summarized below and each situation is given a letter such that, e.g. case (L,I,K,C) describes the case of a large country with transfrontier externalities through consumption which is relatively scarcely endowed with the environment, i.e. relatively well-endowed with capital and/or labor. Some of the different possible configurations are given in the following list:

- Small country (S) - large country (L);
- no transfrontier pollution (N) - transfrontier pollution (I);
- relatively scarcely endowed with environment (K) - rel. well-endowed with environment (E);
- tax on - domestic - production (P) - on consumption (C) - on emissions (X).

The most important cases will be discussed in the following by using a Heckscher-Ohlin trade model framework where the international division of labor is driven by comparative advantage through differences in the resource endowments. The technology and homothetic preferences are assumed to be identical between countries for the moment, and the country has balanced trade. Deviations from these assumptions will be discussed subsequently.

The basic difference between the small and the large country case is that in the former the imposition of an environmental tax will not influence relative world market

[2] See OECD (1991).

prices, whereas in the latter case it will. E.g., a carbon tax unilaterally imposed by Belgium will not change the world market prices for steel, but the same tax imposed by all OECD countries might do so. The implications of this distinction are important. If the environmental tax is imposed on emissions in a small country, consumer prices - which are determined by the perfectly elastic world market supply - will not change such that the only adaptation in the economy will take place within the sectoral production structure. In contrary, the same situation in the large country case will have repercussions on demand through the change in relative prices on the world market.

Distinguishing between transboundary and national pollution problems is important from a welfare standpoint and in terms of spillover effects of the reallocation of production among countries. Policies towards pollution which does not cross the frontiers will only indirectly change the environmental quality in the foreign country, whereas transfrontier pollution has direct spillovers as well as indirect ones through changes in trade flows. As long as only the allocation effects of an arbitrarily set environmental tax are considered a distinction between local and transfrontier pollution is not necessary. Choosing optimal tax rates or analyzing overall welfare effects, however, would require to distinguish between the two cases.

The relative factor endowments of countries determine their comparative advantage and the trade structure. Environmental policies which directly limit the use of the environment or which directly raise the costs of using environmental resources will consequently change the comparative advantage of that country. Hence, a relatively capital rich country by reducing the use of the environmental resource will even increase its comparative advantage in the production of goods which use capital intensively. In contrary, a country which is relatively well endowed with the resource "environment" would by imposing environmental policies reduce its comparative advantage and - in an extreme case - even reverse the comparative advantage.

The next three sections will summarize the results of a simple Heckscher-Ohlin model of trade for the case of an emission tax, a product tax which is levied on domestic production - in the following called a production tax -, and a tax which is levied at the retail level - in the following called a consumption tax. Other ways of introducing environmental taxes are conceivable but will not be discussed here.

2.1.1. Emission Taxes

A first best environmental tax is one which is directly levied at the emission which is to be controlled by the economic instrument. The emission can take place during the production of a commodity, during its transport, or during, resp. after, the consumption of a commodity. In the following only the case of an emission tax in the production process is considered. This seems to be the most frequent case, and it is tractable within the standard trade models.[3] Emissions are assumed to represent the factor input "environment". The imposition of an environmental tax on emissions during

[3] Emission taxes in the consumption process would require an analysis of household consumption decisions, presumably within a household production function framework. This case is ignored as well as emission taxes on transport activities.

production in a small country increases the price of the factor "environment". Consequently the derived input demand for that factor falls and less of the factor "environment" will be used. The production of the "dirty" goods which use the environment intensively will therefore decrease and that of the emvironmentally friendly, i.e. capital/labor intensive, good will increase. This parallels the classical Rybczynski-effect of a change in the resource endowment, except that the factor price of the environment is set exogenously determining the quantity demanded of that factor whereas in the former the quantity is set and results in an endogenously determined factor price. If trade barriers do not exist the world market prices will govern consumer demand and the change in the production structure of the small country will therefore not influence output prices and demand. As a result of the tax the economy will move to a lower production possibility frontier and it will shift its production structure towards the low emission commodity.[4]

The effect of the emission tax on trade flows depends on the comparative advantage of the country under consideration. Suppose the country is relatively well-endowed with the factor environment, i.e. the country is an exporter of the environmentally intensive good and an importer of the capital/labor intensive good (case S,N,E,X). The environmental tax has reduced the relative production costs of the capital/labor intensive good leading to the above mentioned reallocation of production. But at the same time the lower factor endowment has induced a negative income effect such that the domestic demand for both goods will fall if they are normal goods. Consequently the country looses some of its comparative advantange and it looses real income such that imports as well as exports will fall. If the environmental tax is raised sufficiently far until the reduction in the production of the "dirty" commodity falls below domestic demand, then the comparative advantage - and the trade structure - will change towards the clean good becoming an export and the "dirty" good becoming an import good.

If the country, however, is an importer of the taxed product (case S,N,K,X) then the trade effect is different. Whereas there is little change in the production of the clean commodity, the environment-intensive good production falls strongly such that the gap between domestic demand and domestic production for this commodity widens even when the negative income effect is taken into account and if it is not too strong. The imports of the taxed commodity as well as the exports of the clean commodity are therefore likely to increase. This increase in trade volumes comes about through an increase in the comparative advantage of that country which has been forced upon it by the tax induced change in the resource endowments.

2.1.2. Production Taxes

Emission control through taxes or charges can often not be performed at the emission source because monitoring is infeasible or too costly, or because the number of emission sources is large or non-stationary. In such cases product charges can act as an - often imperfect - substitute for emssion charges (OECD 1991, 1993a). They should also

[4] This is illustrated in Figures 1 and 2 in the Appendix.

be applied if the product itself has some negative impact on environmental quality (ibd.). In all these cases the product charge remains a second best instrument which does not directly address the environmental damage but acts as a proxy for that damage thus leaving untaxed some other impacts of minor importance. The environmental impact of a product charge on the overall environmental quality is therefore not clearly predictable since the reallocation of the factors of production towards untaxed products also changes their emissions. This issue is ignored here since optimal taxes are not subject of this analysis. It has been noted that the trade effects of product charges may be quite different from emission charges or taxes (OECD 1993a). Yet they also require a different model.

The previous model with the environment - or more precisely, the environment's assimilative capacity for emissions - as a factor of production is inappropriate for modelling product or consumption taxes. Contrary to a partial equilibrium analysis which shows a reduction in the production and consumption of a taxed commodity and - in connection with this - a reduction of emissions, in a general equilibrium analysis of a perfectly competitive economy without factor market rigidities, a product tax at the producer or at the consumer level would have no influence on the full use of all available factors of production of which one would be emissions. The reallocation away from the environmentally intensive product would take place, but the factors becoming idle through this reduction would be used in the production of the capital/labor intensive product. Hence emissions would remain constant.

A meaningful simple model for analysing the effects of such taxes could consist of emissions being the joint product of the production process. Hence, an economy produces with some unspecified factors of production two different products which both have the same joint product, called "emission". Now suppose that the emission coefficient of one product is higher than that of the other. A second-best policy of taxing the "dirtier" product will then shift the production away from the commodity with a high emission coefficient to that with a low emission coefficient. This is illustrated in panel (a) of Figure 3 in the Appendix. The corresponding effect on total emissions is shown in panel (b) of Figure 3. In the particular situation chosen, total emissions increase as the economy moves from specializing in the product with a high emission coefficient to the product with the low emission coefficient, but the opposite is also possible and in general more likely.

Suppose now that the taxation of emissions is not feasible for whatever reason such that a policy of taxing the product at the producer level (case S,N,K/E,P) is chosen. In this case the imports are not taxed whereas the exports of domestic producers are subject to the tax.[5] If domestic production is taxed and imports are not taxed then the elastic world market supply will determine domestic consumer prices and producer prices net of taxes need to adjust to them. The domestic producers will shift production from the high to the low emission product because its relative price has risen. Thus the production tax has forced producer to switch to the low emission commodity while it leaves consumer prices untouched. Consumers will adjust their consumption bundle only because their real income has changed due to the change in the production structure.

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[5] This type of taxation resembles the case of an indirect tax under the country of origin principle. See Baldwin (1970) for such an analysis.

The change in the trade structure and trade volumes again depends on the country's comparative advantage. Suppose case S,N,E,P, i.e. the country is an exporter of the high emission commodity. Since the economy has moved away from the production of the commodity in which it has a comparative advantage, trade volumes will shrink if both goods are normal goods. The terms-of-trade remain constant by the assumption of a small country. The trade effects of the production tax are therefore quite similar to the emission tax. Only the emissions are more effectively reduced by the emission tax which directly affects the environmental resource through the change in the resource price.[6]

The opposite effect on trade volumes can arise, if at the same original allocation the emission intensive commodity is an importable. Then the reallocation of production will increase trade volumes. i.e. more of the emission-intensive good will be imported[7]. In summary, the effect of an environmental tax on emission-intensive domestic production or products will change trade volumes as expected. If the tax is on the importable trade volumes increase, if it is on the exportable trade volumes generally fall. Total emissions can fall or rise depending on the compound effect of the difference in emission coefficients, on the technical rate of substitution, on preferences, and on the tax rate.

2.1.3. Consumption Taxes

A tax on consumption will by definition be a tax on domestic products only if they are sold domestically and on imports but not on exports, i.e. the domestic consumer price will rise and producer prices remain equal to world market prices. The domestic demand for the taxed product will fall and that for the substitute will rise. Domestic production remains unchanged. Hence, a second-best policy of emission control through a tax on the consumption of the "dirty" good has only a chance of becoming effective, if the externality is indeed a consumption and not a production externality because the production of the two goods will not change. In the case of a consumption externality total emissions will only fall if the relative domestic price of the high-emission to the low-emission good is smaller than the inverse ratio of the emission coefficients of those two goods.[8]

In a country which is well endowed with capital/labor, i.e. it is importing the environmentally intensive commodity (case S,N,K,C), imports as well as exports will decline at the same rate since the producer's terms-of-trade have not changed. If the tax rate is sufficiently high the direction of trade can change as soon as the domestic demand for the importable falls below domestic production - which is determined by the world market price - and that of the exportable rises beyond domestic production. This can easily happen despite the negative real income effect which is induced by the divergence between relative producer and consumer prices if the imports of the low emission commodity are low. Hence, if the externality is indeed a consumption externality then the negative environmental effect is exported. If the consumption tax is used for controlling production externalities but is levied at the retail level in order to also tax imports, it will

[6] For a graphical presentation see the Appendix, Figure 4.

[7] This only holds if the good with the low emission coefficient, i.e. good k, is not too inferior.

[8] A graphical illustration of these cases can be found in Figures 6 and 7 of the Appendix.

have no environmental effectiveness since the lack in domestic demand is taken up by exports.[9]

If the comparative advantage of the economy is in the environmentally intensive good (S,N,E,C), domestic sales will decline but since the world market demand is perfectly elastic exports will increase by the same amount by which domestic sales have been reduced. At the same time imports of the low-emission commodity will increase. Hence, trade volumes will always increase in this case.

2.1.4. Terms-of-Trade Effects

If the emission, production, or consumption taxes are high enough to influence domestic production and/or consumption decisions and the country is large enough that these decisions also influence world market prices, the analysis of the domestic adjustments to internal price changes - as it has been done in the small country case - needs to be supplemented by an analysis of the repercussions through the world market. Unilateral policies in a large country will influence supply and demand of tradable commodities on the world market such that prices on these markets will also change. Consequently, the envirnmental tax will not only influence the allocation in the rest of the world, but the repercussions in the world market will again change the internal allocation in the taxing country. Again, the effects of imposing an emission tax upon producers or consumers are presented first, followed by the second-best options of production or consumption taxes.

Introducing an emission tax reduces the economic use of the resource endowment "environment". The corresponding rise in the relative world market price of the commodity which requires the relatively high share of the factor environment in production will induce domestic producers to exploit this increased price by producing more of that commodity at the expense of the other commodity. The production effect of the terms-of-trade change will therefore to some degree counteract the objective of the emission tax, i.e. to move domestic production away from the environment-intensive commodity. The difference is illustrated in Figures 1 and 2 of the Appendix where in both figures point B represents the production point without terms-of-trade changes and point C represents the production point after the terms-of-trade effect.

The consumption, trade, and welfare effects depend on the comparative advantage of the economy. If the environment-intensive commodity is the exportable (case L,N,E,X) the terms-of-trade for the country improve such that the tendency for a reduction in exports due to the higher production costs is alleviated somewhat. Consumers experience an increase in real income through the terms-of-trade change and thus reach a higher welfare surface than under constant world market prices.[10] The opposite happens when the emission-intensive commodity is the importable. Then the change in relative prices amounts to a deterioration of the terms-of-trade. The increase in the production of the importable high-emission commodity reduces the country's comparative advantage

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[9] See also chapter 5.

[10] Points b and c in Figure 1 of the Appendix.

thus leading to a reduction in trade volumes as well as a further loss in welfare due to the income effect of the fall in gains from trade.

In the case of a production tax similar effects of the terms-of-trade effect come into play although through different channels. The production tax on the high emission commodity will reduce the world supply of this commodity such that its relative price rises. At a given tax rate the price wedge between consumer prices, i.e. world market prices, and producer prices net of taxes can only be sustained if the producer price of the high emission commodity increases. Hence, the incentive effect of the production tax will be lowered somewhat through the terms-of-trade effect. Since in case L,N,E,P the terms-of-trade change in favour of the exportable there is a tendency for a higher trade volume and higher welfare as in the case of an emission tax case. When the comparative advantage is in the low emission product (case L,N,K,P) trade volumes shrink and welfare falls below that of the small country case.

Under a consumption tax there was no change in domestic production as long as the relative world market price was constant. The terms-of-trade effect will then induce a reallocation of resources towards the low emission commodity because the increased consumer price will reduce domestic demand for the high-emission product and increase it for the low-emission product. This corresponds to a parallel change in world supply and demand such that the relative world market price, i.e. the domestic producer price, for the high emission product falls. Hence, not only consumption - as in the small country case S,N,E/K,C - but also production shifts away from the high emission commodity. This production effect reduces the consumption induced expansion of trade when the high-emission commodity was exported (case L,N;E,C), firstly, because the country's comparative advantage in the high-emission product has deteriorated and, secondly, because the terms-of-trade effect goes hand in hand with a fall in real income.

If the country's comparative advantage is in the low-emission product the consumption tax on the high-emission product will through the terms-of-trade effect also force a specialization towards the low-emission product, i.e. it supports the commodity with the comparative advantage. Yet, at the same time the substution of consumer demand away from the emission-intensive commodity towards the low-emission commodity absorbs this additional production such that the trade volume shrinks. When the substitution effect in consumption is much stronger than the substitution effect in production the direction of trade can possibly change. In this case domestic production of the low-emission exportable will increase but it will also become an importable due to the change in domestic demand. Hence, a reduction in trade or even a change in the trade direction of a commodity needs not conicide with lower domestic production.

2.2 A Diagrammatic Summary

The different cases discussed so far have not distinguished between national and transborder pollution problems. This has not been necessary because the analysis was not concerned with optimal tax levels but only with the effect of marginal changes in the tax rate on production, consumption, trade, and prices. In these cases the type of pollution

Table 2.1. Environmental Taxes in a Relatively Capital-Rich Country@

	Small Country (No ToT-Effect)			Large Country (ToT-Change)		
	Emission Tax	Product Tax	Consump -tion Tax	Emission Tax	Product Tax	Consump tion Tax
Relative Producer Price*	0	-	0	+	-	-
Relative Consumer Price*	0	0	+	+	+	+
Production (Env.-Intens. Com.)	-	-	0	-	-	-
Production (Cap.-Intens. Com.)	+/-	+	0	(+)/-	+	+
Consumption (Env.-Intens. Com.)	-	-	-	-	-	-
Consumption (Cap.-Intens. Com.)	-	-	+	+/-	-	+
Imports (Env.-Intens. Com.)	+/-	+	-	(+)/-	+/-	-
Exports (Cap.-Intens. Com.)	+/-	+	-	+/-	+/-	-

* Price of the environment-intensive commodity relative to the capital-intensive commodity.

@ 0 := no change; + := increase; - := decrease; +/- := uncertain effect; (+)/- := uncertain, but decrease likely. Both commodities are normal.

does not make a difference. Transborder pollution would also need to be taken into account if the welfare effects of the tax were to be assessed. However, this would require to have available a technique for measuring not only the welfare effects of consuming products but also the welfare effects of the environmental externalities and the possible welfare of the environmental stock which is preserved. Such an analysis is beyond the scope of this paper.

By ignoring these distinctions between national and international pollution problems, one can summarize the other configurations - i.e. large vs. small country, factor endowments, and type of tax - in a tabular form. Table 2.1 presents the effects of the different types of environmental taxes on prices, production, consumption, and trade within a country which is relatively well endowed with capital/labour. The left-hand side of Table 2.1 presents the case where no terms-of-trade effects occur on the world market. The output price effects of the different taxes are shown in the first two rows. Under the emission tax no output price changes take place, whereas the product tax lowers relative producer prices without changing consumer prices and the consumption tax raises consumer prices without changing producer prices. This does not hold for a large country, because the world market price will change. Table 2.1 also shows that the trade effects depend on the particular type of tax chosen irrespectively of the presence of the terms-of-trade effect.

Table 2.2. Environmental Taxes in a Relatively Environment-Rich Country@

	Small Country (No ToT-Effect)			Large Country (ToT-Change)		
	Emission Tax	Product Tax	Consump -tion Tax	Emission Tax	Product Tax	Consump -tion Tax
Relative Producer Price*	0	-	0	+	-	-
Relative Consumer Price*	0	0	+	+	+	+
Production (Env.-Intens. Com.)	-	-	0	(+)/-	-	-
Production (Cap.-Intens. Com.)	+/-	+	0	(+)/-	+	+
Consumption (Env.-Intens. Com.)	-	-	-	+/-	+/-	-
Consumption (Cap.-Intens. Com.)	-	-	+	+/-	+/-	+/-
Imports (Env.-Intens. Com.)	+/-	-	+	(+)/-	(+)/-	+/-
Exports (Cap.-Intens. Com.)	+/-	-	+	+/(-)	(+)/-	+/-

* Price of the environment-intensive commodity relative to the capital-intensive commodity.
@ 0 := no change; + := increase; - := decrease; +/- := uncertain effect; (+)/- := uncertain, but decrease likely. Both commodities are normal.

The same summary is given in Table 2.2 for the case in which the country is relatively well-endowed with the factor environment. In this case the price effects remain the same, but the adjustment of the economy in production, consumption and trade will be different.

The two tables reveal that one can not predict the trade impact of an environmental tax without explicitly stating the particular situation of the economy and the specific form in which the environmental tax is imposed. Trade volumes can increase or decrease depending on whether the comparative advantage of the taxing country in its export product has been strengthened or weakened. It is clear, however, that the consumer surplus of commodity consumption in general falls. But this is only a partial welfare measure since the gains in environmental quality are not taken into account.

2.3 EXTENSIONS TO THE BASIC RELATIONSHIP

The simple mechanics of the preceding paragraphs ignore several important relationships. In reality factors of production are not completely immobile. At the extreme, only the natural environment itself can be considered an immobile factor whereas labor and evidently capital are mobile factors of production. The classical trade models with mobile factors (e.g. Jones et al. 1986, Bhagwati/Srinivasan 1983) do not include an immobile factor. Kuhn and Wooton (1987) have added such an immobile factor and did investigate the impact of factor movements. Environmental taxes will then induce factor flows which in turn change the comparative advantage of the countries and as a consequence the sectoral production and trade structure. Environmental taxes which reduce the availability of the immobile factor environment by raising its price will then induce an outflow of the mobile factors since the larger immobile resource endowments in the rest of the world will secure a higher marginal product of the mobile factors than in the country from which the factors have emigrated.

Mobile factors of production would then strongly increase the adjustment cost to the imposition of environmental taxes since they reduced stock of the environment which is available for production purposes will also reduce the supply of other factors of production. This complementary relationship between the availability of the environment and other mobile factors of production introduces a strategic element into environmental policy by allowing a country to attract mobile factors of production by imposing lower environmental standards than the rest of the world.

If the 2x2x2 Heckscher-Ohlin model is extended to higher dimensions, the already ambiguous predictions become even more dependend on the particular situation in which the environmental tax is imposed. In a multi-factor, multi-commodity world the sectoral structure of trade can not predicted according to factor intensities, i.e. the good which uses the most abundant factor most intensively will not necessarily be exported any more. The trade flows are rather determined by the factor content of the commodities (Helpman/Krugman 1986). Consequently, a tax on emissions need not necessarily have a direct trade impact on the sector with the highest emission intensity. The only prediction which can be made is in terms of the factor content of trade; a prediction which is difficult to implement empirically because especially the factor endowment "environment" can hardly be measured with the necessary accuracy.

Environmental policies are not implemented in isolation from other policy objectives. The concern over the loss of international competitiveness of industries through environmental taxes or standards will also have industrial and trade policy aspects. Governments may therefore wish to consider industrial targeting goals and environmental goals simultaneously thus aiming at the achievement of two end with just one instrument. It is well known that such an approach in general yields suboptimal outcomes. Barrett (1992) has modelled the interaction between strategic trade policy considerations and environmental policy objectives.[11] By considering the trade effects of environmental regulations governments will set environmental targets which are above or below the optimal level, i.e. the induced marginal abatement costs are below or above the marginal damage. The results depend on the particular set-up of the behaviour of governments and of firms. In the case of domestic monopolies, a unilaterally set environmental target by one country would result in a target which is below that which would be imposed for environmental reasons alone.[12]. This also carries over to the case where both countries set their targets strategically. The resulting Nash-equilibrium has sub-optimal environmental standards in both countries. This result, however, does not hold for olgopolistic market structures. In this case, predictions about the restrictiveness of the environmental standard can not be made. However, both countries have an incentive to cooperate and impose targets which are above the environmentally optimal ones independently from the market structure in the two countries.[13] All these results hold for firms competing in quantities. Under price competition (Bertrand behaviour) the noncooperative results are reversed.

Barrett's model has been extended by explicitly considering the strategic aspects of R&D in abatement technologies by David Ulph (1993). The strategic interaction of firms in abatement technologies which is added to the strategic gevernment behaviour increases the complexity of the model in such a way that no predictions about the optimal environmental policies can be made. Despite the inconclusive results of these models, a comparison with the perfectly competitively non-strategic framework of a Heckscher-Ohlin model shows that higher environmental taxes need not result in a deterioration of the competitive position of the industry exposed to the tax. Moreover, in noncompetitive markets a variety of effects can occur which mainly depend on the type of behaviour governing the firms in such industries and on the shape of the abatement cost function. Therefore, one can at least say that environmental taxes will not necessarily reduce the competitiveness of particular sectors of the economy. This is again a case where the inconclusive trade effects of the simple model of perfectly competitive markets are even less predictable in general.

A model which explicitly models locational choice of imperfectly competitive firms also produces results which can be opposite to the simple model presented above (Alistair Ulph 1993). The introduction of an environmental tax which usually is designed to raise producer prices might even lower these prices. This result again stems from the non-competitive market structure which is changed through the environmental tax and the subsequent locational decisions. Since the degree of competitiveness of a market depends on the locational decisions of firms, Ulph generates cases where low environmental taxes wouls lead to price increases and less competition whereas high taxes in the same situation can lead to lower prices and increased competition. In addition, the locational choice will increase leakage rates far beyond those in competitive models.

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[11] Barretts analysis is not for environmental taxes but for targets. This may make a difference because of the additional tax burden.

[12] See Proposition 1 in Barrett (1992):

[13] See Propositions 3 to 6 in Barrett (1992).

3. Empirical Evidence

3.1. Statistical Ex-Post Evidence

Efforts to relate the theoretical results of the possible impact of environmental policies on the economy to empirical evidence have begun only recently. Empirical research on this issue is faced with a number of problems. First, as it has been shown above, the theoretical predictions about trade and allocation effects are not at all clear due to the complexity of the models. Secondly, the data basis for measuring the relationship between environmental intensity of production and trade patterns of goods and factors is still scarce.

The older empirical studies on the impact of environmental policy on trade are summarized by Dean (1992). The first studies (Walter (1973), U.S. Department of Commerce (1975), Yezer/Philipson (1974)) all come to the conclusion that the environmental policies did not have a significant effect on trade. However, their evidence was based on environmental regulations in the late 1960s which by now has been greatly intensified such that it is conceivable that the potential for negative impacts on trade as they are voiced by Walter (1973) could be observed for the 1980s.

Robison (1988) updates the study of Walter (1973) and determines the "pollution content", i.e. the factor content of U.S. trade for the years 1973, 1977, and 1982 by using an input-output-analysis. Since such an approach implicitly assumes a complete pass-through of abatement costs or taxes on prices this estimate presents an upper bound on the potential general equilibrium effect which would also allow for alleviating reallocations of resources. He finds that the pollution content of imports relative to exports has shifted over the period under consideration towards pollution intensive imports thus indicating a slight tendency towards a loss of competitiveness of pollution intensive sectors. This finding could not be reproduced for bilateral trade between the U.S.A. and Canada which could be explained by the fact that both countries have changed their environmental policies in a comparable fashion such that no changes in comparative advantage have occured. Robison also computes from his data a kind of trade elasticity of abatement costs. An increase in abatement costs leading to a rise in prices of 1 percent will on average lead to a reduction of the trade volume in the merchandise sector of 2.69 per cent. The highest reduction on the two-digit level of disaggregation was found in copper with 7.08 per cent. If the reduction in trade is measured relative to domestic consumption, the highest impact is just 0.8 per cent in the ferrous metal industry (Robison 1988, p.195). Whether this change in the trade structure is attributable to increased environmental regulations or to the secular trend away from high-polluting sunset industries remains an open question.

There are some recent studies on the impact of environmental regulation on competitiveness in connection with the debate on the North American Free Trade Argeement (NAFTA) which can give some hints as to how large the price effect of environmental taxes and other regulations could be today - at least as far as the United States are concerned. Low (1992a) finds that in 1988 the abatement costs for the

American industry overall amounted to a weighted average of 0.54 percent of total output. Even a disaggregation to the three-digit level reveals that out of 123 three-digit industries only seven had pollution abatement operating costs in excess of 2 percent of output, and that the cement industry shows the highest percentage with just 3.17% pollution abatement costs. Table 1 summarizes the abatement costs for the USA on the two-digit level and distinguishes between internal operating costs and payments to the government. Although it does not include taxes, fees, and the like, it still gives an indication of the potential cost effect of taxes since the tax rate would represent an upper bound on the marginal abatement cost. If the marginal abatement costs would rise above the tax firms would prefer to pay taxes instead of engaging in pollution abatement.

The pollution abatement operating costs in the USA which are presented here suggest that the impact of environmental taxes is practically negligible if one takes into account that many of the environmental regulations are not taxes but consist of other regulatory instruments. E.g., the payments to government in Table 3.1 which contribute on average roughly 10 percent to total pollution abatement costs are most likely induced by legal requirements instead of taxes. In addition, the internal disposal costs for solid waste amounting to almost 4 billion US$ would need to be subtracted from those total operating costs which could possibly be induced by taxes such that the cost to output ratio could at most amount to 0.34 percent on average. One can therefore hardly expect to identify with econometric methods the impact of environmental taxes on specific trade flows or on the trade structure in general because the potential impact of rising costs on supply prices would be too small and because the sectoral variation - although large in relative terms - is too small in absolute terms in order to have an impact on comparative advantage.

Similar results finds Tobey (1990) who identifies the most polluting three-digit industries in the USA in order to test the impact of different stringencies of the regulatory framework with respect to the environment in different countries upon the international division of labour. In his study pollution abatement costs are computed inclusive of indirect costs which are derived from the current input-output table. Even then the share of direct and indirect pollution abatement costs does not rise above 3 percent. Tobey goes on and tries to perform several tests on trade flows in order to see whether there may be some impact of environmental controls on the comparative advantage of the polluting sectors of the American economy. His findings support the suspicion that such a relationship can not be detected at the current degree of environmental regulation.[14]

[14] One could argue that the tests may be too crude to detect such relationships. The omitted variable test in which the trade equation is estimated without the factor environment assumes that the error term should reveal in a consitent manner exactly this omitted vaiable is probably to crude if one considers the small impact of the omitted variable relative to other error terms. Similar arguments can be given for the introduction of an index of environmental regulations for the size of the resource andowment. Tobey also gives some theoretical arguments why the effect under investigation could not be detected from the trade data.

Table 3.1 Pollution Abatement Operating Costs in the USA 1988 (mio. US$)

SIC No.	Industry	Total Cost	Total Output	Cost/ Output in %	Payments to Gov.ment	Internal Operating Cost
20	Food &kindred products	1,160.1	351,514.9	0.33	398.6	761.5
21	Tobacco manufactures	37.6	2,831.8	0.16	6.1	31.5
22	Textile mill products	177.0	64,767.9	0.27	62.4	114.6
24	Lumber & wood products	236.1	72,065.4	0.33	20.2	215.9
25	Furniture and fixtures	118.4	39,226.1	0.30	11.1	107.3
26	Paper and allied products	1343.3	122,556.2	1.10	141.6	1,201.7
27	Printing and publishing	206.4	143,906.8	0.14	41.8	164.6
28	Chemicals & allied products	3,074.9	259,699.1	1.18	181.8	2,893.1
29	Petroleum and coal products	2,005.5	131,414.8	1.53	30.5	1,975.0
30	Rubber & misc. plastic prod	278.0	94,200.2	0.30	50.7	227.2
31	Leather and leather products	23.1	9,663.7	0.24	7.8	15.3
32	Stone, clay and glass prod.	438.5	63,059.4	0:70	27.7	410.7
33	Primary metal industries	1,809.0	149,079.8	1.21	63.4	1,745.6
34	Fabricated metal products	761.9	158,833.8	0.48	73.1	688.9
35	Machinery, exc. electrical	429.7	243,260.8	0.18	56.6	373.1
36	Electrical equipm.	659.3	186,950.8	0.35	86.0	573.2
37	Transportation equipment	974.5	354,047.8	0.28	82.6	891.9
38	Instruments & rel. prod.	197.7	114,528.4	0.17	23.1	174.6
39	Misc. manufacturing ind.	76.7	34,869.4	0.22	12.7	64.0
	Total	14,008.6	2,617,476.9	0.54	1,378.7	12,629.9

Source: Low (1992a)

The potential trade impact of environmental regulation was also calculated by Low (1992a) for the NAFTA between Mexico and the USA through a quite different procedure. Low calculates the tariff which would be necessary to equate pollution control costs between the two countries under the assumption that Mexico will not undertake any additional pollution control following the introduction of the NAFTA. This exercise yields an average tariff rate of just 0.6 percent for all imports and tariffs for specific polluting products. This artificial environmental tariff would in most cases lie far below the current tariffs.

A recent study on the impact of environmental policy on pollution intensity[15] did test the hypotheses that

"(1) industrial pollution intensity follows an inverse U-shaped pattern as development proceeds; and

(2) OECD environmental regulation has significantly displaced toxic industrial production toward less- regulated LDC's."[16]

[15] Toxic intensity is measured in emissions per unit of GDP.

The findings of Hettige, Lucas, and Wheeler (1992) can be summarized as follows: The inverse U-shaped relationship between toxic intensity per unit of GDP and per capita incomes holds, but it is - according to the authors - attributable to the structural change of high income economies away from manufacturing and towards services. This is supported by the fact that this relationship does not exist if toxic intensity is measured per unit of industrial output. This would indicate that - at least on this aggregate level - the introduction of environmental policies in higher income countries together with structural changes in the economy has not had a statistically significant effect on industrial abatement activities. Given this result and given the low cost estimates of industrial pollution control one can not expect measurable trade impacts to occur in the industrialized countries.

In order to test whether the structural change away from the manufacturing sector has dislocated manufacturing production into LDC's the authors have separated the data into three decades and found that in the 1980s which had experienced the advent of stricter regulations the toxic intensity in OECD countries grew slower than in LDC's - contrary to previous periods. Unfortunately, one can still not discern whether this shift is due to more intense regulation within the OECD countries or due to the rising income in LDC'S inducing a structural change away from agriculture towards manufacturing

The evidence from ex-post statistical analyses can apparently not clearly indicate a negative impact of environmental regulations on the competitiveness of high polluting sectors in industrialized countries. The studies on costs of environmental regulations relative to the value of the product seem to indicate that such a negative competitiveness effect could not be detected since costs are simply too low.[17] The observed shift in the high growth rates of toxic intensity away from industrialized countries towards the developing countries can but need not be attributable to increased environmental regulation. Hence, the impact of environmental taxes on comparative advantage seems to be either not measurable given todays statistical information or - if it were measurable - negligible so far. That still comparatively low levels of environmental regulations are likely to be responsible for these findings can be seen from simulation studies which investigate much higher levels of intervention and come to quite different conlusions.

3.2. Simulation Studies

Larger trade effects of environmental taxes can only be investigated in simulations studies which try to project the incidence of environmental policy instruments at levels which are widely believed to be efficient or at levels which governments have agreed to pursue in international conventions, declarations and treaties, but which are not implemented at all or at less than the declared and aimed at levels. The in many cases

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[16] Hettige/Lucas/Wheeler 1992; see also Lucas/Wheeler/Hettige 1992.

[17] It should be added that Chapman (1991) claims that the conventional way of measuring environmental abatement costs underestimates drastically because some costs can not be separated from generalproduction costs, because joint costs of monitoring, planning etc, costs of health regulation, and others are not included in these calculations.

inefficient rates of environmental taxes, subsidies, or other regulations which are to a large extent responsible for the overall negative results of the econometric studies mentioned in chapter 3.1. should become amended by the "correct" interventions and then their impact on the international division of labor should be assessed. This approach needs to rely on scenarios of counterfactual experiments. Unfortunately such simulations studies seem to be done only for climate policies, in particular CO_2 policies. In addition, these climate studies are mostly concerned with the implications of tradable or non-tradable permit systems or with predetermined reduction quotas.

One can, however, derive some conclusions for environmental taxes from these studies because they usually employ models with perfectly competitive markets such that there is no difference between quantative restrictions and price regulated policies; in fact, some studies on emission quotas work with the shadow prices of these quotas which can be interpreted as the dual taxes achieving the same objective. This advantage of competitive models comes with the cost of being unrealistic for many especially polluting industries which often do not

There exists a number of different multi-country applied general equilibrium models which assess the impact of different CO_2 reduction strategies and offer some insight into the adjustments of sectoral production as well as changes in the volume and structure of international trade. They include comparative-static models comparing 1990 with 2100 in present value terms (e.g. Whalley/Wigle 1991, or Perroni/Rutherford 1993), recursive dynamic general equilibrium models (Rutherford 1992, the GREEN-Model of the OECD, or Felder/Rutherford 1993). All these models have in common a detailed structure of the energy sector coupled with highly aggregated non-energy sectors. They will therefore average out some of the sectoral changes within these sectoral aggregates. The regional structure is generally highly aggregated. These models do not report specifically the impact of their simulation experiments on world trade but focus on specific questions of instrument choice such as coordinated vs. uncoordinated strategies, the distribution of tax revenues, the sectoral cost structures, etc. Some of these issues are discussed in the following sections.

An indication of the relative price changes which would determine the trade effects of a CO_2 tax in different countries is given by Pezzey (1991). He has computed the increase in production costs by sector of a \$100/tC carbon tax from which the tax revenues are redistributed to industry per unit value of production. His results are reproduced in Table 3.2 and can be interpreted as the change in the relative prices of the different commodities if the industries were perfectly competitive. Mainly the basic energy intensive industries experience cost increases, in particular the iron & steel industries in the USA, Germany, and Japan.

Table 3.2 Impact Cost of a \$100/tC Carbon Tax with Redistribution of Tax Revenues@

	Iron & Steel	Chem-icals	N-F Metal	N-M Mineral	Transp. Equipm	Machi-nery	Food etc.	Paper etc.	Wood etc.	Cloth. etc.
USA	10.5	4.5	4.9	5.4	-1.8	-1.9	-1.1	0.2	-1.1	-0.8
Japan	6.8	2.0	0.5	1.7	-1.1	-1.2	-1.0	-0.3	-1.3	-0.5
Germany	6.6	3.7	3.3	3.5	-1.5	-1.8	-1.3	0.1	-1.4	-1.2
France	4.7	2.0	1.9	2.5	-1.0	-0.9	-0.8	-0.5	-1.0	-0.8
UK	2.4	2.1	2.9	2.8	-0.7	-1.0	-0.8	-0.7	-1.4	-0.7
Italy	3.0	1.9	0.3	4.1	-1.3	-1.0	-1.0	-0.5	-1.1	-1.0
Spain	4.1	1.8	2.3	2.4	-1.1	-1.2	-1.1	-0.3	-1.1	-0.9

Source: Pezzey (1991) Table 6.9

@ Cost of tax minus rebate as a percentage of the value of production of the sector.

These additional costs translate into losses of international competitiveness only in so far as these industries are subject to international competition. Pezzey assumes that the trade volume can be used as a proxy for the dependence of an industry on international markets and finds that the previously high losses of sectoral competitiveness of the American energy intensive industries are much lower than those of more outward oriented economies like Germany and Japan. But at the same time the gains in international competitiveness of the other manufacturing industries are lower in the USA and quite high in Germany.[18] Measuring the competitiveness with sectoral trade volumes, i.e. the sum of exports plus imports, is a crude indicator, however. It has been shown in chapter 2.1 that the net trade position - and not the trade volume - is important in determining the impact of an environmental tax on the international competitiveness of a sector.

The numbers computed by Pezzey (1991) show again as other studies like that by Low (1992a) that the impact of an environmental tax such as a carbon tax on costs is quite low. They still indicate that a reallocation of production towards sectors which use the untaxed factors of production intensively is likely to take place although to a limited extent. The repercussions of this reallocation on sectoral trade balances are not reported in the models mentioned above. These trade effects can hardly be predicted in general. The discussion in chapter 2.1 has already shown that the trade effect depends even in the very simple context on the net trade position of the sector and on the impact of the tax. In the carbon tax models repercussions of a multi-sector structure, of the multi-country framework, of differing emission coefficients and input coefficients, and the exact design of the tax - unilateral or global, with or without international redistribution of tax revenues - all interact to determine a specific outcome. In any case, the changes in trade flows may not be negligible when high and important environmental taxes are introduced. Whalley and Wigle (1991) report that their simulations of CO_2 taxes produce frequent cases were the direction of trade changes but they do not provide exact numbers for these trade flows.

[18] See Pezzey (1991), Table 6.11.

4. POLICY ISSUES

4.1. LEAKAGES

Imposing an environmental tax unilaterally or only regionally will necessarily improve the comparative advantage of the other countries in those activities which use the taxed commodity intensively thus having the tendency to increase their production. Through this channel at least a part of the emissions which have been reduced in the taxing countries will then become emitted in the unregulated countries. Such a leakage of emissions is not important from the viewpoint of the regulating country if by imposing a tax it is not concerned about foreign pollution because it sees such pollution as a local phenomenon and if the taxing country follows only domestic interests. In the case of transfrontier pollution this is different. In the most extreme case of climate policies it is irrelevant where the emissions of carbondioxid, methane, CFC's, and other gases take place as their impact remains the same for all parties involved. Consequently, there have been concerns that "carbon leakages" may be so strong that unilateral policies may be self-defeating since they only lead to the relocation of production but not to global reductions of emissions of greenhouse gases.

A number of studies have investigated the extent of carbon leakage of a CO_2 tax imposed in one or all OECD countries unilaterally (Oliveira-Martins et al. 1992; Pezzey 1993; Felder/Rutherford 1993, Perroni/Ritherford 1993). Simulations of the OECD's GREEN-Model (Burniaux et al. 1992, 1992a, 1992b; Oliveira-Martins et al. 1992a) had computed the carbon leakage for unilateral action of the USA, Japan, the EC, Other OECD, and the whole OECD (Oliveira-Martins et al. 1992) and found that the overall leakage is "less serious than some observers have argued" (ibd. pg. 124). Table 4.1 summarizes the leakage rates for these countries and country groups. The leakage rate is defined as the change in emissions of those countries not participating in the reduction policy relative to the emission reduction of the region imposing the policy.[19]. It turns out that the carbon leakage is relatively low with at most 15.8 percent of emission reductions. It is also evident that more export oriented regions are more strongly faced with carbon leakage. Consequently, the United States has low leakage rates. The coordinated policy of all OECD countries would result in leakage rates of less than 3.5 percent which even become negative with the advent of backstop technologies around the year 2010.[20]

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[19] Negative leakage rates then mean that the policy will reduce emissions in non-paritcipating regions as well.

[20] Such low leakage rates should not be misunderstood as successful climate policies. Even a coordinated policy of stabilizing CO_2-emissions within the OECD would only reduce global emissions by 10 percent relative to the business as usual scenario in 2050 which is little compared the Toronto target of 20 percent by the year 2005 (Oliveira-Marins et al. 1992).

Table 4.1 Leakage Rates for Unilateral Stabilization Scenarios of CO_2 Emissions (in percent)

Unilateral Action by:	1995	2000	2005	2010	2030	2050
United States	2.8	2.4	1.5	0.5	-0.7	-0.2
Japan	15.8	13.5	10.2	3.1	1.2	2.1
EC	11.9	11.2	8.6	5.5	2.9	2.2
Other OECD	7.7	8.4	6.2	5.8	3.2	0.6
All OECD	3.5	2.4	0.9	-0.5	0.3	1.4

Source: Oliveira-Martins et al. 1992.

The GREEN model captures three channels of transmissions of carbon leakage. The CO_2-tax leads to:

- shifts in the comparative advantage of energy intensive industries,
- income effects through lower resource use, and
- price adjustments for the world market price of crude oil.

The first effect is induced by the change in the relative input prices which will shift the comparative advantage in energy-intensive products towards those countries with low energy prices. However, this classical competitiveness effect is mitigated by the two other reactions. The reduction in the use of carbon fuels will reduce energy demand in the energy-importing regions and thus reduce income and growth perspectives for the energy-exporting regions. The resulting income effect will reduce the use of carbon fuels, hence a negative leakage. The negative leakage through the income effect will be accentuated by the change in oil prices. The fall in demand for crude oil lowers world market oil prices thus leading to a substitution away from coal towards oil with lower CO_2-emissions. But lower oil prices will also increase demand for energy such that the just mentioned substitution effect may compensate the price effect. The net effect remains unclear at least on the basis of a qualitative analysis.

The model of Felder and Rutherford (1993) investigates in more detail the leakage of different OECD wide targets for CO_2 reductions until the year 2100. Unlike the GREEN model, this study presents marginal leakage rates which are derived from the marginal externality of reducing carbon emissions within the OECD through a tradable certificate system such that between 1% and 4% of emissions are reduced yearly. The marginal leakage rate is simply the marginal emission in the rest of the world induced by the marginal emission reduction in the OECD. These marginal leakage rates - not surprisingly - are significantly higher than those of the GREEN model, going up to 45 percent. The corresponding average leakage rates peak at about 35 percernt. A comparison of the low reduction target of 1% to the higher targets reveals quite different paths of leakage rates over time. Whereas the 1% path has low leakage rates between 1990 and 2010 - even negative in 2010 - they rise to over 40% after 2030. In contrast, under the high reduction scenarios the leakage rates peak in the first 50 years and then fall to become negative after 2040.[21]

These studies necessarily ignore several adjustment processes because they are diffcult to model and difficult to predict. The simulation models do not allow for factor movements which might at first increase leakage rates. Later on, however, the diffusion of new abatement technology which has been developed in the regulated economies might well reduce leakage rates. The study of Wheeler and Martin (1992) suggests that such positive effects are possible if the economies do not restrict capital movements and if the abatement technologies are tied to the production technologies.

Environmental regulations generally induce the development of abatement techniques. At first they mostly consist of end-of-pipe measures to control emssions. Yet, process changes towards clean technologies have recently become more frequent, sometimes because end-of-pipe reduction possibilities are exhausted, sometimes because integrated abatement turns out to be less costly. These new processes often do not only possess lower emission intensities but they also exhibit lower unit production costs. Klepper/Michaelis (1992) illustrate this relationship between emission control regulation for Cadmium and the improvements in dust arrester technologies and new production processes in the non-ferrous metal industry. These joint advances in technology not only mitigate the reallocation of resources away from the taxed commodities, they might even create new comparative advantage in environmentally friendly products.

Another phenomenon which is not modelled in the simulation studies comes from the non-competitive character of some of the industrial sectors. The discussion of the model of Ulph (1993) has shown that non-competitive markets structures can lead to much higher leakage rates either because the location decision of firms is more sensitive to the regulation at hand such that plants are preferrably opened in less regulated countries or because the scale effects lead to a stronger reaction of firms than when they are operating under increasing marginal costs.

It is practically impossible to predict in general the likely impact of environmental taxes on leakage rates. The detailed GREEN-Model does create low leakage rates, but misses several factors which would increase leakage. Innovation oriented adjustments to environmental taxes might even support negative leakage. The overall result therefore remains inconclusive.

4.2. Short-Term vs. Long-Term Effects

There is an important difference in the impact of environmental taxes on trade structure and trade volumes whether the short-term or the long-term adjustment by producers and consumers is included in the analysis. A short-term reaction of a firm to the imposition or an increase of an environmental tax would be a reduction in supply or a change in the input mix, for consumers it would consist of a change in the consumption

[21] See Fig. 8 in Felder/Rutherford 1993.

basket as well as a substitution through imports. The long-run reaction of firms will typically involve either changes in the technology, i.e. innovation, or a relocation of plants, i.e. capital exports, since such activities typically involve considerations with a longer time horizon.

The ability of producers to adjust to the increased environmental tax is the smaller the shorter the time period in which the adjustment can take place. The opportunity for moving inputs between sectors remains rather limited such that the reduction of production in the most affected sector will not - or only to a very limited extent - immediately become compensated by an increase in production in the unaffected sectors. Consequently, the short-run will be characterized by a move inside the transformation frontier with an inefficient allocation which is induced by the time the economy needs to adjust to the new optimal allocation. Therefore, the reduction in production and real income under an emission tax will be stronger in the short- than in the medium- or long-run. The resulting short-run trade effects will therefore turn out to as ambivalent as they are in the case under a more flexible response. The same will happen in the case of a production tax, whereas the adjustment under a consumption tax is less important since the reallocation of production is smaller than under the other two taxes anyway.

The speed of adjustment on the demand side depends very much on the characteristics of the products involved. The direct and cross price elasticities elasticities are important as well as preferences and product loyalty of consumers for the taxed product. It is clear, that long-rung elasticities are larger such that on the demand side the short-run adjustment on the new relative prices will be slower. Only a quantitative analysis on a case by case basis can assess by how much the short- and the long-run differ.

In the medium- and long-run the factors of production will move from the less competitive, i.e. taxed, sector towards the untaxed sector such that the economy moves to a new efficient production point. A reduction of the capital stock and reduced employment in the "dirty industries" will take place but it normally will be ameliorated somewhat by introducing abatement efforts. As far as abatement is of the end-of-pipe type, the negative employment effect is probably relatively stronger than the reallocation of the capital stock since the end-of-pipe technologies are usually capital-intensive.

Innovation as another long-term strategy has effects which involve not only the abatement of emissions but they often occur concurrently with new production techniques which themselves possess lower emission coefficients. In the case of innovation in pure end-of-pipe technologies, the long-term reaction will typically differ from short-run adjustments in such a way that the new abatement technology will be cheaper to operate than the paying the environmental tax or than reducing output. Hence the impact of the environmental tax will in the long-run be stronger in terms of emission reduction but the reallocation of factors of production between sectors may be smaller than in the long-run. Consequently, the trade impact in terms of losses in competitiveness will be mitigated by the lower cost of the new technology.

For two reasons, the long-run adjustment of the economy will differ from the just described situation if the innovation consists of the development of new integrated technologies. First of all, these new technologies often are more efficient not only with respect to emissions but also in terms of private production costs. Consequently, the long-run effect of the environmental tax will not only result in a reduction of emissions as in the short-run, but it can - contrary to the short-run - improve the competitive situation of the firm or industry under consideration. Secondly, because of their superior efficiency such new technologies can become diffused to other countries even without environmental regulations in the rest of the world. The environmental tax therefore would produce positive spillovers for foreign countries in terms of an improved environment even without transfrontier pollution. Of course, this positive welfare effect will be amplified if transfrontier pollution problems are involved. Then the transport of pollutants from the foreign country will become reduced in the same way as the internal emissions.

A final long-run effect concerns international factor movements. Especially capital might move from the high taxing country to countries with weaker environmental regulations. Persistent differences in environmental taxes can lead to the shrinking of the resource base which has been described in chapter 2.3. This could increase at least the real income effects if labour is less mobile than capital, and it could amplify the loss of competitiveness of the environment-intensive sectors of the economy.

The long-run effects of environmental taxes will most likely result in larger emission reductions than in the short-run. The overall long-run effect on the allocation of resources in general and the subsequent welfare effects, however, depends on the type of innovation incentive which the environmental tax induces upon firms. Higher taxes which impose a high burden of adjustment in the short-run may have better long-run effects since the incentives to innovate are higher in terms of taxes saved. Yet, such a strategy might impose excessively high short-run costs because the short-run reaction to the introduction of environmental taxes is already more costly than the long-run adjustment. These costs may become more balanced by preannouncing environmental taxes thus giving firms time to adjust their technologies before it is actually imposed but would still contain the incentives to innovate in new technologies. Similarly, a stepwise increase of environmental taxes which is preannounced could reduce the above mentioned differences in adjustment costs to the economy.

4.3. Distributional Effects

Imposing environmental taxes which either have strong incentive effects thus changing the allocation of resources or which create large revenues for the government will result in a redistribution of incomes within a country and possibly between countries. The redistributive effects depend upon the incidence of the tax on the side of the collection as well as on the spending side. For many environmental taxes this issue may be rather irrelevant since the tax revenue as well as the reallocation of resource is small compared to other allocative effects in the economy. However, some taxes like a CO_2-tax would - if implemented - create large amounts of revenue which need to be redistributed with possibly large income effects which may have repercussions on the international division of labour. Numerous possible configurations of tax systems and tax rates within and between countries as well as mechanisms to redistribute tax revenues result in widely differing distributional impacts.

Internal distributional effects of a carbon tax have been investigated by Symons et al. (1990) for the UK. The impact of the carbon tax was evaluated by using an input-output table to calculate the price effect of direct and indirect fossil energy inputs. This is coupled with a disaggregated demand model in order to estimate the shifts in demand away from carbon intensive products. Symons et al. (1990) find that even a moderate carbon tax would increase the relative prices of foodstuffs thus making the carbon tax regressive. Yet, even the possibility of substituting carbon tax increases by lower direct taxes would not be sufficient to effectively change its regressive character because lower income groups tend to consume relatively energy-intensive commodities.

The importance of international distributional effects is illustrated by a simulation study on "The International Incidence of Carbon Taxes" by Whalley and Wigle (1991) who have found that policies which curb global greenhouse gas emissions by 50 percent through taxes would yield revenues amounting to about 10 percent of world GDP. Such a policy would induce a sizable reallocation of resources in the world economy through large relative price movements and through the need to distribute the tax revenues such that large income and terms of trade effects are created. Depending on the type of tax and the distribution mechanism, these changes could go hand in hand with a large international redistribution of incomes with strong political repercussions.[22] Although the study by Whalley and Wigle does not directly address the trade issues of carbon taxes it offers imteresting insights into the distributional effects of different carbon tax systems and their impact on trade volumes and trade flows.

Whalley and Wigle simulate three different scenarios of CO_2-taxes designed to curb emissions by 50 percent,

- a production tax collected by national government to achieve the 50% reduction nationally,
- a consumption tax collected by national govenrments to achieve the same reduction nationally, and
- a global tax (production or consumption) collected by an international body, with revenues distributed according to population, again to achieve a 50% reduction of greenhouse gases.

Whereas the two national approaches result in tax rates which differ across countries, the global tax achieves an efficient solution with a uniform tax rate and at the lowest social cost. It turns out that the three scenarios yield quite different allocations with varying distributional effects. These differences are mainly the result of the different ways in which the taxes are collected and distributed.

[22] This has already become evident by the planned introduction of exemptions of carbon taxes for energy-intensive industries within the EC. See also chpt. 5 for the likely impact of such tax exemptions.

Table 4.2 Revenue Redistribution of Alternative CO_2-Taxes for a 50% Reduction of Emissions@

Region	National Production Tax	National Consumption Tax	Global Tax		
			Taxes Paid	Transfers Received	Net Transfer
European Community	3,324.7	6,698.2	6,492.3	3,270.1	-3,222.2
North America	11,039.1	12,362.0	11,824.6	2,765.2	-9,059.4
Japan	98.7	1,998.2	1,957.6	1,273.8	-683.8
Other OECD	1,078.5	1,144.4	1,116.4	537.3	-579.1
Oil Exporters	9,404.3	2,505.7	2,517.1	4,029.7	+1,512.6
Dev./centrally planned	21,681.2	21,950.1	22,410.8	34,442.6	+12,031.8
Global Revenue	46,626.5	46,658.6	46,318.7	46,318.7	-

@ Taxes paid and revenues received by region under each tax option over the period 1990-2030; in billions of 1990 US$.
Source: Whalley/Wigle (1991).

The production tax and the consumption tax yield the same revenue, but they differ with respect to the international distribution of the revenues (Table 4.2). Whereas the user price of carbon based energy will rise by 145.4 percent, the seller price will fall by 72.7 percent such that not only the price difference due to the tax but also part of the scarcity rent of fossil energy will go to the respective taxing authority. Consequently, the oil exporters will experience large revenue losses under a consumption tax compared to the production tax. The European Community and Japan as large importers of fossil fuels will face the just the opposite effect. The production tax will therefore work like an export tax of the oil exporters improving their terms of trade and will thus redistribute wealth from the energy importing to the energy exporting countries. The consumption tax applied in the energy importing countries, on the other hand, will work like an import tax thus raising the terms of trade of their export goods.

The welfare calculations of Whalley and Wigle emphasize this redistributive effect. The production tax would increase welfare[23] of the oil exporting countries by 4.5 percent whereas the consumption tax would lower it by 18.7 percent. Conversely, Japan which looses 3.7 percent under the production tax would even gain 0.5 percent with a consumption tax through improved terms of trade of Japans manufacturing exports. The difference for the European Community is similar but it experiences negative welfare effects even under the consumption tax. These simulations help to explain why politico-economic aspects are so important in designing internationally coordinated environmental taxes.

[23] Measured in Hicksian Equivalent Variation over the period 1990-2030 in percent of GDP in present-value terms.

5. MITIGATING TRADE IMPACTS

Several arguments can and have been developed which could support policy initiatives intended to mitigate adverse impacts of environmental taxes on competitiveness. The introduction of substantial environmental taxes might create large short-run adjustment costs which quickly endanger the competitive position of an industry, possibly beyond the level which it would loose in the longer run. Another argument would be that industries facing strong international competition should not be forced to bear the burden of the environmental tax alone. Hence heavily polluting industries under fierce foreign competition should be exempted from the environmental taxes as it has been planned in the energy tax proposal of the European Union or as it has been already introduced through the Danish energy tax.[24] Finally, unilaterally introducing an environmental tax in a world with inefficiently low taxes will itself create distortions which impose efficiency costs on the country with the efficient tax level. These could only be completely avoided in a situation where all countries impose taxes which equate marginal damage avoided with marginal abatement costs.

Regardless whether these arguments are considered to be valid or not. Any relief from an environmental tax for specific groups of firms, industries, or consumers through exemptions, compensations, or rebates will disort the incentive effect of the environmental tax. Any tax with some form of exemption will therefore necessarily fail to achieve its environmental objective in the most efficient way. If the same environmental quality is to be preserved with exemptions, it needs to be met by larger reductions in emissions from other sources such that the costs of any environmental tax relief will be paid by other emittors with higher abatement costs than thosee emittors which are exempted from the tax.

The basic allocation effect can be described in the simple framework of chapter 2. Exempting the sector which uses the environment most intensively from say an emission tax would first of all not reduce the demand of this sector for the environment as a factor of production, hence the emission of this sector will not fall. In addition, the exemption would force the reduction upon the non-polluting sector such that it would need to shrink more the the polluting sector since it has lower emission coefficients. Yet, this reduction in the low-polluting sector would also free some other resources - capital or labour - which could now move in the polluting sector. In a general equilibrium framework an emission tax with tax exemptions would therefore reduce the factor demand for the environment in the controlled sector but this reduction would be counteracted by the tendency for increased production in the high emission sector. If the polluting sector produces intermediate goods which are used in the low-polluting industry this positive factor supply effect can become offset by a negative demand effect through the reduced production in the down-stream sector.

These effects have been studied within the Green-Model. Oliveira-Martins et al. (1992) present a simulation of the change in the sectoral impacts and the carbon leakage

[24] This tax is effectively levied on private households only, but not on firms. See Sørensen (1993).

of a unilateral CO_2-tax for the EC with tax exemption for energy-intensive industries[25] and compare this to the same emission target without the tax exemption. The tax exemption requires higher taxes for the other sectors in order to compensate for the higher emissions in the energy-intensive sector such that the intial CO_2-tax will be $35 per ton carbon in 1995 instead of $26 and it will rise to $79 instead of $50. Consequently the adjustment costs to the economy will be higher overall. More interestingly, the carbon leakage which was 11.9 percent without the tax exemption (see Table 1) would only fall by 0.2 percentage points to 11.7 percent. Moreover, the output loss - averaged over the period 1990 to 2050 and relative to the business as usual scenario - will be practically identical for the energy-intensive industries with (2.5%) and without tax exemptions (2.4%); it will be somewhat lower for the coal industry - 34 percent vs. 35.5 percent - presumably because less energy substitution takes place in the energy-intensive sector. The slightly larger output loss of the energy-intensive sector may be due to the increased distortion of the CO_2 policy targeted exclusively against the rest of the economy. The secondary effects of exemptions would therefore hurt the exempted sectors more than they can gain from the tax exemption itself. Tax exemptions could therefore help to alleviate the trade impacts of foreign competition, but they will have costs in terms of domestic demand distortions which could be as damaging as those of foreign competition.

These simulations of the EC's tax exemption plan are likely to represent a rather crude bound for the carbon leakage since a more precisely targeted policy towards minimizing leakage would produce less distorting scenarios if done in a more disaggregated sectoral model. The reason for such a little effect of tax exemptions is partly due to the already small leakage of unilateral action without corrective measures and it is partly due to a number of specific aspects of that industry. The CO_2-tax mostly affects coal prices, yet the energy-intensive industry has a relatively small share of coal in its intermediate consumption such that the tax exemption will not be as powerful as it were if the industry would depend more on coal (Nicoletti/Oliveira-Martins 1992). In addition, under the CO_2-tax without tax exemption output of the energy-intensive industry in the EC would shrink by between 2.5 and 3.5 percent - depending on the simulation (Nicoletti/Oliveira-Martins 1992 or Oliveira-Martins et al. 1992) compared to a decrease of that industry's output in the world overall by 0.1 percent. All these factors together explain that tax exemptions for energy-intensive industries will provide little relieve from carbon leakage. This may be different if the tax exemption were specifically targeted at the coal consuming production processes; this would, however, impose an even greater burden and heavier distortion on the rest of the economy because it would need to contribute an even larger reduction effort in emissions or the environmental objectives will simply not be achieved.

If the environmental objective is partly ignored the policy with the lowest price effect on producers relative to foreign suppliers is a consumption tax since it taxes imports in the same way as domestic production and it is not levied on exports. Hence, regardless whether the economy is a net-importer or a net-exporter of the environment-intensive commodity the consumption tax creates the smallest price differences between domestic and foreign suppliers which is possible. In the case of environmental production

[25] Energy-intensive industries are defined as those producing pulp and paper products (ISIC 341), chemicals (ISIC 351 and 352), iron and steel (ISIC 371), and non-ferrous metals (ISIC 372).

externalities the environmental effect of such a consumption tax could well be non-existent if no terms-of-trade effects occur. In this case the production decision will be unaffected and only consumption is substituted away from the environment-intensive commodity.[26] The only environmental incentive effect can therefore come from the terms-of-trade effect which would be a grossly inefficient way of tackling environmental problems.

[26] See Figures 6, 7, and the accompanying text in the appendix.

6. CONCLUSIONS

It is by now widely accepted that the use of economic instruments in environmental policy has many advantages over command and control measures (OECD 1989, 1991). The implementation of environmental taxes and their role in the general system of fiscal policies have been considered at the OECD (OECD 1993). The widespread introduction of environmental taxes - especially if they cover more than a small part of the economy, e.g. a CO_2-tax - will generally have economy wide repercussions for which presumably negative employment effects and the expected loss in international competitiveness belong to the politically most important ones. This paper has investigated the general equilibrium effects of different environmental taxes and has reviewed the empirical evidence concerning the relationship between trade and environmental policy.

The conceptual simple model has shown that no clear-cut prediction about the impact of environmental taxes on trade flows and trade volumes can be made. Even in a simple theoretical frameword, the impact on trade depends on

- the resource endowment of the country relative to the rest of the world,
- the type of the environmental tax, i.e. a tax on emissions, on products, or on consumption,
- the presence or absence of terms-of-trade effects.

If, in addition to the pure marginal effects, welfare considerations or optimal taxes are considered, it also matters whether the environmental problem is confined to the national borders or is a transborder pollution problem.

It becomes even more difficult to predict the impact of environmental taxes on trade if the simple trade model is extended to incorporate imperfect competition and mobile factors of production. Under imperfect competition, the strategic behaviour of firms in making locational choices as well as the impact of environmental taxes on the degree of competition within the industry can produce rising as well as falling prices in the industries facing environmental regulations. As the trade impact depends on these price changes anything can happen after the imposition of an environmental tax and predictions can only be made by considering the exact situation of the industry, the behaviour of firms, their technological characteristics, the degree of competition, and many more factors. Factor mobility has the tendency to increase the probability that environmental taxes lead to a relocation of production facilities into less regulated regions thus increasing the leakage of such taxes.

The historical empirical evidence on the relationship between environmental regulation and changes in trade patterns is similarly inconclusive. As far as cost figures are available, environmental regulations seem to impose only a small burden upon industries and environmental taxes make up only a small part of these costs. Although "dirty industries" are faced with regulatory costs of several percent of their turnover, it is still little compared to the variation of other exogenous factors facing the industries such as exchange rate variations. The statistical analysis consequently find little or no evidence for a loss of competitiveness through environmental policies. In those cases where some change in the factor content of trade has been observed, it is not clear whether it reflects a secular trend in the division of labour between the industrialized and developing countries or whether it is attributable to environmental regulations.

Simulations studies of proposed environmental taxes have been performed mainly for assessing the likely national and international allocation effects of a CO_2-tax. The main conclusions in terms of the changes of sectoral competitiveness is the following: The basic industries like iron&steel, chemicals, etc. of more outward oriented economies like the member countries of the EC and Japan experience a larger loss in competitiveness than e.g. the United States. On the other hand, the other manufacturing sector gains competitiveness, again symmetrically the outward-oriented economies more than the others.

Most simulation studies on CO_2-taxes have considered the much discussed leakage problem according to which the environmental tax will induce increased production of the taxed products in the rest of the world. This will lead to a substitution of domestic production by imports and at the same time to increased emissions in the rest of the world. In the case of transfrontier pollution such as CO_2,the environmental effectiveness of the tax could more or less become compensated through this substitution effect and the loss in competitiveness would need to be added to the economic cost of the tax. The GREEN model of the OECD and some other models find very little leakage. However, since they are all perfect competition models within a Heckscher-Ohlin framework they miss the high leakage potential stemming from strategic firm behaviour and from the movement of capital or labour to the less regulated economies. Factor movements between countries can also include the diffusion of technology which generally has the tendency to reduce leakage since the new technology replaces inefficient older ones and it provides new opportunities for exporting the technology itself thus creating new comparative advantage in the country with the higher environmental taxes.

Imposing environmental taxes on polluting activities is intended to induce a reallocation of resources within an economy away from the polluting towards the cleaner processes and products. This adjustment has costs and it takes time. The reallocation of resources between sectors of the economy produces effiiciency and capital stock losses if the factors of production are at least partially sector specific, and the building up of new capital in the "cleaner" sectors as well as the development of new technologies takes time. One can therefore expect that the economy will incur higher costs in the short-run than in the long-run. Yet, this should not be an argument in favour of lower taxes as these would also undermine the long-run incentive effect of the environmental policy. Preannouncing taxes and designing taxes which increase to their optimal level in preannounced steps would be more effective.

Environmental taxes on products or factors of production which create large revenues also produce differential income effects on the side of the tax collection and through the way in which the tax revenues are recycled. These distributional consequences occur within a country but also between countries when international taxes like a CO_2-tax are concerned. The distributional effect depends on the particular tax such that general predictions can not be made. Projections of the national distributional effects of a CO_2-tax suggest that such a tax is regressive because lower income groups tend to consume relative high energy-intensive goods. In order to counteract this redistributive effect, the recycling of the tax revenues should be channeled towards lower income groups.

In order to alleviate the negative impact of environmental taxes on the competitiveness of the exporting industry measures to reduce the tax burden have been called for. Tax exemptions, compensations, or tax rebates have been advocated and they all amount to effectively not levying the tax on the most polluting sectors. If the same environmental objective is to be achieved with such tax exemptions, the emission reduction must come from the low emission sectors. However, this entails efficiency losses because the abatement costs or the opportunity costs of reduced production are higher in those sectors than in the exempted industries. Moreover, such a policy could be self-defeating if the exempted sector mainly produce intermediate products for the now heavily taxed sectors as it is common in the industrial countries. Seen from the perspective of the tax exempted industry, the reduced domestic demand for intermediate products may be worse than the loss in comparative advantage of the basic industry paired with increased comparative advantage of the other manufacturing sector.

The tentative but general conclusion which can be drawn from the above can be summarized as follows:

- The general equilibrium impact of environmental taxes does not consist simply consist in a reduction of international trade. This rather depends on the particular circumstances in which the tax is imposed.

- The trade impacts of environmental regulation which have been measured empirically are almost negligable. Even simulation studies predict strong effects only for very few sectors of the economy.

- Since the environmental taxes are imposed in order to induce a reallocation of the economy away from the polluting towards the less polluting activities, one can not expect that the polluting industries will not need to shrink or need to introduce abatement measures. This internal reallocation will necessarily be accompanied by a restructuring of trade between economies. Hence, mitigating these trade effects is about as meaningful as mitigating the internal restructuring of the economy.

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APPENDIX

Simple Mechanics of Environmental Taxes

The basic principles of the price and competitiveness effects of different forms of environmental taxes are presented in a simple 2x2x2 Heckscher-Ohlin model of international trade. It has two factors of production, the environment - or environmental services - denoted by E and a composite of other factors, e.g. land, labour, capital, denoted by K. There are two countries, the home country and the rest of the world. Finally two tradable commodoties are produced, one which uses the environment relative intensively Q_E and Q_K which uses the composite factor relative intensively.

The effects of anvironmental taxes depend on several factors. The different cases which need to be distinguished concern the existence of terms-of-trade effects, i.e. whether the taxing country is

- Small country (S) - large country (L).

The environmental and the welfare effects depend on the type of environmental externality, i.e.

- no transfrontier pollution (N) - transfrontier pollution (I).[27]

The trade structure and the trade volume are influenced by the environmental tax in different ways depending on whether the taxing country is

- relatively scarcely endowed with environment (K) - rel. well-endowed with environment (E).

And most importantly, the trade effects of environmental taxes depend on the type of tax which is imposed to mitigate the environmental externalities. Three types of environmental taxes are considered:

- tax on - domestic - production (P) - on consumption (C) - on emissions (X).

All combinations of these different cases are conceivable. It is therefore clear that no clear-cut trade effect of environmental taxes can be expected. To the contrary, it is shown that the effects differ substantially. Instead of going through each combination in detail, some important cases are presented here graphically. They show that especially the decision concerning the tax base is an important determinant of the potential trade and competitiveness effects.

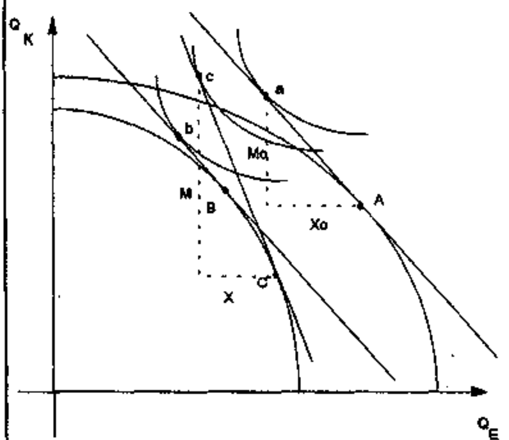
[27] This distinction is important when optimal tax rates are to be determined. In this paper it is ignored.

Emission Taxes

If emissions can be taxed directly as a first best policy the tax acts like an artificially set price for the input factor environment and thus determines the relative factor prices between the composite factor and the factor E and the absolute amount of environmental services which are demanded by domestic producers. If the home country is small such that its policy has no influence on world market prices, the tax will reduce total domestic production because of a reduced use of the factor E. In Figure 1 the transformation frontiers of the home country for the environment-intensive commodity Q_E and the composite factor-intensive commodity Q_K are shown. The home country is assumed to have a comparative advantage in the environmentally intensive commodity (case E), i.e. it is an exporter of Q_E. Commodity prices are equal to world market prices and correspond to the tangent through point A on the out transformation frontier.

Without an emission tax domestic production is located in point A, the consumption point is a with exports X_0 and imports M_0. If the emission tax is imposed the transformation frontier shrinks such that the new production point becomes B and the corresponding consumption point is b. The trade volume will shrink, firstly because the country looses some of its comparative advantage and secondly because the real income has fallen due to the smaller factor endowment in productive use. This parallels the classical Rybczynski-effect of a change in the resource endowment of an economy.

Figure 1 Emission Tax in a Country with a Comparative Advantage in Q_E (Cases S,N,E,X and L,N,E,X)



If the home country is large enough to influence world market prices, the the Rybzcynski-effect will be supplemented by a terms-of-trade effect (Case L,N,E,X). The move from A to B changes world demand and supply of the two commodities such that the relative price of the environmentally intensive good Q_E rises. The production point moves from B to C because of the favourable terms-of-trade change. In addition, consumption rises to c and exports may increase or decrease to X, whereas imports will increase to M.

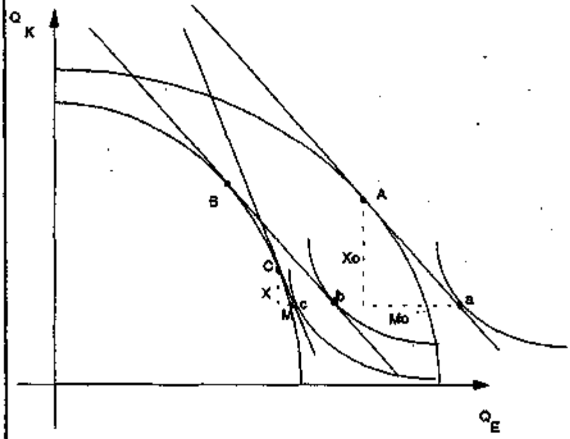
To summarize, in the small country case the imposition of an emission tax will lead to a shift away from the production of the environmentally intensive commodity to the environmentally-extensive commodity. Due to the smaller resource base and the loss in competitiveness of the exportables sector trade volumes will decrease. In the large country case these reduced specialization effects are mitigated by the terms-of-trade effect which works in favour of the exportables sector.

The same analysis can be done for the case in which the home country has a comparative advantage in the commodity which uses the composite factor most intensively, i.e. in which it is an importer of the environmentally intensive good (Cases S,N,K,X and L,N,K,X). Figure 2 characterizes such a situation. Again, the original allocation is A (production point) and a (consumption point) with exports X_0 and imports M_0. The emission tax shifts the transformation frontier inwards such that in the small country case production will take place at B and consumption at point b. The Rybzcynski effect leads to a further specialization in commodity Q_K in which the home country has a comparative advantage. This further specialization has the tendency to increase trade volumes. However, since the real income in the home country falls at the same time, the overall effect on trade volumes remains ambiguous and depends on the degree of homogeneity of the welfare function together with the shape of the transformation surface.

If the home country is large enough to influence through its tax the relative world market prices (case L,N,K,X), the terms-of-trade effect shifts the production point from B to C and consumption from b to c. Trade volumes shrink to X and M because the terms-of-trade effect works against the comparative advantage of the home country.

If trade volumes are small before the imposition of the emission tax and if the terms-of-trade effect is sufficiently strong, then it is possible that the home country looses its comparative advantage in the commodity which uses the composite factor most intensively and becomes an exporter of the environmentally intensive good. This seemingly odd result of the emission tax leading to a specialization in the production of Q_E which uses the factor with the increased price most intensively depends on the price elasticity of world demand for the environmentally intensive good. A lower resource availability of E raises the price of Q_E. If the price elasticity is sufficiently high in the world market the home country may become an exporter of Q_E although at a lower level of production than the the no-tax case.

Figure 2 Emission Tax in a Country with a Comparative Advantage in Q_K (Cases S,N,K,X and L,N,K,X)



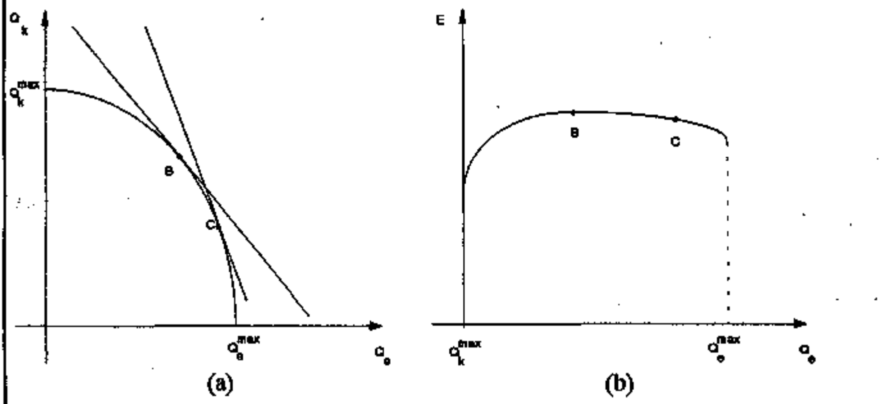
Production Taxes

A production tax is imposed on domestic producers of an emission-intensive commodity. Consequently, imports are not subject to the tax but exports are. Such a production tax might be imposed because emissions occur during the production process and not during the consumption of the commodity and because they may not be directly measurable.

The previous model with the environment - or more precisely, the environment's assimilative capacity for emissions - as a factor of production is inappropriate for modelling production or consumption taxes as a second best policy to control emissions. Contrary to a partial equilibrium analysis which shows a reduction in the production and consumption of a taxed commodity and - in connection with this - a reduction of emissions, in a general equilibrium analysis of a perfectly competitive economy without factor market rigidities, a product tax at the producer or at the consumer level would have no influence on the full use of all available factors of production. The reallocation away from the environmentally intensive product would take place, but the factors becoming idle through this reduction would be used in the production of the other commodity using the composite factor most intensively.

One variant of a meaningful simple model for analyzing the effects of such taxes consists of emissions being the joint product of the production process. Hence, an economy produces with some factors of production two different products Q_e and Q_k which both have the same joint product, called "emission" E. Now suppose, E is a monotonic function of Q_e as well as Q_k and that the emission coefficient of product Q_e is higher than that of Q_k, i.e. $E/Q_e > E/Q_k$ for all levels of production. A second-best policy of taxing the "dirtier" product Q_e will then shift the production away from the commodity with a high emission coefficient to that with a low emission coefficient. This is illustrated in panel (a) of Figure 3 as a move along the transformation surface from C to B. The corresponding effect on total emissions is shown in panel (b) of Figure 3 which maps emissions against the composition of production between Q_e and Q_k under a full resource utilization. At the origin only the good with the low emission coefficient is produced. As more of the resources are shifted towards the production of the emission intensive good emissions increase and Q_k falls. Because of the concavity of the transformation frontier emissions will first increase and reach a maximum at the point where the increase of the emissions from the additional production of Q_e just outweighs the decrease in emissions from the fall in the production of Q_k and will fall thereafter. This maximum may be close to the maximum output of Q_e but it need not be depending on the concavity of the transformation frontier and the difference in the emission coefficients.

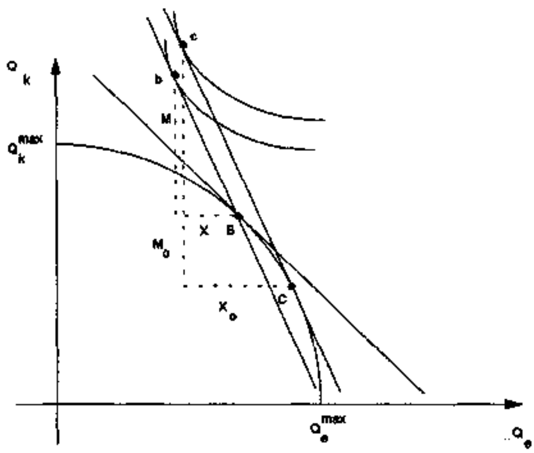
Figure 3 Emissions as a Joint Product



In the particular situation chosen total emissions increase as the economy moves from specializing in the product with a high emission coefficient to the product with the low emission coefficient. It is obviously impossible to predict the environmental effect of a tax in such a situation. If the tax would have shifted the allocation further left to point B, then emissions could fall below the original level of allocation C (panel (b) in Figure 3). However, this is a normal result if the production tax is not perfectly correlated with the emissions for which it was introduced.

The trade effects of a production tax in the small country case with fixed world market prices and a comparative advantage of the taxing country in the production of the relatively emission intensive commodity (case S,N,E,P) are illustrated in Figure 4. The pre-tax allocation is C (production) and c (consumption) with imports M_o and exports X_o clearing domestic markets. The tax drives a wedge between producer and consumer prices. Consumer prices are still determined by world market prices. The optimal production decision is then determined by the relative domestic producer prices, i.e. point B. Consumers choose **b** at world market prices. The product tax reduces the comparative advantage of the taxed product Q_e such that trade volumes shrink because the economy reduces its specialization away from its competitive product.

Figure 4 Production Tax on an Emission-Intensive Exportable (Case S,N,E,P)

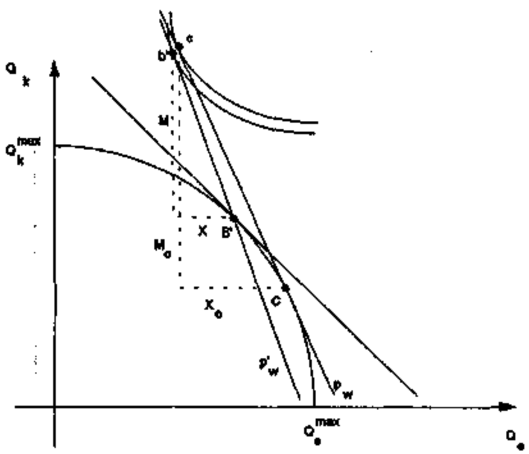


If the taxing country's comparative advantage is in the low emission commodity Q_k, i.e. Q_e is imported and Q_k is exported (case S,N,K,P) then the production tax would force producers to even further specialize in the production of the low emission commodity. Consequently trade volumes will increase since the relative price of the exportable for the domestic producer increases.

Taking account for terms-of-trade changes leads to a softening of the reallocation effects of the production tax. First consider the case of the high emission commodity being the exportable (case L,N,E,P). The imposition of a product tax on Q_e in a large country will reduce the world supply of the high emission product such that its relative price at the world market increases to p'_W in Figure 5 and the corresponding production and consumption decisions move to B' and b'. The tax induced production change is smaller than in the case of a small country. The consumers also gain from the increasing price of the export good and reach a higher indifference curve than under constant world market prices.

Compared to the small country case the new production point will be located between the points B and C (Figure 4). If the commodities are normal goods the new consumption point will be located in the north-east of the consumption point **b**. The extent of the terms-of-trade effect determines whether it will also be on an indifference curve outside the one which is tangent to **c**. In such a case the production tax for environmental reasons has increased the welfare of goods consumption because in addition to the environmental objective it also works like a trade policy instrument.

Figure 5 Production Tax on an Emission-Intensive Exportable (case L,N,E,P)



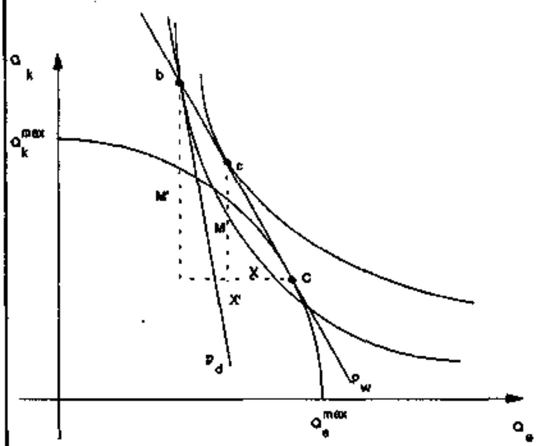
In the case where the taxing country has a comparative advantage in the low emission product (case L,N,K,P) the terms-of-trade works against the country's welfare because the world supply of Q_k increases thus inducing a fall in its relative price. Again the production decision will be located somewhere between the no-tax allocation C and the cum-tax allocation without the terms-of-trade effect B, e.g. at B'. The consumption decision will be on a lower indifference curve than that corresponding to the no-tax consumption point and even possibly below that of the cum-tax small country allocation.

Consumption Tax

Instead of taxing a product at the domestic producer level it can be taxed at the retail level. This implies that not only domestic production is taxed but imports as well whereas exports are not taxed. The price wedge between consumer and producer prices also exists, but relative producer prices are now identical to world market prices whereas relative consumer prices deviate from world market prices.

The analysis for a small country with a comparative advantage in the high emission product (case S,N,E,C) is depicted in Figure 6. The original allocation is C (production) and c (consumption) with the difference between the two being supplied by the world market at the relative price p_w. The consumption tax on Q_e will not change the producer decision since the price net of taxes, i.e. the world market price will not be affected by the tax. Consumers face a higher relative price for Q_e, i.e. p_d, such that they choose the consumption point b. Hence, exports of Q_e and imports of Q_k will rise. In this case there will be merely a reallocation of consumption which will increase trade volumes.

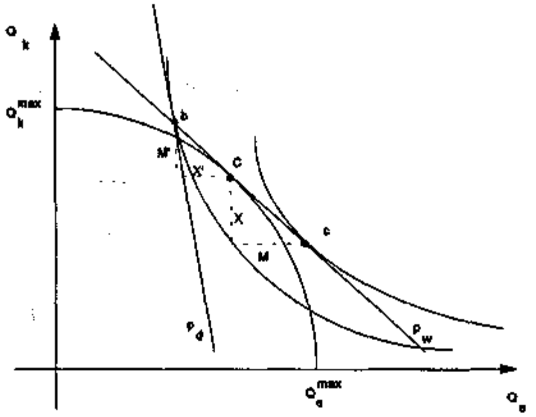
Figure 6 Consumption Tax on an Emission-Intensive Exportable (Case S,N,E,C)



If the country has a comparative advantage in the low emission commodity, i.e. it imports the high emission product, but still can not influence world market prices (case S,N,K,C), then production will again not change. Consumers facing higher prices for the import good will substitute the import by the export good such that the trade volume, i.e. exports and imports, contract. If the reaction on the demand side is strong enough - through preferences or sufficiently high taxes - the direction of trade could become reversed. Such a situation is illustrated in Figure 7. The original trade pattern consisted of exports X of Q_e and imports M of Q_k with consumption c and production C. After the imposition of the tax consumers choose such that imports M' of Q_k and exports X' of Q_e are necessary to meet demand.

If the tax is lower trade flows may not become reversed and the consumption point will be located between C and c on the international price line but the trade volume shrinks relatively fast since there is no reaction on the producer side.

Figure 7 Consumption Tax on an Emission-Intensive Importable (Case S,N,K,C)



Including the terms-of-trade effects in the analysis of a consumption tax extends the reaction to the imposition of the tax to the producers as well. Figure 8 illustrates the case where the country is exporting the taxed high emission product Q_e (case L,N,E,C). Similar to Figure 6, the original production and consumption decisions are C and c. The tax increases the world demand for Q_k and lowers that for Q_e such that the relative world market price changes from p_w to p'_w. The domestic retail price becomes p_d. Producer react to this terms-of-trade change by moving to B thus loosing competitiveness of their export product. In this case consumption as well as production of the high emission product falls and that of the low emission product increases.

Figure 8 Consumption Tax on an Emission-Intensive Exportable (Case L,N,E,C)

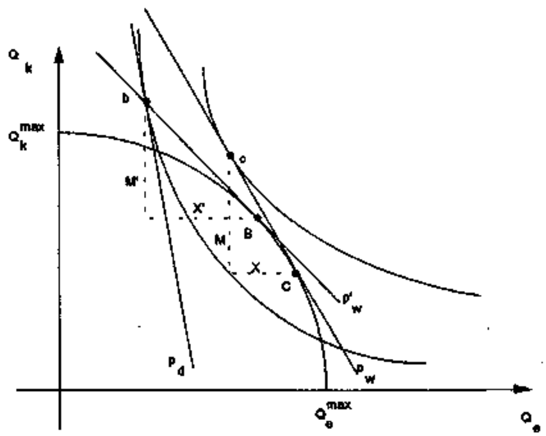
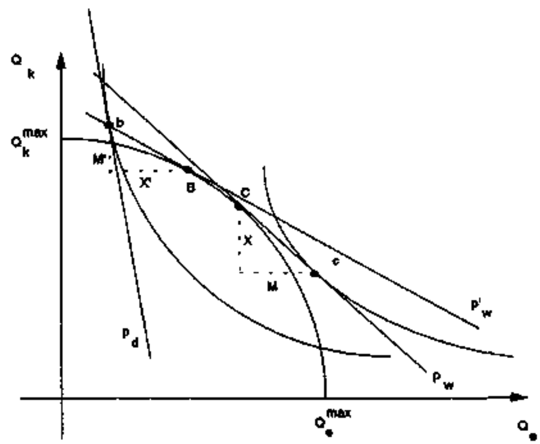


Figure 9 Consumption Tax on an Emission-Intensive Importable (Case L,N,K,C)



If the exportable before taxation was the low emission commodity Q_k and the consumption tax changes the terms-of-trade of the country (case L,N,K,C), the producers will react to this relative price change by moving production from C to B in Figure 9. A reversal of the direction of trade is still possible as in case S,N,K,C but it becomes less likely since production as well as consumption decisions move in the same direction, i.e. to a haigher Q_k and a lower Q_e.