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International trade, foreign investment, and the environment

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Working Paper No. 29

International Trade, Foreign Investment, and the Environment

von

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“International Trade, Foreign Investment, and the Environment”

Michael Rauscher

Abstract

This paper surveys the literature on the relationship between international trade in goods and factors and the environment. Traditional approaches based on the Heckscher-Ohlin trade model and more recent models looking at non-competitive market structures are discussed. Moreover, the paper covers intertemporal aspects (foreign debt, stock pollutants), public-choice models (the political economy), the empirical evidence, and institutional issues. This paper was written for the “Handbook of Environmental and Resource Economics” to be edited by Jeffrey Vincent and Karl-Göran Mäler for the “Handbooks in Economics” series (North-Holland, Amsterdam), where a revised and probably shorter version of it will appear. Comments are very welcome.

0 Introduction

In an interdependent world economy with globally integrated markets, the environmental policy of a single country is not independent anymore of what is going on in the rest of the world. This has been seen as a threat by many concerned groups. Industry lobbies often argue that tight environmental standards and high pollution taxes have a negative impact on competitiveness. Many environmentalists fear that international differences in environmental policies lead to unfavourable patterns of specialisation, e.g. developing countries becoming pollution havens, and an international downward competition in environmental policies which makes all countries, in particular the developing ones, worse off. Examples are Cobb/Daly (1989), Morris (1991), Daly/Goodland (1994), Røpke (1994) and, with a Marxist dependencia approach, Liodakis (2000). Of course, these fears are not new but with the lowering of natural and institutional barriers to trade, cross-country differences in environmental legislation may matter more than in prior decades. Environmental and trade economists have recognised this problem area and the 1990s have produced a large literature on trade and the environment. This paper surveys the results of this literature.

Of course, the literature on trade and the environment that has emerged in the 1990s has not invented the wheel. In the early 1970s, when environmental economics was established as a serious sub-discipline of economics, some authors already asked themselves how the incorporation of the international exchange of commodities and factors of production into the models of environmental economics would change the policy recommendations that have been derived for closed economies. Examples are Baumol's (1971) lecture series and Markusen's (1975) seminal paper. However, the international link has been a side-issue to most environmental economists of that time. The 1980s saw a shrinking interest in environmental economics in general. This was probably due to the fact that unemployment

and stagflation entered the arena and were being viewed as the most pressing problems that economists should address at the time being. In the 1990s, there was a renaissance of environmental economics. When globalisation became one of the catchwords in the debate, not only in business magazines, it was quite natural that the focus became more international. What is different in the open-economy environmental economics of 1990s compared to the 1970s? I think there are basically two issues. The first one is the international dimension of environmental problems. In the early stages of environmental-economics theorising, researchers were concerned mainly with the internalisation of local or national externalities. In most models, the central question was which environmental policy an environmental protection agency should use in order to achieve first-best allocations of scarce resources. Since then, international environmental problems such as the depletion of the ozone layer and global warming have entered the agenda. The recent literature has developed tools to deal with issues of international environmental policy coordination (surveyed, e.g., by Barrett (2001) in this volume). In an international-trade context, the problem arises that even a country acting in a benevolent fashion by unilaterally addressing transboundary pollution and global environmental problems would be discouraged to do so by so-called leakage effects: tighter environmental standards in one country simply move the source of the problem from this side to the other side of the border and global pollution remains unchanged. The second innovation in environmental economics in the 1990s is the use of tools developed in modern industrial organisation theory. This made it possible to abolish the predominance of perfect competition models in economic theorising. Markets with a small number of polluting firms and strategic aspects of environmental policy making became subjects to economic analysis. This was not of mere academic interest. Strategic trade policy models, based on Brander/Spencer (1985) had a significant impact on the economic-policy debate and the obvious question was as to whether the results of strategic trade policy carry over to environmental economics.

This survey covers both the more traditional approaches that address ideal, perfectly competitive economies and neglect transfrontier pollution and global environmental problems and the more recent literature dealing with oligopolistic or otherwise imperfectly competitive markets and international externalities. Part of the former has already been addressed by Siebert et al. (1980) and in Siebert's (1985) article in volume I of this handbook but it appears to be sensible to discuss this literature in a broader perspective and, of course, to incorporate the literature of the 1990s. More recent surveys have been written by Ulph (1997a,b). They are a bit selective in that they present the standard results based on factor proportions theory and then move to trade models based on the theory of oligopolistic markets. I wish to provide a more general overview and start with the traditional trade models based on the idea of comparative advantage. Afterwards modern approaches addressing imperfectly competitive markets will be considered. Moreover, I consider intertemporal issues related to the accumulation of pollution over time and to foreign indebtedness. Additional points to be covered are international factor movements and the political economy of environmental policy in open economies.

Some technical remarks should be made. There are two ways of modelling emissions of pollutants when they occur as a by-product of production activities. The first possibility, which is probably the straightforward one, is to model them as a joint output of the production process. The alternative approach is to model emissions as an input. The underlying idea is that natural resources are taken from the environment, used up during the production process, and then returned into the environment as emissions or waste. For instance consider a production function of an industry i ,

$$F^i(K_i, L_i, E_i),$$

with the usual properties: positive partial derivatives, negative second derivatives, positive cross derivatives, and concavity. K_i is capital input, L_i is labour, and E_i is emissions. Then the production function encompasses a capital and labour intensive abatement process such that emissions can be reduced without affecting output only if the input of at least one other factor is increased.

In many theoretical models, environmental quality is treated as a public consumption good, i.e. environmental disruption affects welfare directly. Environmental externalities on production are usually disregarded. If they are considered, the production function is changed such that

$$\tilde{F}^i(K_i, L_i, E_i, E, E^*),$$

where E and E^* denote aggregate emissions in the country under consideration and in the rest of the world and where the corresponding partial derivatives are negative. This case will also be discussed in this survey, albeit merely verbally as an extension.

As regards definition of terms, it appears to be necessary what is meant by environmental dumping, a term often used in the public debate and in academic papers. In academia, environmental dumping characterises an environmental policy which does not completely internalise environmental externalities for reasons of international competitiveness and/or trade. I will use the term environmental dumping in this sense.¹

¹ This use of the term "ecological dumping" is in accordance with the use of the term "dumping" in traditional trade theory. There, dumping can be defined as pricing at less than marginal cost. See Davies/McGuinness (1982) and Ethier (1982). In the public debate, the term "environmental dumping" is often used to characterise the behaviour of a jurisdiction which implements laxer environmental standards than other jurisdictions. This view is based on the premise that environmental standards and taxes should be equal everywhere. As is well-known from the trade literature, there are good reasons for environmental regulation to differ internationally and, therefore, this definition does not make much sense. An alternative definition chosen by Rauscher (1994a) is based on a distinction between tradable and nontradable goods.

This survey is organised as follows. The first section covers the traditional trade theories based on factor proportions. Important questions are what determines the patterns of trade, whether or not trade is beneficial, whether openness causes ecological dumping, and whether trade restrictions should be used to improve environmental quality. Section 2 is concerned with non-competitive models of international trade. Second-best considerations become important since non-competitive market structure constitute a second distortion in the economy besides the environmental externality. In Section 3, I will look at the political economy of environmental policy in open economies. This approach explains why inefficient or biased policies are chosen by the policy maker and they make predictions on the direction of the bias. Afterwards, international factor movements and the issues of location are considered. Again the issue of ecological dumping and the race towards the bottom are of major concern. Section 5 is concerned with intertemporal aspects of the environmental problem. I will look at stock pollutants, that are accumulated over time, and at the problem of foreign indebtedness. Section 6 deals with the empirical evidence, section 7 with institutional issues and section 8 draws some conclusions.

1 Environmental regulation and comparative advantage

The problem that foreign trade and environmental policy might be interdependent has been a topic of economic analysis since the early seventies. Baumol (1971) is probably the first reference dealing with the issue from an economic-theory perspective. Others such as Markusen (1975), Pethig (1976), Siebert (1977, 1979), Asako (1979), Siebert et al. (1980), McGuire (1982) have elaborated and refined these models and more recent contributions include Merrifield (1988), Krutilla (1991), Anderson (1992), Lloyd ((1992), Snape (1992), Chichilnisky (1994a), Copeland/Taylor (1994a,b, 1995, 1999), Steininger (1994a,b), Rauscher (1997, Ch. 5). The factor abundance approach to trade and the environment has been surveyed by Ulph (1997a,b). The survey provided here summarises the results in a non-technical fashion, using partial-equilibrium diagrammatical approaches. The limitations of this approach will be mentioned and generalisations will be discussed. The algebraic version of this can be found in Ulph's survey papers (1997a,b).

1.1 The endowment of a country with environmental resources

In Heckscher-Ohlin theory of international trade, the patterns of trade are determined by relative endowment differences. Countries relatively well endowed with environmental resources are expected to export environmentally intensively produced, or loosely speaking: "dirty", commodities. Countries poorly endowed with environmental resources tend to export "clean" commodities. What constitutes the endowment of a country with natural resources? As far as other factors of production are concerned, endowments are usually considered as being determined by exogenous supply which is assumed to be inelastic in most models. This

is possible also with environmental resources. Let K , L , and E be a country's exogenously given endowments with capital, labour, and resources, respectively. Then relative endowments can be represented by in a triangle. This way of depicting factor endowments has been introduced by Leamer (1987). See Figure 1. The sides of the triangles measure relative factor abundance, K/L , E/L , and K/E , respectively. Units are chosen such that the factor endowment of the world as a whole is located in the centre of the triangle. All countries located on the dashed line have the same capital-labour ratios but country A is more resource-abundant than country B and should export the environmentally intensive good provided that everything else is equal, preferences are homothetic, and technologies are linear homogenous.

----- insert Figure 1 about here

The endowment of a country with environmental resources is by no means given but is a result of a political process which determines the availability of environmental resources for economic activities. Chichilnisky (1994a,b), for instance, has emphasised that countries with similar natural endowments of environmental resources may differ substantially in the availability of these resources for economic activities. What determines the availability of environmental resources is the environmental policy chosen by the country's government. It depends on the following factors:

- *Natural abundance.* Countries differ in their physical endowments with environmental resources. This does not only apply to resources like petroleum and ores but in a more general sense to all kinds of environmental resources that are used for economic activities, e.g. clean air and water. Factors that determine the abundance of these factor are stocks of renewable resources, the assimilative capacity of nature and climatic variables.
- *Demand for environmental quality.* People in different countries differ in their willingness and ability to pay for environmental quality. Willingness and ability to pay is an increasing function of income. See Panayotou's (2001) contribution in this volume for a comprehensive overview on the issue. The impact of income-dependent differences in environmental regulation on trade has been considered by Copeland/Taylor (1994). Moreover, willingness to pay is affected by tastes.
- *Demand for final goods.* In countries with a low demand for environmentally intensively produced goods, environmental resources will be abundant relative to needs. In other words: Emission taxes or implicit shadow prices for environmental goods tend to be low. In many theoretical trade models this effect is irrelevant since preferences are assumed to be internationally identical and homothetic.

- *The impact of lobbies.* Environmental policy does not always represent the will of the voters but it is captured and biased by various interest groups ranging from industry lobbies to environmentalists.
- *The conduct of environmental policy.* It is not only important to have environmental regulations and norms. These regulations and norms must also be enforced. Anecdotal evidence suggests that this has been a problem particularly in developing countries and centrally planned economies but also in the first world. Enforcement deficits create comparative advantages for environmentally intensive industries.²

Having mentioned the determinants of a country's endowment with environmental resources, one can now apply the Heckscher-Ohlin-Samuelson theorem:

"A country (on average) exports environmentally intensively produced commodities if it is well-endowed with environmental resources."

or the Heckscher-Ohlin-Vanek theorem:

"A country well-endowed with environmental resources is a net exporter of environmental services embodied in traded commodities"

The term "on average" vanishes in the two-factors, two-commodities case. In higher dimensional cases, there may be some environmentally intensive commodities that are imported by a country well-endowed with environmental resources. See Bhagwati (1972), Dixit/Norman (1980, ch.4), Deardorff (1982), and Ethier (1984). One can conclude from this that countries with lax environmental policies tend to export environmentally intensively produced commodities. Besides the "on average" caveat of the many-factors many-goods case, there are three important exceptions from this rule:

- *External effects of emissions on productivity.* If environmental pollution has significant effects on factor productivities, the predictions may be reversed. A country with a lax environmental policy experiences environmental disruption. This may affect different industries differently. Factor endowment effects may be dominated by Ricardian productivity effects and the patterns of specialisation may be reversed. See Copeland/Taylor (1999).³ If transfrontier pollution is considered, emissions originating

² It is interesting to note that some centrally planned economies had very tight environmental standards, particularly in the 1980s. In Poland, one even introduced emission taxes. See Zylicz (1994). However, these standards were often not enforced and emission taxes turned out to be irrelevant for socialist enterprises, whose soft budget constraints were rarely binding. This experience illustrates the enforcement deficits of environmental policy existing in many countries.

³ Externalities of this kind have been addressed by Herberg/Kemp (1969) and Herberg/Kemp/Tawada (1982), however not in an environmental-economics framework.

from the foreign country can have an effect on environmental quality and, thus, on productivities in the home country. As an example, consider a situation were without transfrontier pollution the home country would have a comparative advantage in tourism. This may be turned into a comparative disadvantage if the country suffers from environmental disruption originating from abroad.

- *An impact of environmental quality on the patterns of demand.* Assume the home country is physically well-endowed with environmental resources and therefore would have a comparative advantage for environmentally intensively produced commodities if demand were homothetic and independent of environmental quality. If environmental pollution now has a negative impact on the demand for the other, "clean", commodity, then this may reduce the autarky price of the "clean" commodity by so much that the comparative advantage is shifted to the less environmentally intensively produced commodity. See Pethig (1976).
- *Environmental externalities of consumption.* If consumption also generates environmental pollution, then a strict environmental policy reduces the demand for the commodity which is environmentally intensive in consumption. This price reduction may reinforce, weaken, or reverse the impact of environmental regulation on supply-side comparative advantage. See Rauscher (1997, ch. 5.3).

Figure 2 illustrates these effects in a partial-equilibrium diagram. Let q denote the quantity of a commodity and let p denote its price, measured in units of a numéraire. S and D are the supply and demand functions, respectively. If all parameters in the two countries are the identical then the domestic equilibrium price in autarky equals the foreign autarky price, p^* . Now consider a change in the domestic environmental policy: environmental standards or taxes are relaxed. Normally, the domestic supply function is shifted downwards since marginal production cost is reduced. This results in a new price p_1 lower than p^* and the home country becomes an exporter of this commodity. If there are external effects on production, however, the higher level of environmental pollution, however, may raise marginal cost such that the supply function is shifted upwards to S'' and the comparative advantage is reversed. In the case of transfrontier pollution, a situation can be imagined in which the production of the foreign numéraire good is negatively affected. This reduces the foreign relative price from its initial level p^* . In the case of negative externalities of consumption, lax environmental policies increase demand from D to D' and the domestic producer price may rise to p_2 .

In the many goods, many factors case, all the effects may be reversed by general-equilibrium repercussions, but "on average" the effects are maintained for the economy as a whole.

In their models, external effects on production are related the outputs of industries, but not to the inputs of particular factors like environmental resources.

1.2 Environmental Policy and Competitiveness

All the statements made above are based on the notion that improvements environmental quality can be achieved only at the cost of reducing private-sector output and consumption. The phenomenon of productivity externalities, where tighter environmental standards have a positive effect on factor productivities is an exception to this rule but probably of limited practical relevance, at least on the aggregate scale. In general, tight environmental standards and high emission taxes tend to harm regulated industries and reduce their competitiveness. It has, however, been observed that in some cases industries have in the longer term benefited from strict environmental regulation. Porter (1990) has argued that firms in Northern Europe and Japan have actually benefited from the introduction of tighter environmental standards. He then stated his famous "Porter hypothesis": there are not only environmental gains from stricter regulation but one should also expect improvements in competitiveness. The conclusion is then that a green policy is not only in the interest of environmental lobby groups but also of the regulatees: green environmental policy can be part of strategic industrial policy aiming at improving the international competitiveness of the domestic economy. See Porter (1991) and Porter/van der Linde (1995). Palmer/Oates/Portney (1995), in contrast, argue that there is no gain without pain. Imposing restrictions on the choice set of a single rationally acting firm or individual cannot improve its well-being. This basic economic wisdom is, however, not sufficient in refuting the Porter hypothesis. There are several explanations as to why the hypothesis could be valid in spite of this.

- The first argument is inefficiency. Leibenstein (1966), in his article on X-inefficiency, has argued that firms do general not produce on the edges of their production possibility sets. There are inefficiencies that are recovered only if the firm is put under some external stress. See Frantz (1989) for a broader overview. This external stress or pressure may be due to tightening environmental standards. The reduction of the profit margin makes the firm recover new potentials for increasing efficiency. Although this may explain why some firms subject to strict environmental standards have in the longer term been better off than unregulated firms, this does not imply that a green strategy is the appropriate way of achieving competitiveness. Other instruments may be superior in removing X-inefficiency.
- Another argument is the first-mover advantage. Governments that move first in the implementation of tight environmental standards impose additional costs on domestic firms. However, when other governments follow the trend towards greener policies, domestic firms have already adjusted to these standards and enjoy a competitive advantage over foreign firms. This argument postulates that the private sector is ignorant and myopic and does not foresee trends in future environmental regulation. Even if this is the case, the policy implication would be that the private sector be better informed about future trends in environmental regulation. Tighter environmental standards and high emission taxes are a rather indirect way of solving this information problem.

- Finally, it is possible that there are strategic reasons for tighter environmental policies. In oligopolistic markets, it is possible that the government can improve private profits by restricting the choice set of individual firms. The underlying reason is that firms are unable to commit themselves to follow non-profit-maximising that would yield higher profits in the resulting Nash equilibrium of a oligopoly game. The government then is the first mover and provides the credible commitment in an earlier stage of the game. This is the foundation of strategic trade policy and the idea has been applied to international environmental economics as well.

If one believes in rational economic agents and competitive markets, the Porter hypothesis is discarded easily. Both assumptions are, however, unlikely to be met in reality. Whether strict environmental policy is good or bad for competitiveness, then is an empirical question. Theoretical aspects should be investigated in a non-competitive model framework. Both issues will be taken up later in this survey.

1.3 Trade Liberalisation and the Gains from Trade

In the standard neoclassical models of international trade, free trade is always better than autarky. See, for instance, Dixit/Norman (1980) for a general proof. Trade liberalisation is the removal of a set of restrictions that constrain the economy. With free trade the consumption possibility set of the economy is larger than its production possibility set. The choice set is broadened with autarky still being an option. In a first-best world, the removal of a restriction is always beneficial. barrier to trade is always beneficial if this barrier is the only distortion of the economy. This is a generalisable result from public economics which carries over to situations where environmental pollution matters. Thus, if all environmental externalities are appropriately internalised, free trade is always preferable to autarky.

Matters are different in second-best situations. According to the theory of second best, the removal of a market distortion can be harmful if there exists a second distortion and if the first distortion partially offsets the second one. Since environmental policies in most of the cases do not exactly internalise environmental externalities, a second externality is likely to exist, and it is questionable whether the gains from trade are positive.

Two scenarios may be distinguished. In the first scenario, emissions are given and do not change when relative prices change after trade liberalisation. This may be the case if the government has fixed an emission target which is allocated to individual polluters either by command and control or by a tradable permits scheme. In the second scenario, the emissions are variable and are affected by relative-prices changes. This is possible if, for instance, emission taxes are used as the instrument of environmental policy. Other policies that keep emissions variable are imaginable, e.g. command-and-control regulations that restrict emissions per unit of output: if output rises, emissions are increased.

Let τ denote a trade tax which is reduced (or even removed) when trade is liberalised. The gains from trade, $dw/d\tau$, can be decomposed as follows

$$\frac{dw}{d\tau} = u_C \frac{\delta C}{\delta \tau} + \left(u_C \frac{\delta C}{\delta E} + u_E \right) \frac{dE}{d\tau} \quad (1)$$

where $u(C,E)$ is utility or welfare depending on the consumption vector, C , and the level of emissions, E , where E may be a vector if more than one (aggregate) pollutant is considered. See Siebert (1977) and Rauscher (1997, ch. 5.5). The first term on the right-hand side of equation 1 denotes the efficiency gains from trade it is always negative, i.e. an increase in barriers to trade reduces welfare. This is the standard result from trade theory. The second term is zero if environmental pollution does not matter or if trade liberalisation does not change environmental policy. If E is a scalar, then the interpretation of this term is straightforward. Depending on the patterns of trade, $dE/d\tau$ can be positive or negative. A country exporting environmentally intensively produced commodities experiences an increase in emissions, a country importing such goods experiences an improvement in environmental quality (unless the regulation is such that emissions are fixed). The term in brackets consists of two components. The first one denotes the effect of increased emissions on the consumption possibility set. This is usually positive unless external effects of emissions on production are substantial. The second term denotes the marginal environmental damage, which is always negative. The term in brackets as a whole is zero if the optimal environmental regulation has been chosen, i.e. if marginal environmental damage equals marginal abatement cost. If environmental regulation is too strict, the term in brackets is positive: additional emissions improve welfare. If environmental regulation is too lax, the term in brackets is negative: welfare is reduced by additional emissions.

To illustrate the gains from trade, Figures 2 and 3 are used. They are adapted from Anderson (1992) and show a partial equilibrium for a single country becoming an exporter or an importer of the commodity, respectively, after trade liberalisation. In both cases, the production of the commodity generates emissions. D is the demand curve. MPC and MSC denote marginal private and social costs of production, respectively. MPC is the supply curve in the case of optimal environmental policy p^P and p^S denote the corresponding equilibrium prices in autarky and p^W is the world market price after trade liberalisation. Quantities are depicted only for the trade case, q^C denotes consumption, q^P is output without environmental regulation, q^S is output in the case of perfect internalisation.

----- insert Figures 2 and 3 about here

Figure 2 looks at the country becoming an exporter of the pollution-intensive good. In the case of perfect internalisation, the gain from trade is triangle a . In the case of incomplete internalisation, the private gain from trade is larger because lax regulation reinforces comparative advantage. It is triangle $a+b+c+d$. However, this comes at the cost of increased pollution, $d+e$. Thus, the net welfare effect is $a+b+c-e$, and this may well be negative. In figure 3, the same exercise is done for the importing country. With optimal environmental policies, the gain from trade is $a+b+c+d+e$. With non-optimal environmental regulation, the

autarky price is closer to the world market price such that the private gain from trade is only c . However, there is a second dividend from improved environmental quality measured by the area $b+e+f$ such that total gain from trade is $c+b+e+f$.

Similar arguments apply if consumption – not production – is considered as a source of environmental disruption. See again Anderson (1992) for a graphical representation and Rauscher (1997, ch. 3.5) for an algebraic derivation of the main results. If the commodity which is pollution intensive in consumption is exported, then its price is higher than in autarky, domestic consumption is less, and this is good for the environment. In an analogous fashion, trade liberalisation has negative effect on the environment if the imported commodity is pollution-intensive when consumed. The welfare effect again depends on the adequacy of environmental regulation. If environmental regulation is too lax, then the increase in environmental pollution may offset the efficiency from trade, and the overall gains from trade may be negative.

The theoretical literature on trade and the environment has neglected the environmental impact of transportation. Figure 4 is a partial-equilibrium representation of this problem. The country under consideration becomes an importer of the commodity after trade liberalisation. The relevant world market price is p^w . If the transport externalities are internalised, the price is raised to $p^w+\beta$. With such an environmental policy, the gain from trade is a . Without environmental policy, the private gain from trade is $a+c$ but there are environmental damages measured by the rectangle $b+c+d$ such that the welfare effect is reduced to $a-b-d$, and this may be negative. Basically, this is the same effect as that of an import subsidy. Here, the subsidy is paid not in money but in terms of environmental disruption.

----- insert Figure 4 about here

Besides the three effects that trade theory is mostly concerned with (production, consumption, and transport) some additional effects have to be considered:

- *Trade in primary commodities.* In standard trade models, traded goods are final commodities, trade in primary commodities is often neglected albeit it is of major concern, particularly in an environmental context. An important example is trade in fossil fuels. Here it is the importing country's utilisation of these commodities in production and consumption that generates environmental disruption. Thus, the same arguments as in the case of polluting consumption apply.
- *Trade in hazardous waste.* Trade in toxic and hazardous waste is trade in bads, not in goods. In other words, the good which is traded is not the hazardous waste but the service of storing and treating it. Thus, the conclusions are the same as in the case of polluting production. The country importing the waste (exporting the service) may be better off in the case of insufficient regulation, the waste-exporting country exports its environmental problem and is better off. See Rauscher (1997, ch. 4) and Rauscher (2000).

- *Transfrontier pollution.* Trade liberalisation may lead to an increase in transfrontier pollution if the trading-partner country expands its pollution-intensive activities or to a reduction in transfrontier pollution if it reduces its environmentally harmful activities. This transfrontier pollution may offset the own-pollution effects of trade liberalisation.

The insights to be derived from this literature are twofold. In the first-best case, trade liberalisation is beneficial to all parties involved. If there are additional distortions in the economy, anything can happen. Underregulated countries tend to be worse off if they export environmentally produced commodities. This is of particular concern for developing countries. From the theoretical literature, it is not possible to derive unambiguous predictions on the effect of trade liberalisation on environmental quality. In some countries, it will be improved, in others, it will be deteriorated, depending on the pattern of specialisation. The aggregate effect on the environment is therefore unclear. Many of the theoretical models on which these conclusions are based, however, neglect environmentally intensive consumption and transport. Since these activities increase after trade liberalisation, there is an additional negative impact on the environment. It should be noted, however, that all this is based on the assumption that environmental regulation remains unchanged after trade liberalisation. But this is far from clear.

1.4 Changes in Environmental Policy after Trade Liberalisation

Simple comparative-static analysis of the effects of trade liberalisation is based on the premise that environmental policies remain unchanged after the move from autarky to free trade is undertaken. This is a static view which neglects the effects of trade on relative prices, income, and environmental disruption. Welfare maximising governments should adjust their environmental policies to changes in these variables. This is considered by Rauscher (1997, 141-142) and Antweiler/Copeland/Taylor (1998). Both of these approaches are algebraic and rather technical. This can be avoided by a simple verbal argument based on the Stolper-Samuelson theorem. This theorem states that the price of the factor used intensively in the export industry raises after trade liberalisation and the price of the factor used intensively in the import-competing industry is lower under free trade than in autarky. The Stolper-Samuelson theorem is based on the assumption of fixed factor endowments. Therefore assume that the level of pollution is determined by environmental policy and that the price of the environmental resource is determined in a market for emission permits. This is the standard Heckscher-Ohlin model set-up.

Let us consider a situation where the environmental regulation is optimal in autarky, i.e. the implicit emission tax or the price of a tradable emission permit equals the marginal environmental damage. In a next step the country is opened to free trade. As a consequence the price of the environmentally intensively produced good will rise if this good is exported and it will fall if the good is imported. The Stolper-Samuelson theorem then implies that the prices of emission permits rise if the country exports "dirty" goods and it falls if the country

exports "clean" goods. Let us look at these two types of countries separately. For a moment, income effects are disregarded. Thus, in this first step, I treat marginal environmental damage as being independent of income.

- *The exporter of "dirty" goods.* The price of an emission permit exceeds the marginal environmental damage. This means that environmental regulation must be relaxed. The number of emission permits provided by the government should be increased. Environmental pollution rises. Note, however, that this raises marginal environmental damage. Thus, the resulting price of the emission permit be higher than in autarky. Thus, emissions have increased but implicit pollution taxes are higher than in autarky. If the latter are interpreted as a measure of environmental stringency, then this country uses a stricter environmental policy after trade liberalisation than in autarky.
- *The exporter of "clean" goods.* The price of an emission permit is less than the marginal environmental damage. The government should reduce the number of emission permits. Environmental pollution is reduced. Marginal environmental damage is lower than in autarky and this implies that the resulting implicit emission tax rate is lower than in autarky as well. Emissions are reduced and but environmental policy is laxer than in autarky.

These effects are related to what Antweiler/Copeland/Taylor (1998) term "composition effects". Besides these, there is an income effect. International trade enlarges the consumption possibility set and, therefore, has a positive impact on income. Since environmental quality is a normal good, having a positive income elasticity, one should, *ceteris paribus*, expect tighter environmental policies and lower emissions in all countries. Whether this effect dominates the composition effect in the case of an exporter of "clean" goods is an empirical matter.

Two additional effects have to be considered. First, consumption, too, has a negative impact on the environment. To consider consumption externalities it is more convenient to look at emission taxes than at tradable permits. A country importing goods that are pollution-intensive in consumption consumes more of these goods than in autarky and, therefore, emissions and marginal environmental damages rise. This requires higher emission taxes. The opposite reasoning applies to the country exporting these goods. Domestic consumption is reduced. Due to lower marginal damage, environmental should be reduced. This may be called a "demand composition effect". Second, one should take into account that international transportation is environmentally harmful as well and this requires the introduction of taxes on transportation.

If we now take into account that income does change after trade liberalisation, two additional effects have to be taken into account. On the one hand, there is an increase in the level of economic activity, leading to increasing aggregate emissions. This is the "scale effect". This implies that optimal emission taxes should be reduced. Finally, the increase in income after trade liberalisation has an impact on marginal environmental damage. Since demand for environmental quality is normal, i.e. it has a positive income elasticity, the

marginal environmental damage is raised as a response to the income increase. Environmental regulation should be tightened and emissions be reduced.

Which one of these three effects dominates, is an empirical matter. Thus, it is unclear whether aggregate emissions will rise or fall as a consequence of trade liberalisation and whether or not tighter environmental policies will be employed. What can be said, however, is that the possibility to adjust environmental policies after trade liberalisation reinforces the positive gains from trade in the case of perfect internalisation.

1.5 Environmental Policies in Open Economies

In an small open economy, environmental policy should be designed according to the Pigouvian tax rule. The emission tax or the implicit shadow price of the environmental resource should equal the environmental damage. The reason is that there is only one distortion, i.e. the environmental externality, and this can be taken care of by the appropriate policy instrument, i.e. an emission tax or standard. Moreover, a small country has no power in international markets that it can use to manipulate prices and exploit foreign consumers. Let $D(E, E^*)$ be the damage function depending on domestic and foreign emissions with positive first and second partial derivatives and a positive cross derivative. The optimal emission tax for pollutant i , t_i , equals marginal domestic environmental damage,

$$t_i = D_{E_i} \quad (2)$$

Of course, there is no incentive to internalise foreign environmental damage if the government follows purely national welfare objectives.

Matters are different if a large open economy is considered. This case has been analysed by Markusen (1975) in a general-equilibrium framework and by Krutilla (1991), Lloyed (1992) and Snape (1992) in partial equilibrium. See Rauscher (1997, ch. 5) for extensions of the standard model. What are the effects of a change in environmental policy in such a country. First, if environmental externalities have only small effects on productivity, there is a detrimental effect on output and consumption. Second, there is a positive effect on environmental quality. If the economy were small, the environmental policy should be designed such that these effects cancel out at the margin. In a large open economy, there are two additional effects.

- The first one is a terms-of-trade effect. Tighter environmental policy increases the prices of environmentally intensively produced commodities by more than those of commodities with relatively clean production processes. Thus, the country's terms of trade improve if it is an exporter of "dirty" products and they deteriorate if it is an exporter of "clean" products. Should consumption be the source of the environmental externality, then tighter environmental policies have negative effects on the demand for "dirty" products their world market prices are reduced and this is good if the country under consideration is an

importer of the commodity and bad if the country is an exporter. As an example consider the game between the industrialised countries and the OPEC in the 1970s and 1980s. Of course, the oil price shocks of that time amounted to a terms-of-trade deterioration for the oil-importing countries. For reasons of energy conservation and environmental protection, many of these countries raised their energy taxes which reduced world energy demand, contributed to the erosion of the OPEC cartel.

- The second one is the leakage effect. If world market prices change, this can have an impact on foreign emissions. In the cases of transfrontier pollution and global environmental problems, this change in foreign emissions affects domestic environmental quality and domestic welfare. There are two mechanisms that explain leakage effects. In the case of pollution-intensive production, tighter environmental policies raise the world market prices of pollution-intensive goods. This implies that the marginal value product of the environmental factor of production increases in the rest of the world. If emissions are fixed by environmental policies, e.g. in the framework of a tradable-permits scheme, nothing happens. If however, the foreign country uses emission taxes as its environmental policy instrument, then the wedge between the marginal value product and the emission tax induces producers to utilise more of the environmental resource, and the foreign emissions are increased. The other mechanism is relevant if consumption goods or intermediates such as fossil fuels are traded. Tighter environmental standards reduce the demand for these commodities and, therefore, world market prices. This induces additional demand elsewhere. Both mechanisms discussed here lead to a negative leakage effect. Tighter environmental standards at home lead to more emissions abroad, and this has a negative impact on domestic welfare.

Environmental policy in a large country should take leakage and effects terms-of-trade effects into account. In the two-goods case, the problem the government has to solve is to maximise

$$w = u(F^1 + pX(p), F^2 - X(p), E_1, E_2, E^*), \quad (3)$$

where $u(\cdot)$ is a utility function with the conventional properties, the first two arguments denoting consumption of commodities 1 and 2, where $X(p)$ is the country's exports of commodity 2 and p is the terms of trade, i.e. the relative price of the export good. In the large country case, $X(\cdot)$ depends on the relative price of the export good since domestic exports by definition equal foreign imports and foreign import demand depends on the price. Thus $X'(p) < 0$. The last three arguments are emissions; they have a negative impact on welfare, and this reflects the disutility from environmental disruption. This function is maximised with respect to domestic emissions. Some terms cancel out since the marginal-value products of the other factors are equal across sectors in the Heckscher-Ohlin and since the relative price equals the marginal rate of substitution. The marginal products of emissions then determines the emission tax rates:

$$t_i = D_{E_i} - X \frac{dp}{dE_i} + D_{E^*} \frac{dE^*}{dp} \frac{dp}{dE_i}. \quad (4)$$

Where D_{E_i} and D_{E^*} denote marginal environmental damage measured in terms of the numéraire. The first term on the right-hand side is the direct marginal environmental damage, the second term is the terms-of-trade effect, which can be negative or positive, depending on whether the country is a net exporter or net importer of environmentally harmful goods and depending on whether environmental disruption is caused by production or consumption. This model can be extended easily to encompass consumption externalities (see Rauscher (1997, p. 150)). The following conclusions can be drawn:

- The terms-of-trade term is positive if the country exports commodities that are harmful in production or if it imports commodities that are harmful when consumed or used in downstream production processes.
- The terms-of-trade term is negative if the country imports commodities that are harmful in production or if it exports commodities that are harmful when consumed or used in downstream production processes.

Finally, the third term is the leakage term, and it is always negative.

The following implications can be drawn from this result. Neglecting transfrontier pollution for a moment, it is not clear that countries have incentives to engage in environmental dumping, i.e. to use emission taxes or standards that under-internalise environmental externalities. This depends on their position in the international division of labour. Countries exporting environmentally intensively produced goods by no means benefits from lax environmental standards (an argument which is frequently made by environmentalists) Instead, they should use stricter standards than in autarky. However, given that the impact of environmental regulation on trade is very small empirically (see Section of this essay), its impact on the terms of trade is to be expected to be small as well and the corresponding tax component should be small. Thus, it is rather unlikely that terms-of-trade considerations influence environmental policies. An exception possibly is the energy market, where some countries rely almost completely on imports to satisfy their demand on fossil fuels. In such cases, an environmental tax has the same effect as an optimal tariff. See Snape (1992) for diagrammatical illustrations of this case. The existence of leakage effects leads to environmental dumping. The objective, however, is not to increase the international competitiveness of domestic industries but to reduce transfrontier pollution from abroad. Leakage reduces the benefits of tighter environmental standards because part of the environmental improvement achieved through lower domestic emissions is offset by the increase in foreign emissions.

----- insert Figure 5 about here

It would be interesting to derive more general conclusions by looking at strategic interactions of different countries that use environmental policies that take terms-of-trade and leakage effects into account. However, this is not possible for the general case.⁴ What can be done is to look at the impact of leakage in the case of identical countries. The terms-of-trade component in the optimal tax rate vanishes because there is no trade anymore. Then one can consider a representative large country. This is depicted in Figure 5. The horizontal axis measures emissions, the vertical axis marginal benefits and marginal costs. The negatively sloped line represents the marginal benefit, MB , from increased emissions in terms of higher consumption levels. It has a negative slope due to declining marginal productivities. The positively sloped lines represent environmental damages. The highest line measures total environmental damage in the home country and abroad, the medium line represents damage in the home country only, and the lowest line takes the leakage effect into account: higher emissions at home lead to less emissions abroad. In an international environmental agreement, the optimal emissions level would be E^O , in autarky or in the small country case it would be E^A , and if leakage effects are taken into account, it is E^L . The corresponding emission taxes can be found along the MB curve. A small open or autarchic economy following purely national policy objectives could increase its welfare by reducing emissions and the welfare gain is area a . A large country acting in its own interest, however, would experience a welfare loss measured by b and c if the rest of the world does the same. Leakage effects tend to amplify international externality problems. In the case of transfrontier pollution, a country has insufficient incentives to internalise external environmental effects. If leakage matters, these weak incentives are eroded even further.

1.6 Trade Interventions as an Instrument of Environmental Policy

There are basically four motives for using trade interventions to achieve environmental goals:⁵

⁴ The reason for this is the occurrence of second derivatives of the production function in the first-order condition determining the emission tax rate. It is explained by the fact that the private-sector optimality conditions enter the government's objective function as a constraint. Comparative statics based on the government's optimality conditions then contain third derivatives.

⁵ For a broad overview of "green tariff" issues in theoretical economic framework, see Kraus (2000).

- As a substitute for harmonisation of environmental regulation. Countries with tight environmental standards impose tariffs or other restrictions on the imports of foreign goods that have been produced under less restrictive environmental regulation.
- As a means to avoid or reduce a negative impact of trade on the environment and on economic welfare. If trade is harmful, then trade restrictions must be beneficial.
- As a means to reduce environmental leakage. Leakage results from changes in the terms of trade, and tariffs are the first best instrument to influence the terms of trade.
- As a means to stabilise international environmental agreements. Trade restrictions can be used as sanctions to enforce compliance.

The first type of trade intervention resembles the anti-dumping duty of conventional trade theory, albeit only to a very limited extent. Anti-dumping measures should be based on the dumping margin, i.e. either the difference between the foreign country's home market price and its (lower) export price or the difference by which marginal production costs exceed the price. International differences in environmental regulation constitute differences in production costs but these may be just reflections of differences in factor endowments, i.e. in natural scarcities. Levelling the playing field by creating trade distortions that smooth international differences eliminates comparative advantages that are the basis for gains from trade. See Bhagwati (1996). If foreign environmental regulation does not internalise foreign environmental costs, then this can be interpreted as indirect subsidisation of environmentally harmful production. In this case, the countervailing-duty argument may apply. See Markusen et al. (1995) for a simple geometric representation. If the foreign country uses an export subsidy (or if it relaxes environmental standards in its exporting sectors), then this leads to the deterioration of its terms of trade and to an inefficient extension of its production of the export good. A countervailing duty, i.e. a tariff imposed by the importing country, reduces foreign output of this good and thus re-establishes global efficiency. Moreover, the domestic terms of trade are even further improved. In the extreme case, the foreign subsidy plus domestic countervailing duty has the same effect as free trade plus a lump-sum transfer from the foreign to the home country. It should be noted, however, that the domestic motive for the trade intervention is a simple terms-of-trade argument, which is not related to environmental issues and which applies only in the large-country case. In the small-country, case tariffs are always harmful at least as long as there are no other distortions in the domestic economy

If there are distortions, then second-best considerations apply. If, for instance, the domestic environmental regulation is non-optimal, then trade interventions may be beneficial. This can be seen from Figure 2. If the country with sub-optimal environmental regulation is worse off after trade liberalisation, it benefits from restricting international trade. However, the trade restriction is not the first-best instrument here. The appropriate intervention would be to use the right environmental policy that correctly accounts for environmental scarcity. Thus, the negative-gains-from-trade argument is ultimately not convincing.

Green tariffs are appropriate instruments for assessing pollution leakage effects. It has been argued earlier that leakage effects are caused by changes in relative world market prices caused by changes in a country's environmental policy. The optimal instrument to assess relative prices on international markets, i.e. the terms of trade, is the optimal tariff. This is intuitive but it can also be shown algebraically. See Markusen (1975) for the first derivation of the result. An optimal environmental policy in the presence of trade interventions can be characterised as follows.

Environmental externalities should be internalised by Pigouvian taxes, i.e. the tax rate should equal the marginal domestic environmental damage: $t_i = D_{E_i}$. Moreover, in a two-sectors economy, the tariff rate, τ , in a two-sector model is determined by

$$\tau = \frac{X(p)}{X'(p)} + \frac{D_{E^*}}{X'(p)} \frac{dE^*}{dp} \quad (5)$$

See Rauscher (1997, 151). The first component is the classical optimum tariff depending on the shape of the foreign import demand curve. $X(p)$ denotes exports. Thus if $X(p) < 0$, then this means that the commodity is imported and $X/X' > 0$ is related to the foreign country's export supply elasticity. This is well-known from the trade literature. The second component is the leakage component. p is the relative price of the country's export good. If an increase in this price reduces emissions, i.e. if $dE^*/dp < 0$, then the tariff rate is increased by transfrontier pollution. If, an increase in the price, rises emissions, the tariff rate is negatively affected by pollution leakage. Of course, the size of the tariff rate depends on the significance of transfrontier pollution, i.e. on the marginal environmental damage caused by foreign emissions in the home country, D_{E^*} . In higher-dimensional models, with more than two goods, a system of trade taxes should be introduced, but the basic conclusion remains the same. The practical policy implications of this equation are the following ones:

- *Pollution intensive production.* If production is the main source of the environmental problem and if the home country is an importer of pollution-intensive goods, then it should use an import tariff. This reduces the world market price for the pollution-intensive good and, therefore, reduces foreign production of these goods. If it exports these goods, it should subsidise its exports for the same reason.
- *Pollution-intensive consumption.* If consumption (or downstream use) of traded commodities is the major source of the environmental problem, policy implications are different. If the country is the importer of the pollution-intensive consumption good, it should subsidise imports. This raises the world market price and thus has a negative effect on foreign demand. If it exports this good, it should tax exports in order to raise the price and reduce foreign consumption.

One should mention that this type of environmental policy is only second best from a global perspective. The first-best solution is to use environmental policies and abandon trade interventions. If an agreement on the first best is impossible, then the use of tariffs plus

national Pigouvian tax policies creates two distortions. First, since each country internalises only domestic externalities and neglects the transfrontier effects of its emissions, there is an international prisoners' dilemma in environmental regulation. Second, since countries use trade taxes, the price system is distorted.

As a fourth argument in favour of trade interventions, the sanction argument is often used. Trade restrictions might be used to enforce international environmental agreements by punishing non-compliers. A problem with sanctions is that they are often not credible since they do not only harm the non-compliant but also the country that imposes them. The leakage argument, however, shows that trade interventions can be in the genuine interest of the country implementing them. Assume that the country under consideration becomes an importer of environmentally intensively produced good when it signs the agreement. An import restriction would have two effects: it would improve its terms of trade and it would be the appropriate instrument to cope with pollution leakage. Thus, trade restrictions would be credible. In contrast, consider a country importing goods that are environmentally harmful when consumed or used in downstream production processes. A trade restriction would have a positive effect on the terms of trade but would obviously aggravate the leakage problem. Thus, in such a situation, the use of trade restrictions might not be credible.

2 Imperfect Competition, International Trade, and the Environment

A major innovation in international trade theory in the 1980s was the consideration of imperfect competition. This has been surveyed by Helpman (1984), Helpman/Krugman (1985,1989), Kierzkowski (1987), Krugman (1988a), Vousden (1990, chs. 5-7) and by Krugman (1995). Models involving imperfect competition can explain phenomena that have been left unexplained by the traditional trade theories based on perfect competition and additional assumptions à la Ricardo or à la Heckscher-Ohlin. An example is intra-industry trade, i.e. trade in similar commodities amongst similar countries. Moreover, some of these models have arrived at policy implications contradicting those derived from earlier models.

Besides the consideration of non-competitive markets, the new trade theory models left the general-equilibrium framework that had been the standard tool of trade theory before. Instead of looking at interdependent factor and goods markets, one looks at partial equilibria and market interactions and income effects of policy changes are neglected. Finally, the new trade theory is quite eclectic. There is no unified framework like the many-countries, many-goods, many-factors version of the Heckscher-Ohlin and Ricardo models but a collection of rather diverse models that often do not have much in common. The environmental-economics literature has taken a similar direction and has incorporated models and tools of modern microeconomic theory in general and of industrial organisation in particular like those discussed in Tirole (1988). I will present three type of modelling frameworks, the monopoly, the oligopoly, and the monopolistic competition model.

2.1 The monopoly case

The introduction of monopoly into the environmental economics literature is due to Buchanan (1969). This paper shows that the use of emission taxes may lead to welfare losses. The monopolist supplies less than the optimal quantity and the supply is reduced by even more by stricter environmental policies. The improvement of environmental quality can be offset by a loss of consumer surplus. This is a typical second-best result. There are two distortions, the environmental externality and the non-competitive market structure, and they would require two policy instruments. If the appropriate instrument to increase the output of the monopolist firm (e.g. a subsidy) is not available, the second-best emission tax will be biased downwards to raise the monopolist's supply.

Second-best considerations of this kind are also relevant if a monopolist is involved in foreign trade or competes against foreign suppliers in the domestic market.

- Investigating the use of tariffs in the case of a foreign monopolist supplying a domestic market, Brander/Spencer (1984) argued that a tariff might also serve the purpose of shifting some of the monopolist's profits back to the home country. Environmental policies use instruments that can be used as a substitute for the tariff and, therefore, may serve the same purpose. Rauscher (1997, 163-166) shows that an environmental consumption tax exceeding the marginal environmental damage to can be used shift profits from a foreign monopolist to the domestic economy. Moreover, the optimal tax rate contains a term addressing transfrontier pollution generated by production activities of the firm abroad if this is a relevant problem. The latter component can be positive or negative depending on the technology used by the foreign firm. The first component of the optimal tax rate is a hidden tariff used for shifting profits to the home country like in Brander/Spencer (1984).
- A domestic monopolist selling in the foreign market only should be regulated by Pigouvian taxes, that internalise environmental externalities. This can be explained by the fact that the monopolist exploits only foreigners, whose interests are not represented in the domestic government's objective function. See Rauscher (1997, 167-168). If the firm sells in the home market as well, environmental taxes should be relaxed since the Buchanan (1969) argument applies.
- In the case of an import-competing monopolist, Buchanan's (1969) argument applies again. The behaviour of a monopolist with a competitive fringe does not differ in a substantial way from that of a monopolist without a fringe. The marginal revenue exceeds the price, domestic consumers are exploited (probably to a lesser extent than without the presence of a fringe) and the environmental policy is used to correct this externality.

2.2 International Oligopoly and Strategic Environmental Policy: The Nash-Cornot Model

Strategic trade policy in general and export subsidisation in particular have been central issues of the trade-policy debate since the mid 1980s. Strategic trade policy seemed to provide strong arguments in favour of trade interventions and industrial policy supporting the neo-mercantilist view that exports are good (and imports are bad). Moreover, it seemed to offer explanations for the success of the Japanese economy after the second world war, which has

often been attributed to an active government policy of export promotion. The original model of export subsidisation had been developed by Brander/Spencer (1985). They use a partial-equilibrium model in which two firms, a domestic and a foreign one, compete in a third country's market. The competition is of the Nash-Cournot type. It is shown that export subsidies given by the home government can induce an increase in domestic profits which is larger than the subsidy. The explanation is that subsidies provide incentives to increase output and this shifts the Nash-Cournot equilibrium to the Stackelberg point where the firm enjoys the benefits of market leadership. Two caveats must be mentioned in respect to this policy. First, the policy recommendations of the theoretical model are not necessarily applicable to the real world. The Brander/Spencer model is based on a number of particular assumptions (e.g. Cournot instead of Bertrand competition, perfect knowledge, no retaliation by the foreign government, etc.) and the results turn out to be sensitive to changes in these assumptions. See Grossman (1987) and Brander (1995). The second problem is that export subsidies are considered as a practice of unfair trade by other countries and they may have an incentive to retaliate by using countervailing duties. Alternative policy instruments may be more useful if they help to disguise strategic export subsidisation. One possibility is public funding of export-related research and development. Spencer/Brander (1983) show that this policy leads to similar conclusions as a direct subsidy. Another possibility is to disguise subsidies by giving them in terms of lax pollution abatement requirements. This reduces production cost and has an effect similar to direct subsidisation. This strategic environmental policy has been considered by Ulph (1992), Conrad (1993, 1996), Barrett (1994), and Kennedy (1994). Ulph (1997a,b) provides for a survey on the subject.

A very clear and accessible exposition of the strategic environmental policy argument has been presented by Barrett (1994). His model is extended here by the consideration of transfrontier pollution. For similar approaches see David Ulph (1994) and Rauscher (1997, 181-186). Assume that a domestic and a foreign firm compete in a third country's market. This assumption is made (i) to concentrate on export-related subsidisation and (ii) to simplify the analysis by disregarding consumer surplus.⁶ In the first stage of the game, governments set the emission targets. Afterwards the firms decide on their outputs. Assuming subgame perfection, the game is solved in the usual backward fashion. Profits are

$$\pi = p(q, q^*)q - c(q, E), \quad (6)$$

$$\Pi = p^*(q, q^*)q^* - c^*(q^*, E^*). \quad (6^*)$$

$p(q, q^*)$ and $p^*(q, q^*)$ are inverse-demand functions, i.e. the prices of domestic and foreign goods, p and p^* , depend on the output levels, q and q^* . As a special case, one may assume that the domestic and the foreign goods are perfect substitutes and that their prices are identical. E and E^* are the levels of environmental regulation at home and abroad,

⁶ For models in which the third-country assumption is relaxed, see Conrad (1993, 1996) and Kennedy (1994).

respectively.⁷ The cost functions $c(.,.)$ and $c^*(.,.)$ are increasing and non-concave in quantities and decreasing in emissions.

The first-order conditions for an optimum are

$$p_{qq}q + p - c_q = 0, \quad (7)$$

$$p^*_{q^*} q^* + p^* - c^*_{q^*} = 0. \quad (7^*)$$

Marginal revenues equal marginal costs. Assume that the second-order conditions are satisfied, i.e. $p_{qq} < 0$ and $p^*_{q^*} q^* < 0$. The comparative-static results are obtained by application of Cramer's rule to

$$\begin{pmatrix} \pi_{qq} & \pi_{qq^*} \\ \pi^*_{qq^*} & \pi^*_{q^*q^*} \end{pmatrix} \begin{pmatrix} dq \\ dq^* \end{pmatrix} = \begin{pmatrix} c_E dE \\ c^*_{E^*} dE^* \end{pmatrix}. \quad (8)$$

As usual, we assume that the cross derivatives of the profit functions are negative and the determinant of the matrix on the left-hand side, Δ , is positive. Then, the reaction functions, $q=R(q^*,E)$ and $q^*=R(q,E^*)$ are negatively sloped in the (q,q^*) space and that the domestic firm's reaction curve is steeper than the foreign firm's curve. This is depicted in Figure 6. See Dixit (1986) for a comprehensive discussion of the properties of the Cournot-Nash equilibrium. The Nash equilibrium, N , is the point of intersection of the reaction curves, R and R^* . Moreover, the domestic and foreign firm's iso-profit curves are depicted in this diagram. Everything else being equal, a firm would be better off if its rival reduced its output. The shaded area depicts the potential of profit increases that can be achieved by cooperation, i.e. cartelisation. . If the domestic firm were the Stackelberg leader, it could attain point S where it maximises its profits for a given reaction function of the foreign firm. In the simple Brander/Spencer (1985) model, this is achieved by export subsidisation. As an alternative to direct subsidies, the government can support its firm by low abatement requirements. Changes in environmental policy affect the location of the reaction curve. Laxer environmental standards induce an outward shift: for any given output of the rival, the firm's output is increased. This is shown for the home country by the by the dashed line.

As a reference case, a situation is considered in which the government does not behave strategically. It does not take account of the possibility of shifting profits to the domestic supplier from abroad. The impact of domestic environmental policy on foreign output is disregarded. The domestic firm is treated like a monopolist selling in the foreign market only and it has been argued in the preceding section that the optimal regulation in this case is a Pigouvian tax, i.e. $t=d_E$ or $t^*=d^*_{E^*}$. If both countries coordinated their environmental policies and used very strict standards this would lead to an increase in profits :producers would reduce their outputs and profits could be increased at the expense of consumer surplus in the third country.

----- insert figure 6 about here

⁷ A problem with these environmental standards is that they are firm-specific. Other firms that discharge the same pollutant but are operating in other industries without oligopolistic market structure.

Let us now introduce strategic aspects in environmental policy making. The domestic government's objective is to maximise domestic profits minus environmental damage, $\pi(q, q^*, E) - d(E, E^*)$. Differentiation with respect to E and the use of the firm's first-order condition, $\pi_q = 0$, yield the optimal environmental policy:

$$t = -c_E = d_E - p_{q^*} \frac{dq^*}{dE} - d_{E^*} \frac{dE^*}{dq^*} \frac{dq^*}{dE}. \quad (9)$$

The emission tax rate or shadow price of the environmental resource equals the marginal abatement cost ($-c_E$). On the right-hand side, there are three terms. The first one is the domestic environmental damage. The second term is a rent-shifting effect. Laxer environmental standards reduce foreign output and this raises domestic profits. Rents are shifted from abroad to the domestic firm. The rent-shifting effect reduces the optimal emission tax rate. Finally, there may be a leakage effect. Since tighter domestic environmental standards induce an expansion of foreign output, the foreign firm may have incentives to increase its emissions. This is possible, if the foreign environmental policy uses an output-related emission standard, i.e. if dE^*/dq^* is constant, or if the foreign emission tax rate is given.⁸ The home country is hurt by this if there is transfrontier pollution. The leakage effect, thus, implies a further reduction of the emission tax rate. The same three effects can be derived for the foreign country. The conclusion is that strategic use of environmental policy in oligopolistic markets leads to ecological dumping: emission taxes are lower than marginal environmental damage.

It can be shown that such a strategic emission tax in general does not establish Stackelberg leadership. If transfrontier pollution is negligible, the equilibrium is located between the Nash and the Stackelberg points in Figure 6. The underlying reason is that, unlike an output subsidy, a modification of environmental policy generates an additional distortion: the marginal social cost of pollution exceeds the marginal benefit to the firm if the tax rate is reduced to a level lower than the Pigouvian tax rate. See Barrett (1994), Rauscher (1997, 185), and Walz/Wellisch (1997). Thus, the relaxation of environmental policy is only second best compared to a direct export subsidy. If the input of a factor of production (e.g. an environmental resource) is subsidised to promote exports, a deadweight loss has to be taken into account compared to a situation where the correct instrument (an export subsidy) is chosen. The marginal deadweight loss is increasing with the rate of subsidization and, therefore, the welfare maximum is attained at a lower level of exports. Thus, the Nash equilibrium with strategic choice of emission taxes is located between N and S in figure 6.5, for instance in point E . If leakage effects are substantial, then the new Nash equilibrium is moved further to the right, possibly even beyond the Stackelberg point, depending on the strength of the leakage effect.

⁸ If the foreign emission tax rate is given, then this implies that $c^*_{E^*}$ is given. Total differentiation of this and the foreign firm's first-order condition with respect to output then gives the results that foreign output and emissions are increased if the domestic firm reduces its output.

It should be noted that the policy recommendation of laxer environmental standards than in the competitive case depends on the assumptions made in this model framework and, unfortunately, changes in the assumptions may lead to drastically different results.

One first problem here is retaliation. Just as the home government supports its firm by means of lax environmental standards, the foreign government can also use environmental policy strategically. This may result in a rat race where each country responds to lower emission taxes abroad by reducing its own emission taxes. Each government responds to a reduction in foreign emission taxes by relaxing its own environmental policy. The shapes of the reaction functions in this game amongst the governments are indeterminate in the general case; it is, however, plausible that their slopes are negative and that an equilibrium with positive tax rates exists. Nonetheless, these taxes are too low and at least one country is worse off compared to a situation in which each country does not behave strategically but only internalises the externalities created by its own firm.

2.3 Strategic Environmental Policy: Variations and Extensions

The basic model of strategic environmental policy has been extended and modified in various respects. As the original Brander/Spencer model has turned out to produce results that are highly sensitive to variation in the underlying assumptions of the model, the policy implications derived from the Nash-Cournot model discussed in the preceding section are rather unstable. See also Grossman (1986) and Brander (1995) for surveys of the critique of the Brander/Spencer model. We will look at several extensions and variations of the basic model.

- *Price competition.* Oligopolists do not always choose quantities as their strategic variables. If the commodities that they produce are only loose substitutes, it may be more realistic to assume price competition à la Bertrand. Eaton/Grossman (1986) have shown that the policy implications derived from the Nash-Cournot model are reversed if prices instead of quantities are used as strategic variables. This conclusion carries over to the environmental-policy model as has been shown by Barrett (1994). Let $q(p, p^*)$ and $q^*(p, p^*)$ denote the demand functions for the domestic and the foreign good, respectively, having the conventional properties. Domestic profits are

$$\pi = pq(p, p^*) - c(q(p, p^*), E) \quad (10)$$

The first-order condition is derived by maximisation with respect to the price, p . The same is done by the foreign firm, and the comparative statics are determined by

$$\begin{pmatrix} \pi_{pp} & \pi_{pp^*} \\ \pi_{pp^*}^* & \pi_{p^*p^*}^* \end{pmatrix} \begin{pmatrix} dp \\ dp^* \end{pmatrix} = \begin{pmatrix} c_E dE \\ c_{E^*}^* dE^* \end{pmatrix}. \quad (11)$$

If the profit functions are strictly concave in prices, if the cross derivatives of the profit function are negative and if the determinant of the matrix on the left-hand side of the equation is positive, which is the standard case, then the reaction functions are positively sloped in the (p, p^*) space,⁹ the domestic firm's reaction curve is steeper than the foreign firm's curve and a tighter environmental standard leads to an outward shift of the domestic curve. As a result, both prices increase. It is possible to show that firms benefit from rivals' price increases. It follows that a policy which raises prices is beneficial to both firms. The optimal environmental policy is determined by

$$t = -c_E = d_E - \pi_{p^*} \frac{dp^*}{dE} - d_{E^*} \frac{dE^*}{dp^*} \frac{dp^*}{dE}. \quad (12)$$

Again, there are three terms, the marginal environmental damage, the strategic aspect, and the leakage effect. The strategic component is positive: lower domestic emissions induce foreign price increases and this is beneficial to the domestic firm. The sign of the third component, the leakage effect, is indeterminate. Thus, if the transfrontier pollution problem is negligible, the optimal policy is to tighten environmental standards and taxes beyond the Pigouvian level. The underlying reason is that the use of prices as strategic variables generates too much competition, and the intensity of competition can be mitigated by policies that increase production costs such as strict environmental standards.

- *More than two firms.* The number of firms is also a decisive variable. If there is more than one domestic firm, then cartelisation is beneficial. Like in the competitive model, the potential market power of the export industry can be brought into effect by higher emission taxes. This reduces domestic output and, thus, induces cartel-like behaviour. See *Barrett* (1994). Basically, this is a terms-of-trade argument. The terms-of-trade improvement must be weighed against the profit-shifting motive, and the policy implications become unclear.
- Domestic consumers have been neglected in this model since it has been assumed that the output is exported to a third country. If consumer surplus is taken into account, then some of the result change. In the Bertrand price competition model, a tight environmental policy raises prices and causes losses of consumer surplus. This mitigates or reverses the policy implications. In the Cournot model, the effects are unclear since the change in environmental policy moves the domestic and the foreign supplies into opposite directions: laxer taxes and standards raise domestic supply and reduce foreign production. If the home-market effect dominates (as it does under realistic parameter constellations) this provides an additional incentive to relax environmental standards. See *Conrad* (1996) and *Kennedy* (1994) for models that take account of the demand side. *Kennedy* considers an intra-industry trade model of the *Brander* (1981) type with two identical countries and

⁹ Or, using the terminology of *Bulow/Geanakoplos/Klemperer* (1985), prices are strategic complements.

$n \geq 1$ firms in each country. Although n may be large, terms-of-trade effects do not occur: net exports are zero since the countries are identical.

- *Retaliation.* If the home country relaxes environmental standards to shift rents from abroad into the domestic economy, the foreign country can retaliate. In the symmetric case, both countries are worse off in an equilibrium with environmental-policy competition than without. See Rauscher (1997, 185-186) and Walz/Wellisch (1997). The underlying reason is that both countries relax environmental policies, outputs rise, and prices decline. This benefits consumers in the third country but harms producers and the environment in the exporting countries. If countries are asymmetric, then it is possible that one of the countries is better off with relaxed environmental policies even though the other country retaliates.
- *Trade liberalisation.* Walz/Wellisch (1997) consider the effects of trade liberalisation in a slightly modified Nash-Cournot model. They interpret trade liberalisation as a reduction of instrument set of the policy maker. Tariffs and other trade interventions become unavailable after liberalisation. In the case of strategic trade policy, the first-best instrument, an export subsidy, is abandoned when a free-trade agreement is signed, and the second-best instrument, the environmental policy has to be used. In a first step, this leads to laxer environmental standards in both countries: trade liberalisation as defined by Walz/Wellisch harms the environment. However, trade liberalisation increases welfare. The underlying reason is that compared to the export-subsidy, the emission tax is more costly to use due to additional distortions. Thus, in the Nash equilibrium the use of environmental policies generates less competition amongst governments than the use of export subsidies. Thus, restricting the instrument set available to the policy maker turns out to be beneficial in the resulting Nash equilibrium. As a caveat, one may add that this result requires some degree of symmetry of the two countries. It does not necessarily generalise to the case of asymmetric countries.
- *Strategic behaviour of firms.* In the standard model producers just vary prices or quantities. Additional variables are often available, however. Ulph (1992), for instance, considers a model where firms choose outputs after having decided on their capital stocks. He shows that governments have incentives to use environmental standards rather than taxes. This is explained by the fact that a government by setting such a standard precommits the level of its domestic producer such that the other producer is discouraged to behave strategically. This model is extended by a more general formulation of the technology and by the consideration of domestic consumption in Ulph (1996b). There, it is shown that this result may be reversed. Taxes may Pareto-dominate standards. However, the resulting Nash equilibrium is a prisoners' dilemma. Both countries would be better off, had standards been chosen instead of taxes. In a similar paper, where strategic behaviour of producers is modelled by investing in research and development, Ulph (1996a) shows that strategic behaviour of firms reduces the incentive for governments to relax their environmental policies. This can be explained by the fact that firms can at least partially precommit themselves to higher outputs by using their strategic variable in an

earlier stage of the game. This implies that the government intervention can be smoother. Moreover, he shows that distortions in environmental policy and research and development are larger in the case of taxes than in the case of standards. Like in the other paper, both countries are better off with standards than with emission taxes.

- *Innovation, competitiveness, and strategic environmental policy.* Tighter environmental standards and taxes may induce research and development towards new environmentally friendly technologies and products. This has been modelled by David Ulph (1994) for the case of process innovation and by Rauscher (1997,193-201) for the case of product innovation. Both papers arrive at the conclusion that even though the oligopolists behave according to the Cournot conjecture there exists a possibility that optimal environmental policies over-internalise environmental externalities. The critical parameter is the shape of the R&D success function. If tight emission standards or taxes induce substantial research and development, then one should employ strict policies. A generalisation of the model is investigated by Ulph/Ulph (1996), where environmental research and development and normal process research and development are analysed jointly and the results derived by Ulph (1994) are confirmed. Similar results are reported by Rauscher (1997, 1993-207), who looks at product standards.. Tighter environmental product standards may serve as a precommitment device to gain a larger share of the high-quality product market. This works if the major cost component is the research and development but not the production cost of the environmentally friendlier product. Using similar models as the two mentioned here, Reitzes (1992) and Motta/Thisse (1993) come to unambiguous conclusions regarding strategic environmental policies. These models, however, are based on rather idiosyncratic specifications of demand and cost functions that rule out many otherwise possible scenarios.
- *General equilibrium.* Rauscher (1994a) embeds a strategic-trade-policy model into a general-equilibrium framework. It is shown that even with a Cournot-Nash specification of the oligopolistic industry the emission tax rate may be higher than the Pigouvian tax rate. This is to be explained by general-equilibrium repercussions in a multi-sector model involving non-tradable commodities.

On the whole, these extensions show that strategic environmental policies applied to oligopolistic industries arrive at rather ambiguous or even contradictory results. In some cases, environmental policy should be relaxed, in others, they should be tightened. If the policy recommendation is a tightening of environmental standards, can this be interpreted as a theoretical foundation of the Porter (1991) hypothesis that strict environmental policy is good for competitiveness? In some cases it can, in others not. In the Bertrand-competition scenario, strict environmental policies are advisable. However, not because they improve competitiveness. Rather on the contrary, in the Bertrand case, there is too much competition and the government raises welfare by reducing competitiveness of its producer. This can be seen from the fact, that the foreign firm gains from the introduction of stricter domestic standards. Matters are different in the case of environmental innovation. Tighter standards may serve as a precommitment device that induce firms to credibly engage in research and development

towards new abatement technologies or new products. However, the results are ambiguous and depend on the parameters of the model. Therefore, a general Porterian policy conclusion cannot be drawn.

2.4 Monopolistic competition and intra-industry trade

About half of the global commodity trade is intra-industry trade, i.e. trade in similar commodities and among similar countries. This trade cannot be explained by theories that are based on differences between countries and commodities. Moreover, an explanation of this phenomenon on the basis of partial-equilibrium oligopolistic models à la Brander (1981) or Brander/Krugman (1983) seems to be implausible. The standard models of intra-industry trade now look at general equilibria. It is assumed that there are increasing returns to scale, free market entry, and, therefore, monopolistic competition like in Chamberlin (1933). There are basically two modelling approaches to intra-industry trade:¹⁰ the love-of-variety approach developed by Krugman (1979,1980) and Dixit/Norman (1980) based on the Spence (1976) and Dixit/Stiglitz (1977) models of monopolistic competition, (2) the specific-preferences approach by Lancaster (1980), and Helpman (1981) based on Hotelling's (1929) model of spatial competition. These models have only rarely been used in environmental economics, probably because they are difficult to handle. An exception is Rauscher (1997, 201-212). The approach is love-of-variety.

There is a differentiated commodity with potentially infinitely many varieties. Only a finite number of varieties is actually produced, n in the home country and n^* abroad. For simplicity, assume that the demand sides of the two countries are identical. All commodities are produced with the same technology and they are equally desirable from the point of view of the consumers. Consumers like variety and their love of diversity is introduced via a particular utility function, which is composed of identical sub-utility functions for each variety:

$$u(q_1, \dots, q_N) = \sum_{i=1}^N q_i^\theta, \quad (13)$$

where q_i is the quantity consumed of commodity i , N is the number of commodities available and θ is a preference parameter, $0 < \theta < 1$. $(1-\theta)^{-1}$ is the elasticity of substitution between two of these commodities expressed in absolute terms. It makes sense to assume that substitution possibilities for consumers are improved if the number of goods is raised, i.e. $\theta'(N) > 0$. Based on these assumptions, one can derive demand functions for all commodities like in Dixit/Stiglitz (1977) such that $p_i = \phi q_i^{\theta-1}$ where ϕ is a parameter which is taken as given by

¹⁰ See also Greenaway/Milner (1986, chs. 2-3) for an overview.

the firms.¹¹ All domestic producers are identical in all respects except in the designs of their products. Thus, we can drop the subscript i for the price. Output is a concave function $F(\cdot, \cdot)$ of variable capital K_i and emissions E_i having positive partial derivatives, negative second partial derivatives, and a positive cross partial derivative. A third input is not considered for the sake of convenience. The rental rate of capital, r , is taken as given by each firm. Increasing returns to scale are introduced by assuming some fixed capital K_0 which has to be installed before any production can take place. Thus, a representative firm maximises $\pi = pF(K_i, E_i) - r(K + K_0)$ with respect to K_i . The first-order condition is that of a monopolist in the goods market. There is a mark-up over marginal cost, which depends on the price elasticity of demand. Moreover, free market entry guarantees that profits are zero in equilibrium. Finally, it is assumed that the total capital stock of the economy, K , is fixed. Given that the foreign economy is of the same monopolistically competitive type with the same consumer preferences, the equilibrium in the two economies is characterised by:

$$F - \theta F_K(K_i + K_0) = 0, \quad (14)$$

$$n(K_i + K_0) = K, \quad (15)$$

$$F^* - \theta F_{K^*}^*(K_i^* + K_0^*) = 0, \quad (14^*)$$

$$n^*(K_i^* + K_0^*) = K^* \quad (15^*)$$

The first of these equations characterises the competitive monopolist on the supply side. It is derived from the zero-profit and the first-order condition. The marginal product is larger than the average product. The second equation represents the factor-market equilibrium: the number of firms times the capital demand per firm is the supply of capital. The other two equations state this for the foreign country. Interestingly, these four equations determine the equilibria of the economies in autarky and with free trade. In the latter case, additional conditions are needed to determine the terms of trade but this is not considered here.

Consider first a move from autarky to free trade. If the demand parameter, θ , is constant, not much happens: the supply side remains unchanged but intra-industry trade is generated because consumers demand additional variety. Foreign goods are demanded by domestic consumers and domestic goods are demanded by foreigners. See Krugman (1980). If θ is increasing in the number of goods, i.e. if demand for each individual variety becomes more elastic as the number of varieties is increased, then there will be a concentration process and some of the $n+n^*$ firms will have to leave the market. If the environmental regulation aims at keeping the emissions of the whole industry constant, then environmental quality remains unchanged. If the regulation is such that emissions per firm are fixed, then the reduction of the number of firms has a positive effect on the environment. Thus, the gains

¹¹ This is not an innocent assumption as Hejdra/Yang (1993) and Yang /Hejdra (1993) have shown.. The main conclusions to be drawn from the model, however, are not affected by this simplification

from trade have three components: increased variety, lower prices and better environmental quality. However, if consumption is environmentally harmful as well. Finally, if the environmental policy instrument is an emission tax and the emission tax rate is constant, then the pollution level tends to increase since the total output of the industry increases. See Rauscher (1997, 207). Finally, the aggregate consumption level increases (concentration reduces the fixed-costs share in the economy and this rises aggregate output).

The effects of trade policy in open economies in the monopolistic-competition trade model have been explored only to a limited extent. Work by Lancaster (1984) and Gros (1987a,b) on the effects of trade policy in intra-industry trade models suggests that environmental policies tend to have terms-of-trade effects even for the small country case. This can be explained by the fact that each country, even a small one, enjoys monopolistic market power in its export market since each variety is produced by only one firm/country. From this, one may conjecture that strict environmental policies always have positive terms-of-trade effects since they raise the relative prices of the exported goods. Thus, welfare-maximising countries should tax emissions at higher than the Pigouvian rates. This would be the opposite of ecological dumping.

Leakage effects can have unexpected signs in the intra-industry trade model. See Grtzgen/Rauscher (2000). Tighter environmental policies in the home country have two effects on competitive monopolists. On the one hand, they are cost-increasing and, therefore, tend to induce exit of existing firms. There is a countervailing effect, however. Tighter environmental standards raise marginal cost and this implies that, for a given mark-up factor, the monopolist charges a higher price. This price effect has a positive impact on profits and this may induce new producers to enter the industry. The resulting net change in industry structure is ambiguous. Depending on the parameters of the production and cost functions, there will be entry or exit on the domestic supply side. If there is exit, then the number of varieties is reduced, the price elasticity of demand rises, foreign profits rise, and new producers enter the foreign industry. This leads to an increase in foreign emissions. Matters are different, if strict environmental standards induce additional entry into the domestic industry. The price elasticity is reduced, foreign profits shrink and foreign firms leave the industry. This causes an improvement in environmental quality. It is, thus seen, that the endogeneity of market structure in the intra-industry trade model can produce new and unexpected effects such as a unconventional leakage effect where emissions abroad are reduced after the introduction of stricter environmental policies at home.

On the whole, it seems that the potential of the monopolistic-competition model of international trade for the analysis of trade policies in open economies still remains to be explored. The fruitfulness of employing this tool has been shown in the recent economic-geography literature, e.g. in Fujita/Krugman/Venables (1999), and I think that comparable progress is possible in the area of environmental economics.

3 Political Economy and the Environmental Policy in Open Economies

Most of the theoretical literature in environmental and international economics is concerned with normative issues: what should a benevolent government do to maximise social welfare? A much smaller part of the literature addresses the question why these measures are not taken. In the area of international economics, this has resulted in a substantial body of literature dealing with the political economy of protectionism. See Mayer (1984), Hillman (1989), Magee/Brock/Young (1989), and Grossman/Helpman (1994). Environmental economics, in contrast, has been orientated much more to normative questions. Exceptions are Buchanan/Tullock (1975), Pashigian (1985), Hahn (1989), Aidt (1998). Different approaches to model the political decision making process are possible. On the one hand, there is the median-voter model predicting that a majority decision will not represent the average voter's but the median voter's will. This model can be used to analyse majority decisions in direct democracies. On the other hand, there are lobbying models that analyse political processes in representative democracies.

Only recently has modern public choice theory been applied to issues of international trade and the environment. The main contributions are Oates/Schwab (1988), Hillman/Ursprung (1992, 1994), Hoekman/Leidy (1992), Leidy/Hoekman (1994), Fredriksson (1997, 1999), Rauscher (1997, Ch. 7), and Schleich (1999). The main objective of this literature is to show in which direction the outcome of the political process is likely to deviate from what is being regarded as optimal by welfare theorists. In particular, it is interesting to address the issue of ecological dumping: given that benevolent governments have only limited incentives to engage in ecological dumping, can too-lax environmental standards be explained by the particularities of the political process of environmental-policy formation in open economies? Another issue is the use of environmental regulation as an instrument of disguised protection.

Three approaches to analyse the process of economic and environmental policy formation have been used in the literature. The first one is the median voter model, which is applicable in direct democracies, where the voter herself decides on the issues. This approach has been used by Oates/Schwab (1988) in a model of interjurisdictional competition with mobile factors of production. This model is not really related to international trade and will, therefore, be discussed in the next section. The second approach is based on the idea of an incumbent government which is subject to regulatory capture by powerful lobbies. Traditionally, this has been modelled by using the concept of the political-support function, that has been introduced into the literature by Stigler (1971) and Peltzman (1976). This concept has been considered as being ad hoc until it has been given a behavioural foundation by Coughlin/Mueller/Murrell (1990) and, particularly, Grossman/Helpman (1994), who used game-theoretical concepts from the theory of menu auctions developed by Bernheim/Whinston (1986) to show that political-support functions can be derived from the interactions of lobbies and an incumbent government. The third approach is based on electoral competition influenced by lobbying activities. In this theory, there are competing candidates rather than a single government, and the probability to win the election depends on campaign contributions provided by lobbies representing idiosyncratic interests. The latter two

approaches have their shortcomings, but they are currently the best and most consistent theories available.¹²

Fredriksson (1997) looks at environmental policies in open economies using a model based on the Grossman/Helpman (1994) approach. There are two goods, a clean and a dirty one, and two lobbies, the environmentalists and the unions and "industrialists". Utility functions are quasilinear such that this model, although being, general equilibrium can be equivalent to a partial equilibrium model. Workers and industrialists are interested in consumption only whereas environmentalists have environmental quality as an additional argument of their utility function. The marginal environmental damage is constant. Environmentalists and workers have wage income and a share of redistributed emission taxes and industrialists have profits as an additional income source. The emission tax rate in the political equilibrium depends on the power of the environmentalists and the industrialists. Workers are assumed not to form an active lobby (which is a rather unrealistic assumption). Assume that the tax elasticity of pollution is negative and constant. Then, the green lobby obviously has a positive impact on the tax rate. With increased political influence of the greens, the recognition of their interests in the political process rises and this has a positive impact on environmental taxes. Industrialists influence the tax rate into the opposite direction. The underlying reason is that the wage rate is constant and that the industrialists receive a sector specific factor reward that is inversely related to the emission tax rate. Given these assumptions, the result that emission taxes are increasing in environmentalists' influence and decreasing in industrial interests is intuitive and plausible.

Additional - and less straightforward - insights are gained if the world market price changes. It is shown that in the general case where some of the individuals in society are workers and do not lobby, the emission tax rate is declining in the world market price. The intuition behind this result is that the industrialists' incentive to lobby is increasing in the world market price of the pollution-intensive good. If all individuals are members of lobbies, then the tax rate equals marginal environmental damage, which is constant. Of course an increasing world market price leads to an additional incentive to increase output and, therefore, pollution. If the emission tax is reduced, this effect is reinforced.

Even more surprising results turn up when the tax elasticity of emissions is not constant. Then the redistribution of the tax revenue becomes a decisive explaining variable for the characterisation of the political equilibrium. An increase in green lobbying may under extreme circumstance have a negative impact on the tax rate. The reason is that the greens do not only benefit from better environmental quality but also from an increase in the tax revenue. Thus, if emission taxes reduce the tax revenue drastically, the environmentalist group may be interested in lower taxes. Similar reasoning applies to the impact of the industrialist lobby. In a final step, Frederiksson introduces abatement subsidies as a second, exogenous instrument and shows that higher abatement subsidies may lead to more pollution. The abatement subsidy may induce an output increase and, thus, the industrialists' specific

¹² Austen-Smith (1991) has questioned the microfoundation of the contest success function of the electoral-competition model, and the Grossman/Helpman (1994) model is based on the idea of an enforceable contract between policy makers and idiosyncratic interest groups.

factor income which makes them increase their campaign contributions and gain more influence.

A similar model with two goods and five policy instruments has been analysed by Rauscher (1997, Ch. 7). The lobbies are modelled slightly differently, i.e. the greens are interested in the environment only and the industrialists only consider their specific-factor income. Domestic and foreign goods are imperfect substitutes and cause environmental damage both by being produced and by being consumed. The policy instruments are environmental product standards, consumption taxes, and a domestic tax on emissions from production. The model is solved by maximising a political-support function. If only one policy instrument is available, then the lobby impact is as expected. The greens support measures to clean up the environment, the industrialists those that protect their rents. Green interests and industry interests converge when foreign polluters are regulated by special product standards and tariffs. Environmental protection and conventional protectionism share forces. Some counter-intuitive results are derived for a situation where environmental policy as a whole, i.e. the whole set of environmental policy instruments, is subject to lobbying activities. Interestingly, the industry lobby has a positive impact on environmental production taxes. The reason is that the emission tax has two effects on specific-factor income. The first one is negative: higher production taxes lead to a decline in demand and, therefore, in income of the specific factor. The second one, however, is positive. Higher emission taxes lead to substitution of pollution-intensive technologies by specific-factor intensive technologies. The second effect influences the emission tax rate, to cope with the first effect, the sector-specific factor lobbies for a reduction in consumption taxes. Moreover, for similar reasons, the impact of industry lobbies on domestic environmental product standards is positive.

Particularly, the results derived for the impact of the industry-specific factor are counter-intuitive and perhaps also counter-factual. They are based on the assumption that the government acts completely rationally and always uses the most efficient instrument to provide protection to the interest group. Owners of pollution abatement capital are supported by product design standards and production taxes. Owners of usual production capital are subsidised by means of low consumption taxes but not by means of any other instruments since their use would cause greater income losses to the general public than subsidisation. This looks counter-intuitive and even counter-factual. However, the theoretical model does not predict that industry lobbies are interested in tight standards and taxes but that tight standards and taxes are what they get as a outcome of the political process. Thus, the observed lobbying activities are not a genuine test of such a model.

Schleich (1999) shows that with more than one policy instrument available, it is possible that the increase in specific-factor lobbying power does not necessarily lead to laxer environmental standards. A rational government may find it optimal to serve this lobby by other instruments such as import tariffs

The impact of trade liberalisation on the political equilibrium is investigated by Frederiksson (1999). In the presence of trade distortions the socially optimal emission tax rate deviates from the Pigouvian tax rate. The tariff leads to more-than-optimal polluting production in the economy and this is corrected by a particularly high tax rate. Of course, this tax rate should be reduced if trade is liberalised. Matters are different in a lobbying

equilibrium. If the reduction of the tariff has a contracting impact on the polluting industry, then both the incentives of the environmentalists and of the specific factor to spend resources on lobbying are reduced. The resulting effect on the political equilibrium is ambiguous and depends on the parameters of the model. The polarisation of green and industrialist lobbies measured by the difference in the intensities of lobbying efforts.

A completely different approach to modelling the political process in a trade-and-environment framework is chosen by Hillman/Ursprung (1994). They neither employ the simple political-support-function approach nor the incumbent government model introduced by Grossman/Helpman (1994). Instead they look at a two-country model, where in each country there are two parties or candidates who compete in an election and their probability of success depends on campaign contributions made by different lobbies. Without environmental concerns, i.e. if only industrialists lobby, then the two candidates announce extreme policies. There is political polarisation. The liberal candidate announces free trade and the protectionist candidate announces a prohibitive tariff. In a next step, green lobbying is introduced. Green interest groups are interested in free trade if production is the source of environmental disruption and if they do not care about environmental quality abroad. Otherwise, i.e. if consumption is environmentally damaging or if environmentalists care about pollution in the rest of the world, they favour protectionist policies. It is then shown, that environmentalist lobbying does not affect the outcome of the political process: the polarisation equilibrium is maintained. As an alternative policy instrument, Hillman/Ursprung (1994) analyse voluntary export restraints. With this instrument, the political platforms of the two candidates converge. The reason is that foreign firms support the liberal candidate but foreign firms derive benefits from voluntary export restraints. Thus the liberal candidate can increase her election probability by offering trade protection through voluntary export restraints. This convergence equilibrium can be unstable if environmentalist interests are introduced. If externalities are generated by production activities and environmental damages are substantial. Then the convergence equilibrium in voluntary export restraints vanishes. Two new equilibria arise, a first one where the parties converge to a liberal trade policy and a second one where the parties diverge towards free trade and autarky positions, respectively.

On the whole, the literature on the political economy of environmental policy in open economies is still in its infancy. The Grossman/Helpman (1994) approach has provided useful tools for the investigation of political-economy issues. It has been established that environmentalists often have common cause with protectionist interests expressed by owners of sector-specific factors. Moreover, both groups often have a genuine interest in the regulation of foreign suppliers. However, many questions are still open and unresolved. One aspect is the use of environmental taxes and standards as a non-tariff barrier to discriminate against foreign producers. Environmental protection and environmental protectionism, using the environmental concern only as a pretext to disguise harmful barriers to trade, are difficult to disentangle (Saunders, 1992). An argument behind the use of such trade interventions that are often rather inefficient is obfuscation. See Magee/Brock/Young (1989, ch. 18). The political support a policy maker acquires does not only depend on the gains and losses that accrue to different groups in society but also on the visibility of these gains and losses. From the point of view of the policy maker, inefficient policy instruments may be useful if they allow to hide the costs of distortive policies. For this purpose, environmental quality standards

and technological product standards may be much more useful than price instruments like taxes and tariffs, that make the costs and benefits of a policy measurable and, thus, more obvious. A behavioural model of obfuscation using results from information economics is still missing. See also Rodrik (1994) on this point.

4 International Factor Movements and the Environment

Environmental policies in open economies are affected not only by international trade in final goods but also by international factor movements. In particular, the international mobility of capital has been increased substantially in the 1980s and 1990s. It has been argued that this leads to "environmental capital flight" to pollution havens and, if governments respond to this by relaxing environmental standards, to a race towards the bottom in environmental regulation. This section looks at what has been achieved in the theoretical literature that has applied models of international factor mobility to environmental economics. A survey on the race-towards-the bottom hypothesis can be found in Wilson (1996) and Oates's (1998) survey article on interjurisdictional competition. Nonetheless, I wish to start at an earlier stage and look at what determines international factor movements in the presence of environmental externalities.

The analytical framework of most of this section is the standard model of international factor mobility developed by Jasay (1960), MacDougall (1960), and Kemp (1964, ch. 13) and surveyed by Ruffin (1984). This model produces results that are closely related to those derived in the Heckscher-Ohlin trade framework, that has been the subject of section 1 of this paper. The similarities arise from the fact that international trade and factor movements are substitutes in this framework under standard conditions including perfect competition and absence of market interventions. See Markusen (1983) and Wong (1986). The environment as an additional variable has been introduced into the model by Merrifield (1988) and Baumol/Oates (1988, Ch. 17), and Oates/Schwab (1988). Merrifield (1998) considers international trade and factor movements in a common framework, which is possible since he has more than two factors in his model. Thus his results are a combination of those presented in this section and in the first section of this article. For extensions of these models see Wang (1995) and Rauscher (1997, Ch. 3). Later on, the world of perfect competition will be left and non-competitive market structures will be introduced.

4.1 International Capital Movements and Environmental Regulation under Perfect Competition

We follow Oates/Schwab (1988) in assuming a world consisting of at least two countries or jurisdictions using capital, labour, and environmental resources as factors of production. Capital and labour are the fixed factors of production, environmental resources are available in variable supply where the supply is determined by the government's environmental policy. There is a single commodity which can be traded internationally. Trade is necessary to remunerate internationally mobile factors of production or - loosely speaking - to repatriate

profits. The production function, $F(K,L,E)$, is constant-returns-to-scale, increasing and concave in all arguments, and the cross derivatives are negative as it has been specified in the introduction. Environmental damages are generated by the use of resources in the production process and the environment is a public consumption good. Environmental externalities caused by consumption and externalities affecting factor productivities are not modelled explicitly but will be mentioned. The remuneration of the factors of production is determined by their marginal productivities, i.e. $F_K=r$, $F_L=w$, and $F_E=t$, where r , w and t denote the factor rewards. The welfare of the home country is determined by its output minus the factor reward going to foreign factor owners who have invested in the home country minus the environmental damage, which depends on domestic and foreign emissions:

$$w = F(K, L, E) - r(K - K_0) - D(E, E^*), \quad (16)$$

where K_0 denotes the original capital endowment of this economy.

----- insert Figure 7 about here

Capital moves from countries with a low marginal productivity of capital to the country with a higher productivity. Thus, capital movements may depend on differences in technology or on the availability of the other factors. Since we want to look at differences in environmental regulation assume that everything else is equal. This is depicted in Figure 7, where the total capital endowment of the home country and the rest of the world (indicated by the asterisk) is on the horizontal axis and capital remuneration is measured on the vertical axis. Starting from a situation in which both countries use the same regulation, one of the countries changes its environmental regulation. Its marginal-productivity curve is shifted upwards (as shown by the dashed line in Figure 7). This induces a relocation of capital to this country as can be seen from the shift of the equilibrium point. If environmental externalities on production are small, then this shift is the result of laxer environmental standards. If environmental externalities on production are substantial, the upward movement of the marginal-productivity curve may be due to a tightening of environmental standards. Thus, depending on whether environmental quality is a consumption good or a factor of production, tighter environmental standards reduce or increase competitiveness. As already mentioned in section 1, the environmental policy is determined by the natural abundance of environmental resources, by the willingness and ability of the citizens to pay for environmental quality, and by regulatory and enforcement deficits.

4.2 The Gains from Factor Mobility

The removal of barriers to the functioning of markets is usually regarded as being beneficial. Thus, barriers to factor mobility should be abolished to increase economic welfare. However, this is based on the assumption that there are no other distortions in the economy. If the economy is distorted, second-best considerations apply and the removal of a restriction may turn out to be harmful to the economy. A typical distortion which is interesting in the context of environmental economics is insufficient environmental regulation. Two cases can be distinguished. In the first scenario, emissions are fixed, then the only thing which happens after factor market liberalisation is a movement of the mobile factor to the location where its productivity is higher. This is clearly beneficial. Matters are different if the environmental policy uses instruments that allow emissions to vary. As an example consider an emission tax. The change in the capital stock after factor market liberalisation on domestic emissions is $dE/dK = -F_{KE}/F_{EE} > 0$. Emissions and capital are positively related to each other. The welfare effect of factor market liberalisation follows from differentiating (16):

$$\frac{dw}{dK} = (F_K - r) + (F_E - D_E) \frac{dE}{dK} - D_{E^*} \frac{dE^*}{dK} \quad (17)$$

It is seen that there are three effects of liberalisation. The first is positive since K is increased if the term in brackets is positive and K is decreased if the term in brackets is negative. This is the traditional gain from trade in a factor movements model. The second effect depends on the sign of $(F_E - D_E)$. If the country under consideration attracts capital, then emissions are increased and this is beneficial if the additional production exceeds the additional environmental damage. This is true if the environmental regulation is too strict and over-internalises environmental damages. If the environmental regulation is too lax, then the effect is negative. Finally, there is a leakage effect. Since capital invested in the home country is withdrawn from abroad, $dE^*/dK < 0$. A country attracting capital from abroad benefits from less transfrontier pollution. A country investing abroad is harmed by additional transfrontier pollution.¹³

Additional effects have to be considered if consumption causes environmental harm. If consumption externalities are insufficiently internalised, then the increase in consumption possibilities may be offset by deterioration of environmental quality.

Like in the case of trade in final goods, one can address the question how environmental regulation should be adjusted after a move from autarky or restricted mobility to free factor movements. The first one is an income effect. The efficiency gains from liberalisation raise the income and this should have a positive impact on the demand for environmental quality. In the simple model considered here, however, this effect is excluded by assumption since the welfare function is quasilinear. In a richer model, one would observe

¹³ This was a fear expressed by US environmentalists before the NAFTA agreement with Mexico. It was argued that pollution-intensive industries would move to the Mexican side of the border causing additional transfrontier pollution that would deteriorate environmental quality in the US.

a shift in the damage function. Marginal damage would be increased because it is taken more seriously by the citizens and this would lead to a reduction of emissions. Moreover, there are two opposite productivity effects in the capital-importing and in the capital-exporting countries. In the capital-exporting country, the marginal productivity of emissions would be reduced and this implies that emissions should be reduced. The reduction of emissions can be achieved by a higher emission tax rate. In the capital-importing country, the marginal productivity of emissions is raised. It now exceeds the marginal damage and this implies that more pollution is desirable. Emissions should be raised and emission tax rates reduced. The aggregate effect of factor mobility on emissions is ambiguous in the capital-importing country and negative in the exporting country. Interpreting the exporting countries as industrialised countries and the importing countries as the importing countries, one would identify a environmental benefit in the industrialised countries and ambiguous effects on the environment in the Third World.

4.3 Environmental Policy in Open Economies and Interjurisdictional Competition

In a small open economy without additional distortions, the optimal environmental policy equalises marginal costs and marginal benefits. The emission tax rate should equal the marginal environmental damage. There is no race towards the bottom. Matters are different if distortions are introduced. To make matters simpler assume initially that all jurisdictions are identical. This is an assumption often made in the theory of interjurisdictional competition and fiscal federalism. See Zodrow/Mieszkowski (1986), but also Wilson (1986, 1987), and Wildasin (1988), for example. The assumption leads to the result that factors do not move internationally because there are no factor productivity differentials that can be exploited. *Ex ante*, however, policy makers consider the possibility to influence the factor allocation by their actions and this drives the results.

Some of the results derived in the following sections have been derived by Oates/Schwab (1988), Rauscher (1997, Ch. 3), and Wilson (1997). They will be presented in a common simplified framework and extended in various respects.

4.3.1 The Small Open Economy with Factor Market Distortions

As standard distortion considered in the fiscal-federalism literature is a source tax. Let its rate be γ and let the tax revenue be redistributed in a lump-sum fashion. Such a situation has been considered by Oates/Schwab (1988, 341-345) and Wilson (1997, 407-408). The factor demand equation is changed such that $F_K = r + \gamma$. Producers who employ capital have to pay the world market rate of interest plus the tax rate. Welfare maximisation yields the optimum tax rate on emissions:

$$t = F_E = D_E - \gamma \frac{dK}{dE}. \quad (18)$$

where dK/dE follows from total differentiation of the factor demand equation. dK/dE is positive in the standard case and negative if there are substantial externalities affecting factor productivities. The latter case is not considered here but it can be investigated easily by just turning the arguments around. The optimal emission tax rate has two components. The first one is the marginal environmental damage. The second one is a tax-base effect. Since capital is a part of the tax base, governments wish to attract capital by laxer environmental standards. The Nash equilibrium in which all governments choose such a policy leads to a prisoners' dilemma in which all countries are worse off compared to a situation with Pigouvian taxes. The underlying problem is a fiscal externality known from the tax-competition. By taking actions to increase its own tax base, a government reduces the foreign tax base. This negative externality is not taken into account and the consequence is a prisoners' dilemma. The competition for a mobile tax base leads to less-than-optimal supply of public goods. For an example from the tax-competition literature see Zodrow/Mieszkowski (1986). Of course, the dilemma is due to a restriction on the set of policy instruments: if the capital tax rate could be

chosen freely, then its optimal value would be zero, the fiscal externality would vanish, and the emission tax would equal marginal environmental damage. See Wilson (1997, 409-410).

An variation and extension of this model is considered by Kanbur/Keen/van Wijnbergen (1995), who take country size into account. A large country hosts many firms, a small country only a few. By reducing its environmental standards, the small country attracts many foreign firms which generate a tax revenue which is by assumption larger than the increase in the environmental damage. This net gain is partially offset by the increase in emissions by domestic producers who are only a small number, however. The large country, in contrast, can attract only few firms from abroad and the corresponding net benefit is, therefore, small. The costs of this policy are high, however. Since there are many domestic producers, the pollution level is increased substantially. Thus, everything else being equal, small countries should be expected to have laxer environmental standards than large ones. Like before, this is a second-best result based on the existence of a distortion generated by the tax system.

Another distortion could be created by the use of particular environmental policy instruments that generate rents which are appropriated by the private sector. Using the command-and-control approach, the government does not collect a tax revenue and the scarcity rent of environmental resources is appropriated by the private sector. As long as this does not affect the factor allocation, this is of not much interest. If, however, this rent becomes part of the factor income of the mobile factor, then this policy instrument becomes distorting. This distortion has been discovered by Sinn (1994) and Wellisch (1995). The resource scarcity rent going to the mobile factor is just a subsidisation of the use of this factor. Thus, we have a kind of reversed fiscal externality. Since the use of the mobile factor is indirectly subsidised, capital is not a tax base but a subsidy base and, by analogy, the objective is to drive capital out of the country. If this can be done by tight environmental standards, then the resulting Nash equilibrium is characterised by too-strict environmental policies.¹⁴

A third decision involves majority voting. Assume that there are workers and other individuals earning no wage income. Moreover, assume that the tax revenue is divided between the workers and non-workers such that each group receives a constant share σ . Oates/Schwab (1988, 346-348) show that the workers then prefer a negative tax on capital, i.e. a subsidy. The reason is that they share the burden of paying the cost of attracting capital with the rest of the population but they do not share the benefit that they receive in terms of higher wages. The equation determining the emission tax rate, (19), is changed slightly such that

$$t = F_E = D_E - \sigma \gamma \frac{dK}{dE}. \quad (18)$$

¹⁴ For algebraic proofs see Wellisch (1995) and Rauscher (1997, 81-84). Krumm/Wellisch (1995) derive this result in a more general setting where producers and countries are diverse.

Since γ is now negative, the tax rate is higher than in an undistorted economy. The underlying reason is the same as before. There is a fiscal externality which leads to a deviation of the second-best policy from the first-best policy. If the non-wage earners are the majority, they will determine the policy in a direct democracy. The objective of the non-wage earners is different from that of the workers. They maximise capital-tax revenue minus environmental damage. The optimal tax rate for them is positive. They are interested in maximising the tax revenue. On the other hand, the optimal resource use is determined by

$$D_E = \sigma\gamma \frac{dK}{dE}. \quad (20)$$

The marginal environmental damage should equal the marginal fiscal gains that the non-wage earners derive from an increase in emissions. Whether this tax rate is too high or too low than the first-best emission tax rate depends on the shape of the production function and the non-wage earners' share in the total population.

In a next step, I wish to consider labour market distortions. The most important labour market distortions in the 1980s and 1990s was involuntary unemployment, at least in Europe and many developing countries. There are many theories offering explanations for unemployment, but I want to keep it simple and consider a minimum wage as a binding restriction in the process of wage formation. In such a situation the wage rate is higher than the opportunity cost of time, which is the marginal utility of leisure, $v'(-L)$. Algebraically, $F_L = w > v'$. Extending the welfare function by a leisure term, yields

$$w^L = F(L, K, E) - r(K - K_0) + v(-L) - D(E, E^*) \quad (21)$$

and the optimal emission tax rate is

$$t = F_E = D_E + (v' - F_L) \frac{dL}{dE}. \quad (22)$$

The environmental policy is less restrictive than in the case of no unemployment. Since the distortion, a rigid wage, cannot be overcome, a second-best approach is chosen. There is now a benefit from reducing the tax rate below the Pigouvian tax rate because this increases employment and reduces the welfare cost of unemployment. The unemployment correction term in (22), $(v' - F_L)dL/dE$ however, occurs independently of whether capital is mobile or not. But dL/dE depends on capital mobility. In the case of mobile capital, the effect of a reduction in environmental stringency has two effects whereas it has only one in autarky. In autarky, a lax environmental policy increases the marginal product of labour and this leads to more employment. In the case of unrestricted factor movements, laxer environmental policies attract more capital and the additional capital has an additional impact on labour productivity. Thus, the benefit of relaxing environmental regulation is larger in an open economy than in autarky. One can extend this model by introducing taxes on capital line in Wilson (1997, 413-414). It can be shown that labour market imperfections aggravate the race to the bottom induced by the fiscal externalities arising from taxation of the mobile factor.

4.3.2 The large-country case

Until now small open economies have been the subject of the investigation. In the large-country case, the world market interest rate is not given but can be influenced by the country under consideration. r is endogenous. If there are no market distortions, the capital-market equilibrium is determined by

$$F_K(L, K, E) = r = F_{K^*}^*(L^*, K_0 + K^* - K, E^*). \quad (23)$$

Both domestic and foreign producers take the world market interest rate as given, and in the equilibrium, it equals the marginal product of capital. Assume, moreover, that the home-country takes the foreign emission tax rate, t^* , as given. Note that $t^* = F_{E^*}^*$. This implies that $dK/dE > 0$ and $dE^*/dE < 0$.¹⁵ A stricter environmental policy at home leads to a reduction of the capital stock and to an increase in emissions in the rest of the world. This effect of course requires the absence of significant externalities on production. The second effect is a "leakage" effect. Stricter environmental policies lead to environmental capital flight. Additional capital is employed abroad. This increases the marginal productivity of the environmental resource abroad. With a given emission tax rate in the foreign country, the incentives to use environmental resources are increased and, thus, foreign emissions tend to rise. The world market interest rate now depends on the environmental policy. It can be shown that $dr/dE > 0$. Laxer environmental policies raise the marginal productivity of capital in the international market (again under the proviso that factor productivities are not reduced by too much by environmental disruption). The optimal environmental tax rate consists of three components now:

$$t = D_E + (K - K_0) \frac{dr}{dE} + D_{E^*} \frac{dE^*}{dE} \quad (24)$$

The first component is the marginal environmental damage. The second one is the interest-rate effect. Tighter environmental policies reduce the marginal productivity of capital and, thus, the interest rate in the world capital market. This is good for the home country if it is an importer of capital, $K > K_0$, and bad if it is an exporter, $K < K_0$. Thus, everything else being equal, the capital-importing country has an interest in a strict environmental policy and the capital-exporting country prefers a laxer policy.¹⁶ The third effect is the leakage component. It is always negative. The reason is that the leakage reduces the benefits from tight environmental policies. Since tight environmental policies are costly in terms of reductions in domestic output, the emissions will be increased. It would be interesting to consider Nash equilibria in environmental policies. However, this leads to ambiguities in the general case

¹⁵ Total differentiation of (21) and the foreign emission tax equation, $t^* = F_{E^*}^*$, yields

$$\begin{pmatrix} F_{KK} + F_{K^*K^*}^* & -F_{K^*E^*}^* \\ -F_{K^*E^*}^* & F_{E^*E^*}^* \end{pmatrix} \begin{pmatrix} dK \\ dE^* \end{pmatrix} = \begin{pmatrix} -F_{KE} \\ 0 \end{pmatrix} dE$$

and then Cramer's rule is applied to obtain the comparative-static results.

¹⁶ This is closely related to the terms-of-trade effect of environmental policy in an economy trading final goods. Here, this may be called a factor-terms-of-trade effect

since third derivatives are involved in the determination of the slopes of reaction function. Matters are simpler in the case of identical countries. The interest-rate effect vanishes. The remaining components of the emission tax are marginal environmental damage and the leakage component. Since the latter is negative, it follows that environmental policies do not even internalise the domestic share of the negative environmental externality. Thus, emissions in both countries are increased and welfare is reduced. International capital mobility aggravates transfrontier pollution problems

4.3.3 Partial equilibrium models of foreign direct investment and the problem of small numbers

The previous sections have assumed that there are many enterprises and that the mobile can be cut into arbitrarily small pieces. This may be realistic from the point of view of a large country or the world as a whole. However, many environmentally problematic investments are mega-projects that have supra-marginal effects on the economy, both in terms of environmental damage and national income. As an example consider a nuclear power station. Following the literature, this will be modelled in a partial equilibrium framework, where only one sector but not the economy as a whole is taken into account. The presentation is based on Rauscher (1995) and Hoel (1997).

There is a single potential investor who wishes to build a polluting plant in one of n identical jurisdictions. This is a large-scale project involving high fixed costs. Thus, there are decreasing returns to scale that generate a kind of natural monopoly. Moreover, since transportation costs of the good produced in the plant are sufficiently small, the whole market, i.e. all countries or jurisdictions are supplied by the single firm. Total demand is given and the firm produces according to the mark-up pricing rule. The price exceeds the marginal cost of production and the mark-up depends on the elasticity of demand. Factor demand is less than in perfect competition: the marginal value products exceed the prices of the factors of production. Increases in emission taxes lead to reductions in emissions and in the demand for the other factors of production. Moreover, they have a negative effect on profits. Given the high fixed costs, it is possible that profits become negative for a high emission tax rate. This emission tax rate is termed t^{max} . As the reference case consider cooperation of the economies. An optimal environmental policy maximises the welfare which is total consumer surplus, $CS+CS^*$, plus tax revenue, TR , minus environmental damage, D_i . In Figure 8, the consumer-surplus, tax-revenue, and environmental-damage curves are depicted. For later purposes, three different damage functions are shown but marginal damage is the same in all cases. The optimum is achieved where the slopes of the damage curves equal the slope of the $CS+CS^*+TR$ curve. In the diagram, this is the case for a tax rate larger t_1 .

Let us now look at the uncoordinated case where each country decided independently of the others whether or not to become the host of the polluting plant. Three parameters influence this decision:

- Consumer surplus. If the country decides to be the host, consumer surpluses accrue to all jurisdictions independently of which one is the host. The host country generates a positive external effect on the other jurisdictions.
- Tax revenue. The tax revenue is collected by the host country. Thus, there is a competition for the tax base involving negative fiscal externalities.
- Environmental damage. In the case of purely local pollution, the host bears the environmental cost of the investment. In the case of transfrontier pollution, some of this is externalised.

Producer surplus is not considered since the investor is a foreign firm. Let us assume in a first step that pollution is purely local. Depending on the level of the environmental damage function, the following cases can be distinguished:

- The first scenario corresponds to small environmental damages, D_1 . The environmental cost of hosting the polluter is small. Since it is obvious that someone will host, each jurisdiction will participate in the consumer surplus independently of whether it hosts the plant or not. Thus, consumer surplus becomes irrelevant for the decision. The important variable is tax revenue minus environmental damage. As long as this net benefit is positive, it is optimal for a country to undercut the emission tax rates of other countries in order to attract the foreign investor. This downward tax competition ends when $tE = D(E)$, i.e. when the tax rate equals average environmental damage. In the case of small damages, the tax rate is likely to be too low as can be seen from Figure 7. Ecological objectives of environmental policy are dominated by fiscal considerations. The underlying reason is a fiscal externality: one can increase in a country's tax base is accompanied by the reduction of the tax base in another country but this effect is neglected.
- If the environmental damage is higher, D_2 , the countries may end up in a chicken-game situation. The tax revenue is less than the damage such that the host is worse off than the other countries. Nevertheless, the host is better off than in a situation without an investment taking place. All countries are confronted with the same problem and one of them is the chicken. The chicken should choose a tax rate which maximises consumer surplus. There, however, are multiple equilibria in this game since each country could be the chicken. If the players adopt mixed strategies, it is possible that no jurisdiction offers the investor an environmental tax regime with less than the prohibitive tax rate.
- Finally, if the environmental damage is very large, D_3 , there is a prisoners' dilemma: the benefits from becoming the host are negative even if the alternative is that the investment is not undertaken at all. This scenario has been termed "not in my backyard" (NIMBY).

One can show that this diversity of non-optimal results is the consequence of a second-best situation. The first best would be characterised by the availability of a second policy instrument, a direct tax or subsidy affecting the investor's behaviour. It can be shown

that the first-best environmental tax, equalling marginal damage, is charged if such an instrument is introduced into the model.

Extensions of the model include the consideration of transfrontier pollution, the introduction of transportation costs, and alternative market structures with more than one firm and endogenous entry and exit. In the case of transfrontier pollution, leakage problems have to be considered. Then, the cost of not being the host is not only the loss of tax revenue but also the additional transfrontier pollution to be expected if the firm invests abroad. Thus, the cost of not being the host is increased compared to a situation with purely local pollution. The extreme case is the global-pollutant scenario. The environmental damage of a global pollutant is independent of the geographical location of the source of the emission. This translates into 100 per cent leakage if the investor moves from one jurisdiction to another and this reduces the opportunity cost of becoming the host country to zero. If transportation costs are taken into account, like in the article by Markusen/Morey/Olewiler (1995), additional patterns of localisation become possible. The monopolist may find it profitable to open plants in each jurisdiction. If there is more than one firm, the results do not change significantly as long as transportation costs are negligible: all producers locate where the emission tax rates are the lowest. See Hoel (1997). Matters are different if transportation costs are significant. Then a large variety of results become possible. E.g. one possibility is a situation where firms invest in different countries and there is intra-industry trade like in the Brander/Krugman (1983) model of reciprocal dumping. Moreover, multinational firms, which run plants in various countries, enter the arena. Due to the increase in complexity, these models cannot be solved analytically any more but require numerical solution methods. See Markusen (1997).

4.4. Green Capital market Interventions

Like in the case of international trade where tariffs can be motivated for environmental reasons, one may think about interventions affecting the allocation of the mobile factor of production. Since factor movements may be welfare deteriorating in the presence of regulatory or enforcement deficits in environmental policy, restricting factor movements ought to be beneficial. This is a second-best result, however, the first best would be to remove the original distortion, i.e. to implement the correct environmental policy. Like in the trade case, however, interventions may be beneficial in the large country case. Assume that the other country has chosen an emission tax rate as its policy instrument. Maximisation of the social welfare function yields

$$t = D_E \quad (25)$$

$$\gamma = -\frac{F^*_{K^*K^*} F^*_{E^*E^*} - F^*_{K^*E^*}{}^2}{F^*_{E^*E^*}}(K - K_0) + \frac{F^*_{K^*E^*}}{F^*_{E^*E^*}} D_{E^*} . \quad (26)$$

The emission tax rate now equals the marginal environmental damage. The tax rate on capital consists of two components. The first one addresses the factor terms of trade. See Sinn (1989, Ch. 7). It is positive if the country is a capital exporter and negative if it is an importer. This can be explained as follows. A high tax on capital increases the supply of this factor in the rest of the world. The world market interest rate is reduced and this is good for a country that

imports capital. Thus, the importing country is interested in taxing capital and, by analogy, the exporting country subsidises capital. The second term represents the leakage component of capital taxation. It is always negative. Capital is subsidised in order to avoid that investments that pollute the domestic environment are made on the other side of the border.

From the point of view of a single country, this is a first-best policy. From the point of view of the world as a whole, such a policy is non-optimal. First, transfrontier pollution externalities are not taken into account since the emission tax rate is based on domestic externalities only. Second, the allocation of capital is distorted by the capital market intervention. A global first-best policy would encompass stricter environmental standards on the one hand and undistorted capital movements on the other hand.

A final question that can be asked is whether two instruments (capital and emission taxes) are better than one (emission taxes only) in the uncoordinated-policies scenario. In general, the answer is ambiguous: it depends on the parameters of the production and damage functions. However, if the countries are sufficiently similar, one can easily show that two instruments are indeed better than one. To see this, compare equations (24) and (25). In both equations, the factor-terms-of-trade component becomes very small. If in the scenario with two instruments, all countries subsidise capital at similar rates the capital market distortion becomes very small and vanishes if they are identical. The tax rate then is Pigouvian. In the case of the emission tax as the only instrument, this tax is biased by the leakage component even if the countries are identical, the level of pollution is higher and welfare is lower.

4.5 Some Conclusions

Many of the results derived from the competitive trade models discussed in Section 1 carry over to the case of mobile factors of production. This is not surprising since trade in final goods and factor movements are substitutes in the standard neoclassical models of the open economy. Like in Section 1, a general conclusion as to whether factor market liberalisation is good or bad for the environment and for welfare cannot be drawn. Moreover, there is no clear answer to the question whether interjurisdictional competition leads to a downward competition of environmental regulations. These issues have to be addressed empirically.

5 Intertemporal Issues

Most models look at the trade-environment relationship from a purely static or comparative-static perspective. There are, however, two aspects that cannot be covered by such analyses: intertemporal trade and long-term stock-pollutant effects of emissions. Both aspects are important in theory and in practice. First, static theoretical models are usually based on the premise that trade is balanced in equilibrium. Empirically, unbalanced trade is, however, the rule rather than the exception. Second, many pollutants have long-term effects. Examples are radioactive substances, heavy metals but also carbon dioxide and sulphur dioxide emissions.

In the following two sections, I will present some of the central results in a continuous time optimal control framework. The solution method is Pontryagin's maximum principle, and

it is presented in Feichtinger/Hartl (1986), Chiang (1992), and Léonard/Van Long (1992). Other approaches such as the two-periods model are possible but the main conclusions are the same.

5.1 Stock Pollutants and International Trade

Many emissions do not only affect the well-being of the current generation but also that of future generations. This implies that long-term effects of current emissions matter if decisions on environmental policy are made. There are several ways of modelling intertemporal impacts of emissions. If pollutants are non-degradable, then we have an exhaustible-resources problem. The stock of environmental quality is reduced by every unit of the pollutant discharged by economic activity and decontamination is not possible. Exhaustible resources and trade have been addressed by Siebert (1985b) in the context of the resource-exporting country. Pollutants, however, are degradable, albeit often only in the very long run. The degradation of environmental pollution and the decontamination of environmental policy can be modelled in two different ways. Either one can look at cases where the rate of pollution degradation is constant and exogenous. This is appropriate when radioactive substances are concerned, that degrade at a constant rate. Alternatively, one can assume that the regeneration of environmental quality is stock-dependent. The better environmental quality, the larger is the natural rate of decontamination. The underlying reason is that the resilience of ecosystems is negatively affected by environmental pollution. Natural recovery is a declining function of the necessity of recovery. Formally this is equivalent to the renewable-resources approach mostly used to model fisheries and sometimes also forestry problems. For a comprehensive overview of such models, see Munro/Scott (1985) and Clark (1990). Let R measure the stock of renewable environmental resources (environmental quality) available at time t , the time argument being omitted. Moreover, let q_i measure the extraction rate. Then the depletion and recovery of the resource can be modelled by

$$\dot{R} = g(R) - q_i, \quad (26)$$

where $g(\cdot)$ is the regeneration function, which is increasing for low values of R and declining for large values. At R^{max} , the maximum level of environmental quality is attained, i.e. the virgin state of nature in the absence of human intervention. MSY is the maximum sustainable yield or, applied to the environmental degradation problem, the maximum amount of pollutants that can be discharged into the environment without harming environmental quality permanently. See Figure 9. If it is assumed that extraction costs are inversely related to the resource stock, then a market equilibrium is characterised by an extraction rate which is an increasing function of the stock, e.g. γR , and a long-term equilibrium is attained where the regeneration function and the equilibrium locus intersect.

----- insert Figure 9 about here

If interpreted as a renewable resource, e.g. as the biomass of a particular species, the shape of the $g(\cdot)$ represents logistic growth: if the maximum stock of the species is attained, there is no further growth because the carrying capacity of the ecosystem for this species is attained. If R is interpreted as environmental quality, the unpolluted state of environment is denoted by R^{max} . At this level, the decontamination rate, measured by the absolute value of the slope of the $g(\cdot)$ function in this point, is large. It becomes smaller as R is reduced, i.e. as the environment is becoming increasingly polluted. The marginal rate of decontamination becomes zero at the maximum of the $g(\cdot)$ function and is negative at lower values of R . The average rate of decontamination is reduced as R decreases and becomes zero for $R=0$: there is an irreversibility problem. This line of arguing shows that renewable-resources and stock-pollutant problems are indeed algebraically equivalent.

Dynamic optimisation theory has been used to show that in a the simple case without stock externalities, the long-term stock of the renewable resource is determined such that the marginal rate of regeneration, g' , equals the market rate of interest, r . The marginal rates of return to all assets must be the same in equilibrium. $g'=r$ implies that the long-term extraction rate is lower than the sustainable yield. The optimum is stable in the saddle-point sense as shown by the trajectories depicted in the diagram. The introduction of stock externalities shifts the equilibrium to the right and the long-run resource stock is increased.

-----insert Figure 10 about here

Brander/Taylor (1997, 1998) look at the case of open-access renewable resources.¹⁷ Open access implies that the scarcity of the resource is not taken into account. They model a renewable resource with a quadratic regeneration function. Thus $g(\cdot)$ is parameterised and has a specific shape. Let q_1 be the extraction rate. Labour is the only factor of production, its supply, L , being exogenous and fixed. Like in the Ricardo trade model, the production functions are linear and in the resource sector the marginal productivity of labour depends on the resource stock:

$$q_1 = \alpha R L_1 \quad (27)$$

where α is a constant parameter. To produce one unit of the other commodity, the manufactured good, one unit of labour is required. Since this good is chosen to be the numéraire, its price equals one and, since there is perfect competition, the real wage is one as well. If labour is mobile across sectors, wage rates must be equal, and the price of the resource is

$$p_1 = \frac{1}{\alpha R} \quad (28)$$

Moreover, a Cobb-Douglas utility function $u = q_1^\beta q_2^{1-\beta}$ is assumed such that the price elasticity of demand is -1 and the income shares spent on the resource and on the

¹⁷ For a similar model, which is a bit more complex than the Brander/Taylor model, see Chichilniski (1994b).

manufactured good are β and $(1-\beta)$ respectively. Given the constancy of the income shares, it follows that the supply-demand equilibrium is characterised by the extraction rate being a linear function of the resource stock and the labour endowment of the economy:

$$q_1 = \alpha\beta LR . \quad (29)$$

This is represented by the linear function γR in Figure 9.

Assume that two economies of this type, having different regeneration functions such that $g(\cdot) = \xi g^*(\cdot)$ but being identical otherwise, move from autarky to free trade. If $\xi > 1$, the hump-shaped curve in Figure 9 is at a higher level for all R except 0 and R^{max} and the home country has the larger long run resource stock in autarky. If each country remains diversified after trade liberalisation, the wage rates will adjust to the same levels. There is factor price equalisation. Moreover, the long-run resource stocks of the two countries will be the same in the long run. This follows from the fact that according to equation (28), the resource stock is inversely proportional to the price of the resource, the parameter α being the same in both countries. One can then show that the world market price of the resource in the trade equilibrium lies between the two autarky prices. From this, it follows directly that resource stocks in the trade equilibrium lie between the autarky equilibrium resource stocks of the two economies. In other words, the long-run equilibrium resource stock of the resource-rich economy has been reduced and the resource stock of the resource-poor country has been increased. In Figure 9, the market equilibrium locus, γR , is shifted upwards for the resource-rich country and downwards for the resource-poor country. It can now easily be shown that the resource-poor country is harmed by trade liberalisation. Since its resource stock has declined, labour productivity in the resources sector is smaller than in autarky and the production possibility set has shrunk. Since the resource stocks of the two countries are identical in long-run equilibrium, the labour productivities are identical as well and there is no trade anymore in the long run. Thus, the two countries can consume only what they produce. Thus, the consumption possibility set of the resource-rich country has shrunk compared to the autarky situation and this country is worse off with trade than without. The resource-poor economy, in contrast, benefits from free trade. According to Brander/Taylor (1997, 1998), this model may be used as an explanation for the observation that resource-rich economies on average have been those that have benefited the least from free trade.

Besides deriving the long-run equilibrium result, Brander/Taylor (1998), investigate the transitional dynamics of the model showing that under realistic parameter conditions the resource-rich economy is worse off not only in equilibrium but also along the trajectory leading to the equilibrium. Moreover, they investigate the effect of trade interventions. Not surprisingly, the resource-rich country benefits from the introduction of trade barriers. Of course, this is only a second-best policy. The first best, like in the static environment-and-trade model would be to limit the access to the resource by using policy instruments that signal resources scarcity to resource users and then liberalise trade.

Renewable resources models that start from socially optimal extraction have been analysed by Barbier/Rauscher (1994), Rauscher (1994b), and Schulz (1996). These models

extend the simple optimal resource extraction model by the introduction of a stock externality or stock-dependent extraction costs. The long-run equilibrium is then determined by

$$g'(R) - u_R(c, R) = r \quad (30)$$

where u_R is the marginal utility derived from a larger resource stock. This may be due to an improvement in environmental quality or to a reduction in extraction costs. For the sake of completeness, c is introduced and denotes consumption.

Schulz (1996) analyses the effects of trade sanctions implemented by the resource-importing countries on the extraction behaviour of the exporting country. It is seen that trade sanctions, that result in a reduction of the extractor's producer price, lead to a larger resource stock in the longer term as one expects.¹⁸ If the marginal utility of the resource stock is income dependent, however, then the long-run stock may be damaged by sanctions. The reason is that sanctions reduce income and with less income the demand for environmental quality tends to decline. As an extension of the model, Schulz considers the case where the resource or species competes for alternative uses of the land such as agriculture or cattle. In parts of the literature, it is argued that lower prices for resources such like hardwood from tropical rainforests reduce the opportunity cost of alternative uses of tropical-forest land and that, therefore, trade sanctions may actually raise the rate of deforestation. It is shown, that the results following from the theoretical model is an ambiguous one. However, if the resource extraction yields a positive profit, then sanctions always have the desired effect of conservation. If sanctions make the extraction of the resource unprofitable, then land conversion that destroys the resource becomes possible. If a more complex model of the ecological system, involving two or more species, is considered then the effects of trade interventions turn out to be ambiguous. Due to the complexity of species interaction, they may have unintended results. The Schulz model is not really a trade model. Trade sanctions or restrictions are introduced as exogenous price changes. The same results could be derived for closed economies where shifts in demand or the introduction of domestic taxes affect relative prices.

Trade is explicitly considered by Barbier/Rauscher (1994) in the framework of a two-commodities model. They show that trade sanctions can have a negative impact of the resource stock if the resource-exporting country is import-dependent. Lump-sum transfers to the resource exporting country relax its balance-of-payments constraint and also tend to increase the long-run resource stock. These results are derived for a situation in which trade is balanced in each period. It is argued that the results carry over to a borrowing-and-lending model, where the balance-of-payments restriction is a binding restriction only in the very long run.

Rauscher (1994b) looks at an even simpler model of resource extraction, where there are neither stock externalities nor stock-dependent extraction costs. Moreover, resource-exporting countries are completely specialised. There are price takers and their balance-of-

¹⁸ One can show that this result carries over to the open-access case where resource scarcity is not taken into account.

trade restriction is binding in each period. The long-run equilibrium is determined by $g'=r$. It is now interesting to consider the transitional dynamics under the assumption of perfect foresight of all market participants. If import demand elasticities of the resource-exporting and importing countries are sufficiently large, the adjustment path is a stable saddle path. If however, the Marshall-Lerner condition is not satisfied, i.e. if the sum of the absolute values of the demand elasticities is less than one, then the system becomes unstable. In this case, the resource stock and the extraction rate go to zero in the long run. Interestingly, the initial extraction rate is indeterminate in this model.¹⁹ It is then shown that the import restrictions tend to make demand more inelastic and, thus, aggravate the problem of exhaustion. Export taxes used by the resource exporting country can stabilise the resource. As a caveat, it should be mentioned that the assumption of balanced trade in each period is certainly restrictive.

5.2 Intertemporal Trade and the Environment

If trade is not balanced, countries incur foreign debts or positive foreign-assets positions. It has been argued in the policy-oriented literature that foreign indebtedness increases pressure on environmental resources, and that the debt and the environmental crises in developing countries are closely related. See Adams (1991) and Miller (1991), for example.²⁰ To start, look at a simple model of foreign debt and/or asset accumulation based on Bardhan (1967). The balance of payments restriction now becomes an intertemporal one. In the long-term, foreign debt has to be repaid and the foreign-assets position has to be non-negative. This relationship can be represented by a differential equation describing the development of the foreign-assets position and a long-term constraint. Foreign assets or debts are accumulated according to

$$\dot{A}=rA + \sum_{i=1}^n p_i \left(F^i(K_i, L_i, E_i) - C_i \right), \quad (31)$$

where A denotes the foreign assets stock of the country at time t , \dot{A} its derivative with respect to time, r the world market interest rate and the other variables are denoted as they have been defined before. Time indexes or arguments are omitted for notational convenience. The right-hand-side of the equation represents the per-period trade-balance surplus or deficit. Assume that the country under consideration is small: relative prices are given and constant. The intertemporal constraint is

$$\lim_{t \rightarrow \infty} A(t) \geq 0. \quad (32)$$

¹⁹ In an economic geography context, Krugman (1991) has derived a similar result: self-fulfilling expectations determine the starting point of the path. Unlike in Krugman's model, the externality producing Rauscher's (1994b) result is a purely pecuniary one.

²⁰ Hansen (1989), however, has argued that the opposite may be the case, too. If high levels of debt induce balance-of-payment problems, indebted countries may find it difficult to import foreign equipment necessary to expand resource-depleting industries such as tropical forestry.

The objective is to maximise the present value of future utility,

$$\int_0^{\infty} e^{-\delta t} u(C_1, \dots, C_n, E, E^*) dt, \quad (33)$$

where δ is the exogenous rate of discount. Moreover, we need that factor inputs add up to total factor supplies, which are also given and constant. From application of Pontryagin's maximum principle, we get that the shadow price of foreign assets, λ , equals marginal utility and grows at a rate equalling the difference of the international interest rate and the discount rate:

$$\lambda p_i = u_{C_i}, \quad (34)$$

$$\dot{\lambda} = (\delta - r)\lambda. \quad (35)$$

From the first condition, one can infer that relative prices equal marginal utilities. The second equation states that the shadow price is not constant over time. It declines if the interest rate is larger than the time preference rate. Given that the shadow price is proportional to marginal utilities, it follows that consumption tends to rise if the time preference rate is small and it tends to grow if δ is large: if the future is heavily discounted, then saving does not pay and present consumption is larger than future consumption.

Moreover, one can derive optimality conditions for factor utilisation. The marginal value products of the private factors of production should be equal across sectors and the emission tax rate should equal the marginal environmental damage. The latter follows from

$$\lambda f_E = u_{E_i}, \quad (36)$$

The foreign-assets position does not enter the conditions that determine factor and goods prices, at least not explicitly. This is a case of Fisher's separation theorem, which states that with perfect capital markets production decisions are independent of savings decisions.²¹ Nonetheless, the foreign debt can have an impact on environmental regulation. The initial debt and the initial consumption vector are closely related to each other. The higher the debt, the larger is the savings rate needed to satisfy the intertemporal constraint, i.e. the lower the consumable income along the economy's development trajectory.²² If the marginal environmental damage is an increasing function of income, i.e. if people become increasingly aware of environmental problems as their incomes rise, then there is an impact of foreign debt on emission taxes and thus on environmental quality. Environmental damage is increasing in foreign debt. To show this, I simplify the model such that there is only one good. Then, the index i vanishes and trade is purely intertemporal. From (34) and (36) it follows that $u_C F_E + u_E = 0$, i.e. marginal resource productivity equals marginal environmental damage, and this implies

²¹ See Fisher (1930) for the basic argument and Siebert (1985a, Ch. 4) for an application to exhaustible resources problems.

²² This can be shown by simple phase diagram techniques for the one good case and the argument generalises to the many-goods case.

$$\frac{dC}{dE} = -\frac{u_C F_{EE} + F_E u_{CE} + u_{EE}}{F_E u_{CC} + u_{CE}}. \quad (37)$$

The sign of dC/dE depends on the cross derivative of the utility function, u_{cE} . This is negative for many utility functions, but not in general. Usually, dC/dE is negative, i.e. a high level of consumption is accompanied by low emissions and vice versa. According to (35), depending on the sizes of r and δ , the economy will grow at a positive or a negative rate. The growth path is a saddle path in the (A, C) or in the (A, E) diagrams. Wrong initial levels of C and E lead to either long-run over-saving or to violation of the intertemporal budget constraint. The following graphical representation is based on no growth, i.e. $r = \delta$, but this can be generalised. The equilibrium is determined by $\dot{A} = 0$. Moreover, it follows from the first-order optimality conditions that c and E remain constant along the optimal path. Then, the $\dot{A} = 0$ line in the (A, E) phase space is the long-run equilibrium and E is determined by A_0 . It follows that $r dA_0 + (F_E - dc/dE)dE = 0$, or

$$\frac{dE}{dA_0} = -\frac{r}{F_E - dC/dE}. \quad (38)$$

With the usual parameters, this is negative, i.e. pollution is aggravated by foreign debt.

Various extensions of this basic model can be found in the literature:

- In Rauscher (1997, ch. 8) it is assumed that the interest rate is increasing in the level of the debt. The underlying reason is that highly indebted countries pay a risk premium. This increases their debt burden and the incentive to use environmental resources intensively. Strand (1994) models the risk problem explicitly and comes to the same conclusion.
- The intertemporal aspect of natural resource use can be introduced. For the case of exhaustible resources, see Siebert (1985), for the case of renewable resources Rauscher (1990). If the resource stock is not an argument in the utility function and if the rate of interest is constant, the resource extraction path is not affected by the foreign debt. This is a direct implication of Fisher's separation theorem. Otherwise, with the assumption that either the interest rate is increasing in the foreign debt or that the resource stock is an argument in the utility function, the conclusions derived from the analysis carried out above carry over to renewable and non-renewable resources. If the both the interest rate is debt-dependent and utility is derived from the stock of the resource, then matters are more complex since the resource extraction path may be unstable or cyclical. See Rauscher (1990) and Feichtinger/Novak (1991).

Policy implications have been analysed by Strand (1994) and Rauscher (1997, ch 8). Given that foreign debt leads to an aggravation of environmental problems, an unconditioned debt relief has a positive impact on environmental quality. From the point of view of the creditor country, however, the costs of the debt relief will in most cases be higher than the benefit, the creditor derives from the improvement of the environmental quality in the indebted country. This has led to the introduction of debt-for-nature swaps. The indebted

country is given a debt relief in exchange for the promise to use a specified part of its resource base, e.g. a tropical rain forest, in a more sustainable way. This can be in the interest of both countries and a Pareto improvement can be achieved. In general, this instrument is not first best, however. From the point of view of the of the foreign conservationist, it may be optimal to vary the compensation payment over time. A one-time debt-for-nature swap can be too inflexible to achieve the objective. Further Pareto improvements are possible if more flexible types of side payments.

6 The Empirical Evidence

Cropper/Oates (1992) in their survey on the state of environmental economics argue that the impact of environmental regulation on international trade is weak to insignificant. Similar conclusions are drawn by Ugelow (1982) and Dean (1992). Here we will go into the details of the this literature to some extent to establish a differentiated picture of the interdependencies of trade and the environment.

A major problem of the empirical assessment of the relationship between trade and the environment is the measurement of the environmental variables. Two approaches are possible. The first one is to look at particular industries and particular pollutants, i.e. to carry out case studies. The second one is to be chosen if the purpose is to draw a more general picture. Then, an index of environmental pollution or of the stringency of environmental regulation needs to be constructed. Of course, the researcher has some discretion here what to include and what to omit when developing such an index. List/Co (2000), for instance, use four different measures of environmental stringency in their empirical study on the location of pollution-intensive industries in the US and find that some of these measures are not correlated at all. The conclusion to be drawn from this is that careful sensitivity studies should be undertaken and different measures should be used if they are available.

6.1 Environmental regulation and competitiveness

Microeconomic theory postulates that strict environmental policies reduce factor productivities and, therefore, are harmful to the international competitiveness of regulated firms. In contrast, the Porter hypothesis claims the opposite.

The empirical evidence is mixed. Some productivity studies have established that environmental regulation can have significant effects on production costs and factor productivities and that the signs are in accord with standard microeconomic theory. Examples are Barbera/McConnell (1986), Conrad/Morrison (1989) and Gray/Shadbegian (1993). Brännlund/Färe/Grosskopf (1998), using data from the Swedish pulp and paper industry, find only limited evidence that environmental regulation has an impact on firm profitability. Scholz/Staehler (1999) examine the German titanium dioxide industry and the Swedish pulp and paper industry and find no support for the Porter hypothesis. In the titanium-dioxide case study, an increase in innovation activity was observable after the implementation of tighter environmental standards, but the potential competitive advantage was eroded quickly by the

public-good character of the innovations. In the Swedish example, a first-mover advantage was observable but this did not improve competitiveness measured by revealed-comparative-advantage numbers. An interesting result, supporting the Porter hypothesis, has been obtained by Bioern/Golombek/Raknerud (1998). They look at a panel data set of Norwegian firms from three different environmentally intensive industries and find that non-regulated firms have a higher probability for exiting the market than regulated firms. This suggests that there are cases where the impact of environmental stringency on competitiveness is counter-intuitive. This study suggests that there may be some truth in the X-inefficiency explanation of the Porter hypothesis.

6.2 The impact of environmental regulation on the international division of labour

Given that the evidence at the firm and sectoral level is mixed, it is not surprising that most empirical studies did not find significant evidence in favour of an impact of environmental regulation on the international division of labour and on the patterns of trade. First-generation studies addressing this issue, used on Leontief's (1954) approach based on input-output analysis. Using data for a particular year and a particular country, one computes the factor content of exports and imports. This has been done by Walter (1973), who uses US data on pollution abatement costs to calculate "overall environmental-control loadings", i.e. the ratio of environmental-control cost, including those of the intermediate inputs, to the final price of the output. Using these shares, one can determine the abatement-cost content of US trade. Walter (1973) shows that the abatement-cost content of US exports is slightly higher than that of US imports. This suggests that the US are exporting environmentally intensively produced goods and should, therefore, be well-endowed with environmental resources. A shortcoming of the approach is the construction of the environmental cost components of US imports. It is estimated on the basis of US data - a procedure which is correct only if the trading partners use the same technologies and the same factor intensities as the US. This is a deficiency not only of this but also of the other studies published in the seventies. See Ugelow (1982) for a survey.²³

A similar approach is chosen by Robison (1988). The study is done for several years in the 1970s and 1980s and the abatement costs that are implicit in the capital stock used in the production process are taken into account. Because of tighter environmental standards, the abatement-cost contents of output, exports and imports have risen from 1973 to 1982. The change in the abatement-cost content of imports turns out to be larger than that of exports and output. This suggests that there has been a shift in US imports from goods with relatively low abatement requirements towards goods subject to relatively tough regulation. Or in other words: domestic production of environmentally harmful goods has been substituted for by imports from abroad. This is in accordance with predictions of trade theory. However, this is plausible only if foreign environmental standards remained unchanged or were changed by

²³ For some more recent results using this method for Korean data, see Kim (1990). In this study, no significant difference between the pollution contents of imports and exports is found.

less than US standards. Due to a lack of foreign data on abatement costs, this is not tested by Robison.

Different results are reported by Sorsa (1994), who uses more recent data. This study considers trade flows in environmentally intensive goods and environmental expenditures in seven industrialised countries. It is shown that for most countries changes in exports in environmentally intensive goods and changes in environmental expenditures were uncorrelated, the exception being Austria being with a positive correlation. During the period 1970-1990, comparative advantages have not changed substantially despite the significant changes in environmental regulation during this period. Only Japan has experienced a drastic reduction in its environmentally intensive exports. Austria and Finland, in contrast, have become slightly more competitive in environmentally intensive products. The Japanese result reflects the drastic tightening of environmental standards in this country in the 1970s and 1980s. The lack of evidence in the other countries is a result of a rather simultaneous move towards tighter environmental standards in the industrialised countries.

Three conceptual shortcomings are intrinsic to the Leontief approach. The first one, which has already been mentioned, is that pollution abatement data are taken into account only for the country (or countries) under consideration but not for the trading partners. The second one is that the analysis is only bivariate. Trade data and intensity data are used but endowment data are not considered. Thus, the results reported in these studies are useful as a description of the evolution of the patterns of trade, but they do not constitute genuine tests of Heckscher-Ohlin trade theory. Thirdly, other variables that influence trade patterns, e.g. wages, are neglected.

Tobey (1989, 1990) has overcome these problems. His study is the first attempt to test the predictions of Heckscher-Ohlin trade theory applied to environmental issues. A problem here is the measurement of the environmental-resources endowment of the countries. Tobey uses an index measuring the stringency of pollution control measures based on a 1976 UNCTAD survey.²⁴ The trade data used are only those of the pollution-intensive sectors. They are identified on the basis of 1977 US data. Net exports of these goods are regressed on the factor endowments of different countries in 1975. The environmental-policy variable is insignificant for all five industries under consideration. This result is confirmed by an omitted-variables test.²⁵ Tobey argues that this insignificance result does not necessarily prove that environmental regulation does not affect international trade. Heckscher-Ohlin trade theory assumes perfect mobility of factors of production across sectors. This is realistic only in the long run. So changes in environmental policy cannot be expected to have short-term impacts on the patterns of trade. To take account of this, Tobey also regressed changes in net exports on the stringency of environmental policy and finds a significant impact only for one

²⁴ This survey resulted in a partition of countries into seven categories ranging from "tolerant" to "strict". Tobey (1990) quantified this variable by assigning the values 1 to 7. For a detailed description of the data, see Walter/Ugelow (1979).

²⁵ The omitted-variables test looks at the residuals of a regression in which the environmental-endowment variable is omitted. If it is a relevant variable, it should be correlated with the residuals.

out of five sectors - albeit with the "wrong" sign. Murrell/Ryterman (1991) come to similar results. Using 1975 data, they do not find evidence in favour of the hypothesis that environmental policy affects trade. Like in Tobey's study, this result may be explained by the choice of 1975 as a base year where strict environmental standards were introduced in many industrialised countries but the trade impact, if there was any, occurred only with considerable time lags.

A recent study on environmental regulation and trade has been carried out by Van den Bergh/Van Beers (1998). They use a gravity model, where bilateral trade volumes - like gravity - depend on size and geographical distance of the countries. This gravity model is augmented by factor endowment variables. Several measures to approximate environmental stringency are employed. The surprising result is that strict environmental policies in the exporting and in the importing country have a negative impact on net exports commodities. The only exception is the impact of the environmental policies in the exporting country on the exports of environmentally intensive goods, which is insignificant. This confirms Tobey's (1990) findings. The negative impact of environmental regulation in the exporting country on net exports is straightforward: stringent environmental policies raise production costs and negatively affect the exporting (and the import-competing) industries. The importing-country effect is surprising. Stricter standards in the importing country should raise rather than reduce net exports. Van Beers/van den Bergh (1998) argue that this might be explained by barriers to trade that governments introduce in order to protect industries that are harmed by strict environmental standards. This hypothesis cannot be tested with the available data, however.

Summarising the insights gained from the empirical literature on the impact of environmental regulation on international trade, one finds that there is only weak evidence that environmental regulation affects the patterns of trade. A recent studies that finds some evidence, however, produce results that are not in accordance with standard economic theory.

6.3 The Impact of Trade on the Environment

From an economic-theory point of view, the impact of free trade on the environment is ambiguous. Trade theory has traditionally looked at the patterns of specialisation. Liberalisation of international goods markets may result in "polluting one's neighbour via trade", which can be good for environmental quality in one country and bad in the other. The empirical literature has identified a number of other effects that are usually neglected in Heckscher-Ohlin models of international trade.

Hettige/Lucas/Wheeler (1992) and Lucas/Wheeler/Hettige (1992) find evidence in favour of the hypothesis that the pollution intensity of production has grown much more for high-growth inward-oriented developing countries than for high-growth outward-oriented economies. They explain this by differences in the investment behaviour between industrialising countries. Outward-oriented economies tend to expand their labour-intensive production, which is relatively clean. Protectionist economies following strategies of import substitution, in contrast, develop their capital-intensive dirty industries. So at least for many developing countries, free trade appears to be good for the environment.

Industrialised countries can be expected to follow the opposite pattern of specialisation after trade liberalisation and the effect of trade on the environment may be negative. This issue is taken up by van Bergeijk (1991). He uses a pooled set of data for OECD countries data from two years (1980 and 1985). The emissions of three pollutants (SO_2 , CO_2 , and NO_x) are regressed on a set of explanatory variables, including a trade variable. van Bergeijk finds negative impacts which are significant for SO_2 and NO_x and insignificant for CO_2 . This suggests that openness is good for the environment also for the industrialised countries. A possible explanation is that pollution-intensive production might have moved to countries that are not in the data set. It is known, however, that most of the trade of the OECD countries is within the OECD group. Thus, positive and negative specialisation effects should nearly cancel out. Alternatively, one may argue that the efficiency gains from trade lead to higher income, which then induces higher demand for environmental quality and tougher environmental standards.

This idea is taken up by Grossman/Krueger (1993) in their analysis of the environmental effects of the North-American Free Trade Association. They find environmental Kuznets curve effects and conclude that the gains from NAFTA should drive Mexico towards implementation of stricter environmental policies. For many pollutants, the income elasticity of the demand for environmental quality appears to be such that higher income reduces emissions in the longer term - even though higher income is accompanied by more output. In a more detailed and more sophisticated study, Antweiler/Copeland/Taylor (1998) find strong support for this result. They use a panel data set for several countries and look at SO_2 emissions. The impact of trade on the environment is decomposed into three effects: a scale effect, a technique effect, and a composition effect. The scale effect is negative: trade liberalisation increases output and this leads to more pollution. The technique effect is positive: trade liberalisation raises income and part of this income is used to reduce emissions by employing better technologies. Finally, the composition effect is ambiguous: trade affects the output mix and this may be good or bad for the environment. It is shown that the second effect dominates the other two effects such that the net result is an improvement in environmental quality after trade liberalisation. For further evidence of the income environmental quality relationship see Pannayotou's (2000) contribution in this volume.

Further mechanisms by which trade affects the environment are identified by Birdsall/Wheeler (1992). They use a pooled cross section for time series for Latin American countries and regress the toxic intensity of production on a set of explanatory variables including an index of openness. They find that openness leads to cleaner production in these countries. Using the Chilean economy as a case study, they look at the economic mechanism explaining this relationship. They argue that in this case the reason is the availability of modern, new technology developed in industrialised countries to meet strict environmental standards. The issue of diffusion of clean technologies is addressed by Wheeler/Martin (1992). For the case of the pulp industry, they find that the adaptation lag for the introduction of new, clean technologies is significantly raised if countries are inward-oriented. This supports the hypothesis that trade is good for the environment.

Some studies on the impact of free trade on the environment deal with particular markets. Agriculture is addressed by Anderson (1992a,b). It is known that these markets are in many countries highly regulated and distorted by subsidies and barriers to trade. Anderson

shows that the correlation between domestic prices and the utilisation of fertiliser and pesticides is positive and significant. High domestic prices for goods that are traded internationally are possible only if there are barriers to trade. Abolishing these barriers would result in a relocation of production from highly protected industrialised countries to less developed countries. There would be a shift in the use of fertiliser and pesticides from the industrialised to the developing countries. Since the less developed countries tend to use more labour-intensive methods of production that require less chemicals, one can conclude that the average use of these substances tends to decline. Similar results are obtained by Harold/Runge (1993) who find a significant positive effect of agricultural subsidies on the intensity of fertiliser use.

Another case is the energy market. In most countries, the energy market is highly distorted. Removing these distortions by and allowing for free trade would have substantial effects. Burniaux/Martin/Oliveira-Martins (1992) use a computable general-equilibrium (CGE) model and show that the removal of existing distortions in energy markets, which predominantly take the shape of subsidisation for protectionist reasons, would result in a drastic reduction of CO₂ emissions on a global scale. It should be noted, however, that CGE models cannot be used to test theories. They are calibrated models that are based on the validity of a particular theory and can, therefore, only be used for simulations but not for testing purposes.

Notwithstanding that there are serious arguments for a positive impact of trade liberalisation on the environment, there are situations where the negative effects of free trade dominate the positive ones. An example is trade in endangered species. For example, Barbier/Burgess/Swanson/Pearce (1990) and Barbier (1991) look at the market for ivory and concludes that barriers to trade such as tariffs, quotas, and trade bans can contribute to the preservation of endangered species.

Traditional trade theory is silent about trade costs. Thus, the literature on trade and the environment has neglected the issue of transportation externalities by and large. An exception is Gabel/Röller (1992). They investigate the effects of trade liberalisation on international transportation for a set of European countries. Non-tariff barriers have a significant negative effect on the volume of trade. Complete removal of these barriers would raise the volume of trade by a quarter. It is argued that, everything else being equal, there would be a more than proportional increase in international transportation due to the increasing share of long-distance traffic. For a study looking at the particular case of trans-alpine traffic in Europe, see Reggiani (2000).

6.4 Leakage Effects

Up to now, there is no empirical evidence concerning the importance of leakage effects. What has been done, however, is an assessment of the potential importance of these effects by means of CGE models. CGE models cannot determine the magnitude of these effects empirically. They can be used for policy simulations and under the assumptions that the economic theory underlying the model and the chosen set of parameters used for the calibration are correct, one can determine ranges of leakage elasticities. The first attempts to

calculate leakage figures for carbon dioxide emissions have been made in the first half of the 1990s by Oliveira-Martins et al. (1993), Felder/Rutherford (1993), Manne/Oliveira-Martins (1994), and OECD (1995). The results are sensitive to the parameters chosen. Decisive parameters are energy supply and demand elasticities and the assumptions about future role of China in the world economy. Leakage elasticities are in the range of 3 to 40 per cent of original emission reductions. A. Ulph(1994a) using a non-competitive partial-equilibrium model which he calibrates to reflect the properties of the fertiliser industry finds leakage figures of even more than 60 per cent. A recent survey by Burniaux/Oliveira-Martins (2000) summarises the results of various CGE models and arrives at the conclusion that carbon leakage elasticities should be expected to lie in the range of 2 to 20 per cent. The major part of this leakage is due to energy market interdependencies. Reduced energy demand in one country leads to lower energy prices in the world market and, therefore, to higher energy demand in other countries. As one may have expected from the results on the impact of environmental regulation on the patterns of trade, the leakage effect caused by changes in specialisation and corresponding price changes in markets for final goods appears to be rather weak. The decisive energy market parameter is the supply elasticity of coal. With extremely (unrealistically) inelastic coal supply, leakage figures can approach 100 per cent.

6.5 Green Tariffs

To my knowledge, there have not been empirical studies on the significance of environmentally motivated barriers to trade. A simulation study by Mani (1996), however, has tried to quantify the impact of environmentally motivated tariffs on the patterns of trade. Starting from an existing partial equilibrium, a scenario was investigated in which the USA introduced countervailing tariffs that just offset the cost advantages foreign producers enjoyed because of laxer environmental standards abroad. It was shown that the impact of these tariffs on trade is very small. Even under unrealistic parameter constellations designed to obtain strong effects, the changes in trade revenues remained in the range of 2 to 3 per cent even for the pollution-intensive industries. Basically, Mani (1996) asks the same question that has been posed in the literature on the effects of factor endowments on trade but reverses the direction of the mechanism. What would happen if comparative advantages caused by differences in environmental regulation were eliminated by the introduction of countervailing tariffs. The results confirm the other existing evidence: trade and environmental regulation are only weakly linked.

6.6 International Factor Movements

Besides via trade in final commodities, environmental regulation can have an impact on the allocation of factors via trade in factors of production, i.e. mobile factors tend to move to less regulated jurisdictions. Walter (1982) using data on the sectoral and firm levels concludes that generally there is no evidence that pollution-intensive industries have moved to less regulated countries and regions. Exceptions from this rule are cases where major projects have been

obstructed for environmental reasons. This finding is confirmed in subsequent studies by Bartik (1988), Leonard (1988), McConnell/Schwab (1990), and Levinson (1996). This is confirmed in the survey article by Jaffee et al. (1995).

Rowland/Feiock (1991), in contrast, come to the conclusion that environmental regulation does affect locational decisions of investors. They look at the distribution of the investments of the chemical industry across federal states of the USA. Rowland/Feiock (1991) find a non-linear relationship between the stringency of environmental regulation and the investment decisions: there is threshold value of pollution-abatement costs below which relocation effects of environmental-policy changes cannot be observed. List/Co (2000) and List/McHone (2000) also claim to find evidence in favour of relocation effects of environmental policies. List/Co (2000) look at the regional distribution of foreign direct investment across the federal states of the USA and find parameter values with the expected signs and larger in magnitude than those derived in earlier publications. One may conclude that the foreign direct investment by multinational firms is more sensitive to environmental regulation than purely domestic investment. List/McHone (2000) use a US panel data set on a county basis. According to the 1977 Clean Air Act Amendment counties are designated in-attainment and out-of-attainment areas. An in-attainment county meets certain well-defined environmental quality standards, an out-of-attainment county does not. Out-of-attainment areas have to take measures to improve environmental quality, and this can translate into high costs for new plants that are subject to very strict environmental standards. The evidence reported by List/McHone (2000) suggests that the investment behaviour of manufacturers in pollution-intensive sectors is significantly influenced by environmental regulation in the predicted fashion. Since their results are derived on the basis of a distinction between in-attainment and non-attainment areas, which differ substantially in the strictness of environmental regulation, they suggest the existence of substantial thresholds that have to be surpassed before environmental stringency starts to matter.

Most of the studies reviewed up to now look at data for a specific country and analyse the effects of intranational variety of environmental standards on location. International differences in environmental regulation have been addressed as well. Hettige/Lucas/Wheeler (1992) and Lucas/Wheeler/Hettige (1992) claim to find evidence in favour of a relocation of environmentally intensive industries to developing countries. Low-income countries have experienced higher growth rates of pollution intensity per unit of output than high-income countries, particularly in the 1970s and 1980s, when industrialized countries tightened their environmental standards. This, however, is not a proof that there has been a relocation of dirty industries. Low/Yeats (1992) employ a similar approach but look at trade data covering the period from 1965 to 1988. They show that the share of "dirty" industries in exports has increased for some developing countries whereas it has declined for the industrial countries.

On the whole, the direction and magnitude of the effect of environmental regulation on industry location is an unsettled issue. Many studies do not establish a significant relationship. If there is a relationship, it is likely that it is characterised by non-linearities. Small differences in environmental policies have no significant effect, large differences produce significant effects. Most of the papers use cross-sectional data and, therefore, the time components of environmental policy cannot be identified.

6.7 Not in My Backyard or a Race towards the Bottom?

Levinson (1999) analysed taxes on hazardous waste in the USA. These taxes vary quite a bit across federal and they have changed during the time period 1988 to 1993. It is shown that taxes have tended to rise and the empirical results suggest that this is explained by NIMBY behaviour. High taxes rates are used to keep waste outside the federal state borders . As a result, waste disposal in the USA has become more decentralised during the observation period. Levinson (2000) shows that the waste-intensive industries are those that are the least footloose. Environmental authorities can tax these industries at high rates without causing undesired relocation effects.

Of course, these results apply to a particular part of the US economy and cannot be generalised. Anecdotal evidence suggests that NIMBY behaviour is not a singular phenomenon but can be observed in different industries and different countries. It is, however, much more difficult to empirically detect races towards the bottom where jurisdictions undercut each other in environmental taxes or standards. The benchmark to which real-world environmental taxes should be compared is the true marginal environmental which in most cases is not accurately known. Thus, it is to be expected that the question whether the race-towards-the-bottom hypothesis is supported by the data will remain undecided.

6.8 Foreign Debt and the Environment

A part of theoretical literature and many policy oriented papers as well have argued that foreign debt of developing countries has a negative impact on environmental quality. Highly indebted countries have incentives to overuse their natural resources. Diwan/Shafik (1992) use a sample of 109 countries. In a regression analysis with CO₂ emissions per capita being the dependent variable, it is shown that per-capita foreign debt has a positive significant effect on emissions.

6.9 Conclusions from the Empirical Literature

There are two important conclusions to be drawn from the empirical literature on trade and the environment:

- The impact of environmental regulation on international trade and factor allocation is rather weak. Many studies do not find significant parameters. For particular industries and in the case of substantial inter-jurisdictional differences in environmental regulation, the data support the theory.
- On average, trade liberalisation is good for the environment.

The small and often insignificant effects of environmental regulation can be explained as follows. See Levinson (1996) and Jeppesen/Folmer (2000). First, in most industries, the cost of complying with environmental regulation is rather small compared to other cost components such as labour, capital and intermediate inputs. OECD figures suggest that the share of total costs that can be attributed to environmental regulation is about 2 per cent on average. Second, the move towards stricter environmental standards has been an almost simultaneous one in many countries. Thus, the cross-country variability of environmental regulation has been rather small in the past. Third, even if differences in environmental policies exist, historical experience suggests that less regulated countries will follow the trend and adjust their policies towards those of the first movers. Thus, rational investment decisions may be based on the assumption of converging environmental policies. Fourth, consumers and downstream producers often refuse to buy commodities from manufacturers that exploit the advantages of investing in pollution havens. If multinational firms invest in lax-regulation developing countries, they therefore often install technologies that comply with the strict regulation of their home countries. Sometimes they even require the fulfilment of strict environmental criteria from their upstream suppliers. Fifth, there is the empirical problem of how to measure environmental stringency. This has been mentioned already, and it is possible that a part of the problem of the lack of empirical evidence is merely a measurement problem.

As far as the effects of trade liberalisation are concerned, the composition effects are very small. Since environmental regulation and the allocation of the factors of production are only loosely linked, trade liberalisation has only small effects on the environment via structural change. The most important impact is that of the income increase. With higher income, tighter environmental standards and higher prices for environmentally intensively produced goods become affordable and in the longer term, this leads to improvements in environmental quality.

7 Institutional Issues

Institutions change. Nonetheless, it is sensible to address the institutional framework in which trade-and-environment issues are currently embedded. The basic problems here are to avoid that particular interest groups are over-represented in the political process and to find mechanisms by which international trade and environmental disputes can be solved. The problem to design institutions that resist regulatory capture will not be addressed here. Instead, I will concentrate on international aspects and discuss international agreements that address environmental and trade issues simultaneously.

7.1 International Environmental Agreements with Trade Provisions

As the theoretical literature has shown, trade interventions can sometimes make sense for environmental reasons. Esty (1994) finds that since the 1930s there have been 20 multilateral environmental agreements that allow for trade restrictions. The most significant of these are probably the Convention of Trade in Endangered Species of Wild Flora and Fauna (CITES),

the Montreal Protocol on Substances that Deplete the Ozone Layer (hereafter: Montreal Protocol), and the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Its Disposal (hereafter: Basel Convention).

CITES went into force in 1973. It is a multilateral agreement which regulates the trade in rare species of animals and plants or in products made from them. Many of these species are threatened by extinction and often species extinction is not driven by domestic demand but by import demand from abroad. Therefore main instrument used by the CITES signatory parties to preserve them is trade restrictions. All international trade in rare species requires import and export permits and signatory parties are given the right to restrict international trade. Free trade is non-existent for in the area covered by CITES. Apparently, these trade restrictions are regarded as being justified not only in environmentalist circles but also in the international-trade community.

The Montreal Protocol, launched in 1987, regulates the use of substances that deplete the ozone layer, in particular chlorofluorocarbons (CFCs). The signatory parties agree to participate in a schedule of CFC reduction until a complete phase-out. The Montreal Protocol contains interesting trade provisions. See Enders/Porges (1992) for a more detailed discussion. Signatory parties to the Protocol are requested to ban imports and exports from non-parties of different types of goods relevant to the process of ozone depletion. The ban proceeds in a number of steps that are defined in Article 4 of the Protocol. Firstly, imports of controlled substances themselves, mainly CFCs, are banned. The second step requires a ban of products that contain controlled substances. Finally, an import ban of products that do not contain controlled substances but have been produced with them becomes possible. To the trade economist, these trade restrictions are interesting for two reasons. First, the introduction of trade restrictions is based not only on properties of a good as such but also on the way in which it has been produced.²⁶ Secondly, this measure catches two birds with one stone. On the one hand, it serves as a sanction to discipline non-compliers. On the other hand, it reduces leakage effects like the optimal tariff that has been mentioned in Section 1 and, therefore, is in the self-interest of the countries using the instrument. This increases the credibility of the sanction and reduces the likelihood of non-compliance.

The Basel Convention constrains international trade in hazardous waste. Its basic principles are the requirement of written consent by the authorities of the importing, exporting and transit states, the duty to re-import and the prohibition of waste movements to non-parties. See *Esty* (1994a, p. 280). All international waste trade must be supervised by the authorities of the states involved. Purely private transactions are not allowed. Information requirements have to be met and written permissions by the importing and the transit countries are needed. Moreover, the exporting country is responsible for re-importing the toxic waste if the movement cannot be completed in accordance with the terms of the contract and if no alternatives are available for an environmentally sound disposal. The export of toxic waste to non-parties is - with some exemptions - prohibited. There are some problems

²⁶ There is currently only a single other environmental agreement that provides for trade restrictions in case the commodity is unsustainably produced: the Convention of the Prohibition of Fishing with Long Drift Nets in the South Pacific of 1989. See *Esty* (1994a, 280).

inherent in such a convention, e.g. the definition of what is hazardous waste. To the trade economist, the interesting aspect of the Basel Convention is the elimination of all private trade. All transboundary movements of hazardous waste are state-controlled and to some extent also state-managed. This restriction and the re-importation requirement have been implemented to protect importing countries, particularly developing ones, from imports of hazardous substances they cannot or do not want to handle. The exclusion of non-parties from the trade may be viewed as a violation of the non-discrimination principle.

7.2 The GATT and the Environment

The General Agreement on Tariffs and Trade was formulated in the 1940s, a time when environmental issues were not an issue. Therefore, the environment is not mentioned explicitly. The main purpose of the GATT has been to promote the free exchange of goods. Its main principle is non-discrimination and the instrument for its implementation is the most-favoured-nation clause (Articles I and III). Trade restrictions may take the shape of tariffs only, non-tariff barriers to trade are prohibited (Article XI). Countervailing duties are possible in the cases of foreign dumping and subsidisation. However, there is nothing in the GATT that could make these measures applicable to environmental dumping. Other barriers to trade may be used if one of the escape clauses in the GATT applies. One of them is Article XX, which is now used to deal with environmental issues:

Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures:

(b) necessary to protect human, animal or plant life or health;....

(g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption;

Although the historical roots of these parts of Article XX have nothing to do with environmental concern, they are now used to deal with environmental issues. In some respects, this article is rather vague. For instance, it is unclear if trade in goods that have only been produced in a way regarded as being unsustainable but are not harmful by themselves may be restricted. It is also far from clear under which circumstances discrimination becomes arbitrary or unjustifiable.

Some GATT Panels offer insights on how the relationship of free trade and environmental protection is being viewed by the GATT. The tuna dispute between Mexico and the USA was the most prominent case in the early 1990s.²⁷ The US had launched an

²⁷ For a more detailed discussion, see the original GATT Panel, GATT (1993) but also Körber (1998).

embargo on Mexican tuna imports since the Mexican tuna fishery killed more dolphins than was compatible with the US Marine Mammals Protection Act. The GATT Panel decided that this ban was incompatible with GATT rules. The USA had argued that this measure was in accordance with Article III (which states that imported goods should be treated in the same way as like or competing domestic goods) and with Article XX. Moreover, it was claimed that Mexican tuna was sufficiently different from tuna caught by US fishermen since Mexico used different (less dolphin-safe) fishing methods and that, therefore, the non-discrimination principle of Article III was not applicable. Article XX was used to justify the import ban as a means of environmental policy. The GATT decided that Article III referred to products but not to methods of production and that the ban, therefore, was not in accordance with the non-discrimination principle. This can be interpreted as an acknowledgement of the origin principle. Differences across countries in the regulation of production processes do not constitute a justification to intervene into foreign trade. The GATT Panel's main arguments concerning Article XX were that the measure was discriminatory, that it was a disguised barrier to trade, and that less distorting measures of environmental policy would have been possible in this case. Moreover, the Panel argued that Article XX does not permit a country to take measures to enforce its own environmental standards outside its jurisdiction.

A more recent GATT Panel decision in the shrimp-turtle case (see GATT, 1998) comes to a different view although the ultimate result is the same: the trade restriction used to protect the environment is not in accordance with GATT rules. The US had launched an embargo on shrimps import from various Asian countries since the shrimp fisheries in these countries caused the killing of sea turtles that are threatened by extinction. This new Panel did not refer the extraterritoriality principle, which is nowhere contained in the GATT. Moreover, it did not discard the measure because it discriminated against "like products". Nevertheless, the way in which the embargo was implemented, was regarded as being discriminatory. This Panel marks a significant progress in the GATT's perception of environmental issues. Two sources of incompatibility between the GATT in its earlier interpretation and international environmental agreements are eliminated: the extraterritoriality principle and the principle that commodities cannot be defined by the way in which they are produced. According to the new Panel, it is now compatible with GATT to use trade interventions to protect extraterritorial resources, and the way in which imported goods have been produced matters. Relating this to the Montreal Protocol, for instance, one is lead to conclude that the trade interventions required by the Protocol are compatible with the GATT. There is nothing in the GATT to prevent the signatory parties of the Montreal Protocol to protect the ozone layer, an extraterritorial resource, by using trade sanctions including the ban of imports of commodities that have only been produced with CFCs without containing them.

Given this new interpretation of GATT rules by a GATT panel, the necessity of adjusting the world trade order to the requirements of environmental protection looks less pressing than it did in the mid 1990s. Nonetheless it might be useful to clarify the relationship of GATT rules and those international environmental agreements that permit or even require trade restrictions. One possibility is to use an "environmental window" like Article 104 of the North American Free Trade Agreement. This article states that international environmental agreements like the Montreal Protocol, the Convention of Trade in Endangered Species, and

the Basel Convention, that propose restrictions of international trade, are given prevalence over the NAFTA in the case of inconsistencies. At the time this survey article is being written environmental problems are a top issue in the World Trade Organization and it would be pure speculation to try and predict the outcome current negotiation process.

8 Summary and Conclusions

The literature on trade and the environment is still not a homogenous body. In economic theory, there are basically two types of papers, those that start from the classical and neoclassical trade theories based on Ricardian and Heckscher-Ohlin-type thought, and those using non-competitive models. Particularly the last group of models produces a set of rather diverse results. Especially, multi-stages oligopoly models are highly sensitive to the assumptions made concerning the sequence of moves and the shape of the functions. Thus, a short and clear policy implication is hard to give. Similar considerations apply to models that look at international factor movements, in particular foreign direct investment, from a theoretical perspective. The consideration of distorted economies leads to second-best results that have rather diverse policy implications as well. Nonetheless, one should not lose sight of the first best. This first best policy is: strict environmental standards plus free trade. Moreover, it is important to note that the subsidiarity principle applies to environmental policy as well. With the exception of global pollutants, there is no reason to harmonise environmental standards internationally. See Hansson (1990) and Bhagwati/Srinivasan (1997) on this. Nonetheless, international policy coordination is necessary in the case of transfrontier pollution. On the empirical side, one must concede that the link between environmental policies on the one hand and foreign trade and foreign direct investment is much weaker than one may have thought a decade ago. This is good news to the policy maker, to the environmentalist, and to the industry lobbyist. The industries affected by environmental regulation suffer much less than is often thought. There may be some exceptions but the impact of environmental regulation on structural change is small. Many environmentalists fear that liberalisation leads to additional environmental disruption and to a race towards the bottom. This view is not supported by the data. On average, trade liberalisation seems to be environmentally beneficial (albeit exceptions exist, of course) and environmental laxity is, if at all, a rather ineffective instrument to increase competitiveness. For policy maker, matters become easier since environmental and trade policies can be by and large be regarded as separate issues.

As regards economic research, extensions and refinements of existing models are still possible. To me some areas seem to be particularly promising. One is the consideration of endogenous market structures. Most theoretical models assume either perfect competition or a constant number of firms. The intra-industry trade model may be a starting point. Closely related to this is the consideration of economic geography. The state of the art is surveyed by Fujita/Krugman/Venables (1999) and it seems to be promising to apply these concepts to environmental issues. A first step into this direction has been undertaken by Haavio (2000). The third theoretical aspect which should attract more research interest is the political economy of environmental regulation in open economies. In this area, the literature is still rather patchy. A better understanding of this process is desirable - not only for its own sake but also for the purpose to design better institutions such that environmental protection and environmental protectionism can be disentangled in the policy process. On the empirical side, much more evidence on the linkages between trade and the environment will be collected. This deepens our knowledge about what drives the real world and about the appropriateness

of our theoretical process. My forecast is that this empirical research will not produce very surprising results but confirm and refine what is known already. Should the insight that environmental regulation and foreign trade are only loosely linked be confirmed, then would have a very simple policy implication: the environment and international competitiveness are separate issues and the purpose of environmental policy is to get the prices right.

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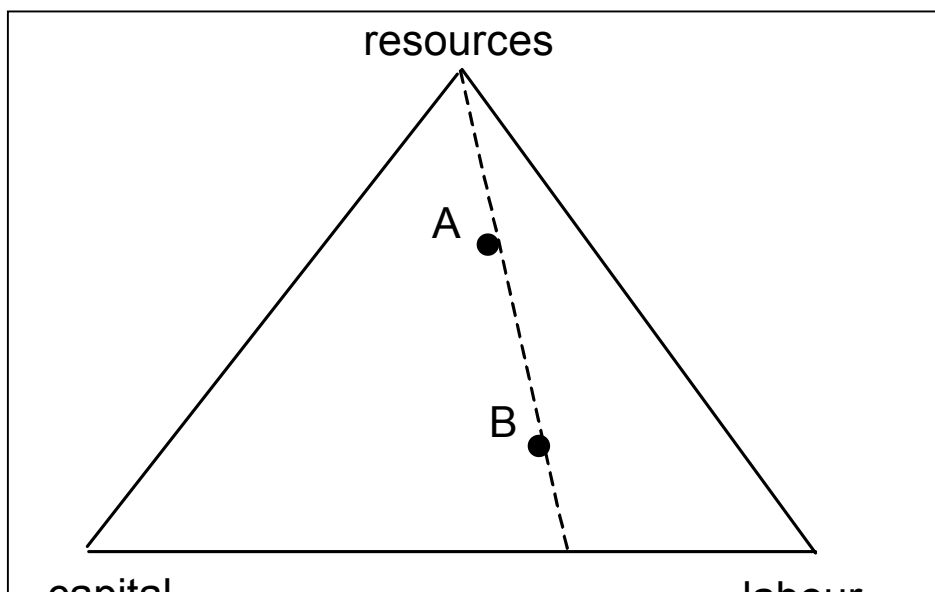
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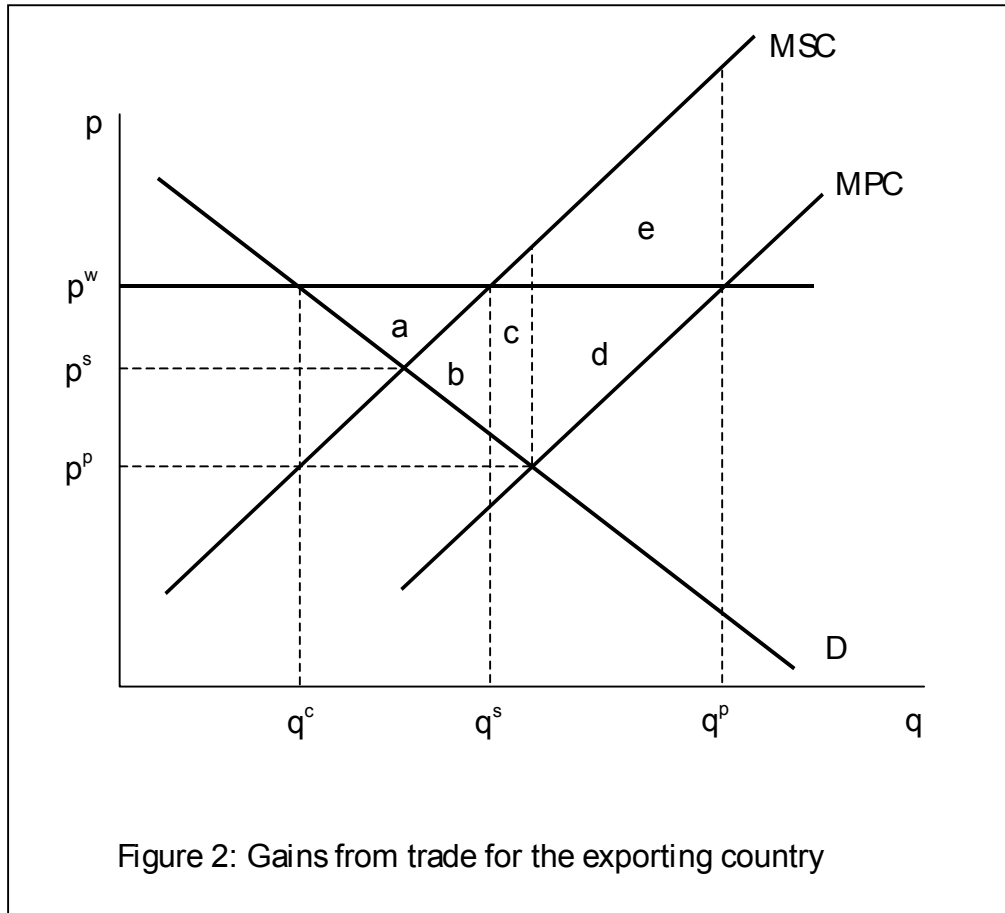
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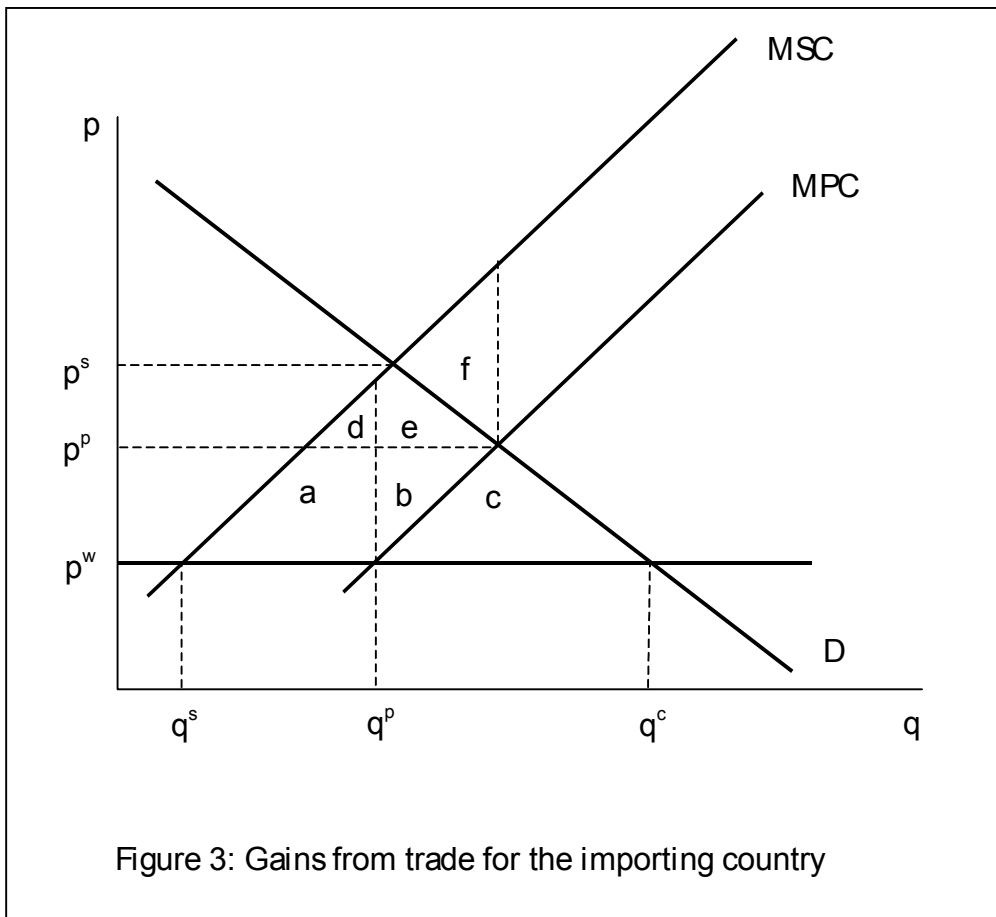
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Figure 1: The Leamer triangle with environmental resources







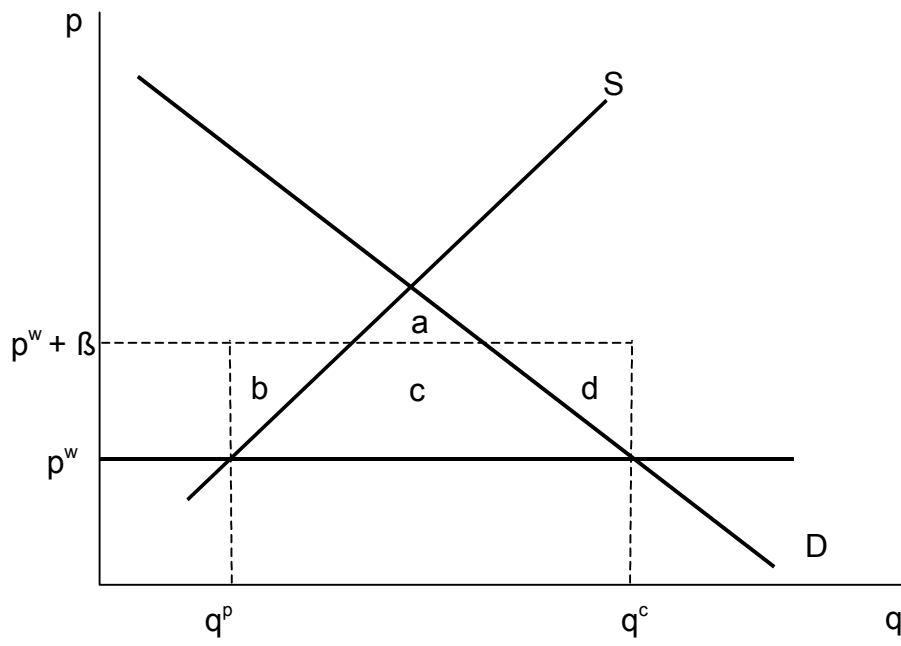
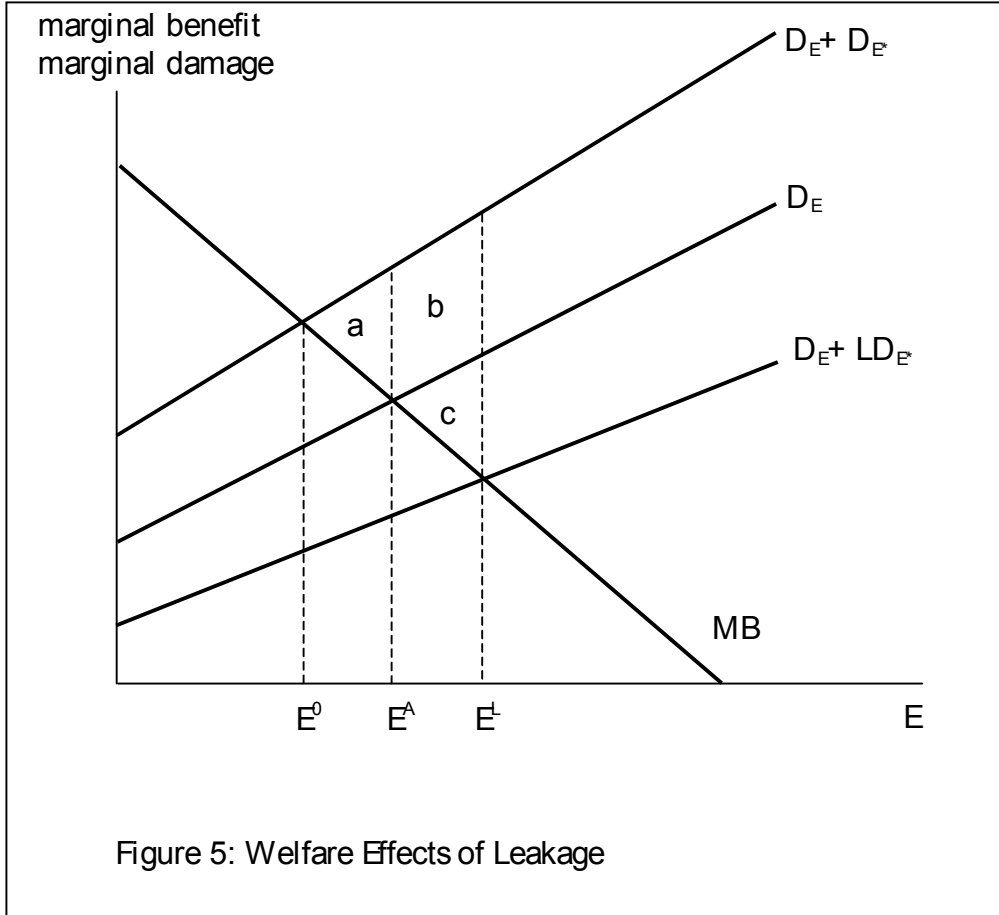
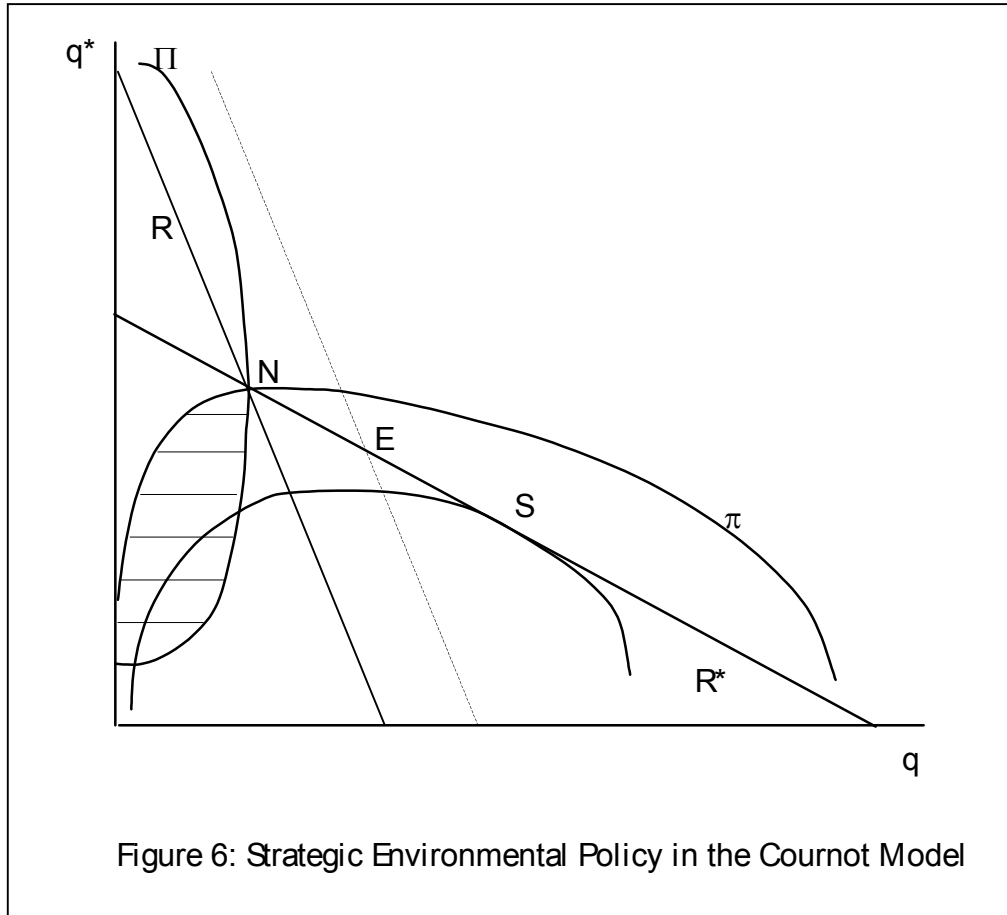


Figure 4: Transport externalities and gains from trade for the importing country





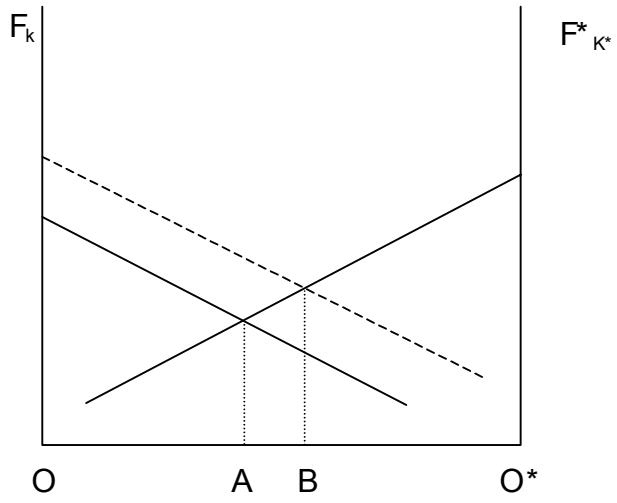


Figure 7: Environmental Regulation and International Capital Movements

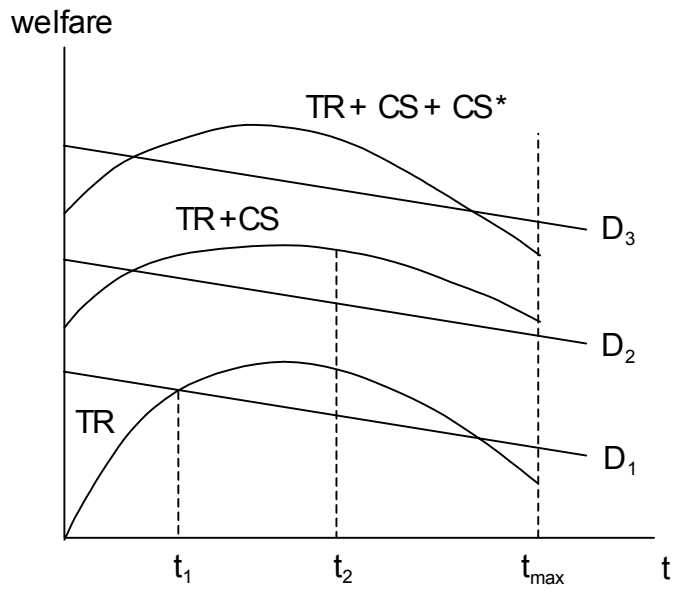


Figure 8: Emission taxes to attract foreign investment

