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HOW MUCH DECENTRALIZATION IN EMISSION TRADING SYSTEMS?

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Abstract

This paper addresses the issue of whether the power of both allocating tradeable emission permits and monitoring compliance within an economic union should be centralized or delegated to the single states. To this end, we develop a two stage game played by two governments and their respective polluting firms. While in the absence of monitoring costs D'Amato and Valentini [4] find that the decentralized setting would result in an aggregate emission target which is greater than the socially optimal target that would arise under the centralized setting, by allowing monitoring cost differences between the centralized authority and single member states this paper show that the delegation of the power of allocating permits can arise as an optimal policy.

(**JEL numbers:** F18, Q50. **Keywords:** emissions trading, environmental dumping, environmental federalism, enforcement, monitoring cost)

1 Introduction

The degree of decentralization of public policies is a controversial topic. Indeed, while the so called "principle of subsidiarity" claims that it would be better to decentralize to the jurisdictional level which is closer to the preferences of consumers and/or producers, in several circumstances environmental policies may represent important exceptions to this principle (Oates [9]). This paper deals with this issue by assessing to what extent the power of both allocating tradeable emission permits and monitoring compliance within an economic union should be centralized or delegated to the single states.

To this respect the implementation by the European Union of a trading system for Greenhouse Gases emissions, as a step towards the achievement of the Kyoto targets (Directive 2003/87/CE) represents an important evidence of a decentralized emission trading system (ETS). Indeed, according to the Directive, permits are traded at the Union level, but each member state has a certain degree of freedom in specifying both the total amount of permits to be allocated within its boundaries and how this amount may be divided among the sectors subject to regulation, and among installations within each sector. Further, monitoring duties are left to single member countries. Our aim is to compare this type of ETS with an alternative system where the power over permits allocation and enforcement is set at a central (economic union) level[1].

A number of theoretical papers deal with questions which are closely related to the issue analyzed in this paper. An important strand of literature, for instance, deal with "environmental dumping" in both international (as in Barrett [1] and Ulph [10]) and federal settings (Ulph [11] and [12]). These papers show how na-

[1]As an example of a *centralized* ETS we can think about the SO_2 trading system implemented in the US where a federal agency controls at a centralized level the allocation of all emission permits for all participating firms in all states.

tional (or regional) governments attempt to relax environmental policy in order to secure to domestic firms competitive advantages in international markets. Our modelling strategy follows the one adopted by the environmental dumping literature but, unlike all the above papers, we *a)* consider emission trading instead of standards or taxes, *b)* extend the analysis also to the case of transboundary pollution (which is more suitable to illustrate the case of Greenhouse Gases emissions), and *c)* do not need to assume any imperfect competition in the output market (which is, in the above cited literature, a necessary condition for having national governments acting strategically). As a consequence, the source of distortion identified in this paper adds to the ones addressed in the received literature.

Among papers dealing with emission trading, Helm [7] analyzes the allocation of emission permits under two alternative regulatory regimes, namely with and without the possibility of trading permits. In his paper Helm finds that the possibility of trading may induce more pollution since the higher number of permits chosen by environmentally less concerned countries may offset the choices of the more concerned ones[2]. Nevertheless since he focuses on an international scenario where the allocation of emission permits *is chosen by interdependent yet sovereign states* (Helm [7], p.2738), his analysis does not allow for the case of a centralized authority.

In an another paper, Böhringer and Lange [2] show that the optimal design for allocating tradeable emission permits depends on whether the system is centralized or decentralized. However, while the main focus of their paper is on the most appropriate metrics for the allocation of allowances - namely lump sum allocation (that is not based on historical emissions/output) versus assignment rules which allocate permits proportionally to the emissions or production of the preceding periods, we evaluate the *centralized* and the *decentralized* solutions by comparing

[2] Boom and Dijkstra [3] expand the analysis of Helm [7]. By including boundary solutions they show that in some cases the results presented by Helm do not hold.

their aggregate emissions targets with the socially optimal one.

Finally, this paper is strictly related to D'Amato and Valentini [4]. In that paper we show in a very similar setting that the *decentralized* solution always results in a lower than optimal price of permits, as well as in an aggregate emission target which is larger than the socially optimal target that would arise under the *centralized* one. Such a result does not hinge only on standard international externality considerations but it also depends on the fact that, in a *decentralized* setting, when national shares in total emissions are large enough, then each government can affect the equilibrium permits price; in that case, national governments choose the amount of allowances to be distributed to domestic firms without accounting for the spillover such distribution generates on other countries *via* the equilibrium price of permits. To derive this result D'Amato and Valentini [4] use a two stage game played by two governments and their respective industries producing outputs that are sold in a third country. Governments move first and choose the amount of permits to be provided to firms operating within their borders. Under the *centralized* institutional frameworks the two governments act as a single entity, while under the *decentralized* one they play a "Cournot game", that is, each government chooses the amount of permits to be issued to the firms located within its borders and takes other government's choices as given. In the second stage each firm observes the amount of permits that have been assigned to it and chooses the level of emissions.

In this paper we expand the analysis of D'Amato and Valentini [4] by including the possibility of non compliance and asymmetries in monitoring costs. More specifically, we assume that production costs, environmental damages and non compliance costs are strictly convex functions. Following Malik [8] monitoring effort is measured by auditing probability and the governments aim at achieving full compliance. By assuming enforcement cost advantage in favour of single states we find that the monitoring effort required to achieve full compliance is strictly decreasing in the number of permits issued. The intuition of this result is that to achieve full compliance the expected marginal fine (the probability of auditing multiplied by the marginal fine) faced by a compliant firm must be equal to the equilibrium price of permits: as the latter is decreasing in the aggregate cap, the same holds for the required monitoring effort (probability of auditing). Moreover, we also find that, if the monitoring cost differentials is sufficiently high, then a weaker environmental policy could result in the centralized case. The intuition in this case is that, if each unit of monitoring is more costly in a centralized setting, then the centralized decision maker has an incentive to reduce the monitoring effort needed to achieve full compliance via the allowance price. A possible implication of the latter result could be that, if the monitoring costs are sufficiently higher in the centralized case, then social welfare could be higher in a decentralized setting.

The main other features of this model are presented in the next section. Section 3 derives the conditions characterizing the optimal choices of the firms in the second stage of the game while section 4 analyzes how the two governments choose (jointly or separately) both the level of enforcement and the amount of allowances to be issued to the firms. Comparisons between the *centralized* and the *decentralized* setting are developed in section 5. Finally, section 6 concludes.

2 The structure of the model

We analyze a stylized model representing an Economic Union formed by two countries (a domestic one, labelled as d, and a foreign one, labelled as f). In each country there is a large number of identical firms. By normalizing to 1 the number of firms in each country, we deal with one "representative" firm in the domestic country (firm d) and one in the foreign country (firm f).

The interactions among the two firms and the governments of the two countries are defined by the following two stage game. In the first stage, the two national governments choose the amount of permits to be issued and the monitoring effort to be devoted to discover and punish non compliant firms. We consider two alternative institutional frameworks, namely a *centralised* one, where the two governments act as a single entity, and a *decentralised* one, where each government chooses the amount of permits to be issued to the firm(s) located within its borders, as well as the monitoring effort, taking other government's choices as given.

Let q_i be the output produced by country i $(i = d, f)$; we assume it to be sold in a competitive market located in a third country[3]. To keep matters as simple as possible, we assume that there is a one to one relationship among output and emissions and the only way to reduce emissions is by reducing output.

The amount of permits allocated to domestic and foreign firms in the first stage of the game by the two governments (or by the central government) is defined, respectively, by $\overline{e}_d$ and $\overline{e}_f$. Following the standard literature (see Malik [8]), we also assume that the governments (or the central government in the centralised case) audit firms with probability u_i $(i = d, f)$ and, if audited, all non compliant firms are discovered and forced to pay a fine and to reduce excess pollution[4]. Given $\overline{e}_d$, $\overline{e}_f$, u_d and u_f, in the second stage, in order to maximize their profits, the two firms choose both their output/emission levels, denoted, respectively, by q_d and q_f and the quantity of permits to be surrendered, e_d and e_f. We assume that the two firms can be not compliant since they can choose $e_i \neq q_i$. Whenever e_i is greater (smaller) than $\overline{e}_i$, country i firm (or firm i, as we will call it in what follows) $(i = d, f)$ can buy (sell) additional permits in a perfectly competitive market at the Economic Union level.

[3]By this assumption we follow standard environmental dumping literature which excludes consumers' surplus from the analysis.

[4]Such assumptions are suitable for describing the current situation under the European ETS.

By $q_{i_{BAU}} = \frac{p_q}{\alpha}$ we indicate the level of emissions chosen by firm i in a *business as usual* scenario, that is when it is not constrained by any form of regulation and its profits are

$$\Pi_{i_{BAU}} = p_q q_i - \frac{\alpha q_i^2}{2}. \tag{1}$$

where p_q is the output price, $\frac{\alpha q_i^2}{2}$ are production costs, which are identical across firms, and α is an exogenous parameter. On the contrary, when the ETS takes place, firm i would maximize

$$\Pi_i = (1 - u_i)\left(\Pi_{i_{BAU}} - p_e(e_i - \overline{e}_i)\right) + u_i\left(\Pi_{i_{BAU}} - p_e(e_i - \overline{e}_i) - N_i(q_i - e_i)\right) \tag{2}$$

where p_e is the permits price, the term $p_e(e_i - \overline{e}_i)$ is the amount of money the firm spends (earns) if it is a net buyer (seller) of permits, while $N_i(q_i - e_i)$ is the function representing non compliance costs by country i if detected. More specifically

$$N_i(q_i - e_i) = \begin{cases} F(q_i - e_i) + \frac{\gamma}{2}(q_i - e_i)^2 & \text{for } q_i \geq e_i \\ 0 \text{ otherwise} \end{cases}$$

where F is the per unit fine (for instance, according to the European Directive on ETS, this is either 40 or 100 euros) and $\frac{\gamma}{2}(q_i - e_i)^2$ is the present value of the costs related to the requirement of reducing emissions/production in the following years. At this stage we follow, again, Malik [8] assuming that the government(s) take as given the parameters determining the shape of the cost function for non compliance N_i (the fine level F and the γ parameter) and choose only the monitoring effort/probability of auditing.

In the following two sections we derive our results solving the two stage game backward.

3 Second stage: the firms

By re-arranging (2) we can define the maximization problem of firm i as follows:

$$\max_{q_i,e_i} \Pi_i = p_q q_i - \frac{\alpha q_i^2}{2} - p_e(q_i - \overline{e}_i) - u_i N_i(q_i - e_i). \tag{3}$$

Firm located in country i chooses q_i and e_i according to the following FOCs:

$$\frac{\partial \Pi_i}{\partial q_i} = p_q - \alpha q_i - u_i F - u_i \gamma (q_i - e_i) = 0$$

and

$$\frac{\partial \Pi_i}{\partial e_i} = u_i F - p_e + u_i \gamma (q_i - e_i) = 0$$

Solving the resulting system of equations we get:

$$q_i = \frac{p_q - p_e}{\alpha} \tag{4}$$

so that, as it is reasonable, $\frac{\partial q_i}{\partial p_e} = -\frac{1}{\alpha} < 0$, and

$$e_i = \frac{u_i F - p_e}{u_i \gamma} + \frac{p_q - p_e}{\alpha} \tag{5}$$

so that, $\frac{\partial e_i}{\partial u_i} = \frac{p}{u_i^2 \gamma} > 0$ and $\frac{\partial e_i}{\partial p_e} = -\frac{1}{u_i \gamma} - \frac{1}{\alpha} < 0$. Further, it is interesting to notice that $\left|\frac{\partial e_i}{\partial p_e}\right| > \left|\frac{\partial q_i}{\partial p_e}\right|$, which implies that the amount of permits held is more elastic than the level of production and emissions to a change in the permits price.

Excess of actual emissions with respect to held permits, that is, non compliance by firm located in country i (call it V_i) will be given by

$$V_i = q_i - e_i = \frac{p_e - u_i F}{u_i \gamma}$$

From the above expression we can derive two results. First, an increase in permits price will lead to an increase in the degree of non compliance, as $\frac{\partial V_i}{\partial p_e} = \frac{1}{u_i \gamma} > 0$. Second, ruling out the case in which the firm is overcompliant[5], we will have $e_i \leq q_i$ as $u_i F \leq p_e$.

[5] We can exclude the case of strict overcompliance ($e_i > q_i$) as the shape of the $N_i(.)$ function implies that, when the firm is compliant or overcompliant, its profit function is strictly decreasing in e_i.

Equilibrium on the permits market requires that:

$$e_i + e_j = \overline{e}_i + \overline{e}_j$$

Solving w.r.t. p_e we get:

$$p_e = (2F\alpha + 2p_q\gamma - \gamma\alpha(\overline{e}_i + \overline{e}_j))\frac{u_i u_j}{2\gamma u_i u_j + \alpha(u_i + u_j)}$$

The equilibrium permits price is decreasing in the amount of monitoring effort chosen by country i. Indeed,

$$\frac{\partial p_e}{\partial u_i} = (2F\alpha + 2p_q\gamma - \gamma\alpha(\overline{e}_i + \overline{e}_j))\frac{u_j}{2\gamma u_i u_j + \alpha(u_i + u_j)}\left(\frac{\alpha u_j}{2\gamma u_i u_j + \alpha(u_i + u_j)}\right) > 0$$

given that, for our model to make economic sense, the equilibrium price of permits must always be strictly positive. To conclude, from the expression for the equilibrium price of permits, we get that $\frac{\partial p}{\partial \overline{e}_i} = \frac{\partial p}{\partial \overline{e}_j} < 0$.

4 First stage: the governments

In the first stage of the game the two governments choose (jointly or separately) the amount of emission allowances to be issued to the two "representative" firms, $\overline{e}_d$ and $\overline{e}_f$, as well as the monitoring effort, taking into account how firms will react in the second stage. In so doing the two governments realize that the equilibrium price in the permits market can be influenced by their choice of $\overline{e}_i$ $(i = d, f)$. The aim of this section is, therefore, to assess how the amount of permits allocated in each country changes when moving from a centralized setting to a decentralized one.

First of all, we follow Malik [8] closely in that we assume the governments to ensure full compliance. This implies the need to impose that the expected fine equals the equilibrium price of permits, that is:

$$u_i F = u_j F = p_e$$

so that full compliance is only possible if $u_i = u_j = u$.

If we exclude the uninteresting case in which $u_i = u_j = 0$, we get:

$$u = \frac{p_q}{F} - \frac{\alpha}{2F}\left(\overline{e}_i + \overline{e}_j\right)$$

$$\frac{\partial u}{\partial \overline{e}_i} = \frac{\partial u}{\partial \overline{e}_j} = -\frac{\alpha}{2F} < 0$$

As the initial endowment in country i increases, the amount of monitoring effort needed in order to achieve full compliance decreases. This result looks counterintuitive at a first glance, but it is perfectly reasonable. An increase in $\overline{e}_i$ leads to a decrease in the equilibrium permits price. A lower expected fine, and therefore a lower monitoring effort, is therefore needed to achieve full compliance, as the fine level F is not under the control of the government(s). Another relevant consequence of this result is that an increase in the endowment of permits in country i leads to a decrease in the needed monitoring effort both in country i and in country j. A positive spillover among governments arises.

The equilibrium price of permits will be, therefore, given by

$$p_e = p_q - \frac{\alpha}{2}\left(\overline{e}_i + \overline{e}_j\right)$$

4.1 Centralised case

We start analyzing what happens when the two governments act as a single entity. Given full compliance, under the *centralized* regime the two governments jointly choose the amount of $\overline{e}_d$ and $\overline{e}_f$, as well as the monitoring effort, in order to maximize the difference between total profits and total environmental damages, minus the expected monitoring costs:

$$W = \Pi_d + \Pi_f - (q_d + q_f)^2 - 2\lambda u$$

where $(q_d + q_f)$ and λ represent, respectively, total environmental damages and the unit cost of compliance effort by a centralized authority.

Substituting from (4), and taking the first order conditions w.r.t. $\bar{e}_i$ and $\bar{e}_j$, we get, after rearranging:

$$\bar{e}_i^c + \bar{e}_j^c = \bar{e}^c = 2\frac{p_q F + \alpha\lambda}{F\,(4+\alpha)}$$

The resulting price of permits will be :

$$p_e^c = \frac{4p_q F - \alpha^2\lambda}{F\,(4+\alpha)}$$

while the needed monitoring effort to guarantee full compliance will be

$$u^c = \frac{4p_q F - \alpha^2\lambda}{F^2\,(4+\alpha)}$$

4.2 Decentralised case

Under a *decentralized* regime, each government chooses its emissions target, as well as the monitoring effort, taking the other government's choice as given and aiming at maximizing domestic firm's profits less damages born by domestic citizens, which are a fraction $\delta \in [0,1]$ of total damages[6] less its specific costs due to the compliance effort. Unit costs related to compliance are denoted by ε for country d and by κ for country f. We assume that decentralisation brings about an advantage in terms of monitoring costs. More specifically, we assume that $\varepsilon < \lambda$ and $\kappa < \lambda$. The objective function of government d can be written as:

$$W_d = \Pi_d - \delta\,(q_d + q_f)^2 - \varepsilon u \qquad (6)$$

Taking the FOCs w.r.t $\bar{e}_i$ and rearranging, we get the following reaction funtion for country d :

$$\bar{e}_d(\bar{e}_f) = \frac{4p_q F + 2\alpha\varepsilon - F\,(8\delta+\alpha)\,\bar{e}_f}{F\,(8\delta+3\alpha)}$$

This reaction function is clearly negatively sloped, $\frac{\partial \bar{e}_d}{\partial \bar{e}_f} < 0$.

[6]Such fraction may be determined, for example, by geographical and/or meteorological reasons.

Government f maximizes

$$W_f = \Pi_f - (1-\delta)\left(q_d + q_f\right)^2 - \kappa u \tag{7}$$

Following the same reasoning as for country d, we get the following reaction function:

$$\overline{e}_f(\overline{e}_d) = \frac{4p_q F + 2\alpha\kappa - F\left(8(1-\delta)+\alpha\right)\overline{e}_d}{F\left(3\alpha + 8(1-\delta)\right)}$$

which is, again, negatively sloped. Solving the resulting system for $\overline{e}_d$ and $\overline{e}_f$ we get:

$$\overline{e}_i^{nc} + \overline{e}_j^{nc} = \overline{e}^{nc} = \frac{1}{2}\frac{\alpha(\varepsilon+\kappa) + 4p_q F}{F\left(2+\alpha\right)}$$

The corresponding equilibrium permits price will be:

$$p_e^{nc} = \frac{1}{4}\frac{8p_q F - \alpha^2(\varepsilon+\kappa)}{F\left(2+\alpha\right)}$$

Finally, the degree of monitoring effort needed to achieve full compliance will be given by:

$$u^{nc} = \frac{1}{4}\frac{8p_q F - \alpha^2(\varepsilon+\kappa)}{F^2\left(2+\alpha\right)}$$

5 Comparisons

We start by comparing the emissions standard arising in the decentralised case with the one resulting from centralisation:

$$\Delta\overline{e} = \overline{e}^{nc} - \overline{e}^{c} = \frac{4p_q}{\left(4+\alpha\right)\left(2+\alpha\right)} - \frac{2\alpha\lambda}{F\left(4+\alpha\right)} + \frac{\alpha\left(\varepsilon+\kappa\right)}{2F\left(2+\alpha\right)}$$

which is negative if

$$2\lambda > \left(\varepsilon+\kappa\right)\frac{\alpha+4}{2\left(2+\alpha\right)} + \frac{4p_q F}{\alpha\left(2+\alpha\right)}$$

that is, if 2λ is sufficiently high with respect to $\varepsilon+\kappa$. As a consequence, we can conclude that if the monitoring cost advantage for decentralised governments is sufficiently high, then a weaker environmental policy could result in the centralised case. This result is in sharp contrast with the conclusion in D'Amato and Valentini [4], where decentralisation always leads to a weaker environmental policy. In that paper, this is the result of two negative spillovers among countries: a standard international externality spillover related to the transboundary nature of pollution and a "price" spillover, related to the influence that the initial distribution of permits in country i has, *via* the permits' price, on the emissions level in country j and, therefore, on the related environmental damage.

Here, we have another spillover which acts in an opposite direction w.r.t. those just analysed. Indeed, as we have shown, each country decreases the amount of monitoring effort needed to achieve full compliance in the other country by increasing the domestic emissions standard. The *net* spillover will, as a result, depend on the relative strenght of such positive spillover w.r.t. to the already investigated negative ones.

From the above conclusion we can also derive the result that a sufficiently large cost differential in favour of single governments could lead to a lower equilibrium permits price under centralisation. On the other hand, in such a case, full compliance would require a lower effort (i.e. a lower u) in the decentralised case.

The intuition for this result is as follows. If we assume that each unit of monitoring is more costly in a centralised setting, then the centralised decision maker has an incentive to reduce the monitoring effort needed to achieve full compliance via the allowance price. When the differential is sufficiently high, this will lead to a very weak environmental policy, but will also produce savings in monitoring costs thank to the very low resulting equilibrium permits price.

6 Conclusion

In this paper we have addressed the problem of whether the power of both allocating emission permits and monitoring compliance might be delegated to the states belonging to an Economic Union. Specifically, we have analyzed a two stage game where governments move first setting the amount of permits to be issued and the level of compliance. They can do this either acting as a single entity or in a decentralized way. In the second stage each firm observes the probability of being detected and the amount of permits that have been assigned to it, and then chooses the level of actual emissions and the amount of held permits. Emission permits are then traded in a perfectly competitive market.

In this theoretical framework the negative spillovers among national governments, related both to the "global" nature of the pollution problem we analyse and to the fact that governments can influence the equilibrium permits' price, may be balanced by the greater enforcement costs of a centralized environmental authority. As a matter of fact, we have shown that a decentralized setting does not necessarily lead to higher pollution and less efficiency. This result seems to represent a possible sound justification for the case of the European emissions trading system which has been recently introduced by the Directive 2003/87/CE.

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