Environmental tax competition among jurisdictions

Caminada, Koen

Department of Economics, Leiden University

1992

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Koen Caminada[1]

Abstract

The use of environmental taxes for pollution problems without spillovers is studied in a multi-jurisdictional setting. The problem is studied using the standard Mintz & Tulkens (1986) model for interjurisdictional tax competition. This is a model with 2 regions, two tradeable private goods: labour and a private consumption good which can be taxed at the production level and one non tradeable local public good.
It is demonstrated that the tax competition literature results can not be translated to the environmental tax competition problem for externalities linked to production.

Leiden, december 1992

[1] Rijksuniversiteit Leiden, Afdeling Openbare Financiën. This article is an adapted version of a presentation from the author and S. Proost at the EAERE conference in Cracow, june 1992.

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1 INTRODUCTION

There is an increased interest in the use of tax instruments in environmental policy in the European Community. One of the important questions is to what extent this policy instrument can be decentralized to the level of the member countries. For a closed economy and in the absence of environmental spillovers a Pigouvian tax is efficient if all sources are equally productive in generating the pollution and if the externality itself or a strictly complementary input or output can be monitored and taxed. Each country can set the tax at the level of the marginal damages.

When environmental spillovers are introduced each country tends to neglect the damages in the other countries and a tax policy, like every decentralised environmental policy, is likely to be inefficient.

In this paper we stick to the ideal case without spillovers and examine the possibilities of decentralisation of environmental taxes in an open economy where no import taxes or export taxes can be used. This will be the case in the EC when all border controls have been removed and where only origin based taxes can be used and no longer destination taxes (FOLMER & HOWE,1991, MOHR,1990, KEEN,1991).

The dominant prescription as regards environmental taxes in a non-spillover case is to leave the use of environmental taxes to the jurisdictions (SIEBERT,1991,MOHR,1990).

The logic being that each jurisdiction can determine its own environmental quality. In the same strand OATES & SCHWAB (1988) demonstrate that jurisdictions competing for mobile capital and offering a combination of capital taxes and environmental stringency will not end up with a suboptimal environmental quality.

The opponents of this decentralisation point to the dangers of a vicious circle of downward tax competition in a federation. The fear for this type of phenomenon has recently lead the EC commission to impose minimum tax rates for certain goods.

In this paper we study the use of environmental taxes for pollution problems without spillovers in a multi-jurisdictional setting. The objective is to know the properties of this tax competition process and to appreciate the effects of federal constraints like tax harmonisation on the equilibria.

The problem is studied by extending the standard model for the study of interjurisdictional fiscal competition (MINTZ & TULKENS,1986, abbreviated as M&T) to environmental problems. The M&T model is a two region model where an origin based commodity tax is levied on some private good to finance the supply of a local public good. Consumers in each region can allocate their consumption between domestic and non-domestic supply and do this in function of the relative prices, transport costs and taxes. In the "non-cooperative fiscal equilibrium " defined by M&T, different regimes can exist. Depending on the tax rates chosen by the regions there can be autarky, tax importing and tax exporting for each region. In general the tax rates tend to be too low, giving rise to an insufficient supply of local public goods. More precisely M&T and DE CROMBRUGGHE & TULKENS (1990) demonstrate that Pareto-improving tax policies never reduce taxes in both regions and always increase taxes in the tax-importing region.

The M&T model is adapted by redefining the local public good as the level of the local environmental externality. A product (origin based) tax is the only instrument which can be used to regulate the level of the externality. The proceeds of the tax are redistributed to the consumers in a lump sum way. Two types of externalities can be considered: a production externality case where pollution is strictly proportional to the level of production in the region and a consumption externality case where the level of consumption is strictly proportional to the environmental externality in the region. There are no environmental spillovers between regions.

It is demonstrated that the tax competition literature results can not be translated to the environmental tax competition problem. In general environmental taxes tend not to be too low at equilibrium. The fiscal equilibrium is however only fully efficient if all jurisdictions have identical production costs and preferences for the local environmental quality. There are no simple restrictions or prescriptions on environmental tax policy to guarantee an efficient environmental fiscal equilibrium.

In chapter 2 we recall the main features of the M&T model and define different regimes for the interregional market economy. In chapter 3 we focus on the production externality case. A regional fiscal and environmental optimum is defined and the properties of the non-cooperative equilibrium are compared to the Pareto-optimum. These properties are illustrated using a numerical example where the sensitivity of the equilibrium to other parameters like the relative size of the two countries are examined.

2 MODEL STRUCTURE

2.1 Basic Assumptions

The M&T model is a two region, three goods model. Every region is homogeneous and has the same number of identical agents. The two regions are denoted i and j. The three goods are: a private good consumed in quantity Q^i , labour supplied X^i (measured negatively), and a local public good (here bad) R^i. The preferences of the consumer in region i are given by the continuously differentiable and quasi-concave utility function, strictly increasing in the private good and leisure but decreasing in the local public bad.

$$U^i(Q^i,X^i,R^i) \tag{1}$$

The quantity consumed of the private good can be supplied by local production Q_i^i or can be bought abroad in a quantity Q_j^i . The total transportation cost of bringing this quantity from j to i is given by the strictly increasing, convex continuously differentiable function $\tau^i_j\ (Q_j^i)$.

Labour can be supplied at home X_i^i or can be supplied in the other region in a quantity X_j^i without transport costs. This supply of labour is the counterpart of the import of the private consumption good.

For each region we have by definition:

$$Q^i \leq Q_i^i + Q_j^i \tag{2}$$

$$X^i \leq X_i^i + X_j^i \tag{3}$$

Perfect competition and constant marginal costs generate fixed producer prices. Labour can be taken as the untaxed good and can be used as numeraire. This results in identical labour prices in both regions but production prices for the consumption good will in general differ because of absolute productivity differentials. Using a tax t^i per unit of the private consumption good produced in region i and returning this tax to the inhabitant in a lumpsum way T^i we have the following two trade or production constraints:

$$p^i Q_i^i + X_i^i = 0 \tag{4}$$

$$(p^j + t^j) Q_j^i + \tau_j^i (Q_j^i) + X_j^i = 0 \tag{5}$$

Which after summation and inclusion of the local tax variables yield the following budget equation (and implicit production possibility frontier) for i :

$$(p^i + t^i) Q_i^i + (p^j + t^j) Q_j^i + \tau_j^i (Q_j^i) + X^i - T^i \leq 0 \tag{6}$$

2.2 Differences with the Mintz & Tulkens model

Our model diverges drastically from M&T in two respects. Firstly we have no local public good which needs resources to be produced, instead we have a negative externality directly linked to the production or consumption activities.

There is a second more subtle difference on the tax instruments side. In M&T lumpsum taxes are absent so that the supply of the local public good always requires distortionary taxation on the consumption good. This is a rigid link in both directions: all tax revenue has to be spend on the local public good. We found this an unrealistic assumption, certainly in our context where the environmental tax revenue is a by-product. Therefore we introduced the possibility of lump-sum taxes or head taxes for all inhabitants of a region. The primary function of this head tax is to rechannel the revenue from environmental taxes to the inhabitants. Once we have this head tax at our disposal we could have included as well traditional local public goods in our model. Contrary to the M&T setting this would make no real contribution to our model because the local public good is financed by inhabitants and in a non-distortionnary way.

We will discuss two different types of externalities: production and consumption externalities. Both will be highly stylized and extreme cases without spillovers between regions.

In the case of production externalities, the level of the externality will be strictly proportional to the total production of the consumption good in the region:

$$R^i = Q_i^i + Q_i^j \tag{7}$$

In the case of consumption externalities, the total level of the externality will be equal to the total consumption of the good in the region:

$$R^i = Q^i = Q_i^i + Q_j^i \tag{8}$$

Examples of production externalities are local air and water pollution, noise etc.. Examples of consumption externalities are congestion or air pollution by gasoline driven cars (both the gasoline and the cars can be bought abroad). It is important not to confuse consumption externality and consumption taxes: in this model all taxes are production taxes by assumption.

We will not distinguish between consumption and production externalities in this prepatory section but will discuss them separately.

2.3 Regional market equilibria

Following M&T we define regional market equilibria (RME) as the allocation chosen by consumers and producers for given levels of taxes and a given level of the local externality which they consider as independent of their consumption decisions.

This assumption can only be justified by considering that there is a large number of consumers in each region.

The optimal choice of the fiscal parameters and the externality will only be discussed in the next chapter, here we concentrate on the behaviour of the representative consumer for given decisions of both local governments.

A RME relative to a given set of fiscal and public good parameters (t^i ,t^j, R^i) is given by the solution of:

$$\max_{\{Q^i,Q_i^i,Q_j^i,X^i\}} \quad U^i(Q^i,X^i,R^i) \tag{9}$$

under constraints (2),(3) and (6)

Depending on the relative production costs, transport costs and taxes, region i can be in an autarkic equilibrium without any trade (I), in a mixed equilibrium (II) where it imports part of its consumption and in a no-

production equilibrium where it imports all of its consumption.
Such a regional market equilibrium is unique [1]and can be characterised by the following two properties:

$$\frac{\partial U^i}{\partial Q^i} - \frac{\partial U^i}{\partial X^i}[\min (p^i + t^i ; p^j + t^j + \tau_j^{i'}(Q_j^i))] = 0 \tag{10}$$

and for the type of equilibrium I (II and III respectively) we have the following relation between the prices of the consumption good:

$$p^i + t^i \leq (= \geq \textit{respectively})\, p^j + t^j + \tau_j^{i'}(Q_j^i) \tag{11}$$

Problem (9) is a traditional consumption problem which yields for each of the three types of equilibria demand functions for X^i , Q^i_i (equilibrium types I and II), Q^i_j (equilibrium types II and III), as well as for the total consumption Q^i. We will focus on the properties of the demand functions for the consumption good, the demand for labour is then determined completely via the budget constraint (6). The demand for Q is a function of the tax rates in both regions, of the lump-sum tax and of the environmental quality in one own's region.
If we assume that the consumption good is not an inferior good we can determine the sign of the partial derivatives of these demand functions for the three different types of market equilibria we distinguished before (all other derivatives are zero):
For autarky (I)

$$\frac{\partial Q^i}{\partial t^i} = \frac{\partial Q_i^i}{\partial t^i} < 0 \tag{12}$$

$$\frac{\partial Q^i}{\partial R^i} = \frac{\partial Q_i^i}{\partial R^i} \leq \geq 0 \tag{13}$$

$$\frac{\partial Q^i}{\partial T^i} = \frac{\partial Q_i^i}{\partial T^i} \geq 0 \tag{14}$$

[1] See M&T prop 1 which applies here.

For a mixed equilibrium (II)

$$\frac{\partial Q^i}{\partial t^i}<0;\frac{\partial Q_i^i}{\partial t^i}<0;\frac{\partial Q_j^i}{\partial t^i}>0 \tag{15}$$

$$\frac{\partial Q^i}{\partial t^j}\leq 0;\frac{\partial Q_i^i}{\partial t^j}\leq\geq 0;\frac{\partial Q_j^i}{\partial t^j}<0 \tag{16}$$

$$\frac{\partial Q^i}{\partial R^i}=\frac{\partial Q_i^i}{\partial R^i}\leq\geq 0 \tag{17}$$

$$\frac{\partial Q_j^i}{\partial R^i}=0 \tag{18}$$

$$\frac{\partial Q^i}{\partial T^i}=\frac{\partial Q_i^i}{\partial T^i}\geq 0 \tag{19}$$

$$\frac{\partial Q^i}{\partial T^i}=\frac{\partial Q_i^i}{\partial T^i}\geq 0 \tag{20}$$

For a no-production equilibrium (III)

$$\frac{\partial Q^i}{\partial t^j}=\frac{\partial Q_j^i}{\partial t^j}<0 \tag{21}$$

$$\frac{\partial Q^i}{\partial R^i}=\frac{\partial Q_j^i}{\partial R^i}\leq\geq 0 \tag{22}$$

$$\frac{\partial Q^i}{\partial T^i}=\frac{\partial Q_j^i}{\partial T^i}\geq 0 \tag{23}$$

These properties (except for the lumpsum tax effect) correspond with those in the M&T model.

Property (18) is somewhat unexpected: the import of the consumption good does not vary with the level of the local environmental quality because the import can be considered as an intermediate good in the supply of the total quantity of the consumption good Q^i. It is the local production which will adjust in quantity because at the equilibrium import level the total marginal import cost (including the non-linear transport cost) equals the local price.

2.4 Regimes of the interregional economy

Combining the type of equilibria in both regions generates a regime of the interregional economy. Any pair of indirect taxes generates a unique regional market equilibrium in both regions and the combination of regional equilibrium types is called a regime of the interregional economy. This notion of regime introduced by M&T is very important because the switching of regimes is important in analyzing tax competition.
Combining the three types of regional market equilibria for two regions gives the following 5 regimes:

TABLE 1.

Regime index (from i's viewpoint)	**Type of equilibrium in Region 1**	**Type of equilibrium in Region 2**
1	I	I
2	I	II
3	II	I
4	I	III
5	III	I

While every taxpair determines a single regime, a given regime may be induced by many different taxpairs. The combinations of indirect tax rates generating these regimes are:

$$r_1 = \{(t^i,t^j) \in r \mid p^i+t^i \leq p^j+t^j+\tau^i_j(0) \; ; \; p^j+t^j \leq p^i+t^i+\tau^j_i(0)\} \tag{24}$$

$$r_2 = \{(t^i,t^j) \in r \mid p^j+t^j = p^i+t^i+\tau^j_i(Q^{j*}_i) \text{ with } Q^{j*}_i \geq 0 \, , \, Q^{j*}_j > 0 \; ; \tag{25}$$

$$p^j+t^j \leq p^i+t^i+\tau^j_i(Q^{j*}_i) \text{ with } Q^{j*}_i > 0 \, , \, Q^{j*}_j = 0 \}$$

$$r_3 = \{(t^i,t^j) \in r \mid p^i+t^i = p^j+t^j+\tau^i_j(Q^{i*}_j) \text{ with } Q^{i*}_j \geq 0 \, , \, Q^{i*}_i > 0 \; ; \tag{27}$$

$$p^i + t^i \leq p^j + t^j + \tau_j^i(Q_j^{i*}) \text{ with } Q_j^{i*} > 0 \text{ , } Q_i^{i*} = 0 \}$$

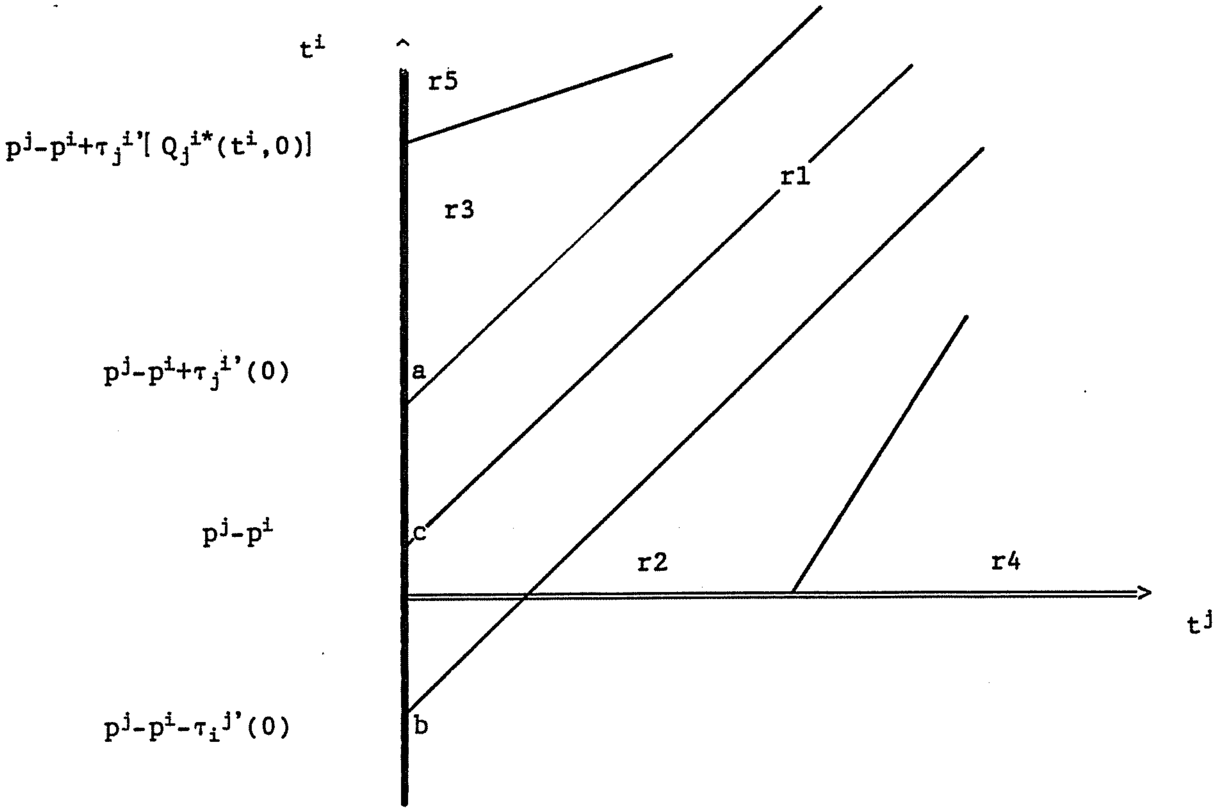
$$r_4 = \{(t^i, t^j) \in r \mid p^j + t^j \geq p^i + t^i + \tau_i^j(Q_i^{j*}) \text{ with } Q_i^{j*} > 0 \text{ , } Q_j^{j*} = 0 \} \tag{29}$$

$$r_5 = \{(t^i, t^j) \in r \mid p^i + t^i \geq p^j + t^j + \tau_j^i(Q_j^{i*}) \text{ with } Q_j^{i*} > 0 \text{ , } Q_i^{i*} = 0 \} \tag{30}$$

It is very convenient to use a graphically representation of these sets (FIGURE I). The slopes of the dividing lines between regimes 3, 1 and 2 equal 1 by definition of regimes 2 and 3. The slope at the border of regimes 3 and 5 is defined by:

$$\frac{\partial Q_i^i}{\partial t^i} dt^i + \frac{\partial Q_i^i}{\partial t^j} dt^j = 0 \tag{31}$$

FIGURE 1. Set of indirect taxes generating the different regimes



3 EXTERNALITIES IN PRODUCTION

3.1 Regional fiscal optimum

A Regional Fiscal Optimum (RFO) is an optimal fiscal choice (and level of the externality) which is embedded in a regional market equilibrium and which takes the fiscal choice of the other region as given.

The local government can choose levels of t^i and T^i which satisfy her budget constraint:

$$T^i \leq t^i[Q_i^i(t^i,t^j,R^i,T^i) + Q_i^j(t^i,t^j,R^i,T^i)] \tag{32}$$

Using the indirect utility function

$$V^i(t^i,t^j,R^i,T^i) \equiv U^i[Q^i(t^i,t^j,R^i,T^i), X^i(t^i,t^j,R^i,T^i), R^i] \tag{33}$$

where

$$Q^i(.) = Q_i^i(t^i,t^j,R^i,T^i) + Q_j^i(t^i,t^j), \tag{34}$$

$$X^i(.) = -[(p^i+t^i)Q_i^i(t^i,t^j,R^i,T^i) + (p^j+t^j)Q_j^i(t^i,t^j) + \tau_j^i(Q_j^i)(t^i,t^j)) + Ti] \tag{35}$$

A Regional Fiscal Optimum is then the maximum with respect to t^i, T^i, R^i of the following Lagrangian problem:

$$\mathcal{L}_r^i(t^i,t^j,R^i,T^i,\psi_r^i,\phi_r^i) = V_r^i() + \psi_r^i(Q_i^i + Q_i^j - R^i) + \phi_r^i[t^i(Q_i^i + Q_i^j) - T^i] \tag{36}$$

in which the constraints are the definition of the local production externality and the local public budget. In this maximisation problem the local government takes the tax rate in the other region as given.
The problem structure is different for regimes 1 and 3 where the region i does not export and for regimes 2 and 4 where region i exports.

For regimes 1 and 3 the following first order conditions hold:

$$\frac{\partial \mathcal{L}^i}{\partial t^i} = -\frac{\partial U^i}{\partial X^i}Q_i^i + \psi_{1,3}^i\frac{\partial Q_i^i}{\partial t^i} + \phi_{1,3}^i(t^i\frac{\partial Q_i^i}{\partial t^i} + Q_i^i) = 0 \tag{37}$$

$$\frac{\partial \mathcal{L}^i}{\partial R^i} = \frac{\partial U^i}{\partial R^i} + \psi^i_{1,3}(\frac{\partial Q^i_i}{\partial R^i} - 1) + \phi^i_{1,3} t^i \frac{\partial Q^i_i}{\partial R^i} = 0 \tag{38}$$

$$\frac{\partial \mathcal{L}^i}{\partial T^i} = \frac{\partial U^i}{\partial X^i} + \psi^i_{1,3}\frac{\partial Q^i_i}{\partial T^i} + \phi^i_{1,3} t^i (\frac{\partial Q^i_i}{\partial T^i} - 1) = 0 \tag{39}$$

summing (37) and (39), premultiplied by Q_i^i ,yields an expression for t^i in regimes 1 and 3:

$$t^{i*}_{1,3} = -\frac{\psi^i_{1,3}}{\phi^i_{1,3}} \tag{40}$$

The numerator represents the marginal welfare cost of a unit of the local externality. Using (40) and (38) we see that the total marginal welfare cost of the local externality equals the partial direct effect on utility. The denominator represents the welfare value of one unit of local tax income, which in our model with lumpsum taxes equals the marginal utility of income of the local residents. This follows from solving (37) for ϕ.

$$\psi_{1,3} = \frac{\partial U^i}{\partial R^i} \quad \phi_{1,3} = -\frac{\partial U^i}{\delta X_i} \tag{41}$$

In this case the indirect tax t^i corresponds to a pure Pigouvian tax. This was expected: in regimes 1 and 3 there are no exports and the only function of the tax is to add to the local production cost, the marginal cost of the externality.

For regimes 2 and 4, the first order condition for the optimal choice of t^i is different:

$$\frac{\partial \mathcal{L}^i}{\partial t^i} = -\frac{\partial U^i}{\partial X^i} Q^i_i + \psi^i_{2,4}(\frac{\partial Q^i_i}{\partial t^i} + \frac{\partial Q^j_i}{\partial t^i}) + \phi^i_{2,4}[t^i(\frac{\partial Q^i_i}{\partial t^i} + \frac{\partial Q^j_i}{\partial t^i}) + Q^i_i + Q^j_i] = 0 \tag{42}$$

Combining this expression with (38) and (39) and using the Slutsky compensated price effects, one can derive the following expression for the optimal tax rate in regimes 2 and 4:

$$t_{2,4}^{i*} = -\frac{\psi_{2,4}^{i}}{\phi_{2,4}^{i}} - \left(\frac{Q_i^j}{\frac{\partial Q_i^i}{\partial t^i} \mid comp + \frac{\partial Q_i^j}{\partial t^i}} \right) \tag{43}$$

In regimes 2 and 4 region i exports to the other region. This explains the extra term in the optimal tax expression. The tax now equals a Pigouvian term to which a kind of disguised export tax is added. Raising the production tax above the marginal damage (the Pigouvian tax level) has two effects: a negative allocative effect and a positive revenue generating effect. The negative allocative effect is given by the compensated price effect in the denominator and represents the allocative distortions linked to overpricing the local consumption good.

The positive effect is the extra revenue which can be raised on exports by raising the price above the social cost. If the allocative effect and the externality damage terms in the first term were absent, the second term would equal the expected inverse price elasticity term multiplied by the production price. This disguised role of Pigouvian taxes as export taxes is discussed in a partial equilibrium framework by KRUTILLA (1991). We use a general equilibrium approach and this explains the presence of a compensated home price elasticity in (43). Another difference with KRUTILLA is that he excludes endogenous reactions of the other countries or jurisdictions. In the next paragraphs we will explicitly consider the behaviour of the trade partner.

3.2 Interregional fiscal externalities

Some jurisdictions may wish to take advantage of the possibility of exporting taxes. The fact that an increase in *j*'s environmental tax rate raises *i*'s tax base can be interpreted as a fiscal externality. The magnitude of these interregional externalities depends on the regime and can be derived by differentiating (36) for the different regimes.

r1

$$\frac{\partial \mathcal{L}^i}{\partial t^j} = 0 \tag{44}$$

r2

$$\frac{\partial \mathcal{L}^i}{\partial t^j} = \psi_2^i \frac{\partial Q_i^j}{\partial t^j} + \phi_2^i t^i \frac{\partial Q_i^j}{\partial t^j} > 0 \tag{45}$$

r3

$$\frac{\partial \mathcal{L}^i}{\partial t^j} = -\frac{\partial U^i}{\partial X^i} Q_j^i + \psi_3^i \frac{\partial Q_i^j}{\partial t^j} + \phi_3^i t^i \frac{\partial Q_i^j}{\partial t^j} < 0 \tag{46}$$

r4

$$\frac{\partial \mathcal{L}^i}{\partial t^j} = \psi_4^i \frac{\partial Q_i^j}{\partial t^j} + \phi_4^i t^i \frac{\partial Q_i^j}{\partial t^j} = 0 \tag{47}$$

r5

$$\frac{\delta \mathcal{L}^i}{\delta t^j} = -\frac{\delta U^i}{\delta X^i} Q_j^i$$

Raising the environmental tax t^j in region j can, depending on the regime have three types of effects on the welfare of region i:

TABLE 2.

Regime index (from i's viewpoint	Pollution	Public Revenue	Private Consumption	Total effect
1 (autarky)	0	0	0	0
2 (i is tax exporter)	-	+	0	+
3 (i imports partly)	-	+	-	-
4 (j imports all)	0	0	0	0
5 (i imports all)	0	0	-	-

Of course in autarky (r=1) there is no effect. When region i exports (r=2,4) there is a negatively valued pollution effect because of the increased exports. In these cases there will also be a positive public revenue effect via the increased exports. When region i imports (r=3,5), raising the environmental tax in j has a negative impact on the consumption possibilities.

For regimes 2 and 3 the signs of the fiscal externality effect can only be determined along the optimal reaction curve of region i, this means by using (40) and (42).

If the effects of the fiscal externality in regimes 2 and 3 would have been positive we would return to the traditional fiscal competition outcome: both regions fighting for the tax base and arriving in an equilibrium which is not public good. As demonstrated by DE CROMBRUGGHE & TULKENS (1990), a simultaneous rise in the tax rate is Pareto-improving because if one of the regions is in regime 2 the other will be in regime 3 and both effects are positive.

This conjecture does not carry over to the case of Pigouvian taxes. One does not have to fear a situation where the competition for the tax base drives all regions to too low tax rates and suboptimal environmental qualities. The exporting tax region (r=2) will always set her tax rate above the marginal externality cost, consequently an increase in the tax rate of the importing region will increase the possibilities for tax exporting which is beneficial for region i, this result parallels M&T. The difference lies in the situation of the importing region (r=3). This region uses the tax for only one purpose: to correct for the externality cost of its own production. A raising tax in j will increase production in region i but this is a reaction trying to limit the negative consumption effect. The two other effects (negative pollution effect and positive revenue effect) always compensate each other when the tax rate is chosen optimally.

In DE CROMBRUGGE & TULKENS (1990), on the contrary, the reason the tax exists is to supply a quantity of the local public good, this supply is too small as well as the local tax because each increase in the local tax forces consumers to import at higher cost abroad (rising marginal transport cost). An increase in the tax rate of the tax exporter relaxes this constraint and this is the reason why the public revenue effect dominates the private consumption effect.

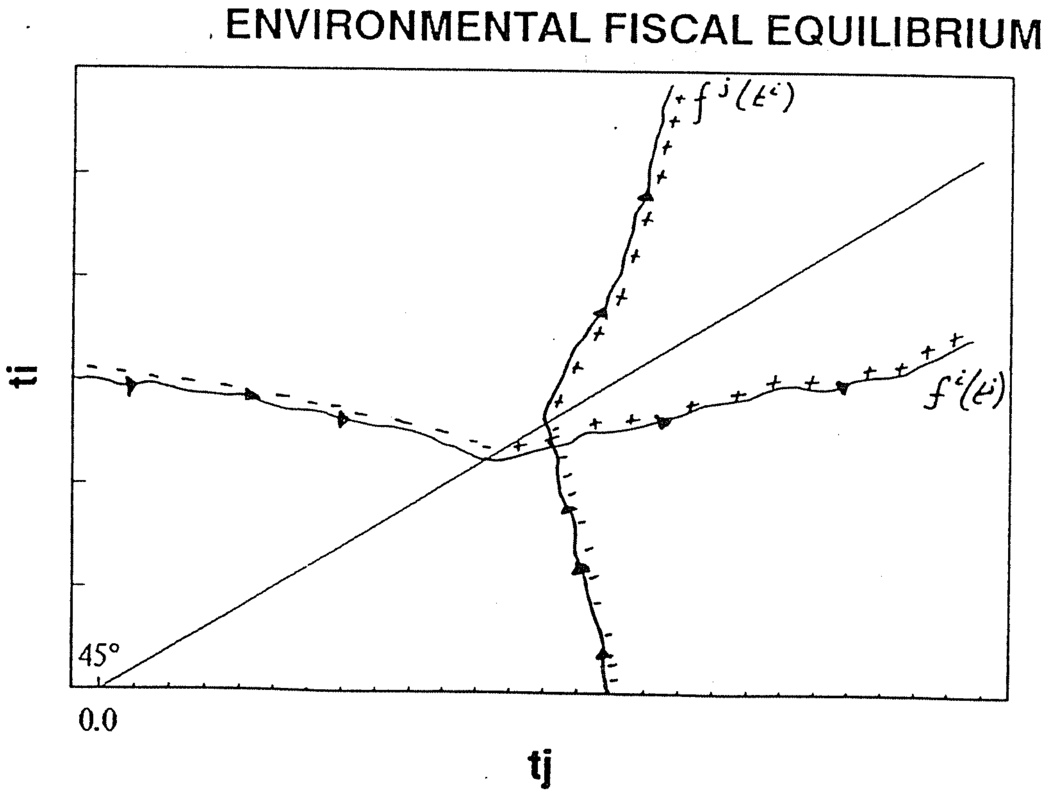
3.3 Fiscal competition

We now can start to analyze the simultaneous tax decisions of both regions. This is done by defining a static non-cooperative game: each region sets the tax rate that optimizes its welfare, taking the tax rate of the other region as given. We have an equilibrium when both tax rates are a best reply.

We can define reaction functions for both regions in the t,t space and look for intersections of both curves.

One of the main results in the tax competition literature is the multi-valuedness of the reaction functions (see e.g.M&T). This multi-valuedness creates problems for the existence of an equilibrium but it is also at the origin of the proposition that there are Pareto-improving tax increases.

FIGURE 2.



We are able to show that the same multi-valuedness does not appear in our modelsetting. A typical reaction function is shown in FIGURE 2. On the reaction functions $f^i(t^j)$ and $f^j(t^i)$ shown the arrows are used to indicate the direction in which the changes in utility are shown. A + (-) sign above a reaction curve means that Utility increases when one moves into the direction of the arrows. For region i, the figure shows that for low tax rates in the other region, region i prefers to import and sets its tax rate equal to the marginal externality cost of production at home. As the tax rate in the other region increases, this reduces the welfare of region i because of the private consumption effect. For increasing tax rates in j , the import of region i decreases to arrive in an autarky equilibrium. For still higher tax rates in j , region i becomes the exporter and adds to the marginal cost of the externality a disguised export term. Now the welfare of region i increases for increasing taxes in j. In this figure one would have a non-cooperative equilibrium in point E. without more specification it is difficult to study the properties of the non-cooperative equilibria. We will therefore explore the properties of this non-cooperative equilibrium with the help of an example in the next paragraph.

Before entering the example it is useful to point out the Pareto-optimal solutions for this taxation problem.
This can be found by maximising the following problem (for regime 2) with respect to the tax rates in both regions:

$$\mathcal{L}_2(t^i,t^j,R^i,T^i,R^j,T^j,\psi^i,\phi^i,\psi^j,\phi^j,\mu) = V_2^i(.) + \psi^i(Q_i^i + Q_i^j - R^i) + \phi^i[t^i(Q_i^i + Q_i^j) - T^i] +$$

$$+ \psi^j(Q_j^j - R^i) + \phi^j(t^j Q_j^j - T^j) + \mu(\overline{V_2^j} - V^j)$$

This generates tax rates, which in the case where i is exporting and j importing (regime 2) equal:

$$t_2^{iP} = -\frac{\psi_2^i}{\phi_2^i} - \left(\frac{Q_i^j + (\varphi_2^j + \phi_2^j t^{jP})\frac{\delta Q_j^j}{\delta t^i} + \mu\left(-\frac{\delta U_j}{\delta X_j}\right)Q_i^j}{\frac{\partial Q_i^i}{\partial t^i}\,|\,comp + \frac{\partial Q_i^j}{\partial t^i}}\right) \tag{51}$$

$$t_2^{jP} = -\frac{\psi_2^j}{\phi_2^j} - \left(\frac{(\varphi_2^i + \phi_2^i t^{iP})\frac{\delta Q_i^j}{\delta t^j}}{\frac{\partial Q_i^i}{\partial t^i}\,|\,comp + \frac{\partial Q_i^j}{\partial t^i}}\right) \tag{52}$$

The structure of these expressions can be compared with expression (43) for the exporting region i and with expression (40) for the importing region j. The differences can best be understood as a typical second best result. The importing region is now required to add a correction term to her Pigouvian tax which will be a function of the deviation from Pigouvian tax setting in region i. The same holds for region i: the tax export term is now corrected for the negative private consumption effect in the importing region and for deviations from Pigouvian tax setting in the importing region. These solutions are clearly different from the non-cooperative case but we will have to wait for a better specified example in order to state whether the taxes are higher or lower. It is also important to see that it is only when lump-sum transfers between regions are allowed that we return to a first best world with pure Pigouvian taxes in both regions for all regimes.

The next step is to compare the non-cooperative tax equilibrium with the

Pareto-optimum solutions. This comparison can generate ideas to discover Pareto-improving tax combinations which might be the object of cooperative behaviour. In a richer institutional context we can consider central government constraints on the tax behaviour and test the performance of tax harmonization rules, closed border solutions etc..

Up to now clearcut results could only be obtained for a more restricted case.

3.4 Fiscal competition illustrated

3.4.1 The simplifications used

It is only when the utility functions are specified that more detailed comparisons can be made of the different tax solutions. We used an additive utility function, quadratic in Q^i and linear in X and R combined with a quadratic transport cost function. This form guarantees the uniqueness of the optimal tax solution in each regime for a given tax rate in the other region (M&T,1986). An additive utility function contains the important simplification that the demand for the local environmental quality is independent of the quantity of private goods. The linearity of the utility function in X makes it an easy numeraire and combined with the linearity of the utility function in R, we have a marginal willingness to pay for the environment which is constant. This latter property will generate simple reaction curves.

The specification used is:

$$\begin{gathered} U^i = a(Q_i^i + Q_j^i) - d(Q_i^i + Q_j^i)^2 + bX^i + cR^i \\ \textit{budget constraint} \quad (p^i + t^i)\, Q_i^i + (p^j + t^j)\, Q_j^i + e(\, Q_j^i)^2 + X^i - T^i = 0 \\ \textit{with} \quad b,d,e > 0 \quad \textit{as well as} \quad p^i + t^i < \frac{a}{b} \end{gathered} \tag{53}$$

In order to structure the discussion we start with regions of the same size and introduce then systematic differences in the production cost and in the preferences for the environmental quality. Next we relax the assumption of identical sizes for the regions.

For each case we discuss five different types of tax equilibria: the Nash non-cooperative equilibrium as the starting point, the Pareto-optimal equilibria and the set of Pareto-improving tax equilibria as cooperative solutions and finally the tax harmonisation and closed border solutions which can be considered as focal points in the negotiation or as institutionally generated cooperative solutions.

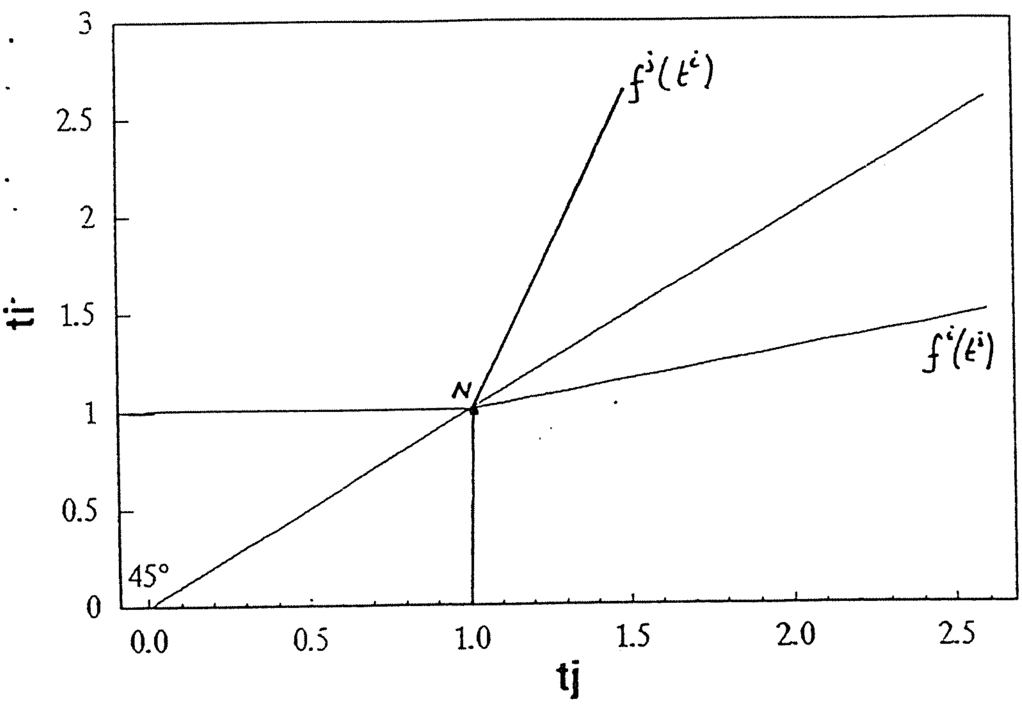
3.4.2 The case of identical regions

This case is graphically illustrated in FIGURE 3. In order to simplify the interpretation, the marginal willingness to pay for the environment and the production cost per unit were calibrated so as to equal 1. The reaction curves (denoted $f^i(t^j)$ and $f^j(t^i)$) are continuous. They are constant when the region imports (equal to the marginal damage of the externality -c/b) and starts to rise from the autarky point onwards. The rate of increase in this zone depends on the parameter choice. This type of shape guarantees a unique equilibrium which in this case equals the Pigouvian tax solution. The non-cooperative solution is here Pareto-optimal.

This contrasts with the tax competition literature (M&T) where, due to the discontinuity in the reaction curves one region either exports or imports but remains never in autarky. The reason is that positive tax rates are needed to finance the supply of the local public good, so each region whenever it is importing but almost in autarky is interested in lowering its tax and to become an exporter and compensate the lower tax rate by an increase in volume.

FIGURE 3.

OPTIMAL ENVIRONMENTAL FISCAL EQUILIBRIUM
Nash equilibrium

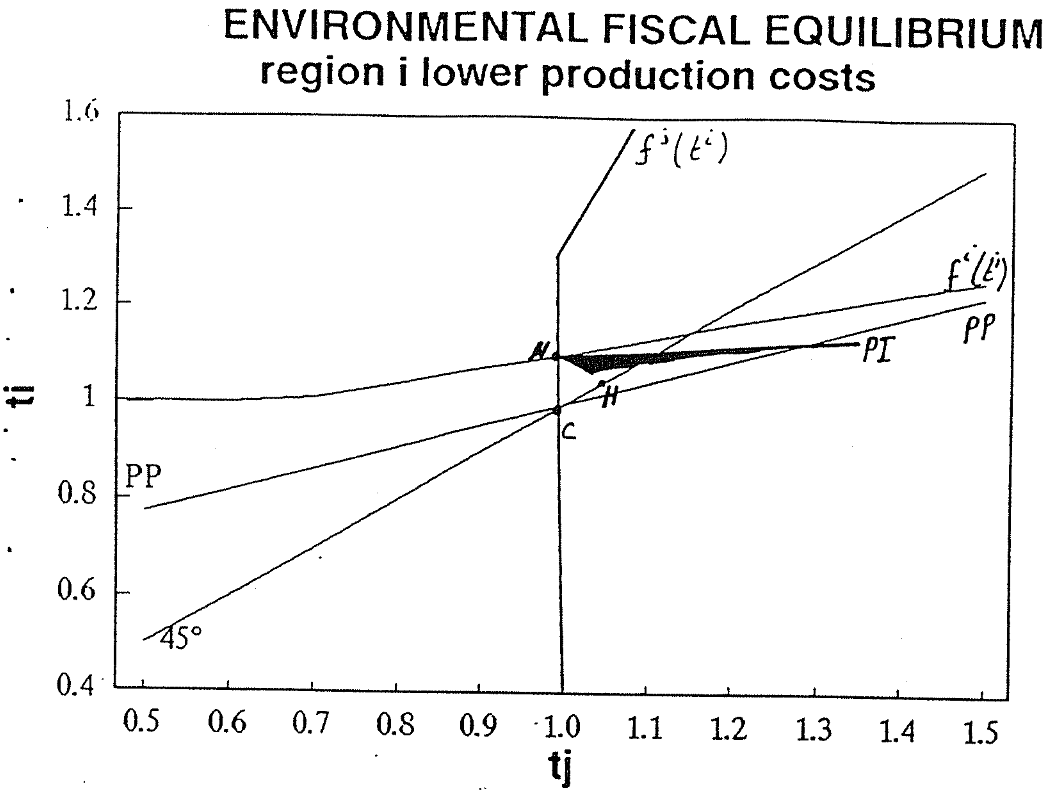


In our case, when both regions use Pigouvian taxes, none of the regions has an interest in deviating from this equilibrium. Starting from the equilibrium, suppose region i lowered its tax, it could export to region j but this would generate negative externalities which are larger than the marginal tax revenue. Suppose now that region i increased its tax above the Pigouvian level, it would start to import from j and would lower welfare because with these imports are associated extra transport costs.

3.4.3 Differences in production costs

The following figure illustrates the case where the production cost in region is 2/3 of the production cost in region j. This generates a Nash equilibrium where the region with the lowest production costs exports and adds an export tax to its Pigouvian tax. The importing region continues to use a Pigouvian tax. This equilibrium is illustrated in FIGURE 4 (the tax rates and utility levels for the different equilibria can be found in the table in appendix).
The Nash equilibrium (point N) can be compared with the set of Pareto equilibria indicated by the line PP. The different allocations on this line differ by the distribution of utility between the two regions. Pareto improving tax combinations can be found in the direction N to PI. This direction implies keeping ti constant or slightly decreased but to increase the tax in the importing region j. This is beneficial for both regions: the export from i to j increases, this means higher fiscal revenues for region i. For region j the higher imports imply higher marginal transport costs but this is compensated by the lower level of the negative externality.

FIGURE 4.



Tax reforms are very often of a non-marginal type. One of the focal points is the harmonization at the average of non-cooperative tax rates. This type of averaging can be Pareto-improving in tax competition situations, this has been shown by (KEEN,1987) for taxes of the destination type. Harmonization has also been the major principle in the latest proposals of the EC.

The average of non-cooperative taxes is represented by point H on the Figure. This implies a welfare gain for region j which has lower import costs but a welfare loss for region i which looses tax export revenue. So harmonization is not necessarily Pareto-improving.

A last type of equilibrium which can be considered is the closed border situation. One could imagine that when one region is really worse off in an open border situation, that this region can threaten to use obstacles to trade. The closed border equilibrium is shown as point C. In autarky every region uses simple Pigouvian taxes.

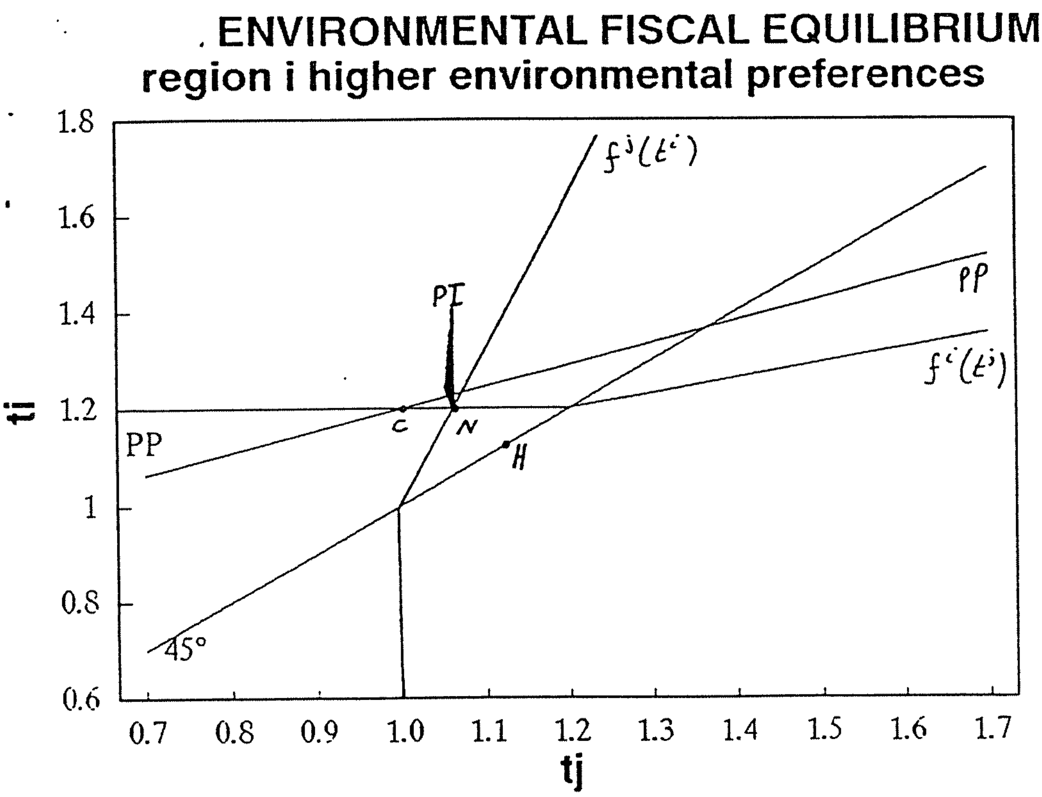
3.4.4 Differences in environmental preferences

Starting with identical regions it is difficult to assume that all regions have the same preferences for environmental quality. The differences in

preferences for local public goods without spillovers are one of the basic motivations for fiscal federalism (OATES, 1972).
In our example it was assumed that in region i the marginal willingness to pay for the environmental quality was increased by 20 %.
The resulting Nash equilibrium (N in FIGURE 5) contains imports by region i. Region j uses the higher Pigouvian tax in region i to set an export tax and to increase its tax revenue.
It would be Pareto-optimal to use Pigouvian taxes or taxes which are higher or lower but where the tax remains relatively higher in region i than in j (line PP). The Pareto-improving direction PI can be explained by the tendency to reflect the real difference in environmental preferences into the tax differences. This implies higher imports for region i, the higher cost of these is compensated by the gain in environmental quality. for region j the higher exports increase its tax revenue.

The harmonization of taxes is here a very bad solution: the differences in valuation of the environment disappear and we end up in an autarky situation (point H) where the beneficial transfer of production from i to j is excluded. The closed border solution (C) is also an autarky situation but is better tan harmonization in the sense that the production level in each region can be adapted to the local preferences. Compared to the non-cooperative open border solution, region i can improve its position by closing its border.

FIGURE 5.



3.4.5 Regions of different size

The relative size of regions seems to play an important role in tax competition. KANBUR & KEEN (1991) show that there is a tendency for the small to exploit the large. This seems to be confirmed by the present tax heavens in Europe.

We introduce the differences in relative size of the two jurisdictions into the model by the parameter N which will take values 1 (regions of identical size), 2/3 which means that region i is 33 % smaller than region j and finally 1.50 which means that region i is larger than region j.

In FIGURE 6 the fiscal reaction curves are shown for different relative sizes. As long as the regions are of same type there will be no trade and we will have no tax competition whatever the relative size of the two regions involved. Whenever there is a production cost difference or a difference in environmental preferences, the relative size will start to matter. At this moment the slopes of the reaction curves come in to play.

We could generate cases where tax competition appears by reintroducing differences in production cost and in environmental preferences. We prefer to illustrate the role of size by showing the dependence of the per capita utility levels of region i associated to varying tax levels in region j. This is shown in FIGURE 7 . As long as the region is importing, its size does not matter for given t^j. When the region is exporting however its relative size becomes important: the lower its size the higher the export tax it can use and the higher the maximum utility level it can attain for given t^j.

FIGURE 6.

ENVIRONMENTAL FISCAL EQUILIBRIA
region i small, equal or larger region

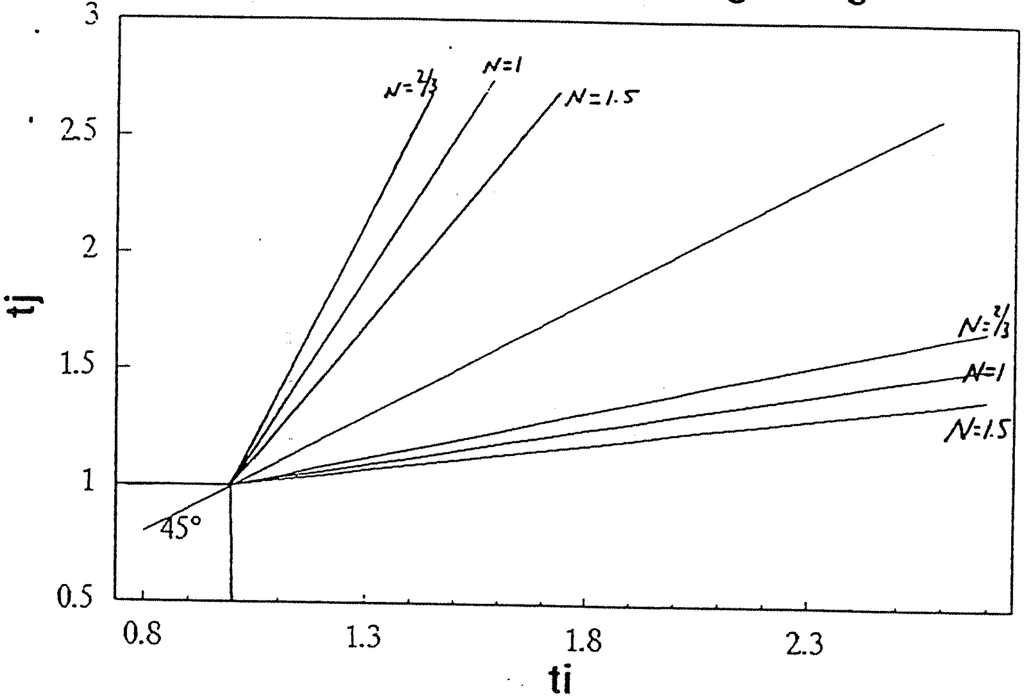
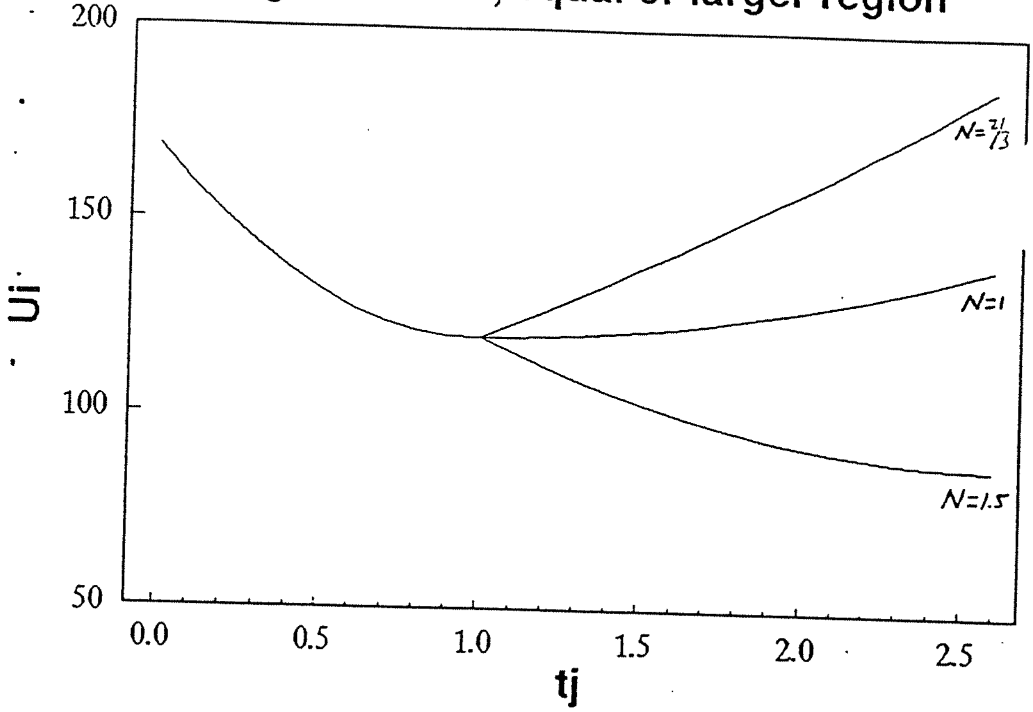


FIGURE 7.

Utility
region i small, equal or larger region



4 CONCLUDING REMARKS

It is demonstrated in a standard model for interjurisdictional tax competition, that the tax competition literature results can not be translated to the environmental tax competition problem for externalities linked to the production. A model is used with 2 regions, two tradeable private goods (labour and a private consumption good) which can be taxed at the production level and one non tradeable local public good. In general environmental taxes tend not to be too low at equilibrium. The fiscal equilibrium is however only fully efficient if all jurisdictions have identical production costs and preferences for the local environmental quality. In this case decentralisation of environmental policy is not very interesting. In the other cases there are no simple restrictions or prescriptions on environmental tax policy like e.g. tax harmonisation to guarantee an efficient decentralised environmental fiscal equilibrium.

APPENDIX

Reference case

Region	NASH equilibrium	Tax harmonization	Closed border solution
i	$t^i = 1$ $U^i = 120$		
j	$t^j = 1$ $U^j = 120$		

REGION i lower production costs

Region	NASH equilibrium	Tax harmonization	Closed border solution
i	$t^i = 1.1$ $U^i = 164.20$	$t^i = 1.05$ $U^i = 164.09$	$t^i = 1$ $U^i = 163.33$
j	$t^j = 1$ $U^j = 122.49$	$t^j = 1.05$ $U^j = 124.31$	$t^j = 1$ $U^j = 120.00$

REGION i higher environmental preferences

Region	NASH equilibrium	Tax harmonization	Closed border solution
i	$t^i = 1.20$ $U^i = 98.04$	$t^i = 1.13$ $U^i = 97.05$	$t^i = 1.20$ $U^i = 99.00$
j	$t^j = 1$ .06 $U^j = 120.31$	$t^j = 1.13$ $U^j = 119.49$	$t^j = 1$ $U^j = 120.00$

Differences of the sizes of the regions involved N=1, N=2/3 or N=1.5

Region	NASH equilibrium	Tax harmonization	Closed border solution
i	$t^i = 1$ $U^i = 120$		
j	$t^j = 1$ $U^j = 120$		

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