Discussion Paper #D-04/1994

Environmental Regulations and International Competitiveness *

By

Eirik Romstad and Bengt Kriström **

---

* Comments on earlier versions of this paper by Michael C. Farmer (Department of Economics and Social Sciences, Agricultural University of Norway), Cathrine Hagem (CICERO − Center for International Climate and Energy Research), Aart de Zeeuw (Tillburg University), Karl-Göran Mähler (The Stockholm School of Economics) and the faculty of CORE, Université Catholique de Louvain la Neuve, are gratefully appreciated. The usual disclaimers apply.

** Respectively from the Department of Economics and Social Sciences, Agricultural University of Norway and Department of Forest Economics, Swedish University of Agricultural Sciences. Economic support for this research from the Nordic Environmental Research Programme is gratefully acknowledged.

File ER e:\eirik\artikkel\intreg\intreg.doc 06.03.97

Environmental Regulations and International Competitiveness

Abstract

Numerous proposed national environmental regulations have been shelved because they would put affected domestic industries at a competitive disadvantage. This has been a particular concern when the environmental problems are trans-boundary.

The effects of regulations on an industry's international competitiveness include (i) reduced profits due to direct limitations in input factor use or emissions (regulation effects), and (ii) increased costs due to the choice of policy instrument(s) (instrument effects). Using game theory this paper shows how environmental regulations with small instrument effects are easier to implement and sustain at the international level (any cooperative agreemet becomes more stable).

The environmental regulations considered in this paper are limited to environmental taxes and transferable emission permits. The instrument effects of a system with environmental taxes without lump sum pay-backs or similar taxes reduce the competitiveness of the regulated industry. Thus it is difficult to use environmental taxes to regulate industries competing on foreign markets, while reduced industry competitiveness from a system of transferable emission permits are basically limited to the regulation effects.

Key words: trans-boundary environmental problems, emission taxes and permits, game theory.

Introduction

Several proposed national environmental regulations have been shelved because they would put affected domestic industries at a competitive disadvantage. This has particularly been a concern regarding trans-boundary pollutants because the national welfare gains from improved environmental quality are more likely to be offset by the welfare losses caused by the affected firms exiting the industry or moving to countries where environmental regulations are less strict.

The merits of incentive based regulations over command and control schemes are well established in the economics literature[1]. The environmental regulations considered here

[1] Oates, Portney and McGartland (1989) show that under certain conditions and when special attention is taken to make a direct regulation scheme cost efficient, such a regime may be as cost effective as incentive based regulations.

are therefore limited to environmental taxes and transferable emission permits. The effects on industry competitiveness caused by regulations include (i) reduced profits due too direct limitations in input factor use or emissions (regulation effects), and (ii) increased costs due to the choice of policy instrument(s) (instrument effects).

The next section formalizes the concepts of regulation and instrument effects. In the succeeding section the regulation and instrument effects for emission taxes and tradeable emission permits are investigated. Finally, the characteristics of trans-boundary environmental problems including the objectives of the respective countries' regulatory agencies are discussed.

Regulation and Instrument Effects

The regulation and instrument effects of environmental regulations are strongly linked to the economics of production. Here these effects emerge due to efforts to curtail externalities. A short discussion of production with externalities is therefore be warranted.

Production With Externalities

Consider the following unconstrained profit function for the nth firm:

$$\pi(\mathbf{y}_n | \mathbf{p},\mathbf{v}) = p\ \mathbf{y}_n - c_n(\mathbf{y}_n | \mathbf{v}) \qquad [1]$$

where $\mathbf{y}_n$ is a vector of outputs produced by the nth firm,
$\mathbf{p}^o$ is an initial vector of product prices, and
c_n is a twice differentiable cost function of the nth firm with respect to the elements of $\mathbf{y}_n$, continuous and homogenous with respect to the vector of initial input prices, $\mathbf{v}^o$.

In the production of multiple outputs it is common that if the firm increases the output of one product, the output of some other product(s) also increase. A classical example is the production of wool and mutton. This also applies to the production of many other goods and the residuals from production, usually termed pollution. Without some corrective mechanism, firms produce their profit maximizing quantities given by the first order condition of [1] and emit the residual products.

Assume that each polluting firm produces one output, y_n, and emits one pollutant, z_n. Let Θ denote the index set of all available production technologies and let θ index these technologies, such that $\theta \in \Theta$. The cost of production for each firm, denoted $C_\theta(y_n,z_n)$, is twice differentiable with respect to y_n and z_n such that $\frac{\partial C_\theta}{\partial y_n} > 0$, $\frac{\partial C_\theta}{\partial z_n} < 0$ for any output $y_n \in Y_n$, where Y_n denotes the set of firm n's feasible output levels, and $\frac{\partial^2 C_\theta}{\partial y_n \partial z_n} \leq 0$, for all $n \in N$ and all $\theta \in \Theta$. Moreover, the second order conditions for profit maximization require that $\frac{\partial^2 C_\theta}{\partial y_n^2} \leq 0$ for all $n \in N$ and all $\theta \in \Theta$. Without any environmental regulations, each firm maximizes:

$$\pi_{\theta n} = \left\{ \begin{matrix} \text{MAX} \\ y_n \end{matrix} \right\} \{p^o \, y_n - C_\theta(y_n, z_n)\} \qquad [2]$$

yielding the unconstrained optimal output level y_n^o for firm n. With the introduction of environmental regulations, the firm's maximization problem becomes:

$$\pi_{\theta n} = \left\{ \begin{matrix} \text{MAX} \\ y_n, z_n \end{matrix} \right\} \{p^r \, y_n - C_\theta(y_n,z_n) - h_s(z_n)\} \qquad [3]$$

where p^r denotes the product price after regulations have been introduced, and
$h_s(z_n)$ is the extra cost incurred by firm n due to the use of policy instrument s, $s \in S$, the set of available policy instruments to reduce emissions.

yielding the constrained (regulated) optimal output level y_n^r and the emission level z_n^r for firm n.

To make [3] into a decision problem with one decision variable, assume that for any production technology θ, $\theta \in \Theta$, $\frac{\partial y_n}{\partial z_n} > 0$. Then for a given level of emissions, z_n, there exists one level of output, $y_{\theta n} = y_\theta(z_n)$. For the marginal costs of production to be non-negative for any emission level, $\frac{dC_\theta}{dz_n} = \frac{\partial C_\theta}{\partial y_n} \cdot \frac{\partial y_n}{\partial z_n} + \frac{\partial C_\theta}{\partial z_n} > 0$ must hold, requiring $\left|\frac{\partial C_\theta}{\partial y_n} \cdot \frac{\partial y_n}{\partial z_n}\right| > \left|\frac{\partial C_\theta}{\partial z_n}\right|$. Reformulating [3] into maximizing profits with the emission level being the only choice variable, yields:

$$\pi_{\theta n} = \left\{\begin{matrix} MAX \\ z_n \end{matrix}\right\} \{p^r\, y_\theta(z_n) - C_\theta(z_n) - h_s(z_n)\} \qquad [4]$$

Let z_n^o denote the emission level resulting from solving the first order conditions of [4] without any environmental regulations. The aggregate emission level without any environmental policy measures in country i is then given by $Z_i^o = \Sigma_{n \in N}\, z_n^o$. Assume that this aggregate emission level exceeds the desired aggregate emission level, Z_i^r, i.e. $Z_i^o > Z_i^r$ which also implies that with environmental regulations, aggregate output, Y_i^r, will be less than the aggregate output without any environmental regulations, Y_i^o.

The Regulation Effect

From [2] and [3] it follows that there exist unique profit maximizing output levels, $y_{\theta n}^o = y_\theta(z_n^o)$ under no regulation, and $y_{\theta n}^r = y_\theta(z_n^r)$ under some regulation. By [4] this can be expressed in term of the respective profit levels $\pi_{\theta n}(z_n^o)$ and $\pi_{\theta n}(z_n^r)$.

DEFINITION 1: The regulation effect of an environmental regulation in a country is the deduced reduction of the value of domestically produced goods and services. It is given by the aggregate least costly way to adapt to the regulation Z_i^r, i.e. by assigning $z_n^r\ \forall\ n \in N$, the index set of firms currently producing, to

$$\left\{\begin{matrix} MIN \\ s \in S \end{matrix}\right\} \Sigma_{n \in N} \{[p^o\, y_\theta(z_n^o) - C_\theta(z_n^o)] - [p^r\, y_{\theta n}(z_n^r) - C_\theta(z_n^r)]\} \geq 0, \text{ s.t. } \Sigma_{n \in N}\, z_n^r \leq Z_i^r$$

where superscript o indicates the base (unregulated) scenario, and superscript r indicates the regulated scenario.

The Instrument Effect

For an industry only producing for the domestic market, all environmental costs of production could be placed on the polluting firms. New and higher product prices would result, giving a partial reduction in societal welfare that would be more than offset by the welfare gains from improved environmental quality provided that the optimal regulation level is reached. In the case of regulating industries creating trans-boundary pollutants and delivering products on an international market, additional welfare considerations need to be made. The instrument effect embeds these welfare effects in an orderly way.

DEFINITION 2: Let N_s denote the index set of firms leaving production due to regulation s, $s \in S$, where S is the index set of possible regulations. For any firm $n \in N_s$ it then follows that

$$[p_s^r \, y_\theta(z_n^r) - C_\theta(z_n^r) - h_s(z_n^r)] - {}_{MIN}\pi_{\theta n} < 0,$$

where p_s^r indicates the resulting product price under regulation s, $h_s(z_n^r)$ is the extra cost incurred by firm n due to the use of policy instrument s, and ${}_{MIN}\pi_{\theta n}$ is the minimum profits required by firm n to continue production. The instrument effect of the environmental regulation s is the additional reduction of the aggregate net value of domestically produced goods and services, caused by firms ceasing to produce due to regulation s, and is given by

$$\Sigma_{n \in N_s} [p_s^r \, y_\theta(z_n^r) - C_\theta(z_n^r)].$$

The interpretation of the instrument effect is that it is the society's loss in income (welfare) when firms are unable to run a profitable operation due to the policy instrument used to induce the regulations. Thus the instrument effect is of particular concern in the regulation of industries competing on international markets.

The instrument effect has some similarities with the income effect that is found in the discussions on the Coase theorem − the distribution of pollution rights does not matter provided that preferences are homothetic (Varian, 1992). More specifically one can envision policy instruments that on the margin yield the same firm level adaption.

Industry Competitiveness − Environmental Taxes and Tradeable Emission Permits

It is well documented that a system of transferable emission permits would yield the same firm specific emissions and thus the same aggregate emission level as would be the case for a system of emission taxes under perfect competition (Weitzman, 1974; Baumol and Oates, 1988). In this paper we claim that this holds when only the regulation effect is considered, but when the instrument effect is added, tradeable emission permits and emission taxes may look very different. Consider the following figure of a tradeable permit and emission tax system where the permit price is the same as the emission tax.

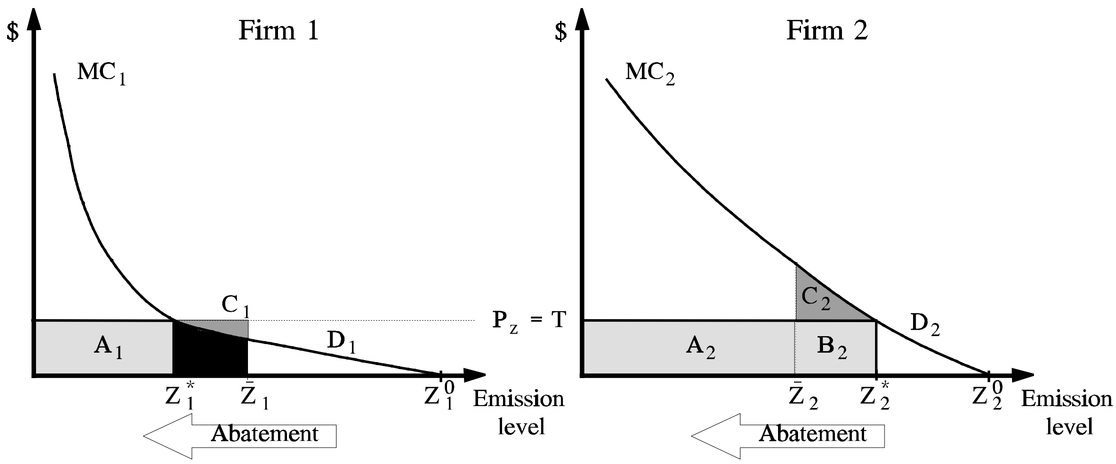

Figure 1: Emission taxes and tradeable permits (emission tax = T = P_z = permit price, z_n^o = initial emission level for firm n, z_n^* = optimal emission level for firm n given environmental regulation, $\overline{z}_n$ = initial emission quota for firm n.

It is not possible to read the regulation effects out of Figure 1, but for both emission taxes and tradeable emission permits the profit maximizing emission levels are the same for the two firms, namely z_1^* and z_2^*. Thus the regulation effects are also the same, barring the instrument effect. The instrument effect can not be read directly from Figure 1. However, the figure provides some insights. With initial emission quotas, $\bar{z}_1 = \bar{z}_2$, given to the firms for free, the extra costs incurred by a uniform emission tax compared to a system of tradeable emission permits are for the seller (firm 1) the sum of the areas $A_1 + C_1$, and for the buyer (firm 2) the area A_2.[2]

The choice of particular policy instruments may therefore lead to additional reductions in an industry's competitiveness.[3] [4] These declines in profits (rents) may be sufficiently large to induce firms to leave production (relocate to areas with less costly/no environmental policies) − i.e. triggering the instrument effect.

Instrument Effects from Transferable Emission Permit Schemes

The two most serious instrument effects from a system of transferable emission permits are probably (i) the costs of acquiring permits in the case they are auctioned off, and (ii) the search and transaction costs associated with permit trading. If the instrument

[2] Viewed from an aggregate perspective, tradeable emission permits and taxes yield are equivalent, as the tax revenues from the latter remain in the country. Unless these tax revenues are returned to the firms, the instrument effect may be considerable. Reaching a political consensus on such a repayment scheme is not straight forward.

[3] In separate studies Batabyal (1994) and Hoel (1994) reach the same conclusion as ours − the choice of policy instrument may influence a country's international competitiveness.

[4] Several advocates of environmental taxes have suggested lump sum repayments or two-tiered tax systems due to the cost push effects of uniform environmental taxes. Reaching agreement on a repayment schedule is in our opinion a new candidate for an "impossibility theorem". Regarding emission taxes that vary depending on the emission level, it is possible to construct efficient schemes of this type in the short run, but the associated instrument effects will never be less than the instrument effects of tradeable emission permit schemes, barring transaction and search costs.

effects of the former is large, it follows that permits need to be grand-fathered.[5] The latter is believed to be a major contributing factor to the lack of trades in existing emission permit trading schemes (Hahn, 1989), and in particular for bubbles where trading is bilateral (Atkinson and Tietenberg, 1991). Listing emission permit prices on the commodity exchanges is one way of lowering the search and transaction costs.[6] Romstad (1992) has shown that for tradeable quotas on (polluting) input factors, fees per transaction could limit the number of transactions severely, and that a fee based on the value of the transaction could make monitoring and enforcement more difficult as large transactions could take place outside the official trading institutions. These results carry over to tradeable emission permits.

Characteristics of Trans-Boundary Environmental Problems

Trans-boundary environmental problems fall into two categories: (i) a country's pollution affects neighboring countries (trans-boundary emissions) or (ii) a county is affected by the neighboring countries' pollution (trans-boundary receipts). Assume that:

- it is costly for a country to reduce its emissions,
- that reductions in own emissions benefits both the country that instigates regulations as well as the neighboring countries, and
- each country's social planner (regulatory agency) seeks to maximize the country's societal welfare, defined by some social welfare function.

---

[5] Grand-fathering conflicts with the polluter's pay principle, a corner stone in the ethics of many environmentalists. We believe that if the choice is between less environmental regulations due to the instrument effect of auctioning permits and tougher environmental standards, the environmentally ethical position is to abandon the polluter's pay principle.

[6] Preparations for listing sulphur dioxide emission permit prices on the Chicago Commodity Exchange are under way.

With these assumptions, the welfare function of the social planner in country i is given by:

$$V_i(M_i, \mathbf{p}_i | \mathbf{Z}_i + \mathbf{Z}_{-i}) \quad [5]$$

where M_i is total money income in country i,
$\mathbf{p}_i$ is a vector of prices for private goods in country i,
$\mathbf{Z}_i$ is a vector of public bads (pollution) originating in country i,
$\mathbf{Z}_{-i}$ is a vector of public bads (pollution) affecting country i and originating in other countries, and
V_i is continuous and bounded in M_i and Z (= $Z_i + Z_{-i}$).

Despite the difficulties in reaching consensus regarding the specification of the social welfare function − as demonstrated by Arrow’s (1951) impossibility theorem − any valid social welfare function must exhibit the same basic properties that can be derived from individual utility maximization, i.e. utility increases with increasing money income, decreases (or at least does not increase) with increasing prices, and decreases with increasing supplies of public bads (like pollution). Using [5] this implies:

$$\frac{\partial V_i}{\partial M_i} > 0, \qquad \frac{\partial V_i}{\partial p_{ij}} \leq 0 \qquad \text{and} \qquad \frac{\partial V_i}{\partial Z} < 0 \qquad \forall\, j \in J \quad [6]$$

where j indexes the commodity and J denotes the index set of commodities.

The social planner is particularly concerned with the externalities (pollution), as the "invisible hand" would correctly adjust prices and wealth if there were no externalities.

Emissions and Welfare

Using a partial equilibrium approach it can be shown that when emissions, Z_i, are reduced, money income, M_i, will fall, and prices, $\mathbf{p}_i$, will increase. By [6] it follows that only for emission levels above the socially optimal emission level, Z_i^*, will $\frac{\partial V_i}{\partial Z_i} < 0$. The magnitude of this welfare gain would be less than one would expect if only the environmental benefits were considered, i.e. the feedback effects on income and prices.

In an open economy these effects may differ somewhat. Krutilla (1991) shows for example that whether commodities are imported or exported are detrimental to the welfare effects of environmental regulations. Another, and complicating factor is interpreting the welfare change caused by unilateral environmental regulations in country i (the country implementing such regulations) because: (i) domestic prices may not increase as much as they would without trade due to import increases[7], and (ii) domestic money income is likely to drop? It is tempting to claim that as prices do not adjust as much upward, a smaller portion of the additional costs will be accounted for, causing output to drop. This is the old argument that environmental regulations may cause firms to locate elsewhere. In discussing the environmental impacts of a single market within the European Community, Folmer and Howe (1991) downplay the relocation effect, claiming that:

> Environmental Policy is only one element of a complex of factors. Other elements are the labor market, accessibility and technological development. Thus the outcome depends on the weight of environmental regulations relative to other location factors. (Folmer and Howe, 1991, p. 23).

In interpreting the above statement, we believe that the essential point regarding the potential relocation of industries is not the environmental performance of proposed environmental policies, but their effects on profits and thus welfare.[8] A direct consequence of this would be that if for example one country decided to unilaterally introduce environmental taxes, the lack of response in product prices could lead to a close-down of factories, thus causing a sharp drop in emissions (and a potential large welfare loss due to reduced money income). In retrospect one would conclude that the strong environmental

[7] To avoid loosing domestic market shares, a "wise" government may consider taxing competing imports regardless of where they are produced to maintain the relative competitiveness of their own industries. However, even such taxes would constitute a welfare loss in the country where such taxes were introduced.

[8] We do not believe Folmer and Howe would disagree on this, but from their article (Folmer and Howe, 1991), it is not clear whether they speak of profits (rents) or environmental performance, when discussing relocation effects.

effect of the tax would have called for a lesser tax. Thus the use of incentive based instruments under free trade requires more "fine tuning" than is the case in a less open economy, a conclusion also reached by Krutilla (1991).

For trans-boundary pollutants country i's own optimal emission level and welfare depends not only on its own emissions, Z_i, but also on the emissions received from other countries, Z_{-i}. Simplifying [5] to embody only one pollutant yields $V_i(M_i, \mathbf{p}_i | Z_i + Z_{-i})$.[9] The ranking of the welfare associated with own environmental actions and those taken by other countries becomes:

$$V_i(M_i^o, \mathbf{p}_i^o | Z_i^o + Z_{-i}^r) > V_i(M_i^r, \mathbf{p}_i^r | Z_i^r + Z_{-i}^r) > V_i(M_i^o, \mathbf{p}_i^o | Z_i^o + Z_{-i}^o) > V_i(M_i^r, \mathbf{p}_i^r | Z_i^r + Z_{-i}^o) \quad [7]$$

where Z_i^o indicates no change in emission policy in country i,
Z_i^r indicates country i regulates its emissions,
Z_{-i}^r indicates that the other countries regulate their emissions, and,
Z_{-i}^o indicates no change in the other countries' environmental policies.

Despite country i benefitting from environmental cooperation, it would benefit even more from everybody else regulating and not having to bear any environmental abatement costs itself (the left expression in the top line of [7]) as indicated in table 1.

Table 1: Pay-off matrix for regulation/no regulation for country i and "rest of the world" (bold face numbers indicate country i's ranking of the various options).

		Country i	
		Regulate	Do not regulate
"Rest of the world"	Regulate	$V_i(M_i^r, \mathbf{p}_i^r \| Z_i^r + Z_{-i}^r)$ **(2)**	$V_i(M_i^o, \mathbf{p}_i^o \| Z_i^o + Z_{-i}^r)$ **(1)**
	Do not regulate	$V_i(M_i^r, \mathbf{p}_i^r \| Z_i^r + Z_{-i}^o)$ **(4)**	$V_i(M_i^o, \mathbf{p}_i^o \| Z_i^o + Z_{-i}^o)$ **(3)**

[9] This specification is consistent with a trans-boundary pollutant that diffuses completely (like carbon dioxide). A more general specification is $V_i(M_i, \mathbf{p}_i | Z_i + d(Z_{-i}))$, where $d(Z_{-i})$ is some diffusion function indicating how the pollutant spreads.

This formulation lends itself to game theoretic analysis. It is for example easy to see that the best reply strategy of country i is always to play "do not regulate", i.e. a "Prisoner's dilemma" situation arises. If all countries play this strategy, the Nash outcome results, yielding the welfare $V_i(M_i^o,\mathbf{p}_i^o|Z_i^o + Z_{-i}^o)$.[10] In a dynamic setting the game theory literature suggests that the "Prisoner's dilemma" may not be the outcome. The undesireable effects on the social welfare of the countries may provide support for cooperative outcomes (confer the Folk theorem, Friedman (1986)). Country i's decision problem can then be described the following way:

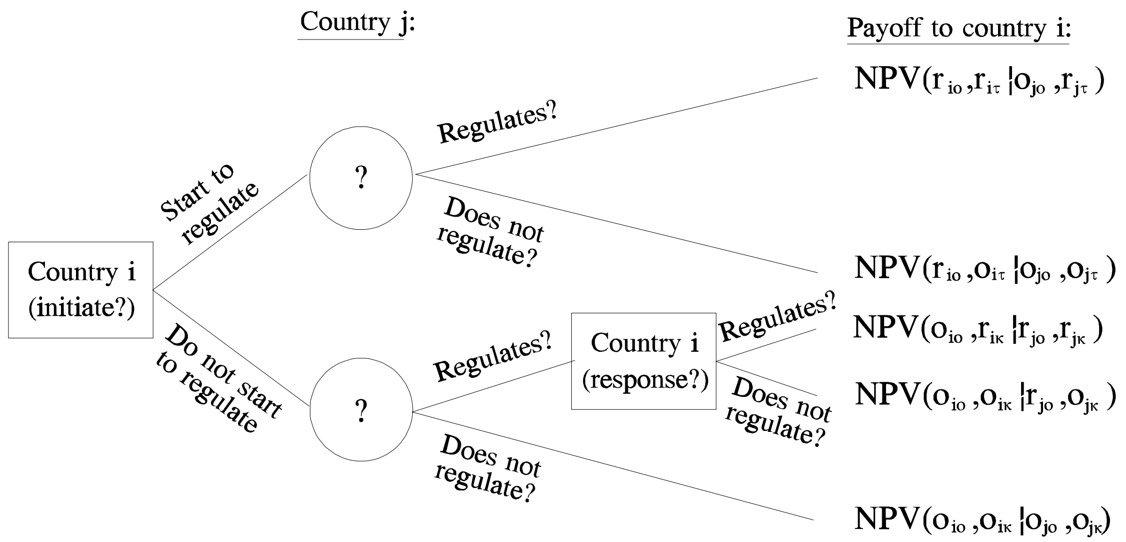

Figure 2: Decision tree for country i. $NPV(r_{io},r_{i\tau} \mid o_{jo},r_{j\tau})$ = net present value for country i if it starts to regulate upon which country j regulates by time τ, $NPV(r_{io},o_{i\tau} \mid o_{jo},o_{j\tau})$ = net present value for country i when it starts to regulate and country j does not regulate by time τ, upon which country i removes regulations, $NPV(o_{io},r_{i\kappa} \mid r_{jo},r_{j\kappa})$ = net present value for country i when it does not start to regulate, country j starts to regulate and country i responds by regulating by time κ (i.e. both countries regulates) $NPV(o_{jo},o_{j\kappa} \mid r_{jo},o_{j\kappa})$ = net present value for country i when country j starts to regulate and country i does not regulate by time κ, upon which country j ceases to regulate, $NPV(o_{jo},o_{j\kappa} \mid o_{jo},o_{j\kappa})$ = net present value to country i when neither country regulates.

[10] Markusen, Morey and Oleweiler (1993) show a different type of game where market structure and plant locations are endogenous. In principle their paper is not very different from the game theoretical extensions of [7]. Also note Mähler (1989), who provides an application of this type of framework (acid rains from sulphur dioxide emissions).

Provided that τ is not known with certainty by country j, κ is not known with certainty by country i, and the time horizon, T, of the game is random, it is no longer granted that the outcome is that neither country starts to regulate.[11] If country i's expected net present value from instigating regulations exceeds the expected net present value from not instigating regulations, country i should instigate unilateral environmental regulations.[12]

To calculate the net present value of not instigating regulations, country i needs to know what it should do in case country j instigates regulations. The expected net present values for country i's response to regulations (to regulate or not to regulate) are given by [8a] and [8b] respectively.

$$\Sigma^{\tau}_{t=0}\ ß^t\ \pi_{it}(o_i,r_j) + \Sigma^{T}_{t=(\tau+1)}\ ß^t\ \pi_{it}(r_i,r_j) \quad [8a]$$

$$\Sigma^{\kappa}_{t=0}\ ß^t\ \pi_{it}(o_i,r_j) + \Sigma^{T}_{t=(\kappa+1)}\ ß^t\ \pi_{it}(o_i,o_j) \quad [8b]$$

By assumption $\Sigma^{T}_{t=(\kappa+1)}\ ß^t\ \pi_{it}(r_i,r_j) > \Sigma^{T}_{t=(\kappa+1)}\ ß^t\ \pi_{it}(o_i,o_j)$. It then follows that if country j instigates regulations, the optimal response for country i is to regulate,[13] yielding the following simplified decision tree for country i:

[11] In particular note that if the stopping time, T, is not random (or infinite), the game collapses to the Nash solution (Friedman, 1986).

[12] This is contrary to the conclusions reached by Hoel (1991). In reaching his conclusions Hoel explicitly states that he has not analyzed the possibilities of unilateral emission reductions triggering similar behavior by other countries (tacit cooperation).

[13] An important implication of this is that if country i instigates regulations, the optimal strategy for country j is to regulate. Hence country i's assessment of the probability that country j will respond to regulations by regulating itself will be close to 1.

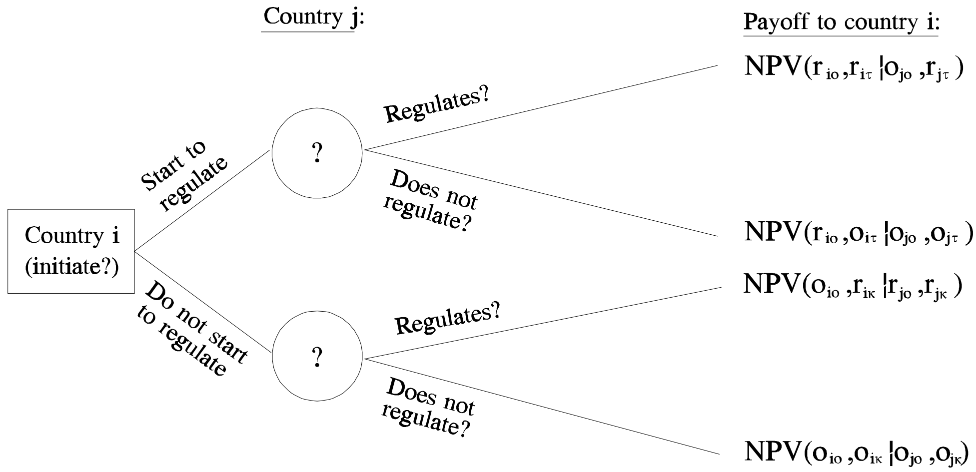

Figure 3: Simplified decision tree for country i.

The expected net present value from instigating regulations for country i is given by:

$$\rho_{r_j|r_i} \left[\Sigma_{t=0}^{\tau} ß^t \pi_{it}(r_i,o_j) + \Sigma_{t=(\tau+1)}^{T} ß^t \pi_{it}(r_i,r_j) \right] + (1-\rho_{r_j|r_i}) \left[\Sigma_{t=0}^{\tau} ß^t \pi_{it}(r_i,o_j) + \Sigma_{t=(\tau+1)}^{T} ß^t \pi_{it}(o_i,o_j) \right] \quad [9a]$$

while the expected net present value of not instigating regulations is given by

$$\rho_{r_j|o_i} \left[\Sigma_{t=0}^{\kappa} ß^t \pi_{it}(o_i,r_j) + \Sigma_{t=(\kappa+1)}^{T} ß^t \pi_{it}(r_i,r_j) \right] + (1-\rho_{r_j|o_i}) \left[\Sigma_{t=0}^{T} ß^t \pi_{it}(o_j,o_j) \right] \quad [9b]$$

where:

- $\rho_{r_j|r_i}$ is country i’s assessment of the probability that country j will regulate once country i has done so,
- $\rho_{r_j|o_i}$ is country i’s assessment of the probability that country j will instigate regulations given that country i has not done so,
- ß is the discount factor,
- τ is the time at which country i no longer is "willing to wait" for country j to respond positively,
- κ is country i’s assessment of the time country j is "willing to wait" before it removes environmental regulations it had implemented if country i does not respond positively,
- $\pi_{it}(r_i,o_j)$ is the pay-off to country i of regulating while country j does not,
- $\pi_{it}(r_i,r_j)$ is the pay-off to country i of regulating when country j also regulates,
- $\pi_{it}(o_i,o_j)$ is the pay-off to country i when neither country regulates, and

$\pi_{it}(o_i,r_j)$ is the pay-off to country i when it does not regulate while country j does.[14]

Deriving analytical results directly from setting [9a] > [9b] is tedious. Therefore consider the following two time-period sub-game condition for the possibility of country i instigating environmental regulations:

$$\rho_{r_j|r_i}\,[\,\pi_{it}(r_i,o_j) + ß\,\pi_{it}(r_i,r_j)] + (1-\rho_{r_j|r_i})\,[\,\pi_{it}(r_i,o_j) + ß\,\pi_{it}(o_i,o_j)] > \rho_{r_j|o_i}\,[\,\pi_{it}(o_i,r_j) + ß\,\pi_{it}(r_i,r_j)] + (1-\rho_{r_j|o_i})\,[\,\pi_{it}(o_i,o_j) + ß\,\pi_{it}(o_i,o_j)] \qquad [10]$$

which after some transformations ends up in the following condition for a Bayesian equilibrium:

$$1 > \beta > \frac{(1-\rho_{r_j|o_i})\pi_{it}(o_i,o_j) + \rho_{r_j|o_i}\pi_{it}(o_i,r_j) - \pi_{it}(r_i,o_j)}{(\rho_{r_j|r_i} - \rho_{r_j|o_i})[\pi_{it}(r_i,r_j) - \pi_{it}(o_i,o_j)]} \qquad [11]$$

From [11] is it evident that the likelihood of country i instigating environmental regulations increases with:

- an increasing probability of country j following suit ($\rho_{r_j|r_i}$),
- an increasing difference in the payoffs from cooperative and Nash behavior, i.e. $\pi_{it}(r_i,r_j) - \pi_{it}(o_i,o_j)$,

and decreases with:

- an increasing probability of country j instigating environmental regulations ($\rho_{r_j|o_i}$),
- an increasing difference of the payoffs from "free riding" and unilateral behavior, i.e. $\pi_{it}(o_i,r_j) - \pi_{it}(r_i,o_j)$.

An important factor in country i's assessment of the probabilities $\rho_{r_j|r_i}$ and $\rho_{r_j|o_i}$ is whether a cooperative solution − i.e. country i regulates, country j regulates − can be

[14] The payoffs given are directly derived from the country i's social welfare function under the various scenarios. For example $\pi_{it}(r_i,o_j) = m_{it}[V_i(M_i^r,\mathbf{p}_i^r|Z_i^r + Z_{-i}^o)]$.

sustained in equilibrium. The Folk theorem gives the condition for such an outcome. For this decision problem. Expressed from country i's perspective[15] the Folk theorem is given by:

$$1 > \beta > \frac{\pi_{it}(o_i,r_j) - \pi_{it}(r_i,r_j)}{\pi_{it}(o_i,r_j) - \pi_{it}(o_i,o_j)} \qquad [12]$$

If [12] holds for both countries, it follows from the rational expectations literature[16] that the probability that country j will respond favorably to country i initial regulations by implementing environmental regulations is close to 1. This does not mean that country i should instigate environmental regulations, as the probability that country j will instigate regulations given that country i does not regulate ($\rho_{r_j|o_i}$) also enters into country i's decision problem (confer with [9a] and [9b] or the condition for country i to instigate regulations [11]). As mentioned before, if $\rho_{r_j|o_i}$ is high, the expected profits from moving first less for country i decreases.

It is in this connection we would like to focus on the importance of choosing policy instruments with the least instrument effects. To clarify this argument, assume one scenario with small instrument effects, π_S, the other with a large instrument effect, π_L. Figure 4 depicts such a situation. Moreover it illustrates that the stability of cooperative arrangements increases with small instrument effects.[17]

---

[15] The expression for the Folk theorem for country j is found by interchanging the indexes i and j in [12].

[16] Confer with Muth (1961:316) "I should like to suggest that expectations, since they are informed predictions of future events, are essentially the same as the predictions of relevant economic theory".

[17] Carraro and Sinisalco (1991) demonstrate that in addition to enhance the welfare of participating countries in international environmental agreements, stability of the chosen agreement is important.

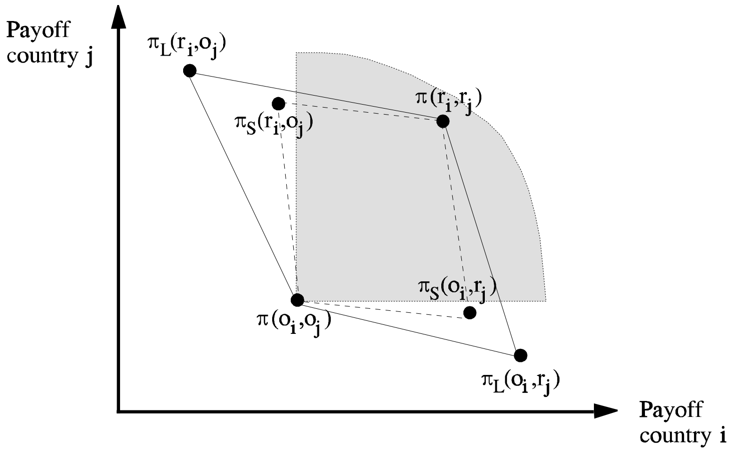

Figure 4: Pay-off space for country i and j. $\pi_S(\bullet)$ denotes pay-offs when instrument effects are small, $\pi_L(\bullet)$ denotes pay-offs when instrument effects are large, and $\pi(\bullet)$ denotes pay-offs under Nash or cooperative behavior in either case. The shaded area indicates the region of possible Pareto-improvements for the two countries.

Even though the ranking of the alternatives is unchanged, i.e. "do not regulate" is still the dominant strategy for both countries in the single shot game, Figure 4 shows how the likelihood of cooperative behavior from the other country increases as the horizontal difference in the pay-offs between free riding, $\pi(o_i,r_j)$, and unilateral regulations, $\pi(r_i,o_j)$, decreases.[18] Also note that the overall stability of the cooperative solution increases as the pay-offs from free riding and unilateral regulations respectively move closer to the left and bottom sides of the gray-shaded area. In case the pay-offs from free riding and unilateral regulations belong to the closed set formed by the gray area, the cooperative solution follows directly. Thus, Figure 4 underlines the argument derived from equations [9a] and [9b], [11] or [12], that choosing policy instruments with lower instrument effects, increases the likelihood of a stable cooperative solution, and makes the expected benefits from instigating regulations higher.

[18] For country j the likelihood of cooperative behavior increases as the vertical difference in the pay-offs between free-riding, $\pi(r_i,o_j)$, and unilateral regulations, $\pi(o_i,r_j)$, decreases.

Conclusions

This paper has demonstrated that it may pay for a country to instigate environmental regulations. The likelihood that another country will respond favorably to such regulations − by regulating its polluting industries − depends on the relative expected benefits that country will get from regulation or no regulation. Small instrument effects increase the relative expected benefits from environmental regulations. One reason for this is that the negative side-effects of regulation − increased costs to the regulated firms − are less than under regulations with large instrument effects. An additional benefit are that small instrument effects make the ensuing cooperative solution to the non-cooperative game more stable.

When designing environmental policies for trans-boundary pollutants and economies involved with international trade, the instrument effects of the chosen policy instruments may be substantial, leading to a loss of welfare. This implies that care should be taken to choose policy instruments that have small negative effects industry competitiveness, all other things equal.

In the case of the incentive based policy regimes (tradeable emission permits and emission taxes), the instrument effects of tradeable emission permits never exceed those of emission taxes, barring search and transaction costs.

An implication of the latter point − of which there also exists empirical evidence (Hahn, 1989; Atkinson and Tietenberg, 1991)) − is that for an emission permit market to work, search and transaction costs need to be kept low. Organizing emission trading through existing stock or commodity exchanges is one way of keeping these costs down.

Literature

Arrow, K.J. (1951): *Social Choice and Individual Values*, John Wiley & Sons, New York, NY.

Atkinson, S. & T. Tietenberg (1991): "Market Failure in Incentive-Based Regulation: The Case of Emissions Trading", *Journal of Environmental Economics and Management*, Vol. 21, pp. 17-31.

Batabyal, A.A. (1994): "An Open Economy Model of the Effects of Unilateral Environmental Policy by a Large Developing Country", *Ecological Economics*, Vol. 10, no. 3, pp. 221-232.

Baumol, W.J. & W.E. Oates (1988): *The Theory of Environmental Policy*, Cambridge University Press, Cambridge MA.

Carraro, C. & D. Siniscalco (1991): *Transfers and Comittments in Environmental Negotiations*, unpublished manuscript.

Folmer, H. & C.W. Howe (1991): "Environmental Problems and Policy in the Single European Market, *Environmental and Resource Economics*, Vol. 1, no. 1, pp. 17-41.

Friedman, J.W. (1986): *Game Theory with Applications to Economics*, Oxford University Press, New York, NY.

Hahn, R.W. (1989): "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders", *Journal of Economic Perspectives*, Vol. 3, no. 2, pp. 95-114.

Hoel, M. (1991): "Global Environmental Problems: The Effects of Unilateral Actions Taken by One Country", *Journal of Environmental Economics and Management*, Vol. 20, no. 1, pp. 55-70.

Hoel, M. (1994): "Efficient Climate Policy in the Presence of Free Riders", *Journal of Environmental Economics and Management*, Vol. 27, no. 3, pp. 259-274.

Krutilla, K. (1991): "Environmental Regulation in an Open Economy", *Journal of Environmental Economics and Management*, Vol. 20, no. 2, pp. 127-142.

Markusen, J.R., E.R. Morey & N.D. Oleweiler (1993): "Environmental Policy when Market Structure and Plan Locations are 'Endogenous", *Journal of Environmental Economics and Management*, Vol. 24, no. 1, pp. 69-86.

Muth, J.F. (1961): "Rational Expectations and the Theory of Price Movements", *Econometrica* Vol. 29, pp. 315-335.

Mähler, K-G. (1989): "The Acid Rain Game", in Folmer, H. & E. van Ierland (eds.) *Valuation Methods and Policy making in Environmental Economics*, Elsevier Science Publishers, pp. 231-252, Amsterdam, The Netherlands.

Oates, W.E., P.R. Portney & A.M. McGartland (1989): "The Net Benefits of Incentive Based Regulation: A Case Study of Environmental Standard Setting", *American Economic Review*, Vol. 79, no. 5, pp.1233-1242.

Romstad, E. (1992): "Omsettelige kvoter på forurensende innsatsfaktorer" (English: "Transferable Quotas on Polluting Input Factors") paper presented at the *National Meeting of Norwegian Economists*, Norwegian School of Management, Sandvika, Norway, January 6-7, 1992.

Varian, H.R. (1992): *Microeconomic Analysis*, 3rd. ed., New York, NY, Norton.

Weitzman, M.L. (1974): "Prices vs. Quantities", *Review of Economic Studies*, vol. 41, pp. 477-491.