TRADABLE EMISSION PERMITS IN A FEDERAL SYSTEM

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Abstract

A system of tradable permits in the standard setting is effective in attaining the policy objective with regard to pollution reduction at the least cost. This outcome is challenged in case of a tradable permit system in a federal state with individual states having discretionary power regarding environmental policy and where pollution is transboundary across states. This paper explores the opportunities of the central authority to influence the effectiveness of the system, under different institutional arrangements, through the initial allocation of permits.

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1. Introduction

A tradable emissions permit (TEP) system is typically associated with the twin aim of attaining the centrally set economy-wide level of emissions, and achieving cost efficiency. All the (federal) government has to do, is to determine the desired pollution level, and to distribute the total number of permits associated with this optimal pollution level among those firms, that emit a pollutant in the production process. The profit-maximizing firms have the possibility to reduce emissions by means of an abatement technology or by buying permits instead. Given the initial allocation of permits to the firms, in a competitive equilibrium the market price for permits equals marginal abatement costs, which are therefore equal across firms implying that total abatement costs are minimised. Furthermore all permits will be used in equilibrium, implying that the goal with respect to pollution is exactly met. The two objectives of minimal abatement cost and attaining the desired level of pollution are achieved whatever the initial allocation of permits. Allocating permits is, therefore, in the standard TEP systems inessential to reaching the objectives.

However, in order for these attractive properties to hold several conditions need to be satisfied. The main problem arising within this setting is the violation of the assumption of competitiveness. A useful distinction is between imperfect competition on the product market on the one hand and imperfect competition on the permits market on the other hand. Sartzetakis (2004) makes the most recent contribution and also provides a nice overview of the work done on imperfect product markets, reviewing among others Malueg (1990), Sartzetakis (1997a) and Long and Soubeyran (2000). The central message from this literature is that perfect competition on the permits markets might not lead to efficiency if the product market is characterized by imperfect competition. Imperfect competition may lead to firms with high abatement costs becoming too aggressive on the permits market. Hahn (1984) and Kolstad (2000 pp. 167-170) show that with one firm having market power on the permits market, efficiency of a TEP system is violated in a world where firms aim at cost minimization, unless the initial permit distribution is such that the allocation to the firm with market power coincides with its optimal use of permits. Misiolek and Elder (1989) consider the case where the firm that is dominant on the product market can by exerting 'excessive' demand for permits, also manipulate the permits market and thereby the cost of its rivals. Subsequent work in this area has been done by Von der Fehr (1993) and Sartzetakis (1997b). Fershtman and De Zeeuw (1996) consider the case of an oligopoly on the product market, and Nash bargaining on the permits market.

The authors of the previous literature probably had in mind market distortions within single jurisdictions. In the present paper, however, we would like to focus on the international dimension. In particular we will consider the case where lower-level authorities such as states in the US or member countries in the EU might interfere with the international permits market. The states' own objectives in environmental policy might prevent the achievement of the federally set standards.

Nowadays TEP systems are in place for several pollutants at national levels within Europe and the US, and a TEP system is currently being implemented for the entire EU for greenhouse gas emissions. In the US there already exists a nation-wide TEP system for sulphur-dioxide. For an evaluation of SO_2 allowance trading program see Schmalensee *et al*. (1998) and Stavins (1998). These federal systems will operate in the way described above, if the individual states just pursue profit maximisation on the part of their (polluting) firms. Obviously, their objective is much broader, including other welfare aspects such as consumer surplus. As is well known, welfare maximization at the state level does not have to coincide with welfare maximization at the nation-wide level. A state fails to take account of the externalities it imposes on the residents of other states, while on the other hand, states are not able to correct for externalities other states are imposing upon their residents. The tax-competition literature concludes in such cases that the federal government should correct inefficient local policies by centralizing the decision power, or by introducing appropriate corrective grants (see Wilson, 1999, for an overview of this literature).

In the context of a TEP-system states can interfere with the objectives of the federal government by setting their own taxes on firms within their own states, or by having their own regulations on the trade of permits by companies within the state borders. This can come down to imposing trade bans on the sale of permits. Under the latter type of intervention states withdraw a certain number of the allocated permits from the market. This has been the case in the US, where the state of New York has prevented its electricity companies from selling permits to companies in Southern and Midwestern States, by imposing fines on utilities making such sales.

State intervention can be motivated by the desire to extract higher revenues from the permits or electricity trade or by the existence of asymmetric transboundary pollution, causing so-called hot spots where a disproportionally large part of the pollution is emitted. In the latter case the resulting uniform market price for permits does not generally correspond with first-best. In particular, asymmetric pollution spillovers will call for differing levels of environmental quality and differing admissible levels of pollution across states. Such requirements for efficiency, however, seem to be impossible to reconcile with a system of a laisser-faire TEP system where the final allocation of emission activities is independent of the initial allocation of permits. It is known from the literature, see e.g., Tietenberg (2003) and Hanley *et al*. (1997), that with non-uniformly mixing pollutants abatement cost minimization calls for an ambient permit system, where permits refer not to the right to emit but to the right to deposit at certain receptor points. However, in practice at federal levels this is not the way pollution is dealt with.

As shown by Santore, Robison and Klein (2001), if asymmetric pollution spillovers occur, in a TEP system where states intervene by imposing taxes on the polluting activities within their state, the outcome of the TEP market will generally not be *permits-constrained* Pareto efficient, meaning that a central authority can improve welfare in one state without decreasing it in another state, *given* the total number of permits issued. Moreover, given that states use their own taxes to steer the decisions of the companies within their own border, it follows that whatever the final allocation, cost efficient abatement will only occur if all states happen to impose identical tax rates. On the other hand, if a Pareto efficient outcome in the presence of asymmetric pollution were to occur, it will not be characterized by cost efficient abatement. The intuition for this result is that minimizing pollution abatement costs will in general not provide the necessary corrections for asymmetric pollution spillovers.

The present paper addresses the case where the central government has some discretion regarding the allocation of permits to states. Therefore, contrary to Santore *et al*., we consider the case where the number of permits and its distribution is not given but where they are policy variables for the central government. The main question in this context is then under what circumstances a combination of centrally set pollution limits and decentralised intervention by means of taxes and/or trade bans on emission activities can lead to a first-best solution. The policy relevance of this is obvious. In the design of a TEP system at the federal level, the policy followed by the member states should be taken into account. In this sense the issue directly touches on crucial aspects of fiscal federalism. In particular, questions like which government level should set environmental standards, and which instruments federal and lower-level governments have and/or should be allowed to use in order to meet the stated objectives are at stake. When transboundary pollution occurs, the "natural response is to invoke central intervention of some kind", Oates (2003, p. 4). But, as he immediately notes, uniform regulations are unlikely to lead to first-best efficiency. He prefers regional cooperation as potentially offering a resolution of jurisdictional spillover effects. What we will show, however, is that a TEP-system in a federation where the federal government sets the nation-wide pollution level and decides on the distribution of permits, while the states decide on the taxes they impose on their local companies, can lead to first-best. The point is that, given enough information on state and market behaviour, the federal government can use the initial distribution of permits as a mechanism to realise first-best production and consumption values. Compared to the unrestricted first-best total social welfare is redistributed among states in this allocation, however.

The analysis takes place in a model that resembles the model used by Santore *et al.*, but there are two important differences, apart from the endogeneity of the permit distribution. We deviate from Santore *et al.* by assuming that one nation-wide electricity market exists. Given such a market, states cannot compensate restraints on the taxes that they can set, by inflicting distortions in the local electricity market. Moreover, as in the context of transboundary pollution cost-efficient abatement is not an issue anyhow, as we argued above, and in order to focus on distributional issues as much as possible, we also abstract from abatement.

The main outcomes of the paper can be sketched as follows. If states impose local taxes, firms' production and polluting behaviour will be affected on the margin, and the federal government can employ this knowledge by distributing the permits across states such that the first-best allocation of production and pollution is attained. This result will also hold if states are not allowed to set negative taxes, i.e., if they cannot give subsidies to their local polluting plants. If states use trade bans to affect the emission of pollution in their state, the federal government cannot attain the first-best allocation by manipulating the distribution of permits. As we show, however, a state government will only have an incentive to withdraw permits from use in its state, if it perceives that by doing so, it can affect the nation-wide electricity price. In other words, if the states do not have, or do not assume to have market power on the electricity market, they will not impose trade bans.

In the next section we introduce the model and determine the first-best optimum. Section 3 deals with the case where individual states can set pollution taxes on their firms, whereas section 4 also allows for trade bans. Finally, section 5 concludes.

2. The model, first-best optimum and laisser-faire

In this section we present the model and derive the conditions for a first-best optimum. We also demonstrate that a standard TEP will not achieve the first-best optimum.

The formal model reads as follows. There are n $(n > 1)$ states. Each state i produces electricity, y_i, with a technology giving rise to an aggregate production cost function C_i that is continuous, increasing and strictly convex. Interstate trade of electricity takes place but no net exports at the federal level are allowed. Production brings along emissions in a one to one way: $e_i = y_i$. In principle, emissions generated by a state do not coincide with depositions in that state, due to the transboundary character of the pollutant. Depositions within state i are given by $d_i(y)$, depending on emissions generated in all states ($y = (y_1, y_2, ..., y_n)$). Agents in each state have preferences defined on the consumption of electricity (z_i), depositions in their own state, and money (capturing all other commodities). It is assumed that consumers are identical within as well as across states. Moreover, population sizes in all states are equal. Social welfare in a state is then given by $W_i(z_i, m_i, d_i)$. Here m_i denotes money holdings, accruing to the state from the net exports of electricity minus production costs: $m_i = py_i - pz_i - C_i(y_i)$. At no cost one could include an exogenous income component. Welfare is decreasing in depositions and increasing in the other arguments. It is additively separable in the three arguments $W_i(z_i, m_i, d_i) = U_i(z_i) + m_i - D_i(y)$, where U_i denotes utility from electricity consumption and D_i is the damage caused by emissions,

From the point of view of the federal government the first-best optimum is the solution of the following optimisation problem:

$$\text{Max} \sum_{i=1}^{n} [U_i(z_i) - C_i(y_i) - D_i(y)]$$

subject to

$$(2.1) \qquad \sum_{i=1}^{n} z_i = \sum_{i=1}^{n} y_i$$

Note that in the federal government's objective function the terms $py_i - pz_i$ are absent because their aggregate over the states equals zero. The Lagrangian reads:

$$\sum_{i=1}^{n} [U_i(z_i) - C_i(y_i) - D_i(y)] + \kappa \sum_{i=1}^{n} [y_i - z_i]$$

Assume an interior solution. Then the following conditions hold

$$(2.2) \qquad U_i^{'}(z_i) = \kappa, \; i = 1,2,...,n$$

$$(2.3) \qquad \kappa = C_i^{'}(y_i) + \sum_{j=1}^{n} D_{ji}(y), \; i = 1,2,...,n$$

where primes denote the derivative in case of a function with a single variable and D_{ji} denotes the partial derivative of D_j with respect to the $i-th$ element (all i and j). The interpretation of these conditions is straightforward. They indicate that marginal utility of electricity in each state should equal marginal cost, consisting of production costs and the costs of emissions, inflicted on all states. In the sequel the values in the first-best optimum will be denoted by hats. The system of equations (2.2) and (2.3) yields the optimal amount of emissions for each individual state $\hat{e}_i = \hat{y}_i$ for $i = 1,2,...,n.$ The first-best optimum will therefore be implemented by allocating this amount of permits to each individual state and by not allowing trade in permits.

However, this is not the way a TEP system works. Instead, in a standard TEP system the federal government issues tradable permits. As a necessary, but as is shown below by no means sufficient, condition to reach the first-best optimum the federal government should issue a total amount of permits equal to the first-best optimum amount, denoted by $\hat{x}.$ The beneficiaries are the electricity companies, or the states who distribute them to the electricity companies without any restriction on how to use the permits. The electricity companies take the price τ on the federal permit market as given. So, we assume that the individual electricity companies are all price takers. In other words there is perfect competition on the product market. This can be justified by the deregulation of this industry, e.g., at the EU level. The TEP regime described above will be called *laisser-faire*. It is well known that it will in general not generate the first-best optimum. Consumer demand for electricity is given by

(2.4) $$U_i^{'}(z_i) = p$$

where p is the market price for electricity. Electricity supply of a firm confronted with a permit price τ follows from the maximisation of its profits

$$py_i - C_i(y_i) - \tau y_i$$

Hence

(2.5) $$p = C_i^{'}(y_i) + \tau$$

Therefore, when taking (2.2) and (2.3) into account one observes that a necessary condition for achieving the first-best solution is:

(2.6) $\tau = \sum_{j=1}^{n} D_{ji}(\hat{y})$ for all i

Except for the case of uniformly mixing pollutants (where $D_i(y) = D_i(\sum_{j=1}^{n} y_j)$ for all $j = 1,2,...,n$) condition (2.6) is unlikely to be satisfied in the laisser-faire equilibrium. Since the federal government issues the first-best amount of permits, it follows, however, that $p = \hat{\kappa}$. This is due to the assumption that emissions are proportional to production with factor of proportionality equal to unity. This implies that total emissions equal total electricity production, which in its turn equals aggregate electricity demand. Hence, the assumption allows for a precise identification of the reason why the first-best optimum is not realised. The reason is not a suboptimal level of electricity production but it comes from an inefficient allocation of production over the individual electricity companies that do not take the spatial aspects of emissions into account.

3. Emission taxes by states

In the present section we only consider emission taxes as a policy instrument at the state level; trade bans will be discussed in the next section. State i maximises its social welfare by imposing an emission tax denoted φ_i on its electricity firm. For the time being, the tax is not bound to be positive, so that it can actually be a subsidy on emissions. The social welfare function of state i consists of consumer surplus from electricity consumption plus the revenues from the emission tax which are transferred to the consumer in a lump sum fashion, the producer surplus from electricity production, including revenues from the sale of permits, minus local emission taxes, and, finally, damage caused by emissions. Since emission taxes cancel out, the objective of the state is to maximise:

$$W_i = U_i(z_i) - pz_i + py_i - C_i(y_i) + \tau[x_i - y_i] - D_i(y)$$

In maximising the welfare of its citizens, the state government takes the behaviour of domestic consumers and firms into account. Profit maximisation on the part of the firms yields

(3.1) $p = C_i^{'}(y_i) + \tau + \varphi_i$

from which follows the supply of electricity, depending on the electricity price, the permit price plus the state pollution tax: $y_i(p, \tau + \varphi_i)$. Consumer behaviour is described by (2.4), so that demand is a function of the electricity price only: $z_i(p)$. Moreover, since $\sum_{i=1}^{n} z_i(p) = \sum_{i=1}^{n} y_i = x$, where x is the total amount of permits issued by the federal government, the equilibrium electricity price follows from (2.4) as a function of x. So, the electricity price is a function of the total amounts of permits only and cannot be affected by the state.

If the individual state took the permit price as given, we would be back in the previous case of laisser-faire. Instead, it is now assumed that the states play a Nash game against each other: each state i takes the emission taxes by all other states $j \neq i$ as given, but in the optimisation it takes account of the impact its own emission tax has on pollution of each other state through the equilibrium on the permits market, i.e., $\sum_{i=1}^{n} y_i(p, \tau + \varphi_i) = x$. As the market price of electricity is beyond the control of individual states, the state perceives the permits price as a function of state taxes only, i.e., $\tau = \tau(\varphi)$, where $\varphi = (\varphi_1, \varphi_2, ..., \varphi_n)$. This implies that, for a given amount of total permits, we can write $y_i = y_i(\varphi)$ $(i = 1,2,...,n)$. In the Nash equilibrium we then have

(3.2)

$$\frac{\partial W_i}{\partial \varphi_i} = (p - C_i^{'}(y_i(\varphi)) - \tau(\varphi)) \frac{\partial y_i(\varphi)}{\partial \varphi_i} + (x_i - y_i(\varphi)) \frac{\partial \tau(\varphi)}{\partial \varphi_i} - \sum_{j=1}^{n} D_{ij}(y(\varphi)) \frac{\partial y_j(\varphi)}{\partial \varphi_i} = 0,$$

for $i = 1,2,...,n$. The leading principle of the planner at the state level is to equalise marginal cost and marginal benefits. These are represented in the three terms on the right-hand side of (3.2). An increase in the local tax rate will in first instance decrease production. Hence, revenues decrease but production costs and expenditures on permits decrease as well. Also the permits price will change. Given fixed emission taxes set by other states less demand from the home firm induces a decrease of permits price, which is beneficial if $x_i < y_i$ and detrimental if $x_i > y_i$. Finally, the effect on pollution in the home country as a consequence of the reaction of other states has to be taken into account.

It is clear from (3.2) that, contrary to the standard TEP system, the equilibrium depends on the distribution of the initial allocation, which is a result that is well known in the literature (see e.g. Santore *et al.* (2001)). We can show, however, that with the total number of permits set at the first-best level, a first-best allocation of production and consumption can be attained. In this so-called permits-constrained first-best allocation individual state welfare need not coincide with first-best welfare, although total social welfare does.

Proposition 1.

Given that states set local taxes according to (3.2), the federal government can find an initial allocation of permits that generates the permits-constrained first-best allocation.

Proof.

A necessary condition for obtaining first-best social welfare is that the federal government issues the first-best total amount of permits $\hat{x}$. Then the market equilibrium price p coincides with the first-best marginal utility $\hat{\kappa}$. Hence each state consumes the optimal amount of electricity. Next consider the following set of equations: $p = C_i^{'}(\hat{y}_i) + \varphi_i + \tau \; (i = 1,2,...,n), \sum_{i=1}^{n} x_i = \hat{x}$ and (3.2). This set constitutes $2n+1$ equations and $2n+1$ unknowns, namely τ, $\varphi_i \; (i = 1,2,...,n)$ and $x_i \; (i = 1,2,...,n)$. Therefore, under standard regularity conditions, the first-best optimum for production and consumption can be realised by a proper initial distribution of tradable permits.■

The proof of the proposition does not make use of our assumption that emissions are uniformly proportional to production $e_i = y_i$ (for all i). It also holds in a more general case where this assumption is not made.

Proposition 1 claims that the 'optimal' allocation of permits by the federal government generates first-best total social welfare, but that in the new allocation welfare is redistributed across states compared to the first-best outcome: the new allocation may be worse for some individual states and better for some others. The loss or gain for individual states can be calculated by comparing the first-best welfare for individual states, i.e., $U_i(\hat{z}) - C_i(\hat{y}_i) - D_i(\hat{y})$, with the maximum welfare under state intervention with an optimal permits allocation, which is given by $U_i(\hat{z}) - \hat{p}\hat{z}_i + \hat{p}\hat{y}_i - C_i(\hat{y}_i) + \hat{\tau}[\hat{x}_i - \hat{y}_i] - D_i(\hat{y})$. Apparently, state *i* will gain, compared to the first-best solution if $\hat{p}(\hat{y}_i - \hat{z}_i) + \hat{\tau}[\hat{x}_i - \hat{y}_i] > 0$. That is, compared to the unrestricted first-best solution a state will gain if it is a net exporter of electricity and of permits. In other words, low-cost states and low-polluting states are likely to see their welfare improve compared to the first-best allocation

It is not true that the initial allocation of permits that generates the first-best total social welfare will never contain negative allocations. As an illustration we consider the following example.

Example 1. *Initial permit allocations can be negative*

There are three states with identical cost functions: $C_i(y_i) = \frac{1}{2} y_i^2$ ($i = 1,2,3$). States 1 and 2 experience no damage from pollution. State 3 is affected by state 1 only: $D_3(y_1, y_2, y_3) = \frac{1}{2}\beta y_1^2$ with β a positive constant. Utility from electricity consumption is logarithmic: $U_i(z_i) = \ln z_i$ ($i = 1,2,3$).

In the first-best optimum we have $\hat{z}_i^2 = \hat{z}^2 = 1/\lambda^2$ for all i, where $\lambda^2 = (3+3\beta)/(3+2\beta)$. Moreover, $\hat{y}_1^2 = \lambda/(1+\beta)^2$ and $\hat{y}_2^2 = \hat{y}_3^2 = \lambda^2$. Notice that, since $\beta > 0$, $\hat{y}_1 < \hat{z}_i = \hat{z} < \hat{y}_2 = \hat{y}_3$, i.e., state 1 should consume more than it produces and emits, while for state 2 and 3 the reverse holds. This makes intuitively sense, as state 1 is the polluting state. The total number of permits in the first-best optimum follows from $\hat{x} = 3\hat{z}$, and the first-best price is given by $\hat{p} = 1/\hat{z}$.

Individual profit maximisation by firms (3.1) gives rise to $y_i = p - \tau - \varphi_i$ ($i = 1,2,3$). Summing these equations over the y_i's, and taking into account that $\sum y_i = \hat{x}$, leads to $p - \tau = \frac{1}{3}(\varphi_1 + \varphi_2 + \varphi_3) + \frac{1}{3}\hat{x}$. As p is given to the state the expression for $p - \tau$ determines the dependence of τ on φ_i for all *i*. Inserting the expression for $p - \tau$ back into the profit maximising equations gives $y_i = -\frac{2}{3}\varphi_i + \frac{1}{3}\sum_{j \neq i}\varphi_j + \frac{1}{3}\hat{x}$, which determines $\partial y_i / \partial \varphi_j$ for all i and j. From state-wise welfare optimisation it then follows that $2(p - y_1 - \tau) = y_1 - x_1$, $2(p - y_2 - \tau) = y_2 - x_2$ and $2(p - y_3 - \tau) = y_3 - x_3 - \beta y_1$. Summing these equations over x_i, and using the optimal total number of permits, i.e., $\sum x_i = \hat{x}$, the optimal price $\hat{p}$, and the first-best production values $\hat{y}_i$ ($i = 1,2,3$), the equilibrium permit price $\hat{\tau}$ can be calculated.

Given the electricity price and the permits price in the first-best, the federal government is now able to calculate the number of permits that has to be allocated to each state such that first-best production and emission levels are attained. In particular, from the separate state welfare maximisation equations we get $\hat{x}_1 = 3\hat{y}_1 - 2\hat{p} + 2\hat{\tau} = (1-\beta)\lambda/(1+\beta)$, $\hat{x}_2 = 3\hat{y}_2 - 2\hat{p} + 2\hat{\tau} = (1+2\beta)\lambda/(1+\beta)$, and $\hat{x}_3 = 3\hat{y}_3 - 2\hat{p} + 2\hat{\tau} = \lambda$ for state 1, 2 and 3, respectively. Obviously, the number of permits to be allocated to state 1 will be negative if and only if $\beta > 1$. Hence, in that case, the polluting state is forced to buy all the permits it needs, but apart from that, it has to pay an 'entrance fee' before it can enter the permits market. State 2 will get more permits than it needs at the first-best production level. As a result, it will sell the permits that are on top of their first-best production levels to state 1.

State 3, finally, will get exactly the permits it needs for production, and will, hence, not engage into trade on the permits market. ■

In example 1 it is immediately clear that state 2 and 3 gain under the permits-constrained first-best, compared to the unrestricted first-best. States 2 and 3 are both exporting electricity, while state 2 is also selling permits to state 1. Obviously, compared to the first-best state 1 is losing under state intervention as it has to import electricity and has to buy permits.

In proposition 1 we did not put any restriction on the state taxes φ_i, $i = 1,2,3$, and they can therefore be negative in the optimum. The following example demonstrates this.

Example 2. *States taxes can be negative in the optimum*

Following up on example 1, we can use individual profit maximisation and first-best values to calculate state taxes from $\varphi_i = \hat{p} - \hat{\tau} - \hat{y}_i$, $i = 1,2,3$. We have $\varphi_1 = \frac{1}{2}\lambda\beta/(1+\beta)$ and $\varphi_2 = \varphi_3 = -\varphi_1$. So, states 2 and 3 subsidise production, while the polluting state 1 taxes domestic production. ■

Now suppose that it is politically infeasible for individual states to allow for negative local emission taxes, the reason being for example that environmental pressure groups are strongly opposed to subsidizing polluting activities. Hence, social welfare maximization by state i is subject to the constraint $\varphi_i \geq 0$. Assume that the constraint is binding for one state only, say, without loss of generality, for state 1. Returning to the proof of proposition 1, there are again $2n+1$ unknowns, namely τ, φ_i $(i = 1,2,...,n)$ and x_i $(i = 1,2,...,n)$ and $2n+1$ equations, namely $p = C_i^{'}(\hat{y}_i) + \varphi_i + \tau$ $(i = 1,2,...,n)$, $\sum_{i=1}^{n} x_i = \hat{x}$, $\varphi_1 = 0$, and the set of equations (3.2), except for the first one. Hence, in principle we can again solve for the unknowns, and there exists a permit allocation generating the permits-constrained first-best outcome. When multiple negative taxes occur in the unconstrained case, we can prove that a permits-constrained first-best outcome can still be realised by an appropriate choice of the initial distribution of permits:

Proposition 2. *In case of taxes bound to be nonnegative a permits-constrained first-best allocation generally exists.*

Proof.

From profit maximisation it follows that for all states *i* whose taxes are constrained to be zero, it holds that $p - \tau = C_i^{'}(\hat{y}_i)$. Consider two states, let us say states *1* and *2*, with negative state taxes in the unconstrained optimum. Assume that in the unconstrained-tax case $0 > \varphi_2 > \varphi_1$. Then, if we constrain the lowest tax to be zero in the new equilibrium, i.e.

$\varphi_1 = 0,$ we get that the other tax rate will be positive as $\varphi_2 > \varphi_1 = 0.$ So, only the constraint on the lowest negative tax rate is binding in equilibrium. As a result, the first-best optimum for production and consumption can again be realised as we have $2n+1$ unknowns, namely τ, $\varphi_i \; (i = 1,2,...,n)$ and $x_i \; (i = 1,2,...,n)$ and $2n+1$ equations, namely $p = C_i^{'}(\hat{y}_i) + \varphi_i + \tau \; (i = 1,2,...,n), \sum_{i=1}^{n} x_i = \hat{x}, \; \varphi_1 = 0,$ and the set of equations (3.2), except for the first one. ■

If a state is forced to impose zero taxes on its firm, the firm can only be incited to produce more if more permits are allocated to this state. Obviously, this implies that other states will get a lower initial allocation, possibly turning positive permits endowment into negative ones, as example 3 demonstrates.

Example 3. *Constrained states taxes can lead to lower permits endowments for other states.* We saw in examples 1 and 2 that states 2 and 3 imposed negative taxes. If we constrain φ_2 to be zero the taxes of the other states turn out to be equal to: $\varphi_1 = \lambda\beta/(1+\beta)$ and $\varphi_3 = 0.$ The optimal allocation of permits now equals $\hat{x}_1 = (1-2\beta)\lambda/(1+\beta),$ $\hat{x}_2 = (1+4\beta)\lambda/(1+\beta)$ and $\hat{x}_3 = \lambda/(1+\beta),$ respectively. Compared to the allocation presented in example 1, states 1 and 3 get fewer permits, while state 2 gets more permits. If $1/2 < \beta < 1,$ for state 1 the positive permits allocation in the unconstrained tax case would indeed turn into a negative one if taxes are constrained to be non-negative. ■

As a further remark to proposition 1, example 1 also makes clear that in general the allocated permits will not equal the first-best emission levels. In a federation with $n > 2$ states $x_i = y_i,$ for all $i,$ will hold by coincidence only. Interestingly, though, in a two-state federation, whatever the shape of the asymmetry in emissions, the permits allocated to the states will always equal first-best emissions, i.e., $\hat{x}_i = \hat{y}_i.$ However, as soon as a non-negativity constraint on state taxes becomes binding, this no longer has to hold. The reason for this is that if subsidies to the firms are no longer feasible, subsidized firms will have to be incited to produce more by being allocated more permits. We formulate these results in the following propositions:

Proposition 3

In the unconstrained-tax case a two-state federation will have no permits trading in the permits-constrained first- best.

Proof

It easy to establish from profit maximisation and the permits constraint $y_1 + y_2 = x$ that $\partial y_1 / \partial \varphi_1 = \partial y_2 / \partial \varphi_2 = -\partial y_1 / \partial \varphi_2 = -\partial y_2 / \partial \varphi_1$. After combining the first-best conditions (2.2) and (2.3) and equation (3.2) this implies that $(x_1 - y_1)\partial \tau / \partial \varphi_1 = (x_2 - y_2)\partial \tau / \partial \varphi_2$. As the permits market constraint holds, permits-constrained first-best welfare can only be attained if permits are assigned to the two states according to their first-best emissions. In the two-state case it is therefore possible for the federal government to completely replicate the first-best solution for each state separately. ■

Proposition 4

In the constrained-tax case a two-state federation can have permits trading in the permits-constrained first-best.

Proof

Suppose two states have identical cost functions: $C_i(y_i) = \frac{1}{2}\gamma y_i^2 \quad (i = 1,2)$. State 1 experiences no damage from pollution, while state 2 is affected by state 1 only: $D_2(y_1, y_2) = \frac{1}{2}\beta y_1^2$ with β a positive constant. Utility from electricity consumption is logarithmic: $U_i(z_i) = \ln z_i \ (i = 1,2)$. In the first-best optimum we have $\hat{z}_i^2 = \hat{z}^2 = 1/(\gamma\lambda^2)$ for $i = 1,2$, where $\lambda^2 = (2 + 2\beta)/(2\gamma^2 + \beta\gamma)$. Moreover, $\hat{y}_1 = \gamma\hat{y}_2/(\gamma + \beta), \hat{y}_2 = \lambda$. Without a tax constraint, Proposition 1 yields $\hat{x}_1 = \hat{y}_1, \hat{x}_2 = \hat{y}_2$. From state welfare maximisation we get $\varphi_1 = 0$ and $\varphi_2 = -2\beta/(2\gamma\lambda + \beta\lambda)$. Inserting the constraint $\varphi_2 = 0$, and calculating the optimal permits allocation, we get that for state 1 the number of initial permits will equal $(\gamma - \beta)\hat{y}_2/(\gamma + \beta)$ which is less than the number of permits state 1 received in the unconstrained tax case. Obviously state 2 will receive more permits, and so, as the first-best production values are unchanged, permits trade will emerge. ■

It is worthwhile to dwell for a moment on related work by Santore *et al.* (2001). The differences in modelling boil down to the following. In their model there is an exogenously given income level, and electricity production is determined by the individual states. Electricity is a non-tradable. Moreover, they do not allow for emission subsidies. We assume a nation-wide competitive electricity market. Unlike in the Santore *et al.* model, in our model states are not able to cause distortions in the electricity market, in case the optimal tax rate might not be feasible for institutional reasons. Santore *et al.* claim that for any given distribution of permits, there exists a Pareto-improving allocation of consumption and emissions. This means that with total initially given exogenous income, electricity consumption and emissions can be reallocated such that for all states involved welfare is not decreased and for one state welfare is increased. The generality of the claim is refuted in our model where there exists a permit allocation that generates the first-best outcome for production and consumption. The point is simply that in our model we allow the federal government to take account of states' behaviour. By employing the mechanisms that determine the state taxes the government can indirectly steer production values to their first-best values. So, we conclude that, although they employ a somewhat different model, their claim that Nash equilibrium with permits trading is generally not (permits constrained) Pareto-efficient, only holds with a non-optimal initial distribution of permits. Second, their restriction to nonnegative emission taxes creates a distortion that may prevent an optimal allocation. In particular when the damage caused by home firms is low, it might be welfare improving to subsidise emissions. If states are prevented from doing this for institutional reasons, they have an incentive to opt for inefficiently high production levels. In our model, this mechanism is not operative as we assumed (thus far) perfect competition on the product market. Moreover, proposition 2 shows that even in cases where tax constraints are binding, the federal government will be able to reach first-best production levels by an appropriate choice of the initial permits distribution.

4. Emission taxes and trade bans

We next consider policy scenarios where states set the emission tax/subsidy and have the capacity to impose trade bans. The concept of a trade ban can be interpreted in different ways. In the present section trade bans are modelled as a state withholding a certain number of permits, that can therefore not be traded by its firm. Another way of representing a ban would be an additional constraint on the firm's profit maximization problem, prescribing the maximal amount of permits sold on the permits market. The advantage of the first approach is that the presence of the trade ban only affects optimal firm behaviour through a change in the permits price. It therefore keeps the analysis more tractable.

It is easy to see that if a state is willing to decrease the total number of permits in the market by imposing a positive trade ban, the federal government no longer has instruments to reach the first-best total social welfare. The problem here is that, contrary to local taxes, trade bans do not affect firm behaviour at the margin, and so by choosing the distribution of permits the federal government is not able to steer production. Or, in other words, the federal government is only able to affect firms' behaviour via the local taxes. In the case of the co-existence of local taxes and trade bans, however, local taxes only take care of the internal pollution, while transboundary pollution is corrected by the state by the imposition of the trade ban. The trade ban depends on the number of permits allocated to the state. But, if the federal government manipulates the allocation of the permits, it affects the permits price (via the number of trade bans). A change in the permits price, however, has a uniform effect on all states and thus is not suitable to correct the asymmetric pollution effects.

So, the question that needs to be addressed is under which conditions states will have an incentive to impose trade bans, thus making it infeasible to get at a distribution of permits that maximizes total social welfare. This appears to depend on the states' capability to manipulate the product price. Thus far, we assumed that states set their taxes in a thin permits market and thus, in their tax policy, take account of its consequences for the permits price, but consider the product price as given. This might be justified by the observation that the product market is typically larger than the permits market, and thus it will be more difficult for states to act as a price setter on this market.

As we saw in section 3, if states take the product price as given, the federal government has just enough degrees of freedom to determine the allocation of permits according to the permits-constrained first-best solution. As we will show below, states will then not have an incentive to introduce a trade ban. However, if states are able to calculate the relationship between a trade ban and the electricity price, they might impose a trade ban.

Proposition 5

If the product price is given, states have no incentive to impose trade bans.

Proof

Suppose that states take the product price p as given. Moreover, assume that the federal government has allocated permits according to the permits-constrained allocation described in Proposition 1. Given this allocation, and assuming that states have implemented their optimal taxes in the absence of trade bans, it will not pay for any state, say state 1, to voluntary take a number of its allocated permits out of the market, i.e., will $dW_1 > 0$ hold for $dx_1 < 0$. To prove this, we consider without loss of generality the marginal welfare change in state 1 after a change in the use of permits, starting in a permits-constrained first-best equilibrium. Hence $\sum_{i=1}^{n} dy_i = dx_1$. Define $\gamma_i = C_i^{''}(y_i)$ for $i = 1,2,...,n$, and $\Gamma = \sum_{i=1}^{n} \frac{1}{\gamma_i}$, all evaluated in the permits-constrained first-best. Using $p = C_i^{'}(y_i) + \tau + \varphi_i$ for all i and $\sum_{i=1}^{n} dy_i = dx_1$, it follows that

(*) $$dp - d\tau = \frac{1}{\Gamma}dx_1 + \sum_{i=1}^{n}\frac{1/\gamma_i}{\Gamma}d\varphi_i$$

and

(**) $$dy_i = \frac{1/\gamma_i}{\Gamma}dx_1 + \sum_{j\neq i}\frac{1/\gamma_j\gamma_i}{\Gamma}d\varphi_j + \frac{(1/\gamma_i)(1/\gamma_i - \Gamma)}{\Gamma}d\varphi_i, \; i = 1,2,...,n$$

With $dp = 0$ the effect of the trade ban on state 1's welfare is given by:

(***) $$dW_1 = (p - C_1^{'}(y_1) - \tau)\frac{\partial y_1(\varphi_1, x_1)}{\partial x_1}dx_1 + (x_1 - y_1)\frac{\partial \tau(\varphi, x_1)}{\partial x_1}dx_1 - \sum_{j=1}^{n}D_{1j}(y)\frac{\partial y_j(\varphi_1, x_1)}{\partial x_1}dx_1 + \tau dx_1$$

In the permits-constrained first-best, without trade ban, we have according to (3.2):

$$(p - C_1^{'}(y_1) - \tau)\frac{\partial y_1(\varphi, x_1)}{\partial \varphi_1} + (x_1 - y_1)\frac{\partial \tau(\varphi, x_1)}{\partial \varphi_1} - \sum_{j=1}^{n}D_{1j}(y)\frac{\partial y_j(\varphi, x_1)}{\partial \varphi_1} = 0$$

Using (*) and (**) we derive:

$$\tau = p - C_1^{'}(y_1) + (x_1 - y_1)\frac{1}{\Gamma - 1/\gamma_1} - D_{11} + \sum_{j=2}^{n}D_{1j}\frac{1/\gamma_j}{1/\gamma_1 - \Gamma}$$

Inserting this expression for τ into (***) we arrive at

$$dW_1 = (p - C_1^{'}(y_1) - D_{11})dx_1$$

In the first-best optimum we have $p - C_1^{'}(y_1) - D_{11} = \sum_{i=2}^{n}D_{i1} \geq 0$. Hence, starting from the permits-constrained first-best (with a first-best allocation of production and consumption) state 1 will not impose a trade ban, when it takes p as given. ■

Proposition 6

If states have market power on the product market, they might have an incentive to impose trade bans.

Proof

We prove the proposition in a two-state example by showing that if one state, say state 2, has an effect on the product price p a trade ban can be welfare improving for state 2. We specify equal production conditions with $C_i(y_i) = \gamma y_i^2/2$ for *i=1,2,* and we assume the utility of consumption to be logarithmic, i.e., $U_i(z_i) = \ln z_i$ ($i = 1,2$). Moreover, we assume $D_1(y_1, y_2) = 0$ and $D_2(y_1, y_2) = ty_1^2/2$. Thus, only state 1 is polluting, and it is emitting in state 2. State 2 considers the introduction of a trade ban, given that in the initial permits-constrained first-best equilibrium, the number of permits it gets corresponds exactly to the first-best level according to Example 3. We can calculate the welfare effect of a change in the number of permits for state 2 as follows:

$$\frac{dW_2}{dx_2} = (y_2 - z_2)\frac{\partial p}{\partial x_2} + \tfrac{1}{2}(p - \gamma y_2 - \tau) + \tau - t y_1 .$$

Notice that in this expression the term $\partial p / \partial x_2$ appears and represents the effect a trade ban by state 2 can exert on the electricity price. The optimal tax rate for state 2, evaluated in the equilibrium without a trade ban, follows from

$$\frac{dW_2}{d\varphi_2} = (p - \gamma y_2 - \tau)\frac{-1}{2\gamma} - t y_1 \frac{1}{2\gamma} = 0$$

Insert the latter result into the expression for dW_2 / dx_2 to get:

$$\frac{dW_2}{dx_2} = (y_2 - z_2)\frac{\partial p}{\partial x_2} + p - \gamma y_2$$

State 1 is assumed to know that in the first-best $p = 1/z = 2/(x_1 + x_2)$ so that $\partial p / \partial x_2 = -2/(x_1 + x_2)^2$. Moreover, using the first-best solutions $x_2 = y_2 = \sqrt{(\gamma + t)/(\gamma^2 + t\gamma/2)}$ and $x_1 = (2\gamma + t)y_2/(\gamma + t),$ we get $dW_2 / dx_2 > 0$ if and only if $-t^2 - \gamma t < 0,$ which obviously is true. ■

Proposition 6 thus claims that trade bans can be rational for some states to impose if they are able to manipulate the electricity price. Proposition 5, on the other hand, claims that in the absence of such market power the permits-constraint first-best can be realised by the federal government as states have no incentive to impose a trade ban on their firms.

In Table 1 the effects of imposing a trade ban are illustrated for the two-state case dealt with in the proof of proposition 6. We employ two sets of parameter values. In the first set with $\gamma_1 = \gamma_2 = 0.1$ and $t = 0.3,$ a trade ban starting from the permits-constrained first-best allocation implies a welfare gain for state 2. From the table it appears that this gain is not due to correcting the emission spillovers, but due to savings in production costs. The second part of the table has $\gamma_1 = 0.1, \gamma_2 = 0.5$ and $t = 0.3.$ In this case state 2 would not gain from imposing a trade ban in the permits-constrained first-best allocation, the reason being here that production costs are already relatively low. This shows that the possibility for states to manipulate the electricity price is only a necessary condition for imposing a trade ban. Notice that if state 2 is allocated 'too many' permits (i.e. $x_1 = 1, x_2 = 2$) a trade ban will be advantageous again. Here the disutility of emission from state 2 is decreased, but here too the largest gain is in the savings on production costs.

Table 1: Effects of trade ban*)

	$\gamma_1 = \gamma_2 = 0.1; t = 0.3$				$\gamma_1 = 0.1; \gamma_2 = 0.5; t = 0.3$					
	First-best		Trade ban		First-best		Arbitrary		Trade ban	
State	1	2	1	2	1	2	1	2	1	2
Permits	1.00	4.00	1.00	3.95	1.67	1.33	1.00	2.00	1.00	1.95
Production	1.00	4.00	0.99	3.96	1.67	1.33	1.40	1.60	1.38	1.57
Permits price	3.00	3.00	3.05	3.05	5.00	5.00	3.27	3.27	3.48	3.48
Electricity price	4.00	4.00	4.04	4.04	6.67	6.67	6.67	6.67	6.78	6.78
Ln(z)	9.16	9.16	9.06	9.06	4.05	4.05	4.05	4.05	3.89	3.89
Production costs	0.50	8.00	0.49	7.83	1.39	4.44	0.98	6.40	0.96	6.14
Value of exports	-6.00	6.00	-5.99	5.99	1.11	-1.11	-0.67	0.67	-0.62	0.62
State tax	0.00	-3.00	-0.01	-2.97	0.00	-5.00	2.00	-4.60	1.92	-4.53
Emission disutility	0.00	-1.50	0.00	-1.48	0.00	-4.17	0.00	-2.94	0.00	-2.87
Welfare	2.66	5.66	2.60	5.72	-5.70	-5.67	1.11	-3.31	0.97	-3.16

*) Except for permits and production, have all results been multiplied by 10. The trade ban equals 0.05.

5. Conclusions

In the present paper we have investigated tradable permit systems in a federal state, where pollution is transboundary across states and individual states can conduct environmental policy by means of emissions taxation and trade bans with regard to permits. The main outcome is that in the design of the initial allocation to individual states, the central authority should take the discretionary power of the states into account. In doing so it can set the initial permits allocation such that production, consumption and overall social welfare correspond to first-best. However, if states have an incentive to manipulate the product market by withdrawing some of their allocated permits from the market, the first-best cannot be attained.

This paper was motivated by the ‘real-world’ observation that in actual permits markets with asymmetric pollution spillovers such as the SO_2 market in the US, states express a willingness to impose trade bans. As we showed, however, if the electricity market is characterized by perfect competition, and states take, therefore, the electricity price as given, trade bans will not be imposed and the federal government is able, by a proper initial allocation of the permits, to attain the first-best. Obviously, this illustrates that making the electricity market more competitive, as currently is being done by the European Commission, is crucial for the welfare maximizing characteristics of tradable emission permits markets.

It is of interest to notice that the results obtained also apply for TEP markets with uniform spillovers. As long as states have an incentive to manipulate the permits market for strategic reasons such as getting a trade advantage on the permits market, our results apply.

Some caution is appropriate as to the actual implementation of the proposed policy. The informational burden on the federal government in calculating the optimal distribution is sizeable. What is needed is insight into production costs, transportation coefficients, and local welfare weights. It would be very interesting to study mechanisms that could reveal the information the federal government needs for her allocation policy in order to approach the first-best solution to a satisfactory degree. An additional step in analyzing this issue is to introduce information asymmetries between the federal government and the states comprising the federation. Another informational burden lies with the individual states that need to know their impact on equilibrium prices on the permits market as well as on the product market. All this is subject to further research. The present paper has provided only a first basic analysis of these issues.

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