The role of international public goods in tax cooperation

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by

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Abstract: We provide a quantitative assessment of the welfare cost of tax competition or, equivalently, the welfare benefit of international tax policy cooperation. We use a simple multi-country general equilibrium model of a world economy, in which there are two types of cross-country spillovers: the first one is generated by international capital mobility and the second by the presence of an international public good. In the absence of international public goods, although welfare in the non-cooperative case is typically lower than in the cooperative case, the welfare difference is negligible quantitatively. Things change drastically, both quantitatively and qualitatively, once we introduce international public goods. Now, there can be big benefits from cooperation and welfare effects cease to be monotonic.

Keywords: Capital mobility; Tax competition; Public goods; Welfare.
JEL Classification: F02, H2, H4.

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I. Introduction

One of the main results in international economics is that non-cooperative (Nash) national tax policies lead to a race-to-the-bottom and suboptimal outcomes. Hence there is need for international cooperation. Such arguments become stronger as the degree of economic integration increases and tax competition becomes fiercer.[1]

But recent quantitative studies using general equilibrium models with Ramsey-type policymakers indicate that the welfare gains from coordinated tax policies are not significant quantitatively (see e.g. Mendoza and Tezar, 2005, and Sørensen, 2004). In most of these studies, the welfare gains from coordination are around one percent of GDP and remain robustly "small" across different model specifications and policy scenarios.[2]

In this paper, we reexamine the quantitative welfare implication of international tax cooperation. The difference from most of the related literature is that we incorporate an international public good, namely a public good whose benefits can extend beyond national boundaries (see Bjorvatn and Schjelderup, 2002, and Tabellini, 2003). As Tabellini (2003) pointed out, such goods constitute an important factor of the EU. Examples include foreign/defense policy and environmental quality. In addition, the abolition of borders between EU member states has generated a status of increased cross-country spillovers in several areas such as internal security, border controls, immigration policy and scientific research. We show that the incorporation of international public goods in a model of international tax competition changes the above mentioned results drastically.

We use a multi-country version of the general equilibrium model in Persson and Tabellini (1992). This is simple, tractable and delivers an analytical solution. There are two types of cross-border spillovers. The first one is generated by international capital

[1] See e.g. Persson and Tabellini (1992, 1995) who also review the literature. The standard race-to-the-bottom result is usually derived in a setup where the only cross-country spillover effect, or externality, is generated by international capital mobility and national policy instruments are chosen by Ramsey (benevolent) policymakers. A similar setup is used here. Note that international cooperation can become counter-productive if we depart from Ramsey policymakers and there are failures at policymaking level. Here we do not study such issues so cooperation is superior to non-cooperation. See Razin and Sadka (1999) for various political-economy aspects of tax competition. For empirical evidence of tax competition in OECD countries, see e.g. Devereux, Lockwood and Redoano (2008).

[2] What is "small" or "large" is of course arbitrary. One percent gain may be considered to be large enough. The key point, however, is whether the welfare gain from cooperation changes substantially across different model specifications. Here we show that it does, once we introduce international public goods.

mobility and results in the problem of tax competition for mobile tax bases. The second spillover is generated by the presence of international public goods and results in the problem of free riding on other countries' contribution.

When we solve the model numerically to get a measure of general equilibrium welfare, our results are as follows. In the absence of international public goods, the welfare gain from cooperation is small quantitatively. The reason is that higher tax rates (as we switch from Nash to cooperation) is good for public goods provision in the short run, but they are bad for private investment and in turn future consumption. The latter offsets the beneficial effect of higher public goods provision in the short run. Thus, in a non-static setup, suboptimally low Nash tax rates are not that bad quantitatively, as already shown by e.g. Mendoza and Tezar (2005).

Results change drastically once we introduce international public goods. Although, as mentioned above, we realize that what is small or large is arbitrary and we should be cautious how to read these numbers, it is fair and robust to claim that: (a) The introduction of international public goods into a rather conventional model with international capital mobility makes the welfare gain from cooperation particularly big. Thus, the argument for international cooperation becomes much stronger when there are public goods that extend beyond national borders. (b) The combination of the two spillovers has qualitative implications too: the welfare gain from cooperation is nonmonotonic in the magnitude of cross-country spillovers from international public goods; after a turning point, the welfare gain falls with this magnitude (see also Bjorvatn and Schjelderup, 2002, for similar effects on tax rates).

The rest of the paper is as follows. Section II solves for a world competitive equilibrium. Section III solves for optimal policies. Section IV concludes.

II. World economy

Consider a world economy composed of a finite number of identical countries N, indexed by $i = 1,2,...,N$. Each country i is populated by a representative private agent and a benevolent Ramsey national government. The private agent in each country consumes and invests at home and abroad, where investment abroad implies a mobility or transaction cost (the latter provides a measure of the degree of capital mobility). The national government in each country can tax domestic and foreign investors at the same rate (source principle of taxation) to finance the provision of a public good whose benefits can extend beyond national boundaries.

We use a simple two-period (present and future) model adapted from Persson and Tabellini (1992). The differences are that here we use a multi-country version of this model and add an international public good as in Bjorvatn and Schjelderup (2002). All countries produce the same commodity and have access to a linear technology.

The sequence of events is as follows. In the beginning of the game, national governments choose once-and-for-all their tax policy and the associated contribution to the public good. In turn, private agents maximize their lifetime utility making their investment and (present and future) consumption decisions. Working with backward induction, we first solve the private agents' problem by taking prices and policies as given. This will give us a World Competitive Equilibrium (WCE) which is for any feasible policies. In turn, we solve for Nash national tax policies. Namely, each national government chooses its own tax rate optimally subject to the WCE by taking as given the tax policies of the other government. We also solve for cooperative national policies; this will serve as a benchmark.

II.1 Behavior of private agents

The representative household in each country i maximizes:

$$U^i = U(c_1^i, c_2^i, G^i) \tag{1a}$$

where c_1^i and c_2^i are private consumption in the first and second period respectively, and G^i is the international public good from the viewpoint of private agent located in country i (see equation (5) below). The utility function is increasing and quasi-concave. For algebraic simplicity, we use an additively separable function of the form:

$$U^i = \log c_1^i + c_2^i + vG^i \tag{1b}$$

where ν is the weight given to public services relative to private consumption.[3]

The first-period budget constraint of the private agent in country i is:

$$c_1^i + k^{ii} + \sum_{j(\neq i)=1}^{N} k^{ij} = e^i \tag{2a}$$

that is, the private agent begins with an exogenous endowment, e^i, and uses this endowment for consumption, c_1^i, investment at home, k^{ii}, and investment in other countries $j \neq i$ denoted as k^{ij}.

The second-period budget constraint of the private agent in country i is:

$$c_2^i = (1-t^i)A^i k^{ii} + \sum_{j(\neq i)=1}^{N} (1-t^j)A^j k^{ij} - \sum_{j(\neq i)=1}^{N} \frac{m^{ij}(k^{ij})^2}{2} \tag{2b}$$

where $0 < t^i < 1$ and $0 < t^j < 1$ are income tax rates in countries i and $j \neq i$ respectively, the parameters $A^i > 0$ and $A^j > 0$ are the exogenous capital returns in i and j respectively, and $m^{ij} \geq 0$ is a measure of transaction costs when an investor located in i invests in $j \neq i$ (as said above, m^{ij} provides a measure of international capital mobility, where $m^{ij} = 0$ implies perfect mobility and $m^{ij} \to \infty$ zero mobility).

Private agents act competitively by taking policy variables as given. Substituting (2a) and (2b) into (1b), the first-order conditions with respect to k^{ii} and k^{ij} give respectively (these are Euler-type equations):

$$\frac{1}{c_1^i} = (1-t^i)A^i \tag{3a}$$

[3] In the numerical solutions below, we set $\nu > 1$. This parameter range is needed to get a well-defined solution in general equilibrium, namely when policies are optimally chosen. In particular, we need $\nu > 1$ to get that the tax rate increases with the initial endowment (see Appendix). With a linear production technology, a higher endowment increases the tax base on a one-to-one basis (see equation (6e) below). We thus need to value the public good a lot in order to make an efficient use of the higher tax revenue. See below about parameter values used in the numerical solution.

$$\frac{1}{c_1^i} = (1-t^j)A^j - m^{ij}k^{ij} \qquad \text{for } j \neq i \tag{3b}$$

so that $(1-t^i)A^i = (1-t^j)A^j - m^{ij}k^{ij}$. Thus, without uncertainty, net returns are equalized.

II.2 National government budget constraint

Each national government i spends g^i on a public good by taxing domestic and foreign investors at the same rate, $0 < t^i < 1$. Thus, assuming a balanced budget, the budget constraint of national government in country i is:

$$g^i = t^i A^i k^i \tag{4}$$

where $k^i = k^{ii} + \sum_{j(\neq i)=1}^{N} k^{ji}$ denotes the total capital stock in country i (k^{ji} is the capital invested in country i by investors located in country $j \neq i$).

II.3 International public good

To model the international public good G^i, as defined in (1a)-(1b) above, we follow e.g. Alesina and Wacziarg (1999) and Bjorvatn and Schjelderup (2002), by assuming:

$$G^i = g^i + b \sum_{j(\neq i)=1}^{N} g^j \tag{5}$$

where the parameter $0 \leq b \leq 1$ measures the strength of international spillovers in public good provision. When $b = 0$, there is no spillover and the public good is national or local. When $b = 1$, there are perfect spillovers and the public good is fully international.

II.4 World Competitive Equilibrium (given policies)

We now solve for a World Competitive Equilibrium (WCE) for any feasible policy. As equation (4) shows, only one of the two policy instruments (g and t) can be set independently in each country. We choose to express the WCE in terms of national tax rates (t). Then, it is straightforward to show that (2)-(4) imply:

$$c_1^i = \frac{1}{(1-t^i)A^i} \tag{6a}$$

$$c_2^i = (1-t^i)A^i k^{ii} + \sum_{j(\neq i)=1}^{N} (1-t^j)A^j k^{ij} - \sum_{j(\neq i)=1}^{N} m^{ij} \frac{(k^{ij})^2}{2} \tag{6b}$$

$$g^i = t^i A^i (k^{ii} + \sum_{j(\neq i)=1}^{N} k^{ji}) \tag{6c}$$

$$k^{ij} = \frac{(1-t^j)A^j - (1-t^i)A^i}{m^{ij}} \tag{6d}$$

$$k^{ii} = e^i - \frac{1}{(1-t^i)A^i} - \sum_{j(\neq i)=1}^{N} k^{ij} \tag{6e}$$

where (6a), (6b), (6c), (6d) and (6e) give respectively the first-period consumption, the second-period consumption, government expenditure on the public good, capital invested abroad and capital invested at home. This is for each country $i = 1,2,...,N$.

We sum up this section. We have solved for a World Competitive Equilibrium (WCE). This holds for any feasible policy as summarized by the national tax rates, t^i, where $i = 1,2,...,N$. In this equilibrium: (i) private agents maximize their utility; (ii) all constraints are satisfied; (iii) all markets clear. This WCE is given by (6a-e) and (5). Notice that, thanks to the model specification, we have managed to get closed-form solutions for equilibrium allocations as functions of t^i and parameters only. This will be convenient algebraically when we endogenize policy, t^i.

Before we move on to optimal policies, it is helpful to identify the nature of external effects from foreign tax policy on domestic welfare. Recall that there are two types of cross-border spillovers in the model: spillovers from international capital movements and international public goods. International capital movements generate the standard tax competition effect (if the foreign country increases its tax rate, the domestic country attracts capital) and the tax-the-foreigner effect (if the foreign country increases its tax rate, it also hurts the income and welfare of domestic investors who invest abroad). International public goods generate a free riding effect (if the foreign country increases its tax rate, it contributes to the provision of the global public good). The tax competition and the free riding externalities are both positive and hence will both tend to push the uncoordinated tax rate below its Pareto efficient value. The tax-the-foreigner effect can be negative or positive depending on whether the domestic country is exporter or importer of capital and hence can work in either direction.[4] We leave the solution below to determine the net final externality and hence how Nash and cooperative policies may differ.

III. National policies and world equilibrium

We move on to the first stage of the game and endogenize national policies, t^i. National policies are chosen by benevolent national governments that either play Nash or cooperate. When they choose t^i, benevolent national governments take into account the World Competitive Equilibrium specified above. We will solve for symmetric (Nash and cooperative) equilibria in national policies. Thus, in equilibrium, $t^i = t^j \equiv t$, $c_1{}^i = c_1{}^j \equiv c_1$, $c_2{}^i = c_2{}^j \equiv c_2$, $k^{ii} = k^{jj} \equiv k$, $k^{ij} = k^{ji} \equiv 0$, $g^i = g^j \equiv g$, where $i \neq j$.[5]

III.1 Nash policies

Each national government i chooses t^i to maximize (1b) subject to (6a-e) and (5). In doing so, it takes t^j, with $j \neq i$, as given. Using equations (6a-e) and (5) into (1b), deriving the first-order condition for t^i, invoking symmetry, and assuming existence of an interior solution we get (we now omit country superscripts):

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[4] These three effects can be also shown algebraically if we differentiate the domestic welfare with respect to the foreign tax rate. The partial is a bit unfriendly but one can distinguish the three effects. Results are available upon request from the authors.

[5] Even if, in a symmetric equilibrium, there are no capital flows ex post (see equation (6d)), decisions are affected ex ante and this is enough to capture the inefficiencies in the absence of cooperation.

$$A\left(e-\frac{1}{A(1-t)}\right)=v\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}-\frac{2A^2t(N-1)(1-b)}{m}\right] \quad (7)$$

which is an equation in the Nash tax rate only. Comparative statics can show that the Nash tax rate, denoted as t^{nc}, follows $t^{nc}=t(\overset{-}{N},\overset{+}{b},\overset{+}{m},\overset{+}{v},\overset{+}{e})$.[6] If in turn we use t^{nc} into (6a-e) and (5), we get a symmetric Nash equilibrium (SNE).

III.2 Cooperative policies

Consider now the reference case in which national tax policies are chosen jointly by maximizing the sum of individual countries' welfare. That is, a worldwide benevolent social planner chooses jointly all t^i to maximize the sum of (1b) over all countries. Working as above, it is straightforward to show that in Symmetric Cooperative Equilibrium (SCE), we have instead of (7):

$$A\left(e-\frac{1}{A(1-t)}\right)=v[1+b(N-1)]\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}\right] \quad (8)$$

which is an equation in the cooperative tax rate only. Comparative statics can show that the cooperative tax rate, denoted as t^c, follows $t^c=t(\overset{+}{N},\overset{+}{b},\overset{+}{v},\overset{+}{e})$.[7] If in turn we use t^c into (6a-e) and (5), we get a symmetric cooperative equilibrium (SCE).

III. 3 Comparison of SNE to SCE

Numerical solutions are reported in Tables 1-5 below. These Tables report the equilibrium tax rates, the associated macroeconomic outcomes and the resulting general equilibrium welfare, in both the non-cooperative and cooperative case, for various parameter combinations. To get welfare in the non-cooperative case, we solve equation (7) for the Nash tax rate, use this solution into (6a-e) and (5), and in turn plug the

[6] See Appendix A for details.

[7] See Appendix B for details.

resulting values of c_1, c_2, G into the welfare function (1b). We work similarly with the cooperative case in which the tax rate is given by equation (8).

We are mainly interested in the effects of the key parameters, $m \geq 0$ and $0 \leq b \leq 1$, where recall that $m \geq 0$ is a measure of international capital mobility and $0 \leq b \leq 1$ is a measure of international spillovers in public goods provision. Tables 1a and 1b report respectively the case in which there is either international capital mobility only, or international public goods only. By contrast, Tables 2a and 2b report the cases in which both types of cross-border externalities coexist. Specifically, Table 1a sets $b = 0$ (i.e. no international public goods) and studies what happens for changing values of $m \geq 0$, while Table 1b sets $m \to \infty$ (i.e. zero capital mobility) and studies what happens for changing values of $0 \leq b \leq 1$. Table 2a studies what happens for changing values of m in the presence of international public goods (say $b = 0.1$), while Table 2b studies the effects of changing values of b in the presence of international capital mobility (say $m = 0.1$).

Tables 1a-b and 2a-b here

There are six results below. Results 3, 4 and 6 give the key points of the paper, while Results 1, 2 and 5 confirm that the model also delivers the main results in the literature.[8]

Result 1. In all cases, the Nash tax rate is less than, or equal to, the cooperative tax rate (i.e. $0 < t^{nc} \leq t^{c} < 1$). Also, welfare under Nash is less than, or equal to, welfare under cooperation. Only when we set $m \to \infty$ and $b = 0$ in Table 1a (i.e. neither international capital mobility, nor international public goods, so that the economies are practically closed), the two solutions coincide. In all "interior" cases ($0 \leq m < \infty$ and/or $b > 0$), the Nash tax rate is found to be sub-optimally low. This means that the existing cross-country

[8] We use Mathematica, version 4.00. Apart from $\nu > 1$, results are robust to changes in parameter values. We also report well-defined solutions only (for instance, we do not report solutions for tax rates higher than one or negative capital stocks). This is not unusual: computable general equilibrium models work for some range of parameter values.

spillovers (from international capital movements and international public goods) generate a net positive externality.[9]

Result 2. It is useful to start with quantitative results in the popular special case in which there are no international public goods. This is the case in Table 1a. In the absence of international public goods ($b = 0$), the welfare difference between the non-cooperative case and the cooperative case is relatively small. This happens even when the tax rates differ a lot between the two cases. For instance, when the mobility cost is $m = 1$, the Nash tax rate is $t^{nc} = 0.298$, while the socially optimal tax rate is $t^{c} = 0.715$. Nevertheless, despite this big difference in tax rates, the utility levels are pretty close: $U(t^{nc}) = 101.871$ in the Nash case versus $U(t^{c}) = 104.646$ in the cooperative case, so that the welfare gains from coordination are 2.7 percentage points.

The intuition behind this result is revealed by looking at macroeconomic outcomes. Recall that utility depends on both private consumption and public good provision (see equation (1b)). Our numerical simulations imply that higher tax rates (as we switch from Nash to cooperation) can be good for public good provision, but are particularly bad for second-period private consumption. This happens because higher tax rates hurt private investment and in turn future private consumption (see equation (6b)) so that the beneficial effect of higher tax rates gets smaller. Therefore, in a dynamic setup, Nash tax rates are not that bad quantitatively. This is different from a static model, where higher tax rates can increase the provision of public goods without hurting the economy in the future. The standard argument - that tax competition is harmful in the presence of cross-country spillovers - becomes weaker in a dynamic setup.

Finally, in Table 1a, the effect of m is monotonic, in the sense that as capital mobility rises and tax competition gets fiercer (i.e. as m gets smaller), the difference between the two (Nash and cooperative) tax rates and hence the gain from cooperation rise. This monotonic effect also holds in the presence of international public goods (see Table 2a below), i.e. it holds for any value of $0 \leq b \leq 1$.

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[9] Recall the game-theoretic result: in the presence of positive (resp. negative) externalities, players strategies are inefficiently low (resp. high) in a Nash equilibrium relative to a cooperative equilibrium. See Cooper and John (1988) and for an extension Philippopoulos and Economides (2003). This applies to symmetric equilibria.

Result 3. Consider now the symmetrically opposite case from the one described above. Namely, there is zero capital mobility ($m \to \infty$) so that it is only public goods that generate cross-border spillovers. This case is reported in Table 1b. The benefits from cooperation become bigger than those in Table 1a. Thus, free riding problems matter more than problems associated with internationally mobile tax bases.

Also note that, in the absence of capital mobility, the welfare benefit is monotonic in b (see Table 1b). That is, without capital mobility, as the magnitude of international spillovers from public goods provision increases, the incentive to free ride on other countries' provision of public goods becomes stronger, and hence the difference between the two (Nash and cooperative) tax rates and the gain from cooperation rise monotonically.

Result 4. In Tables 2a and 2b, both spillovers are present. The combination of international capital mobility ($0 \le m < \infty$) and international public goods ($b > 0$) makes the gains for cooperation really big. For instance, compare Table 1a (zero international spillover from public goods) to Table 2a (a modest degree of international spillover from public goods) by focusing on the same magnitude of international capital mobility; when say $m = 1$, the welfare gain from cooperation is 49 percentage points in Table 2a, while it is only 2.7 percentage points in Table 1a. The fact that it is the combination of the two spillovers that makes the quantitative difference is confirmed when we compare Tables 1b (no capital mobility) and 2b (capital mobility), both for varying values of $0 \le b \le 1$. The benefits are much bigger in Table 2b. Thus, the introduction of international public goods into a model with international capital mobility has drastic quantitative welfare implications.

It is important to note however that, for given $0 \le m < \infty$, the effect of b is not monotonic. This is shown in Table 2b, where we set say $m = 0.1$ and examine the effects from changes in $0 \le b \le 1$. Up to a critical value of b, denoted as b^*, which is around 0.6 in Table 2b, the higher the magnitude of international spillovers from public goods provision, or the worse the free riding problem, the higher the welfare gain from cooperation. But after b^*, the higher is the value of b, the lower gets the welfare gain from cooperation. This happens because, after b^*, as the public good turns from local to international, the incentive to compete for mobile tax bases is reduced. Actually, in the special case of perfect international spillovers from provided public goods ($b = 1$), the incentive to compete for mobile tax bases and the distortions associated with this, are completely eliminated. This is shown by the fact that when $b = 1$, the solution is independent of the assumed value of m (see e.g. Tables 1b and 2b). This is similar to the main result in Bjorvatn and Schjelderup (2002). Of course, as pointed out by Bjorvatn and Schjelderup, there is still undersupply of public goods in the Nash equilibrium due to free riding. Therefore, when both international spillovers are present, they do not simply add up to a single externality. Their interaction is nonlinear in the sense that the effects of b are nonmonotonic.[10]

Result 5. We next report the effects of other parameter values. Tables 3a-c report results for changing values of population size (N), when respectively there is capital mobility but no international public goods ($0 \leq m < \infty$ and $b = 0$), there are both capital mobility and international public goods ($0 \leq m < \infty$ and $b > 0$) and there are international public goods but no capital mobility ($b > 0$ and $m \to \infty$). Results are monotonic. The welfare gain from cooperation increases with the size of population. This happens because, in symmetric equilibria, coordination problems, or Nash-type inefficiencies, get worse with the number of players.[11]

Tables 3a-c here

Tables 4a-c report what happens when the valuation of the public good (ν) changes. We consider the same three cases as above. Results are again monotonic. In Tables 4a-b, with capital mobility, as ν rises, the welfare gain from cooperation gets larger. By contrast, in Table 4c, without capital mobility, as ν rises, the welfare gain from cooperation gets smaller. The idea in Table 4c is that, when the only international spillover is from public goods provision, the more we value public goods, the more we

[10] We are grateful to a referee for pointing this out to us.
[11] In the case of asymmetric equilibria, the relation is ambiguous.

internalize cross-country spillovers even in the absence of cooperation. On the other hand, when there is also international capital mobility, as in Tables 4a-b, the dominant effect of ν is through international capital flows.

Tables 4a-c here

Result 6. Combining the above results, it is only the value of $0 \leq b \leq 1$ that produces humped-shaped effects on the gain from cooperation, and this happens when both international public goods and international capital mobility are present. Results are summarized in Tables 5a-b (two different values of mobility costs), 5c-d (two different values of population size) and 5e-f (two different values of public goods valuation). In all these tables both spillovers are present and we experiment with changing values of $0 \leq b \leq 1$.

Notice that the turning point of b (b^*) depends on the magnitude of all other parameters. Tables 5a-f reveal that the turning point of b arrives later (i.e. b^* gets larger), when international capital mobility increases (i.e. m gets smaller), the number of countries increases (i.e. N gets bigger), or the valuation of the public good decreases (i.e. ν gets smaller). The intuition behind the effects of m (see Tables 5a-b) and N (see Tables 5c-d) is as follows. Lower values of m and/or higher values of N make coordination more desirable or, equivalently, make tax competition costlier. Hence, they delay the possibility to offset - via international spillovers from locally provided public goods - the distortive effects from tax competition. The intuition behind the effects of ν (see Tables 5e-f) is as follows. Both b and ν work through the same channel, namely international public goods. Also, as we have seen above, higher values of $0 \leq b \leq b^*$ (given ν) and higher values of ν (given b) work in the same direction increasing the welfare loss from tax competition. Hence, before the turning point of b (b^*), they can be thought as substitutes. This is why as ν gets smaller, b^* can get larger in Tables 5e-f.

Tables 5a-f here

IV. Conclusions, related work and extensions

We provided a quantitative assessment of the welfare benefits from international tax policy cooperation. We showed that, once we introduce international public goods to a rather standard model of tax competition, the difference in tax policies is reflected to a big difference in welfare and hence there are substantial gains from tax cooperation. Free riding on each other's contribution to international public goods appears to be more important and costly than tax competition for mobile tax bases. On the other hand, welfare effects are not monotonic in the degree of international spillovers from public goods provision.

A mentioned already, a paper close to ours is Bjorvatn and Schjelderup (2002). However there are differences. Here we investigated the quantitative implications of international public goods for the welfare benefits from international cooperation. By contrast, Bjorvatn and Schjelderup focused on the case in which perfect spillovers from international public goods eliminate the detrimental effect from tax competition. Besides, although this is less important, there are modeling differences. For instance, our model allows for various degrees of capital mobility as well as for both current and future consumption (this helps us to identify how tax competition for mobile tax bases is good for current investment and future consumption).

It would be interesting to add more types of cross-country spillovers. Here, we focused on international capital flows and international public goods. It would also be interesting to study the above issues into a fully dynamic general equilibrium neoclassical growth model.

Table 1 : Either international capital mobility only, or international public goods only

Table 1a: b=0, changing m

	Non Cooperative (Nash)					Cooperative					Gains
m	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.1	0.032	1.03	95.8	3.168	99.3163	0.715	3.5	27.54	68.96	104.646	0.054
0.2	0.064	1.07	92.63	6.304	99.6282	0.715	3.5	27.54	68.96	104.646	0.050
0.3	0.095	1.11	89.49	9.403	99.9352	0.715	3.5	27.54	68.96	104.646	0.047
0.4	0.126	1.14	86.40	12.46	100.236	0.715	3.5	27.54	68.96	104.646	0.044
0.5	0.156	1.19	83.35	15.46	100.531	0.715	3.5	27.54	68.96	104.646	0.041
0.6	0.186	1.23	80.36	18.41	100.818	0.715	3.5	27.54	68.96	104.646	0.038
0.7	0.216	1.27	77.44	21.29	101.097	0.715	3.5	27.54	68.96	104.646	0.035
0.8	0.244	1.32	74.59	24.09	101.366	0.715	3.5	27.54	68.96	104.646	0.032
0.9	0.272	1.37	71.83	26.80	101.624	0.715	3.5	27.54	68.96	104.646	0.030
1.0	0.298	1.43	69.16	29.41	101.871	0.715	3.5	27.54	68.96	104.646	0.027
$m \to \infty$	0.715	3.50	27.54	68.96	104.646	0.715	3.5	27.54	68.96	104.646	0.000

(A=1, v=1.1, e=100, N=15)

Table 1b: $m \to \infty$, changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.715	3.50	27.54	68.95	104.646	0.715	3.5	27.54	68.96	104.646	0.000
0.1	0.715	3.50	27.54	165.5	210.834	0.876	8.07	11.39	193.3	226.101	0.072
0.2	0.715	3.50	27.54	262.0	317.022	0.887	8.84	10.31	307.2	350.435	0.105
0.3	0.715	3.50	27.54	358.6	423.211	0.891	9.17	9.903	420.8	475.011	0.122
0.4	0.715	3.50	27.54	455.1	529.402	0.893	9.35	9.690	534.3	599.663	0.133
0.5	0.715	3.50	27.54	551.6	635.593	0.894	9.47	9.558	647.8	724.347	0.140
0.6	0.715	3.50	27.54	648.2	741.785	0.895	9.55	9.468	761.2	849.049	0.145
0.7	0.715	3.50	27.54	744.7	847.978	0.896	9.61	9.404	874.6	973.761	0.148
0.8	0.715	3.50	27.54	841.3	954.175	0.896	9.66	9.355	988.1	1098.48	0.151
0.9	0.715	3.50	27.54	937.8	1060.39	0.897	9.69	9.316	1101.0	1223.20	0.154
1.0	0.715	3.50	27.54	1034.0	1166.09	0.897	9.72	9.285	1215.0	1347.93	0.156

(A=1, v=1.1, N=15, e=100)

Table 2 : Both international capital mobility and international public goods

Table 2a: b=0.1, changing m

	Non Cooperative (Nash)					Cooperative					Gains
m	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.1	0.036	1.04	95.45	8.443	104.769	0.876	8.07	11.39	193.3	226.101	1.158
0.2	0.071	1.08	91.93	16.79	110.471	0.876	8.07	11.39	193.3	226.101	1.047
0.3	0.105	1.12	88.46	25.02	116.093	0.876	8.07	11.39	193.3	226.101	0.948
0.4	0.140	1.16	85.04	33.12	121.621	0.876	8.07	11.39	193.3	226.101	0.859
0.5	0.173	1.21	81.68	41.06	127.037	0.876	8.07	11.39	193.3	226.101	0.780
0.6	0.206	1.26	78.41	48.80	132.321	0.876	8.07	11.39	193.3	226.101	0.709
0.7	0.238	1.31	75.22	56.33	137.453	0.876	8.07	11.39	193.3	226.101	0.645
0.8	0.269	1.37	72.13	63.61	142.410	0.876	8.07	11.39	193.3	226.101	0.588
0.9	0.298	1.43	69.16	70.59	147.169	0.876	8.07	11.39	193.3	226.101	0.536
1.0	0.327	1.49	66.32	77.26	151.706	0.876	8.07	11.39	193.3	226.101	0.490
$m \to \infty$	0.715	3.50	27.54	165.50	210.834	0.876	8.07	11.39	193.3	226.101	0.072

(A=1, v=1.1, e=100, N=15)

Table 2b: $m = 0.1$, changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.032	1.03	95.80	3.168	99.3163	0.715	3.5	27.54	68.96	104.646	0.054
0.1	0.036	1.04	95.45	8.443	104.769	0.876	8.07	11.39	193.3	226.101	1.158
0.2	0.040	1.04	95.00	15.03	111.577	0.887	8.84	10.31	307.2	350.435	2.141
0.3	0.046	1.05	94.44	23.48	120.315	0.891	9.17	9.903	420.8	475.011	2.948
0.4	0.053	1.06	93.68	34.73	131.942	0.893	9.35	9.69	534.3	599.663	3.545
0.5	0.064	1.07	92.63	50.43	148.170	0.894	9.47	9.558	647.8	724.347	3.889
0.6	0.079	1.09	91.06	73.87	172.397	0.895	9.55	9.468	761.2	849.049	3.925
0.7	0.110	1.12	88.46	112.6	212.437	0.896	9.61	9.404	874.6	973.761	3.584
0.8	0.160	1.19	83.35	188.6	291.036	0.896	9.66	9.355	988.1	1098.48	2.774
0.9	0.300	1.43	69.16	400.0	509.555	0.897	9.69	9.316	1101.0	1223.20	1.401
1.0	0.715	3.50	27.54	1034.0	1166.09	0.897	9.72	9.285	1215.0	1347.93	0.156

(A=1, v=1.1, e=100, N=15)

Table 3 : Effect of population size (*N*)

Table 3a: b=0, changing N

	Non Cooperative (Nash)					Cooperative					Gains
N	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1	0.715	3.5	27.54	68.96	104.646	0.715	3.50	27.54	68.96	104.646	0.000
2	0.394	1.65	59.65	38.71	102.722	0.715	3.50	27.54	68.96	104.646	0.019
4	0.146	1.17	84.36	14.47	100.434	0.715	3.50	27.54	68.96	104.646	0.042
6	0.0888	1.10	90.12	8.787	99.8742	0.715	3.50	27.54	68.96	104.646	0.048
8	0.0637	1.07	92.63	6.304	99.6282	0.715	3.50	27.54	68.96	104.646	0.050
10	0.0497	1.05	94.03	4.915	99.4901	0.715	3.50	27.54	68.96	104.646	0.052
12	0.0407	1.04	94.93	4.027	99.4018	0.715	3.50	27.54	68.96	104.646	0.053
14	0.0345	1.04	95.55	3.410	99.3404	0.715	3.50	27.54	68.96	104.646	0.053
16	0.0299	1.03	96.01	2.958	99.2953	0.715	3.50	27.54	68.96	104.646	0.054

(A=1, v=1.1, e=100, m=0.1)

Table 3b: b=0.1, changing N

	Non Cooperative (Nash)					Cooperative					Gains
N	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1	0.715	3.50	27.54	68.96	104.646	0.715	3.50	27.54	68.96	104.646	0.000
2	0.425	1.74	56.51	45.93	107.582	0.783	4.60	20.74	82.13	112.605	0.047
4	0.162	1.19	82.79	20.82	105.869	0.829	5.84	16.11	101.5	129.481	0.223
6	0.0985	1.11	89.15	14.62	105.329	0.848	6.59	14.18	118.8	146.799	0.394
8	0.0707	1.08	91.93	11.89	105.084	0.859	7.09	13.10	135.7	164.300	0.564
10	0.0551	1.06	93.49	10.37	104.945	0.866	7.46	12.40	152.3	181.897	0.733
12	0.0452	1.05	94.48	9.389	104.856	0.871	7.75	11.90	168.7	199.552	0.903
14	0.0383	1.04	95.17	8.710	104.794	0.875	7.98	11.54	185.1	217.245	1.073
16	0.0332	1.03	95.68	8.212	104.748	0.877	8.16	11.25	201.5	234.963	1.243

(A=1, v=1.1, e=100, m=0.1)

Table 3c: $m \to \infty$, changing N

	Non Cooperative (Nash)					Cooperative					Gains
N	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1	0.715	3.50	27.54	68.96	104.646	0.715	3.50	27.54	68.96	104.646	0.000
2	0.715	3.50	27.54	75.85	112.231	0.783	4.60	20.74	82.13	112.605	0.003
4	0.715	3.50	27.54	89.64	127.401	0.829	5.84	16.11	101.5	129.481	0.016
6	0.715	3.50	27.54	103.4	142.571	0.848	6.59	14.18	118.8	146.799	0.030
8	0.715	3.50	27.54	117.2	157.740	0.859	7.09	13.10	135.7	164.300	0.042
10	0.715	3.50	27.54	131.0	172.910	0.866	7.46	12.40	152.3	181.897	0.052
12	0.715	3.50	27.54	144.8	188.079	0.871	7.75	11.90	168.7	199.552	0.061
14	0.715	3.50	27.54	158.6	203.249	0.875	7.98	11.54	185.1	217.245	0.069
16	0.715	3.50	27.54	172.4	218.418	0.877	8.16	11.25	201.5	234.963	0.076

(A=1, v=1.1, e=100, b=0.1)

Table 4 : Effect of public goods valuation (v)

Table 4a: b=0, changing v

	Non Cooperative (Nash)					Cooperative					Gains
v	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1.1	0.032	1.03	95.80	3.168	99.3163	0.715	3.50	27.54	68.96	104.646	0.054
1.2	0.059	1.06	93.13	5.803	100.159	0.779	4.52	21.12	74.36	111.86	0.117
1.3	0.081	1.09	90.88	8.029	101.405	0.808	5.20	18.22	76.58	119.419	0.178
1.4	0.10	1.11	88.95	9.935	102.968	0.825	5.71	16.50	77.79	127.143	0.235
1.5	0.12	1.13	87.28	11.58	104.784	0.837	6.12	15.35	78.53	134.962	0.288
1.6	0.13	1.15	85.82	13.02	106.804	0.845	6.44	14.52	79.04	142.842	0.337
1.7	0.14	1.17	84.54	14.29	108.993	0.851	6.72	13.89	79.4	150.764	0.383
1.8	0.16	1.18	83.39	15.42	111.322	0.856	6.95	13.39	79.66	158.718	0.426
1.9	0.17	1.20	82.37	16.43	113.769	0.860	7.15	12.98	79.86	166.695	0.465
2.0	0.18	1.21	81.45	17.34	116.316	0.863	7.33	12.65	80.02	174.689	0.502

(A=1, N=15, e=100, m=0.1)

Table 4b: b=0.1 , changing v

	Non Cooperative (Nash)					Cooperative					Gains
v	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1.1	0.036	1.04	95.45	8.443	104.769	0.876	8.07	11.39	193.3	226.101	1.158
1.2	0.065	1.07	92.49	15.47	111.112	0.879	8.25	11.11	193.5	245.442	1.208
1.3	0.09	1.10	89.99	21.40	117.894	0.881	8.40	10.90	193.7	264.802	1.246
1.4	0.11	1.13	87.85	26.47	125.020	0.883	8.53	10.72	193.8	284.176	1.273
1.5	0.13	1.15	85.99	30.86	132.420	0.884	8.64	10.58	193.9	303.560	1.292
1.6	0.15	1.17	84.37	34.69	140.041	0.885	8.73	10.45	194.0	322.952	1.306
1.7	0.16	1.19	82.95	38.07	147.844	0.887	8.81	10.35	194.0	342.351	1.316
1.8	0.17	1.21	81.68	41.07	155.797	0.887	8.88	10.26	194.1	361.755	1.322
1.9	0.18	1.23	80.54	43.75	163.876	0.888	8.95	10.18	194.1	381.163	1.326
2.0	0.19	1.24	79.52	46.16	172.063	0.889	9.00	10.11	194.1	400.575	1.328

(A=1, N=15, e=100, m=0.1)

Table 4c: $m \to \infty$, changing v

	Non Cooperative (Nash)					Cooperative					Gains
v	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
1.1	0.715	3.50	27.54	166.4	211.393	0.876	8.07	11.39	193.3	226.101	0.069
1.2	0.779	4.52	21.12	179.5	237.517	0.879	8.25	11.11	193.5	245.442	0.033
1.3	0.808	5.20	18.22	186.1	260.545	0.881	8.40	10.90	193.7	264.802	0.016
1.4	0.825	5.71	16.50	187.0	279.828	0.883	8.53	10.72	193.8	284.176	0.015
1.5	0.837	6.12	15.35	188.2	299.658	0.884	8.64	10.58	193.9	303.560	0.013
1.6	0.845	6.44	14.52	189.6	319.813	0.885	8.73	10.45	194.0	322.952	0.009
1.7	0.851	6.72	13.89	190.8	339.936	0.887	8.81	10.35	194.0	342.351	0.007
1.8	0.856	6.95	13.39	191.4	359.719	0.887	8.88	10.26	194.1	361.755	0.006
1.9	0.860	7.15	12.98	191.6	379.056	0.888	8.95	10.18	194.1	381.163	0.005
2.0	0.863	7.33	12.65	192.6	399.400	0.889	9.00	10.11	194.1	400.575	0.003

(A=1, N=15, e=100, b=0.1)

<u>Table 5 : Effects of *m*, *N* and *v* on the critical value of b</u>

Table 5a: $m = 0.1$, changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.032	1.03	95.8	3.168	99.3163	0.715	3.50	27.54	68.96	104.646	0.054
0.1	0.036	1.04	95.45	8.443	104.769	0.876	8.07	11.39	193.3	226.101	1.158
0.2	0.040	1.04	95.00	15.03	111.577	0.887	8.84	10.31	307.2	350.435	2.141
0.3	0.046	1.05	94.44	23.48	120.315	0.891	9.17	9.903	420.8	475.011	2.948
0.4	0.053	1.06	93.68	34.73	131.942	0.893	9.35	9.690	534.3	599.663	3.545
0.5	0.064	1.07	92.63	50.43	148.170	0.894	9.47	9.558	647.8	724.347	3.889
0.6	0.079	1.09	91.06	73.87	172.397	0.895	9.55	9.468	761.2	849.049	3.925
0.7	0.110	1.12	88.46	112.6	212.437	0.896	9.61	9.404	874.6	973.761	3.584
0.8	0.160	1.19	83.35	188.6	291.036	0.896	9.66	9.355	988.1	1098.48	2.774
0.9	0.300	1.43	69.16	400.0	509.555	0.897	9.69	9.316	1101.0	1223.20	1.401
1.0	0.715	3.50	27.54	1034.0	1166.09	0.897	9.72	9.285	1215.0	1347.93	0.156

(A=1, v=1.1, N=15, e=100)

Table 5b: m=0.5 , changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.16	1.19	83.35	15.46	100.531	0.715	3.50	27.54	68.96	104.646	0.041
0.1	0.17	1.21	81.68	41.06	127.037	0.876	8.07	11.39	193.3	226.101	0.780
0.2	0.19	1.24	79.62	72.71	159.824	0.887	8.84	10.31	307.2	350.435	1.193
0.3	0.22	1.28	77.03	112.8	201.351	0.891	9.17	9.903	420.8	475.011	1.359
0.4	0.25	1.34	73.66	165.0	255.462	0.893	9.35	9.690	534.3	599.663	1.347
0.5	0.30	1.43	69.16	235.3	328.362	0.894	9.47	9.558	647.8	724.347	1.206
0.6	0.36	1.56	62.98	333.3	430.065	0.895	9.55	9.468	761.2	849.049	0.974
0.7	0.45	1.80	54.47	472.2	574.488	0.896	9.61	9.404	874.6	973.761	0.695
0.8	0.55	2.22	43.96	656.6	767.023	0.896	9.66	9.355	988.1	1098.48	0.432
0.9	0.65	2.84	34.26	855.5	976.357	0.897	9.69	9.316	1101.0	1223.20	0.253
1.0	0.715	3.50	27.54	1034.0	1165.48	0.897	9.72	9.285	1215.0	1347.93	0.157

(A=1, v=1.1, N=15, e=100)

Table 5c: N=10, changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.050	1.05	94.03	4.915	99.4901	0.715	3.50	27.54	68.96	104.646	0.052
0.1	0.055	1.06	93.49	10.37	104.945	0.866	7.46	12.4	152.3	181.897	0.733
0.2	0.062	1.07	92.80	17.17	111.750	0.881	8.38	10.93	225.9	261.574	1.341
0.3	0.071	1.08	91.93	25.89	120.476	0.886	8.81	10.35	299.1	341.542	1.835
0.4	0.082	1.09	90.76	37.47	132.067	0.89	9.06	10.04	372.1	421.608	2.192
0.5	0.099	1.11	89.15	53.6	148.206	0.892	9.22	9.847	445.1	501.718	2.385
0.6	0.120	1.14	86.74	77.58	172.204	0.893	9.33	9.714	518.1	581.853	2.379
0.7	0.160	1.19	82.79	116.9	211.557	0.894	9.42	9.617	591.0	662.002	2.129
0.8	0.240	1.31	75.22	192.5	287.203	0.895	9.48	9.543	664.0	742.160	1.584
0.9	0.420	1.74	56.51	379.9	474.990	0.895	9.54	9.485	736.9	822.326	0.731
1.0	0.715	3.50	27.54	689.6	786.640	0.896	9.58	9.438	809.8	902.496	0.147

(A=1, v=1.1, m=0.1, e=100)

Table 5d: N=20 , changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.024	1.02	96.64	2.337	99.2334	0.715	3.50	27.54	68.96	104.646	0.055
0.1	0.026	1.03	96.38	7.528	104.685	0.882	8.44	10.84	234.1	270.452	1.583
0.2	0.029	1.03	96.05	14.01	111.493	0.89	9.10	9.991	388.4	439.407	2.941
0.3	0.034	1.03	95.63	22.34	120.236	0.893	9.36	9.678	542.4	608.568	4.061
0.4	0.039	1.04	95.07	33.42	131.876	0.895	9.51	9.516	696.4	777.789	4.898
0.5	0.047	1.05	94.29	48.91	148.139	0.896	9.60	9.416	850.3	947.036	5.393
0.6	0.059	1.06	93.13	72.06	172.453	0.897	9.66	9.349	1004	1116.30	5.473
0.7	0.078	1.08	91.19	110.4	212.752	0.897	9.71	9.300	1158	1285.57	5.043
0.8	0.120	1.13	87.37	186.3	292.402	0.897	9.74	9.263	1312	1454.84	3.975
0.9	0.230	1.29	76.38	404.1	521.183	0.898	9.77	9.235	1466	1624.12	2.116
1.0	0.715	3.50	27.54	1379.2	1545.20	0.898	9.79	9.212	1620	1793.40	0.161

(A=1, v=1.1, m=0.1, e=100)

Table 5e: v=1.2, changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.059	1.06	93.13	5.803	100.159	0.779	4.52	21.12	74.36	111.86	0.117
0.1	0.065	1.07	92.49	15.47	111.112	0.879	8.25	11.11	193.5	245.442	1.209
0.2	0.073	1.08	91.68	27.52	124.783	0.888	8.95	10.18	307.3	381.163	2.055
0.3	0.084	1.09	90.64	43.00	142.324	0.892	9.24	9.818	420.9	517.096	2.633
0.4	0.097	1.11	89.26	63.57	165.646	0.894	9.41	9.626	534.4	653.096	2.943
0.5	0.12	1.13	87.34	92.25	198.160	0.895	9.52	9.507	647.8	789.125	2.982
0.6	0.15	1.17	84.47	135.00	246.600	0.896	9.59	9.427	761.2	925.171	2.752
0.7	0.19	1.24	79.76	205.30	326.287	0.896	9.65	9.368	874.7	1061.23	2.252
0.8	0.28	1.40	70.64	341.20	480.365	0.897	9.69	9.323	988.1	1197.29	1.492
0.9	0.51	2.03	48.19	677.00	861.302	0.897	9.72	9.289	1101	1333.35	0.548
1.0	0.779	4.52	21.12	1115.40	1360.26	0.897	9.75	9.261	1215	1469.42	0.080

(A=1, N=15, m=0.1, e=100)

Table 5f: v=1.5 , changing b

	Non Cooperative (Nash)					Cooperative					Gains
b	t^{nc}	$c_1(t^{nc})$	$c_2(t^{nc})$	$g(t^{nc})$	$U(t^{nc})$	t^c	$c_1(t^c)$	$c_2(t^c)$	$g(t^c)$	$U(t^c)$	
0.0	0.12	1.13	87.28	11.58	104.784	0.837	6.12	15.35	78.53	134.962	0.288
0.1	0.13	1.15	85.99	30.86	132.42	0.884	8.64	10.58	193.9	303.56	1.292
0.2	0.15	1.17	84.38	54.89	166.883	0.891	9.17	9.907	307.5	473.393	1.837
0.3	0.17	1.20	82.32	85.7	211.046	0.894	9.40	9.637	421.0	643.38	2.049
0.4	0.19	1.24	79.58	126.6	269.642	0.895	9.53	9.491	534.4	813.418	2.017
0.5	0.23	1.30	75.78	183.3	351.035	0.896	9.62	9.399	647.9	983.479	1.802
0.6	0.29	1.41	70.16	267.2	471.37	0.897	9.67	9.337	761.3	1153.55	1.447
0.7	0.38	1.61	61.12	402.5	665.307	0.897	9.72	9.291	874.7	1323.63	0.990
0.8	0.54	2.16	45.25	641.6	1008.37	0.897	9.75	9.256	988.1	1493.72	0.481
0.9	0.74	3.89	24.71	971.0	1482.60	0.898	9.78	9.229	1102.0	1663.80	0.122
1.0	0.837	6.12	15.35	1177.95	1783.062	0.898	9.80	9.207	1215.0	1833.89	0.029

(A=1, N=15, m=0.1, e=100)

Appendices

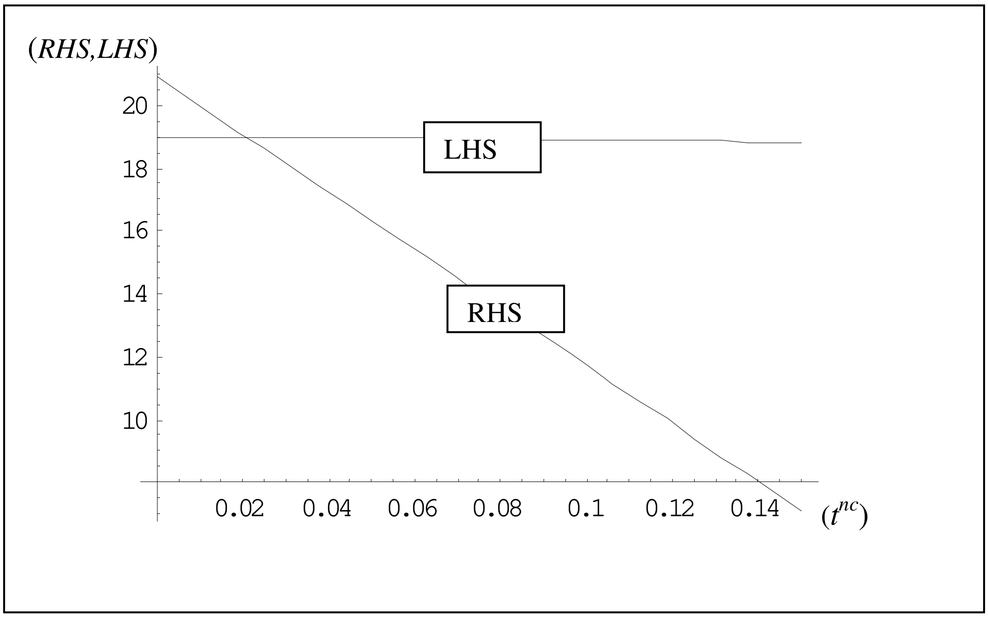
Appendix A: A Nash equilibrium in national policies is summarized by the tax rate that solves equation (7). This non-cooperative tax rate, $0 < t^{nc} < 1$, is unique. Also comparative static exercises imply $t^{nc} = t(\overset{-}{N}, \overset{+}{b}, \overset{+}{m}, \overset{+}{v}, \overset{+}{e})$; thus, the tax rate decreases with the number of countries and increases with the strength of international spillovers, mobility costs, the weight given to public goods, and the initial endowment.

Proof: Consider (7). Define the left hand side as $LHS \equiv A\left(e - \frac{1}{A(1-t)}\right)$, and the right hand side as $RHS \equiv v\left[A\left(e - \frac{1}{A(1-t)}\right) - \frac{t}{(1-t)^2} - \frac{2A^2 t(1-b)(N-1)}{m}\right]$. Then, taking partials with respect to the tax rate, we have $LHS_t = -\frac{1}{(1-t)^2} < 0$ and $RHS_t = -v\left[\frac{1}{(1-t)^2} + \frac{t+1}{(1-t)^3} + \frac{2A^2(1-b)(N-1)}{m}\right] < 0$. Also, from the second-order condition of the maximization problem, $|RHS_t| > |LHS_t|$ for $0 < t < 1$. Hence, assuming existence of a $0 < t < 1$, there is a unique solution t^{nc} as illustrated in Figure 1.

In turn, total differentiation in (7) implies $\frac{\partial t^{nc}}{\partial m} = \frac{2A^2 tv(N-1)(1-b)}{m^2(LHS_t - RHS_t)}$, which is positive since $(LHS_t - RHS_t) > 0$. Also, $\frac{\partial t^{nc}}{\partial e} = \frac{A(v-1)}{(LHS_t - RHS_t)}$, which is positive for $v > 1$.

In addition, $\frac{\partial t^{nc}}{\partial v} = \frac{\left[A\left(e - \frac{1}{A(1-t)}\right) - \frac{t}{(1-t)^2} - \frac{2A^2 t(N-1)(1-b)}{m}\right]}{LHS_t - RHS_t} = \frac{RHS}{v(RHS_t - LHS_t)}$ and $\frac{\partial t^{nc}}{\partial b} = \frac{2A^2 tv(N-1)}{m(LHS_t - RHS_t)}$ which are also positive. Finally, $\frac{\partial t^{nc}}{\partial N} = \frac{2A^2 tv(b-1)}{m(LHS_t - RHS_t)}$ <0, since $0 < b < 1$.

Figure 1: Nash tax rate



(A=1, e=20, v=1.1, b=0.1, N=10, m=0.2)

Appendix B: A cooperative equilibrium in national policies is summarized by the tax rate that solves equation (8). This cooperative tax rate, $0 < t^c < 1$, is unique. Also comparative static exercises imply $t^c = t(\overset{+}{N}, \overset{+}{b}, \overset{+}{v}, \overset{+}{e})$; thus, the tax rate increases with the number of countries , the strength of international spillovers, the weight given to public goods and the initial endowment, but it is independent of mobility costs.

Proof : Consider (8). Define the left hand side as $LHS \equiv A\left(e - \frac{1}{A(1-t)}\right)$, and the right hand side as $RHS \equiv v[1+b(N-1)]\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}\right]$. Then, taking partials with respect to the tax rate, we have $LHS_t = -\frac{1}{(1-t)^2} < 0$ and $RHS_t = -v[1+b(N-1)]\left[\frac{1}{(1-t)^2}+\frac{t+1}{(1-t)^3}\right] < 0$. Also, from the second-order condition of the maximization problem, we have $|RHS_t| > |LHS_t|$ for $0 < t < 1$. Hence, assuming existence of a $0 < t < 1$, there is a unique solution t^c as illustrated in Figure 2.

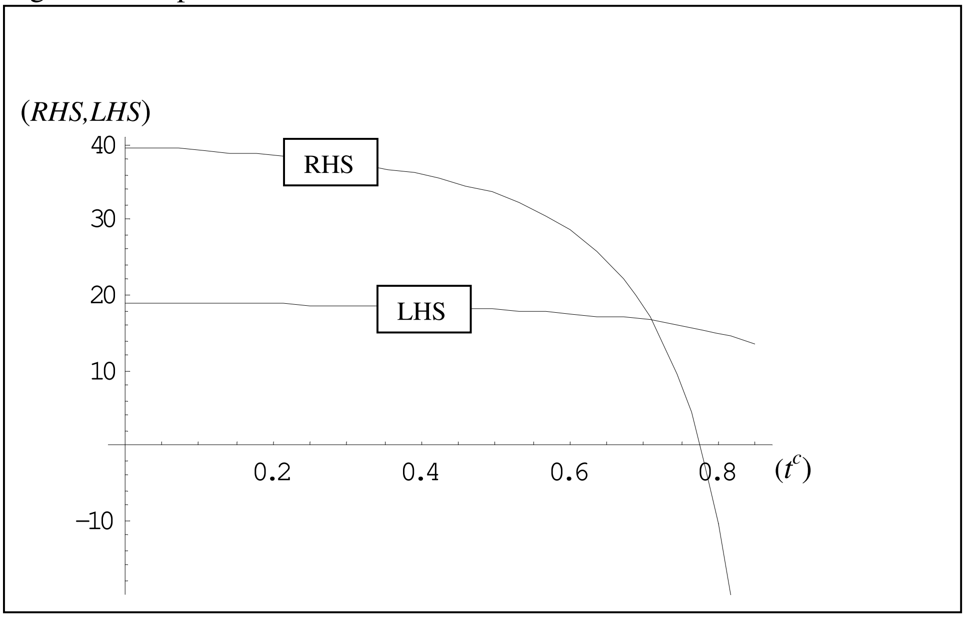
In turn total differentiation in (8) implies $\frac{\partial t^c}{\partial m}=0$, $\frac{\partial t^c}{\partial e}=\frac{A(v(b+1)-1)}{(LHS_t-RHS_t)}$, which is positive for $v>\frac{1}{b+1}$.

In addition $\frac{\partial t^c}{\partial v}=(1+b(N-1))\frac{\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}\right]}{LHS_t-RHS_t}=\frac{RHS}{v(RHS_t-LHS_t)}$,

$\frac{\partial t^c}{\partial b}=v(N-1)\frac{\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}\right]}{(LHS_t-RHS_t)}$ and $\frac{\partial t^c}{\partial N}=vb\frac{\left[A\left(e-\frac{1}{A(1-t)}\right)-\frac{t}{(1-t)^2}\right]}{(LHS_t-RHS_t)}$

which are all positive.

Figure 2: Cooperative tax rate



(A=1, e=20, v=1.1, b=0.1, N=10)

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