The Royal Veterinary and Agricultural University
Food and Resource Economic Institute

A UNIVERSITY OF LIFE SCIENCES

Unit of Economics Working Papers 2003/4

Strategic Choice of International Emissions Trading Scheme in an Open Economy with Perfect Competition.

October 2003

Jan Tjeerd Boom

Strategic Choice of International Emissions Trading Scheme in an Open Economy with Perfect Competition

Jan Tjeerd Boom*†

Abstract

Emissions trading can be organized in several ways. In particular, private emissions trading can be organized as permit trading, or as credit trading. The schemes have a different impact on output with credit trading leading to a higher output level than permit trading. This paper analyzes what the optimal choice of emissions trading scheme is in a model with international trade and perfect competition in the product and emission quota market. Furthermore, I discuss whether it is optimal for the country to allow its firms to trade emissions internationally. The paper shows that countries want to use these schemes in different circumstances, depending on whether they import or export the good. Furthermore, it is shown that in several cases, countries maximize their welfare by *not* allowing international emissions trading.

Key words: environmental policy, emissions trading, credit trading, international trade, perfect competition, strategic behavior.

JEL classifications: F10, L51, Q25, Q28

*The Royal Veterinary and Agricultural University, Department of Economics, Rolighedsvej 25, 1958 Frederiksberg C, Copenhagen, Denmark, Tel.: +45 35 28 22 93, Fax: +45 35 28 22 95, e-mail: jtb@kvl.dk

†I would like to thank Bouwe Dijkstra and Andries Nentjes for comments on previous versions of this paper.

1 Introduction

The Kyoto Protocol of 1997 allows international trade in greenhouse gas emissions between the countries that committed to an emission ceiling (the Annex B Countries). Several countries are already engaged in project based emissions trading and are preparing for international emissions trading between private parties. The most elaborate example of the latter is the EU wide CO_2 trading scheme between several of the most energy intensive sectors.

As the discussion within the EU showed, there are many issue to be settled before an international emissions trading scheme can be implemented. One of the most important issues is what the basis for the national emissions trading schemes should be. Here, the choice is basically between a cap and trade system and a system based on relative standards (Boom (2001), Gielen et al. (2002) and Boom (2003)). In the first system, denoted as permit trading, there is a cap on total emissions. This cap is divided into permits that are distributed over the emissions sources, who are then allowed to trade them. In the second system, denoted as credit trading, firms are allowed to emit a certain amount of emissions per unit of output. This means that the total level of emissions is not fixed, but can change with output. Firms that can stay below the standard can sell emission credits. It is not necessary for a firm to reduce emissions before it can issue credits. Just as with permit trading, a firm can issue a credit if it expects to reduce emissions (see Boom and Nentjes (2003)). The two schemes have a different impact on the industry. Output is higher under credit trading than under permit trading and if the total emission goal is the same under both schemes, marginal abatement costs will be higher under credit trading. Of these two schemes, permit trading is the most efficient and leads to the highest welfare when all emission sources are price takers both in the goods and in the emission quota markets.

Besides the choice between credit and permit trading, governments must decide whether or not to allow international emissions trading. The effect of opening up for international trading is that the price of emission quotas will change, which in turn will affect production within the country. If the regulated industry is small on a world scale, this is how far the analysis goes. A country will then always gain from allowing emissions trading since it will either save abatement costs, or make a gain from the sale of permits. This is the classical case for emissions trading, both nationally and internationally. It also follows that the optimal international emissions trading scheme under these circumstances is permit trading.

However, countries can have market power in a good, even when their firms do not. In that case, the country can affect the price on the world market by altering domestic production through some of the policies it sets. As will be clear from the description of permit and credit trading above, one such policy that potentially could affect the world market is environmental policy.

The main purpose of this paper is to analyze whether countries have an incentive to choose their emissions trading scheme strategically when they have market power in the goods market. To this end, a partial equilibrium model with one industry is developed with perfect competition in both the goods and the emissions quota market. Although a country could have market power in the emissions quota market too, this will be harder to obtain than market power in a good since several industries will be trading emission quotas together. To concentrate on the choice of instrument, it is assumed that the countries involved have committed to a cap on total domestic emissions. Several papers have discussed the effect of environmental policy on international trade and welfare, but not many papers discuss instrument choice of a country in such a setting with perfect competition in the goods market (see next Section for an overview of the literature). This paper differs from previous work in this area in that it compares instruments of environmental policy in their effect on the welfare of a country and in that it considers the choice between national and international emissions trading. The analysis shows that countries have an incentive to distort international trade through the choice of emissions trading scheme and that in certain cases countries have an incentive *not* to allow international emissions trading.

In the next section a brief overview of previous, related work, is given. In Section 3 a partial equilibrium two stage model is presented. In the first stage, the government decides which form of emissions trading to implement and whether or not to allow international emissions trading. In the second stage, firms maximize their profits under perfect competition while taking the choice of instrument by the government as given. As is usual in stage games, the two stages will be discussed in reverse order. The optimal instrument choice for the country is discussed at the end of the section. A summary and conclusions are given in Section 4

2 Literature Review

In all the models discussed in this section it is assumed that firms operate in a market of perfect competition. One of the characteristics of such a market is that no single firm has an influence on the price of the good produced. However a country may be able to affect the price of a good. It will be able to do so when it produces a considerable part of total world output and when it implements some policy that affects all domestic firms in the sector.

Markusen (1975) develops a model of trade and transboundary pollution. In the model, there are two commodities the production of one of these is causing pollution. There is no possibility for substitution among inputs or outputs so as to reduce emissions, and neither is an abatement technology available. Therefore, the only method to reduce domestic pollution is by reducing production. Not only domestic production causes pollution, this is also the case with foreign pollution. The market for the two commodities is assumed to be perfect. The government seeks to maximize welfare and has three instruments to do so; it can use a tariff on exports and imports, a production tax and a consumption subsidy. Markusen first determines the optimal tax structure, after which he analyzes the three cases where only one of these instruments can be used.

The first best tax structure consists of a production tax and a trade tax. The production tax is set at the usual level, where marginal abatement costs equal marginal social damage costs. The trade tax consists of two parts: a trade part and a pollution part. The trade part is the usual optimal tariff formula for the two-good case. This part will be positive if the good is imported and negative (an export tax) when the good is exported. The second part results from foreign pollution. This part is always positive. Hence, the domestic government tries to lower foreign pollution by imposing a tariff on the import of the foreign good.

Of the three cases where only one instrument can be used, the case with product taxes is the most interesting for our purpose. With only a production tax, the three components mentioned above all influence the level of the tax. First of all, domestic pollution calls for a positive tax. However, this production tax will cause the price to rise, which in turn encourages foreign production and thereby foreign pollution. Hence, with foreign pollution, the production tax will be lower than without foreign pollution. The third part is the already mentioned optimal tariff part. When the product is imported, the good should be subsidized, when it is exported, it should be taxed. The resulting tax (or subsidy) depends on the strengths of these three effects.

Krutilla (1991) analyzes essentially the same model as Markusen. However, in the model by Krutilla, pollution is not transboundary but only domestic and only one good is produced. Besides discussing pollution as a production externality, Krutilla also models the case where pollution is a consumption externality. Just as Markusen, Krutilla discusses the use of both an environmental tax and a tariff on the export or import of the good. Not surprisingly Krutilla arrives at the same conclusions as Markusen in the case of a production externality. The optimum can be reached by use of an optimum Pigouvian tax on pollution and an optimal tariff on exports or imports. When the tariff instrument cannot be used, the environmental tax is lower than the optimal Pigouvian tax when the good is imported, while it is higher than the optimal Pigouvian tax when the good is exported.

Dijkstra (1998) develops a model similar to Markusen (1975) and Krutilla (1991). However, Dijkstra makes a comparison between taxes and standards per unit of product. Whereas in the models by Markusen and Krutilla abatement technologies are not available, they are in Dijkstra (1998). Hence, in Markusen (1975) and Krutilla (1991) emissions can only be reduced by reducing production and therefore, an emission tax is equivalent to a production tax. In the model by Dijkstra, emissions can be reduced by reducing production and by increasing the abatement effort.

Dijkstra (1998) analyzes a model with perfect competition between firms and explicitly includes the consumer surplus. He studies four cases: autarky, international trade without pollution, international trade and domestic pollution and international trade and global pollution. The model is a one shot game of instrument choice between governments, where the first two cases are used as benchmarks. Dijkstra (1998) shows that there is no difference between the instruments taxes, permit trading and firm emission ceilings. However, he does find a difference between these instruments and an emission standard per unit of product. The main reason for this is that with a standard per unit of product the producer will produce more than with the other instruments. Hence, in cases where welfare can be increased by higher production, standards per product outperform taxes. Dijkstra (1998) finds two such cases. Production is too low with emission taxes when a country imports the polluting good. This result comes about irrespective whether pollution is local or transboundary. A second case occurs only with transboundary pollution. Dijkstra assumes that the foreign country does not reduce emissions. If the domestic country reduces emissions, domestic output becomes lower and foreign output increases. The latter effect is unwanted because foreign output is more polluting than domestic output. Therefore, it would be better to have both low domestic emissions and high domestic output. This can be achieved with relative standards.

The model presented in the next section builds on the models discussed above, especially on Dijkstra (1998). The model extends previous work in that credit trading has never been considered in this setting before. The main contribution however is that international emissions trading, in two forms, is added to the analysis. The setting makes it possible to analyze instrument choice at the national and international level, and to determine whether it always is optimal for governments to allow international emissions trading. Different from the models discussed above, I assume that the emission level in all relevant countries is fixed. Hence, there is no interplay between instrument choice and levels of emissions. This is done to concentrate on the choice of emissions trading scheme.

3 The Model

In this section, a model is presented with perfect competition in the goods and emission quota market. The good is traded internationally with producers being located both in the home country and abroad. Firms have no influence on the price of the product or emission quotas. However, it is assumed that the country's output of the product is so large compared to total world production that the government can affect the product price by the environmental policy it implements. In the model, it is assumed that countries have no market power in the emissions quota market. The rationale for this is that international emissions trading will occur between firms from several industries from various countries. Therefore, it is harder to gain market power in the emissions quota market through the choice of instrument in an industry that to obtain market power in the market for a good. Essentially, the government has to make two choices: 1) which instrument of environmental policy to choose, where we limit the analysis to permit and credit trading, and 2) whether to restrict trading to national emission sources, or to allow international emissions trading between sources. The model is a two stage model with the government moving first by choosing an instrument. In the second stage, firms maximize profits, while taking the choice of instrument as given. As is usual with stage games, stage two is analyzed before stage one.

There are n_h producers of a homogeneous good in the domestic country, with n_h being large. Each firm maximizes its profits taking the price P as given. Costs are represented by $C(q, E)$, where q is production and E are emissions. We assume that $C_q > 0$, $C_{qq} \geq 0$ and $C_{qE} < 0$. Furthermore, $C_E = 0$ without environmental policy and $C_E < 0$ with environmental policy and $C_{EE} \geq 0$. The government has set a limit on total emissions from the industry equal to L_h. In the following, it is assumed that the government has perfect information about the behavior of the firms. It is therefore always able to set the environmental policy such that the total limit on emissions is realized.

3.1 Stage Two: Firm behavior

In this section we analyze firm behavior. First, we deal with the case when the government implements national policies, but does not allow international emissions trading between private entities. Here we restrict the choice of national instrument to permit trading and credit trading. Permit trading is based on an absolute cap on emissions, while credit trading is based on relative standards that put a limit on emissions per unit of output. As Dijkstra (1999) shows, the outcome under permit trading is identical to that under taxes or absolute standards. Furthermore, the outcome under credit trading is identical to the outcome under relative standards. So, although the analysis is limited to only two instruments, results apply to other instruments as well. In the following we will show that credit trading leads to a higher output level and higher marginal abatement costs than permit trading.

Permit Trading. With permit trading, the ceiling that is placed on total domestic emissions is divided over the firms in the form of emission permits that give the right to emit a certain amount of the pollutant. The initial distribution of permits can either be for free grandfathering) or through an auction, or a combination of the two. After the initial distribution, firms are free to trade the permits. Here, we assume that the permits are grandfathered. With permit trading, the firm's maximization problem becomes

$$\max_{q} \quad \Pi = Pq - C(q, E) - t(E - \bar{E}) \tag{1}$$

Here t is the domestic permit price and $\bar{E}$ is the initial allocation of permits, with $\bar{e} = L_h/n_h$. The first order conditions are

$$P = C_q \tag{2}$$

$$-C_E = t$$

These are the usual conditions under perfect competition; the firm equates marginal costs of production to the price of the product and also equates the marginal costs of emissions to the price of permits.

Credit Trading. With credit trading, the government sets an emission ceiling $\bar{e}$ per unit of production, with $\bar{e} = L_h/n_h q_h$. Firms are than allowed to sell credits if they (think they) can stay stay below the standard. The maximization problem of the firm becomes

$$\underset{q}{max} \quad \Pi = Pq - C(q, E) - t(E - \bar{e}q) \tag{3}$$

where rt is the price of credits. The first order conditions are

$$P + t\bar{e} = C_q$$

$$-C_E = t$$

Combining the two first order conditions gives

$$P = C_q + \bar{e}C_E \tag{4}$$

Comparing equation (4) with equation (2), it is clear that production will be higher with relative targets than with permit trading at the same level of emissions. To see this, recall that $C_E < 0$ and $\bar{e} > 0$. Hence, the factor $\bar{e}C_E$ is negative. The result is that the product price is lower under relative standards than under permit trading. This can only be the case when production is higher under relative standards than under permit trading. The reason for this difference is that with credit trading the firm is allowed to emit more as it produces more.

Another result should also be noted. With relative standards, the marginal costs of abatement will be higher than under permit trading. This result follows from the fact that total emissions are equal under the two instruments, while output is higher under relative standards. As mentioned above, the marginal abatement costs is increasing in output for the same level of pollution. Hence, marginal costs of abatement will be higher with relative standards than with permit trading.

International Emissions Trading. As mentioned above, we assume that neither firms nor governments have market power in the market for emission quotas. This means that the international emission quota price is given for firms. Denote the international quota price by T. The only change in the analysis for the two instruments then is that t is replaced by T.

3.2 Stage One: Choice of Emissions Trading Scheme

We now turn to the instrument choice of a country. The case analyzed is the one where all relevant countries have committed to a certain emission goal. The emission goal of the home country is given by L_h. The assumption that all relevant countries have committed to an emission ceiling makes that the emission levels are fixed, and hence, that countries do not have an incentive to manipulate the level of emissions.

Since now we turn to the level of the country and not the firm or industry, we have to adapt the notation slightly. In the following, q_h denotes the total production of the domestic industry. The home country is large enough to influence the price of the product. This also implies that a change in domestic production leads to a change in foreign production. Total foreign production is denoted as $Q_f(P(y), I_f)$, where I_f is the foreign policy choice. It must hold that $-1 < \partial Q_f/\partial n_h q_h < 0$, i.e., when the output of the home country increases, foreign producers reduce their output, but not by as much as the original increase increase of output by the home country. The overall result is that total output is increased but by less than the initial increase in output. All consumers in all countries are assumed to be identical. In the following, we denote by μ_h the proportion of identical consumers in the home country.

3.2.1 No international emissions trading

We first analyze the case where international emissions trading is not possible, neither between firms nor between governments. The welfare of the domestic country is given by

$$\max_{q_h} \quad W = \mu_h \int_o^y P(y)dy - P(y)\mu_h y + P(y)n_h q_h - n_h C(q_h, E_h) \qquad (5)$$

The first two terms on the RHS of equation (5) give the domestic consumers' surplus. The last two terms give the producers' surplus. Differentiating equation (5) with respect to q_h gives

$$\frac{\partial W}{\partial q_h} = n_h \left(P - C_{q_h}\right) + P' \frac{\partial y}{\partial q_h} \left(n_h q_h - \mu_h y\right) = 0 \qquad (6)$$

The first term gives the aggregate difference between product price and marginal production costs, while the second term gives the trade balance in the product times the market power of the country. As already mentioned in section 2, the optimal policy would normally consist of an import subsidy or export tax combined with an emission tax or permit trading. However, in this paper it is assumed that the government cannot use an import subsidy or export tax. Therefore, it can only affect domestic welfare through the choice of environmental policy instrument.

In one special case it is possible for the government to obtain maximum welfare. This will happen when the implementation of permit trading leads to autarky. This can be seen by setting the term for the domestic excess supply, $n_h q_h - \mu_h y$, equal to zero. The result is equivalent to equation (2), which gives the optimal level of production in the case of permit trading.

Suppose that permit trading does not lead to autarky in the product, but to a net export of the product. We now find $P = C_{q_h}$ and $n_h q_h > \mu_h y$. Equation (6) now becomes negative and welfare would be higher with a lower level of production. However, production should not be so low that the country achieves autarky. With autarky, $P > C_{q_h}$ and $n_h q_h = \mu_h y$ and welfare would be higher with a higher production level. This shows that when permit trading leads to net exports of the product, optimal welfare is reached with a lower production level, but the country should still be an exporter. The reason for this result is that when the country is an exporter, the producers' surplus is more important for the welfare of the country than the consumers' surplus. By reducing output, the country can increase the price of the product, increasing profits for its own firms. When the country is a net importer of the good, the consumers' surplus is more important than the producers' surplus so that the country will want to increase production to reduce the price of the product. In the case where permit trading leads to a net export of the good, permit trading is not optimal since output is too large. However, the only alternative is credit trading, which leads to even higher output. Therefore, permit trading is the best choice under the given circumstances.

We now turn to the case where the imposition of permit trading leads to an import deficit. Then, $q_h < \mu_h y$ and $P = C_{q_h}$. Now production is lower than optimal. Hence, the government would want to increase production. This can be done by the imposition of relative standards. In that case $P < C_{q_h}$. However, the imposition of relative standards may increase production by so much that the import deficit turns into a balanced trade balance or even into an export surplus. In those cases relative standards are not optimal. Hence, the country will only prefer credit trading when it is a large importer of the good.

The result is that permit trading are the optimal instrument when they lead to an export surplus or a small import deficit. When these instruments lead to a large import deficit, the government prefers to use relative standards.

3.2.2 International emissions trading.

We now turn to the situation where firms are allowed to trade emission quotas internationally. As mentioned before, we assume that neither the firms, nor the country have market power in the market for emission quotas. Welfare of a country consists of the consumers' surplus and the producers' surplus. Before we turn to the analysis of the home country's welfare, we first discuss the effect of a shift to international emissions trading on the profits of a firm. Since the profit function differs for the two trading schemes, we will discuss them in turn, starting with permit trading.

What happens to production as firms are allowed to trade emission permits internationally? Suppose the firm sells permits on the international market. This implies that $T > t$. This is the same as a tightening of domestic policy. Hence, the effect is to reduce production. For a buying firm the reverse is true; $T < t$ and production will be increased.

With permit trading, we can analyze the effect of a shift from no trading to trading on profits of the firm by differentiating equation (1) with respect to t.

$$\frac{\partial \Pi}{\partial t} = P_t q + q_t(P - C_q) - E_t(t + C_E) - (E - \bar{E}) \tag{7}$$

Since with permit trading, $P = C_q$ and $-C_E = t$, it follows that the second and third term on the LHS of equation (7) are zero. Hence, we have

$$\frac{\partial \Pi}{\partial t} = P_t q - (E - \bar{E}) \tag{8}$$

Suppose that the country initially implemented domestic permit trading and first afterwards allows international trade in permits. Furthermore, assume that domestic trade in emissions was only allowed within the industry[1]. First we will analyze the case where the firm becomes a seller of permits, i.e. $T > t$. In that case, the firm will reduce its emissions. The result is a rise in production costs and thereby a reduction in production. Since this is the same for all domestic firms in this industry total production will fall and the price of the product will rise. The reduction in emissions will be sold on the market at the price T. In this case we have $P_t > 0$ and $(E - \bar{E}) < 0$ and equation (8) becomes positive. Hence, when the firm becomes a seller of permits, its profits will rise. When $T < t$, the firm becomes a buyer of emission quotas. Now, the first term in (8) gives a reduction in profits, while the second term points to an increase in profits. Firms have lower abatement costs now that they can buy quotas abroad, but this lowers production costs and leads to an increase in production. World production increases and the price of the product decreases, so that firm profits decrease. Whether firm profits increase or decrease depends on how large the gains from emissions trading are relative to the decrease in profits from the lower world price of the good.

We now turn to the case where the industry is regulated through credit trading. The effect of a shift to international emissions trading on the profits of the industry is ca be found by differentiating equation (3) with respect to t

$$\frac{\partial \Pi}{\partial t} = P_t q + q_t(P - C_q + t\bar{e}) - E_t(C_E + t) - (E - \bar{e}q) + tq\bar{e}_t \tag{9}$$

Using the first order conditions, we can see that the second and third term on the RHS of equation (9) vanish. Hence, we have

$$\frac{\partial \Pi}{\partial T} = P_T q - (E - \bar{e}q) + Tq\bar{e}_T \tag{10}$$

[1]This implies that with domestic trading $E = \bar{E}$.

The first term on the RHS gives the effect of the change in price of the product on revenue. The second term is the change in profit due to a sale or purchase of credits. The third term on the RHS reflects the change in profits because of a change in the relative standard. We have to elaborate a bit on the third term. When the world credit price is different from the domestic credit price, firms will start trading credits. This however has an impact on the marginal costs of production, and thereby on the level of production. If $T > t$, marginal production costs will increase and production will be lower. Conversely, when $T < t$, production will be increased. This will have an impact on the relative standard though, since the government sets the standard by dividing the limit on total emissions by aggregate production. Hence, when production is decreased, $\bar{e}$ is increased, i.e., policy becomes less strict. This implies that $\bar{e}_T > 0$, i.e., when the credit price rises, production decreases and the relative standard will be increased.

Suppose that $T > t$ and the firms in the industry become exporters of emission credits and production will decrease. In that case, the first term in (10) become positive, while the second term becomes negative. This is exactly the same as with permit trading. Furthermore, the government will increase the relative standard because of the decrease in production, so that the third term becomes positive. The result is that (10) is positive and profits increase for the firm when it becomes a seller of credits.

When instead $T < t$, the firms will buy emission quotas on the world market. The first term and third term in (10) are still positive, while the second term now becomes positive. The firm gains from emissions trading through lower costs of abatement. However, profits decrease because of a lower world price of the good and a tighter relative standard. It depends on how large the gain from emissions trading is whether firms will be better of from a shift to international emissions trading.

The result for credit trading is thus basically the same as for permit trading. With credit trading, there is however an additional effect because changes in production lead to a change in the relative standard that is set. For a seller of permits, this means an additional gain as the standard is made less strict, while for a buyer, it is an additional loss.

Having analyzed the change in firm profits resulting from a shift to international emissions trading, we now turn to the effect on total country welfare. With international emissions trading, the objective function of the government becomes

$$\begin{aligned} W = \; & \mu_h \int_o^y P(y)dy - P(y)\mu_h y + P(y)n_h q_h - n_h C(q_h, E_h) \\ & -n_h T\left(E_h - \bar{E}_h\right) \end{aligned} \tag{11}$$

Differentiating with respect to q_h yields

$$n_h (P - C_q) + P' \frac{\partial y}{\partial q_h} (n_h q_h - \mu_h y) = 0 \qquad (12)$$

Hence, the optimization problem of the government is essentially the same as when there is no international emissions trading. There are however some important differences. With international emissions trading, the government cannot set the level of emissions, i.e. it cannot set T, the price of permits, through the emission ceiling it sets.

The shift from national emissions trading to international emissions trading can be viewed as a change in the price of emissions quotas. To find out whether allowing international emissions trading for individual firms will lead to a higher welfare, differentiate equation (11) with respect to the price of permits, t. This is not a completely correct way of analyzing this since the change in emission quota price is discrete, but one could imagine that the world price of emission quotas is only marginally different from the domestic price. After rearranging, differentiation of (11) gives

$$\frac{\partial W}{\partial t} = n_h \frac{dq}{dt} (P - C_{q_h}) + P' \frac{\partial y}{\partial q} \frac{dq}{dt} (n_h q_h - \mu_h y) - n_h \left(E_h - \bar{E}_h \right) \qquad (13)$$

A rise in the price of emission quotas is equivalent to a stricter emission standard, implying $dq_h/dt < 0$. As noted before, $0 < \frac{\partial y}{\partial q} < 1$ because of the reaction to a change in domestic output by foreign producers. The first term on the RHS of (13) gives the difference between the price and the marginal production costs times the change in total output. The second term gives the trade balance in the product times the change in the product price due to a change in output. The third term gives revenue from emissions trading. In the following, we will analyze whether a change to international emissions trading leads to higher welfare for each of the two instruments separately. After that, the optimal policy for the country in the four possible cases is discussed.

Permit Trading. With permit trading, $P = C_{q_h}$ and equation (13) diminishes to

$$\frac{\partial W}{\partial t} = P' \frac{\partial y}{\partial q} \frac{dq}{dt} (n_h q_h - \mu_h y) - n_h \left(E_h - \bar{E}_h \right) \qquad (14)$$

Basically, there are four possible cases depending on the balance of trade in the product and on the world price of permits. An overview of these four cases is given in Table 1. In the first case, the country is an exporter of the good and the world price of permits is higher than the domestic price.

In this case, the country will export permits, hence $(E_h - \bar{E}^h) < 0$. The higher permit price will give a decrease in production and this will raise the price of the product. The overall effect is that equation (14) will be positive. Hence, the shift to international emissions trading leads to a welfare gain in this case. It has to be noted though that this only holds as long as the country remains a net exporter of the good. If production is decreased so much because of the rise in the permit price that the country becomes a net importer, welfare may decrease.

In the second case, the country also exports the good, but the world price of permits is lower than the domestic price. This means that production will be increased and therefore the price of the product decreases. Furthermore, because of the lower world price, the country imports emission quotas. In this case, the first term in (14) is positive, but the second term becomes positive. Welfare decreases because the price of the product decreases, while an increase is needed, but welfare increases because of the trade in emissions. If the gains from emissions trading are low, the country may experience a loss in welfare when it shifts to international emissions trading. However, the gain from emissions trading can be so big as to outweigh the negative effect from a decrease in the product price.

The third case consist of the country being an importer of the good and the world price of permits being higher than the domestic price. Also here, the sign of equation (14) becomes ambiguous. The result of the higher world price of permits is a reduction in production. However, an increase in production is wanted. On the other hand, the country exports permits, which leads to higher welfare. This is indicated by the negative sign of the second term. It now depends on the size of the two effects whether welfare is increased as a result of allowing international emissions trading.

In the fourth case, the country is an importer of the good and $T < t$. The country becomes an importer of emission quotas, which leads to an increase in production and a decrease in the price of the good. Both terms in (14) point in the direction of an increase in welfare. However, the increase in production may be so large that the country becomes an exporter of the good. In that case, welfare may decrease. However, since the country always gains directly from emissions trading, the production effect needs to be very large indeed for the change in welfare to be negative.

Credit Trading. With credit trading $P < C_{q_h}$, and equation (13) holds unchanged. Also with credit trading, there are four possible cases, depending on the sign of $(n_h q_h - \mu_h y)$, and on whether T is larger or smaller than t. For an overview of the cases, see Table 2.

In the first case, the country is an exporter of the good and the world price

Table 1: Effect of a shift from national to international permit trading

$(n_h q_h - \mu_h y)$	T	q_h	P	$(E_h - \bar{E}_h)$	Welfare
$+$	$> t$	$\downarrow$	$\uparrow$	$-$	Increase
$+$	$< t$	$\uparrow$	$\downarrow$	$+$	Decrease (amb.)
$-$	$> t$	$\downarrow$	$\uparrow$	$-$	Decrease (amb.)
$-$	$< t$	$\uparrow$	$\downarrow$	$+$	Increase

of permits is higher than the domestic price. This means that production will decrease, the price of the product will increase, and the country exports permits. The result is that equation (13) becomes positive, which indicates an increase in welfare. The country makes a profit from emissions trading and product price increases, leading to higher firm profits. At the same time, the production distortion, given by the term $P - C_{q_h}$ becomes less important because q_h decreases.

In the second case, the country is still an exporter of the good, but now the world price of permits is lower than the domestic price. In this case, production will increase, the product price will fall and the country imports permits. The country still gains from emissions trading because it now faces lower marginal abatement costs. However, the country would like to reduce output to increase the price of the good, but the lower permit price leads to an increase in production. This lowers profits for the firms and gives a larger production distortion. Whether the country gains or looses from the shift to international emissions trading depends on the sizes of the three effects. If the direct gain from emissions trading is low, welfare may decrease because of the shift.

In the third case, the country is an importer of the good and the world price of emission quotas is higher than the domestic price. The country now sells credits, and lowers production, leading to an increase in the world price of the good. In this case, however, the country would prefer an increase in production to increase the consumers' surplus. The first and third term in (13) still point to an increase in welfare though; the country gains from emissions trading and the production distortion becomes less important through the reduction in production. Also here the total effect of a shift to international emissions trading is ambiguous. If the direct gains from trading are large enough to outweigh the detrimental effect on the consumers' surplus, the country will gain from the shift. The reverse is possible too though.

Also in the fourth case the country imports the good, but now the world price of emission quotas is lower than the domestic price. In this case, production rises and the product price falls, this is exactly what the country

Table 2: Effect of a shift from national to international credit trading

$(n_h q_h - \mu_h y)$	T	q_h	P	$(E_h - \bar{E}_h)$	Welfare
$+$	$> t$	$\downarrow$	$\uparrow$	$-$	Increase
$+$	$< t$	$\uparrow$	$\downarrow$	$+$	Decrease (amb.)
$-$	$> t$	$\downarrow$	$\uparrow$	$-$	Decrease (amb.)
$-$	$< t$	$\uparrow$	$\downarrow$	$+$	Increase

wants. At the same time, the country gains from the lower costs of abatement. The only ambiguity in equation (13) is that the production distortion is increased because of the increase in production. This effect is likely to be small though so that, it is likely that the country will want to implement international credit trading in this case. The only problem could be that the world price of emission quotas is so low that production rises enough to make the country only a small importer or even an exporter of the good. In those cases, the country is better of with domestic credit trading.

Optimal Policy. We can now discuss the policy results for all possible cases. The optimal policies in all cases are summarized in Table 3. A comparison of tables 1 and 2 shows that whichever instrument the government chooses, it always gains or looses in the same situations from a shift to international emissions trading. The country gains from the shift when it exports the good and it becomes a seller of emission quotas and it gains when it imports the good and becomes a buyer of emission quotas. In the other cases, welfare may decrease as a result from the shift, depending on how much the direct gain from emissions trading is. This part then shows whether the country should allow international emissions trading or not. Which of the two trading schemes should be chosen can be inferred from equations (6) and (12).

When the country runs a trade surplus and the world price of emission quotas is higher than the domestic price, the country should allow international permit trading, which implies that it uses domestic permit trading too. The reason for this is that in this case the country wants to reduce production. This is done best by international permit trading, because in this case this lowers production in comparison with domestic permit trading, which is the optimal instrument when international trading is not an option. Only when the shift to international permit trading leads to a large decrease in production so that the country achieves autarky in the good, or becomes an importer might the country not allow international trade in permits. This depends partly on the gain from international emissions trading. If this gain is large enough, the country should still engage in trading, even though it

Table 3: Policy

$(n_h q_h - \mu_h y)$	T	Policy
$+$	$> t$	International permit trading
$+$	$< t$	Domestic permit trading
$-$	$> t$	Domestic credit trading
$-$	$< t$	International credit trading

becomes an importer of the good.

When the country runs a trade surplus and the world price of permits is lower than the domestic price, the best policy for the government is to use domestic permit trading and not to allow international permit trading. The reason is that international permit trading leads to an increase in production, while a decrease is wanted. A provision has to be made for the situation where profits from international emissions trading are large. In that case, these profits may compensate the negative effect of an increase in production.

In the third case, the country is an importer of the good and the world price of permits is higher than the domestic price. As we have seen above, when international emissions trading is not possible the country should prefer domestic credit trading when it is an importer, unless it only imports a little. When international trading is possible, the higher world price of credits leads to a decrease in production with permit trading and with credit trading. In this case, the country prefers to use domestic credit trading and will not allow international emissions trading as long as the gain from international emissions trading is small.

In the fourth and final case, the country is an importer of the good and the world price of permits is lower than the domestic price. When the trade deficit is large, the country will want to implement international credit trading since this increases production most. If the trade deficit is small, the country will prefer to use international permit trading or domestic credit trading because these also increases production, but not as much as international credit trading.

4 Conclusions

In this paper, a model on strategic choice of emissions trading scheme was presented. Countries can either choose to implement permit trading, which is based on a cap on emissions per firm, or credit trading, which is based on relative standards per unit of output. The two scheme have a different impact on the regulated industry, with credit trading leading to a higher output level and higher marginal abatement costs.

The main conclusions are that countries do have an incentive to choose their emissions trading scheme strategically and that in some cases, countries are better of when they do not allow international emissions trading. The outcome depends on whether the country is an importer of the good, whether the world price for emission quotas is lower or higher than the domestic price and on how large the gain from international emissions trading is.

In general, when a country exports the good it wants to reduce output to increase the world price of the good and thereby increase firm profits. The best choice of instrument in this case is permit trading since it leads to the lowest production level. When the country imports the good, however, it wants to increase production to increase the domestic consumers' surplus. Since credit trading leads to the highest output level, the country will prefer this instrument.

Whether or not a country wants to allow international emissions trading for its firms depends mainly on two things: the world price of emission quotas relative to the domestic price and the size of the gain from emissions trading. When the country becomes a seller of emission quotas, it will reduce output. However, when it imports the good, the country will want to increase production. Then it may be better not to allow international emissions trading. Only when the direct gain from emissions trading is large enough will the country still profit from international emissions trading. A similar reasoning holds for the case where the country becomes a buyer of emission quotas.

Several issues have not been dealt with in this paper, which could have an impact on the outcome. The model presented only analyzes the behavior of one country. An interesting extension would consist of modelling the choice of international emissions trading scheme in a two-country model to determine the Nash equilibrium choices. Furthermore, throughout the model I have assumed that the countries have no influence on the world emission quota price. Although this will be a realistic assumption for many countries and many industries, it may be relevant to relax this assumption.

References

Boom, J. T. (2001). International Emissions Trading under the Kyoto Protocol: Credit Trading. *Energy Policy 29*(8), 605–613.

Boom, J. T. (2003). Permit Trading and Credit Trading: A Static and Dynamic Analysis. mimeo, The Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Boom, J.-T. and A. Nentjes (2003). Alternative design options for emissions trading: A survey and assessment of the literature. In M. Faure, J. Gupta, and A. Nentjes (Eds.), *Climate Change and the Kyoto Protocol: The Role of Institutions and Instruments to Control Global Change*, pp. 45–67. Cheltenham: Edward Elgar.

Dijkstra, B. R. (1998). The International Dimension of Environmental Policy Instruments. Onderzoeksmemorandum 18, ECOF, Groningen University, Groningen.

Dijkstra, B. R. (1999). *The Political Economy of Environmental Policy: a Public Choice Approach to Market Instruments*. Cheltenham: Edward Elgar.

Gielen, A., P. Koutstaal, and H. Vollebergh (2002). Comparing emissions trading with absolute and relative targets. Paper presented at the 2nd CATEP Workshop, University College London, 25-26 March, Erasmus University, Rotterdam.

Krutilla, K. (1991). Environmental regulation in an open economy. *Journal of Environmental Economics and Management 20*, 127–142.

Markusen, J. (1975). International Externalities and Optimal Tax Structures. *Journal of International Economics 5*, 259–284.