INDIRECT TAX HARMONIZATION AND GLOBAL PUBLIC GOODS

by

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Abstract: This paper identifies conditions under which, starting from *any* tax-distorting equilibrium, destination- and origin-based indirect tax-harmonizing reforms are potentially Pareto improving in the presence of global public goods. The first condition (unrequited transfers between governments) requires that transfers are designed in such a way that the marginal valuations of the global public goods are equalized, whereas the second (conditional revenue changes) requires that the change in global tax revenues, as a consequence of tax harmonization, is consistent with the under/over-provision of global public goods relative to the (modified) Samuelson rule. Under these conditions, tax harmonization results in redistributing the gains from a reduction in global deadweight loss and any changes in global tax revenues according to the Pareto principle. And this is the case independently of the tax principle in place (destination or origin).

Keywords: Origin principle; destination principle; indirect tax harmonization; reform of commodity taxes; global/local public goods

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1 Introduction

The establishment of the European Common Market in the 1960s, and its transformation into the European Union internal market in the early 1990s, recognized the need (for the well functioning of the internal market) for tax harmonization of national tax systems.[1] During the last two decades the academic literature (a review of the literature is postponed until Section 2) has paid particular attention to the welfare properties of tax harmonization, focusing in particular on economic environments with perfect or imperfect competition in the goods market, with and without *local* public goods and under two different tax principles ('destination' and 'origin').

The objective of this paper is to revisit the issue regarding the desirability of indirect tax harmonization, but to do so from a different perspective: That of *global* public goods.[2] In particular, this paper asks: Does, starting from any tax-distorting equilibrium, tax-harmonization deliver potential Pareto improvements in the presence of global public goods? If not, what additional elements are required to support a Pareto improvement? And, finally, does the answer to the above questions hinge upon the tax principle, destination or origin, in place? The central question of interest here is thus whether there are circumstances in which tax-harmonization is part of a globally efficient response to existing inefficiencies from taxation and global public goods provision.[3] This is, clearly, an important (and general) perspective capturing the element of the policy concern that relates directly to cooperative policy. It will be shown that tax harmonization —combined with an appropriate way of allocating revenues—does in general deliver Pareto improvements.[4]

[1]The EC Treaty, and under Article 93, requires the European Union Council of Ministers to adopt provisions for the harmonization of Member States' rules in the area of indirect taxation. Indeed, tax harmonization has been quite pronounced for indirect taxation, following the adoption of a common VAT tax system. Although the discussions regarding indirect taxation in the EU context has shifted in recent years towards minimum taxation, tax harmonization remains high on the policy agenda regarding environmental taxation.

[2]The model is, in fact, general enough to encompass the case in which the public goods exhibit local characteristics. We turn to this later on.

[3]By existing inefficiencies we mean, in the broadest sense, those inefficiencies from taxation (and public goods provision) arising in any tax-distorting equilibrium, including, of course, the non-cooperative one. Since focusing on the non-cooperative equilibrium gives an important perspective, Appendix C characterizes this equilibrium and provides existence results for potential Pareto improvements. See also Navrouzoglou (2012) for an analysis of the cooperative equilibrium in the presence of a global pollution externality.

[4]There is a sizeable literature dealing with the efficiency properties of formula-based grants between

With a notable exception to which we turn to shortly in Section 2, the issue of global public goods and tax harmonization has been rather neglected in the literature. This neglect is rather surprising given that: (a) There is a wide range of public goods that share the characteristics of global public goods (the most obvious ones being environmental clean up, measures for the prevention of infectious diseases, and world peace and international security), and (b) the convergence of tax systems is still an issue that is high on the policy agenda.[5]

The analytics show that, starting from any tax-distorting equilibrium, harmonization of taxes towards a weighted average target-tax does generate Pareto improvements, but it does so—unless global public goods are provided following the Samuelson rule—under two conditions: Availability of unrequited transfers between governments and conditional revenue changes that are consistent with the provision of global public goods relative to the Samuelson rule. The first condition, as will be seen later on, implies that transfers are designed in such a way that the overall gains from the provision of global public goods are distributed among countries, whereas the second ensures that any excess revenue gains to be had, conditional upon the tax-harmonizing reforms, is distributed in such a way that the inefficiency in global public good provision is mitigated. Under these conditions, tax harmonization results in a potential Pareto improvement. And, interestingly, this is true independently of the tax principle in place (destination or origin). This result reinforces, in some sense, the initially held belief of both academics and policy commentators that tax harmonization is desirable. But such statement, the analysis here will show, needs to be qualified: Tax harmonization, starting from any tax-distorting equilibrium, is desirable as long as it is supplemented with a simple form of transfers between governments and the reforms deliver the appropriate conditional revenue changes.

The plan of the paper is as follows. Section 2 briefly reviews the literature, while Section 3 provides the background against which the analysis is developed. Sections 4 deals with

asymmetric jurisdictions. These grants have been shown, if supplemented with lump sum transfers, to neutralize the efficiency loss caused by tax competition among lower-level governments. On this see, among others, Wildasin (1989, 1991), and Smart (1998, 2007). The transfers here perform a similar role.

[5]For a recent contribution that discusses issues of efficient provision of global public goods, see Sandmo (2006) and Keen and Kotsogiannis (2012).

destination-based indirect tax harmonization, whereas Section 5 analyzes origin-based indirect tax harmonization. Section 6 summarizes and concludes.

2 Related literature

A step towards formally evaluating the welfare consequences of indirect tax harmonization was taken by Keen (1987, 1989) who, within a perfectly competitive environment, established that a move of destination-based commodity taxes (commodities are taxed by—and revenues accrue to—the country that final consumption takes place) towards an *appropriately* weighted[6] tax average would indeed generate potential Pareto improvements.[7] Subsequently, such a conclusion—but for a different weighted[8] tax average—was also shown to hold under the origin principle of taxation (commodities are taxed by—and revenues accrue to—the country that produces them), Lopez-Garcia (1996).

A limitation of this early work, however, concerned with the allocation of tax revenues: Tax revenues were returned to consumers in a lump-sum fashion and, thus, potentially important effects through public good expenditure were ignored. Delipalla (1997) incorporated local public goods into the framework of Keen (1987) and showed that the Keen's (1987) tax-harmonizing reforms under the destination principle can lead to a potential Pareto improvement[9] under a fairly restrictive condition: That of the tax-harmonizing reforms satisfying conditional revenue neutrality.[10] This is also true under the origin principle of taxation, Kotsogiannis, Lopez-Garcia and Myles (2005).[11]

The case of imperfectly competitive markets has also received some attention—Keen and Lahiri (1993), Keen, Lahiri and Raimondos-Møller (2002), and Kotsogiannis and Lopez-Garcia (2007)—verifying, to a large extent, the conclusions, regarding the desir-

[6]The weights, under the destination principle, being the demand responses of the participating countries. There is a fairly sizeable literature on piecemeal Pareto-improving tax reforms but Keen (1987, 1989) is the first to focus on tax-harmonizing ones.

[7]Meaning that the country that gains from tax harmonization compensates the one that loses, and still is better off. Section 3 returns to this.

[8]The weights, under the origin principle, being the supply responses of the participating countries.

[9]See also Lahiri and Raimondos-Møller (1998), and Lopez-Garcia (1998).

[10]Conditional revenue neutrality requires that, conditional on the tax-harmonizing reforms, global tax revenues remain unchanged.

[11]Lockwood (1997), specializing the production technology, has established alternative conditions for Pareto-improving harmonization.

ability of tax harmonization, derived by the earlier literature. Keen and Lahiri (1998) investigate the welfare consequences of switching from the destination to the origin principle. This analysis has been extended to include trade costs (Haufler, Schjelderup and Stahler (2000)), product differentiation (Haufler and Pfluger (2004), and Hashimzade, Khovadaisi and Myles (2005)), country characteristics and preferences over tax principles (Hashimzade, Khovadaisi and Myles (2011)). There is an extensive literature that compares destination- and origin-based commodity taxes. Lockwood (2001) presents an excellent unified account of the early literature.

With the risk of oversimplification, a common theme emerging from the contributions that have explicitly considered *local* public goods (either within a perfectly or imperfectly competitive environment) is that tax harmonization might be more difficult to deliver Pareto improvements in the presence of such goods. While this is generally true (and will be re-confirmed by the analytics here), it does not mean that tax harmonization is a bad policy. To the contrary, tax harmonization—combined with an appropriate way of allocating revenues—may be (and indeed it will be shown to be) a potentially Pareto improving fiscal policy.

An earlier contribution that discusses the implications for tax competition and inefficiency in public good provision in the context of global public goods is Bjorvatn and Schjelderup (2002). They show that—in the canonical model of capital tax competition (with perfectly competitive goods and factors markets)—international spillovers from public goods reduce tax competition. Like Bjorvatn and Schjelderup (2002), the analysis here considers global public goods. Unlike that contribution, however, the focus here is not (directly) on tax competition but on harmonization of taxes. This is, clearly, an important (and general) perspective capturing the element of the policy concern that relates directly to cooperative policy.

3 A simple model

The issues identified in the preceding discussion will be addressed within an imperfectly competitive environment. The reason for this is that most markets are neither too small, so to effectively take the market price as given, nor there are many cases of private-sector firms without any competition. The predominant market form is oligopoly.

The model is that of Kotsogiannis and Lopez-Garcia (2007), extended to allow for non-linear demand and cost functions, and it has also been appropriately modified to deal with *global* public goods. The world consists of two countries called 'home' and 'foreign' (variables pertaining to the foreign country being indicated by an asterisk) with a single representative consumer residing in each. Each country produces two tradeable goods. The first one is produced under constant returns to scale by a perfectly competitive firm that uses a single factor of production that is fixed in supply (and suppressed from the analysis). This good is untaxed and taken as the numeraire in both countries. The second good is homogenous and produced by a single firm in each country. The consumer price for this good in the home (foreign) country is denoted by Q (Q^*). Demand for this good in the home (foreign) country is denoted by[12]

$$D(Q)\ (D^*(Q^*)) \quad \text{with} \quad D'(Q) < 0\ (D^{*\prime}(Q^*) < 0)\ . \tag{1}$$

Both firms have nonlinear cost structures given by

$$C(X)\ (C^*(X^*)) \quad \text{with} \quad C'(X) > 0\ \ (C^{*\prime}(X^*) > 0) \quad \text{and} \quad C''(X) \geq 0\ (C^{*\prime\prime}(X^*) \geq 0)\ , \tag{2}$$

where X (X^*) is the quantity produced by the home (foreign) firm.

The tradeable good may be supplied by the firm of either the home or the foreign country. The implication of this is that either country can be an exporter or importer. Market clearing for the world requires that

$$D + D^* = X + X^*\ . \tag{3}$$

Events in the model unfold in the following stages. In stage one, governments set taxes. As noted earlier, the analysis will not restrict attention to a particular tax equilibrium, but will seek to characterize the welfare implications of tax-harmonization starting from any tax-distorting equilibrium. Because of this, the type of conjectures held by the governments will be left unspecified. In stage two, and given taxes, firms make their production decision holding Nash conjectures against each other. Then profits, tax revenues and utilities are realized.

[12]Derivatives are denoted by primes.

4 Destination principle of taxation

Under the destination principle of taxation, arbitrage requires that producer prices across countries are equalized. Denoting the international price by P, consumer prices are then given by

$$Q = P + t_d \quad ; \quad Q^* = P + t_d^* \,, \tag{4}$$

where t_d (t_d^*) is the specific tax rate on consumption in the home (foreign) country. Profits for the home country firm, denoted by Π, and for the foreign country firm, denoted by Π^*, are given, respectively, by

$$\Pi = PX - C(X) \quad ; \quad \Pi^* = PX^* - C^*(X^*) \,. \tag{5}$$

The revenues obtained from taxing the demand of the tradeable good in each country are used to provide a non-tradeable public good, denoted by G (G^*) in the home (foreign) country. These goods are termed *global* public goods and both have the characteristic of being 'pure' in the Samuelson sense: That is, the enjoyment of the public good by the citizen in the home (foreign) country does not diminish its availability for the citizen in the foreign (home) country. The use of unrequited transfers (in terms of the numeraire good) between governments will be initially assumed away and introduced only when required. Given that t_d (t_d^*) and $D(D^*)$ are the destination-based tax and demand in the home (foreign) country, respectively, public good provision in the two countries is given by[13]

$$G = t_d D \quad ; \quad G^* = t_d^* D^* \,. \tag{6}$$

The per-unit cost of public good in both countries is fixed and, for simplicity, normalized to be equal to 1.[14]

The private goods are perfect substitutes and so, for given destination-based taxes t_d and t_d^*, the world price P depends only on the world production $X + X^*$. Substituting (4) into (1) and that into (3) one obtains

$$P\left(X + X^*\right) \,, \tag{7}$$

[13]Of course, different public goods require a different modeling framework. Here it is taken that the global public goods affect the utility of consumers and not the production capabilities of firms.

[14]Notice that the analysis is not concerned with which country will provide the public good. What it is concerned with is whether, given that countries provide global public goods, tax harmonization can deliver a potential Pareto improvement. In this context, the assumption that both countries are equally efficient in the production of global public goods is not a restrictive one.

with, in particular, following from (3),

$$P' = (D' + D^{*\prime})^{-1} < 0 \ , \tag{8}$$

where the inequality follows from the property of the demand functions in (1).

Firms maximize profits, taking the fiscal instruments of the two countries as given, with—following from (5) and (7)—setting marginal revenue equal to marginal cost[15]

$$P + P'X = C' \ , \tag{9}$$

$$P + P'X^* = C^{*\prime} \ . \tag{10}$$

Profits in each country are assumed to accrue to the representative consumer of that country and so indirect utility in the home and foreign country is, respectively, of the form

$$V(Q, \Pi, G, G^*) = CS(Q) + \Pi + \Gamma(G, G^*) \quad ; \quad V^*(Q^*, \Pi^*, G^*, G) = CS^*(Q^*) + \Pi^* + \Gamma^*(G^*, G) \ , \tag{11}$$

where $CS(Q)$ ($CS^*(Q^*)$) is the consumer's surplus (the utility obtained from purchasing the private good at price Q (Q^*)), and $\Gamma(G, G^*)$ ($\Gamma^*(G^*, G)$) is the utility from global public goods in the home (foreign) country.[16] Notice also that (11) does not place any restriction on the relationship between G and G^*, and, therefore, the model allows for the possibility that the two public goods are complements in consumption (and so total consumption matters) in the sense that $\Gamma(G + G^*)$ or that the two countries provide two distinctively different public goods (with utility being $\Gamma(G, G^*)$).

Attention now turns to the tax-harmonizing reforms.

Destination-based tax-harmonizing reforms

The theoretical literature referred to in Section 2 has looked primarily at tax-harmonizing reforms that feature a convergence of the initial taxes towards a common target-tax, with

[15]Second order conditions are assumed to hold. Appendix A discusses, though briefly, issues related to the stability of the equilibrium in the Cournot competition stage of the model.

[16]The underlying assumption here is that utility is additively separable between the (sub)utility from private and public goods, with the (sub)utility function associated with private goods being quasi-linear (with the linear part being the utility derived from the consumption of the numeraire good).

the target-tax being an average of the initial taxes. The destination-based tax reform, in the present context, takes the form

$$\left[\begin{array}{c} dt_d \\ dt_d^* \end{array}\right] = \delta \left[\begin{array}{c} \psi\left(H_d - t_d\right) \\ \psi^*\left(H_d - t_d^*\right) \end{array}\right] , \tag{12}$$

where δ is a small positive number and $\psi,\ \psi^*$ are arbitrary but positive numbers. The target-tax H_d is a weighted average of the existing tax structures—where the weights depend upon the local demand responses D' and $D^{*\prime}$—and is given by[17]

$$H_d = \frac{\psi D'}{\psi D' + \psi^* D^{*\prime}} t_d + \frac{\psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} t_d^* \, . \tag{13}$$

Making use of (13) in (12), the change in the tax rates required by harmonization is given by

$$dt_d = \frac{\delta \psi \psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} \left(t_d^* - t_d\right) , \tag{14}$$

$$dt_d^* = -\frac{\delta \psi \psi^* D'}{\psi D' + \psi^* D^{*\prime}} \left(t_d^* - t_d\right) , \tag{15}$$

which imply that

$$D' dt_d = -D^{*\prime} dt_d^* \, . \tag{16}$$

Equations (14)-(16) have an interesting implication. They imply that (a claim shown in Appendix A) the international price P, and so the world supply of the tradeable good $X + X^*$, remain unchanged (and so does world demand). It is, thus, intuitive that, in this case, the welfare consequences of tax harmonization will depend upon the distortion imposed on world consumer surplus as well as the revenue impact (appropriately weighted by the marginal valuation of the global public goods) of tax harmonization.

To see this perturb (11) and add to its foreign counterpart to obtain, after using (16) and the fact that the reforms imply $dP = dX = dX^* = 0$,

$$\begin{aligned} dV + dV^* = {} & \left[\left(\Gamma_G + \Gamma_G^* - 1\right)\left(Q/e + t_d\right) - \left(\Gamma_{G^*}^* + \Gamma_{G^*} - 1\right)\left(Q^*/e^* + t_d^*\right) - \left(t_d^* - t_d\right)\right] \\ & \frac{\delta \psi D' \psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} \left(t_d^* - t_d\right) , \end{aligned} \tag{17}$$

where $e = D'Q/D$ ($e^* = D^{*\prime}Q^*/D^*$) denotes the home (foreign) country's price elasticity of demand.

[17]It has to be noted that the tax-harmonizing reform in (12) is more general than the one that has frequently appeared in the literature, and in particular in Keen (1987, 1989). The generality here stems from the fact that the convergence of taxes is not uniform but it is weighted by ψ and ψ^*. Notice also that the weights of the target-tax H_d, given by $\psi D'/\left(\psi D' + \psi^* D^{*\prime}\right)$ and $\psi^* D^{*\prime}/\left(\psi D' + \psi^* D^{*\prime}\right)$, are—following from the fact that $D', D^{*\prime} < 0$ and $\psi, \psi^* > 0$—strictly positive.

Condition (17) shows that the welfare consequences of tax harmonization, starting from any tax-distorting equilibrium, depend upon the *balance* of three terms.

The first term in (17), and given by $(\Gamma_G + \Gamma_G^* - 1)(Q/e + t_d)$, gives the impact of the tax-harmonizing reforms on world welfare, an impact that depends on the deviation of the home country's global public good provision from the Samuelson rule (weighted by $Q/e + t_d$, an expression that relates to the change in the home country's tax revenues). The second term, given by $(\Gamma_{G^*}^* + \Gamma_{G^*} - 1)(Q^*/e^* + t_d^*)$, gives, too, the impact of the tax-harmonizing reforms on global welfare, an impact that depends on the deviation of the foreign country's public good provision from the Samuelson rule (weighted by $Q^*/e^* + t_d^*$, which relates to the change in the foreign country's revenues). The third term, given by $t_d^* - t_d$, is not related to global public good provision but gives the (difference in the) change of deadweight loss, for given international price, due the change in consumer prices in both countries (as a consequence of tax harmonization).

Close inspection of the terms identified in the preceding paragraph shows that their balance—and so the existence of potential Pareto improvements—cannot be easily established. The difficulty arises from the first and second terms, which capture the revenue impact of the change in the tax bases in the two countries, as a consequence of tax harmonization. And these are terms that the tax-harmonizing reforms are not designed to account for.[18]

One natural benchmark case to consider is that in which (the global) public goods are provided according to the (modified) Samuelson rule and so $\Gamma_G + \Gamma_G^* = 1$ for the home country and $\Gamma_{G^*}^* + \Gamma_{G^*} = 1$ for the foreign country. This is clearly an extreme case, and to some extent implausible, but it does transparently remove effects arising from the inefficiencies in global public good provision in the two countries. In this case (17) reduces to

$$dV + dV^* = -(t_d^* - t_d)^2 \frac{\delta \psi D' \psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} > 0 \,, \tag{18}$$

and so it is only the impact of the tax-harmonizing reform on global deadweight loss that matters for welfare. This has some straightforward intuition. Since the tax-harmonizing reforms imply that the home country (but also the world supply of) production (and so

[18]It can be shown that, in general, reforms that deliver potential Pareto improvements do exist. It is the identification of these reforms, however, that is the difficult task. On this see Karakosta (2009).

the international price of the tradeable good) remains constant at the pre-reform level, tax harmonization implies that there is no change in profits and so in utility. What is left, therefore, is the change in the deadweight loss from consumption. But this confers an unambiguous gain to consumers. The reason for this is that, with the world price of the tradeable good being unchanged, global deadweight loss is reduced by convergence of taxes towards a weighted average of the initial taxes.[19] To emphasize:

Proposition 1 *With taxes being levied under the destination principle and public goods being global, starting from any tax-distorting equilibrium in which* $t_d^* \neq t_d$*, the tax-harmonizing reforms in (12) and (13) deliver a potential Pareto improvement if both countries follow the (modified for the case of global public goods) Samuelson rule of global public good provision.*

In one sense, this result strengthens the argument in favor of tax harmonization. But it is the explicit recognition that the level of global public good provision will in general differ from that required by the Samuelson rule that ought to concern us. This concern, however, it will be emphasized shortly, will reinforce the view for the need of a proper role of a simple form of intergovernmental transfers.[20]

Suppose now that there exist unrequited transfers between governments that can be optimally set at a stage before tax harmonization takes place.[21] In this case, it can be straightforwardly verified that maximization of (17) implies that[22]

$$\Gamma_G + \Gamma_G^* = \Gamma_{G^*} + \Gamma_{G^*}^* \equiv E_d \ , \tag{19}$$

[19]This is the exact analogue of Kotsogiannis and Lopez-Garcia (2007), carrying over unchanged to the case in which tax revenues finance global public goods.

[20]And in particular so within the European Union where this particular form of tax harmonization has been central in policy discussions during the last two decades.

[21]These transfers can be rationalized by assuming that there is some intervention of some outside agency (for example, a supranational government). While this agency can make use of such transfers (in an optimal sense and satisfying its budget constraint), it cannot decide on tax issues. This, in some sense, is consistent with the workings of the European Union: While European Union decision-making on tax matters requires unanimity (implying that tax-harmonization will only be implemented if it delivers a potential Pareto improvement, a requirement imposed in the present analysis) intergovernmental transfers do not.

[22]To see this, notice that in this case (6) becomes $G = t_d D + B$ for the home country and $G^* = t_d^* D^* - B$ for the foreign (where B denotes unrequited transfers in terms of the numeraire good). Perturbing (17) with respect to B implies that $dV + dV^* = [(\Gamma_G + \Gamma_G^*) - (\Gamma_{G^*} + \Gamma_{G^*}^*)]\, dB$ which, upon setting equal to zero, gives (19).

and so, as one would expect, the marginal valuations for the global public goods are equalized.[23] In this case (17) reduces to

$$dV + dV^* = (E_d - 1)\, d\,(G + G^*) - (t_d^* - t_d)^2 \, \frac{\delta \psi D' \psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} \ , \tag{20}$$

where $d\,(G + G^*)$ denotes the change in global revenues as a consequence of tax harmonization given by

$$d\,(G + G^*) = [(Q/e + t_d) - (Q^*/e^* + t_d^*)] \, \frac{\delta \psi D' \psi^* D^{*\prime}}{\psi D' + \psi^* D^{*\prime}} \, (t_d^* - t_d) \ . \tag{21}$$

(20)—together with (21)—shows that there is an appealing way of expressing what is required for destination-based tax harmonization to deliver a potential Pareto improvement: All is required is that, conditional on the tax-harmonizing reforms, the direction of under/over provision of global public good provision (relative to the Samuelson rule) takes the same sign as the direction of the change in global tax revenues: If global public goods are under-provided (over-provided) relative to the Samuelson rule, in the sense that $E_d > 1$ ($E_d < 1$), and also, following from (21), $d(G + G^*) > 0$ ($d(G + G^*) < 0$), then $dV + dV^* > 0$ and so tax-harmonization delivers a potential Pareto improvement. There is a simple intuition behind this result. Tax harmonization not only reduces global deadweight loss (the second term in the right-hand-side of (20)) but also changes global tax revenues in such a way that there is an efficiency gain, relative to the Samuelson rule, in global public good provision in the two countries (the first term in the right-hand-side of (20)). Summarizing the preceding discussion:[24]

Proposition 2 *With taxes being levied under the destination principle and public goods being global, starting from any tax-distorting equilibrium in which $t_d^* \neq t_d$, the tax-harmonizing reforms in (12) and (13) deliver a potential Pareto improvement if there exist unrequited transfers that can be optimally set, and the tax-harmonizing reforms are conditional revenue increasing (decreasing) when the global public goods are under-provided (over-provided) relative to the Samuelson rule.*

[23] And to the marginal cost which is equal to 1 in both countries.

[24] Suppose for instance—something that, arguably, seems to be a very restrictive requirement—the reforms are conditional neutral (as in Delipalla (1997)). In this case $d\,(G + G^*) = 0$, implying that the welfare loss of one country (as a consequence of tax harmonization) is exactly offset by the welfare gain of the other. In this case (17) reduces to (18) and so the tax-harmonizing reforms in (12) and (13) deliver a potential Pareto improvement.

Outside this case (and the one emphasized in Proposition 1), it is still possible to identify situations in which the tax-harmonizing reforms deliver a potential Pareto improvement, even *without* the use of unrequited transfers. Suppose, to see this, that $t_d > t_d^*$, that is the home country is the high tax one, and both countries under-provide the global public good—with respect to the Samuelson rule of Proposition 1—in the sense that $\Gamma_G + \Gamma_G^* > 1$ and $\Gamma_{G^*} + \Gamma_{G^*}^* > 1$. Then (12) and (13) entail a potential Pareto improvement whenever $(Q/e + t_d) - (Q^*/e^* + t_d^*) > 0$, a condition that relates to the position of each country on the (own) Laffer curve.[25] This, in turn, results in a revenue gain for both countries which, coupled with the under-provision of the global public goods in both countries, implies that $dV + dV^* > 0$.

Interestingly, the conclusions reached thus far regarding the desirability of tax harmonization hold—again starting from *any* tax-distorting equilibrium—even if governments provide *local* public goods. In the present framework, this will be the case if $\Gamma_G^* = \Gamma_{G^*} = 0$. Unrequited transfers between governments are still needed here in order to equalize the marginal valuation for local public goods consumption (and not internalize global externalities as in the case of global public goods), replacing (19) with $\Gamma_G = \Gamma_{G^*}^* \equiv E_d$. With equalized marginal valuations, the conditions on global revenues identified previously still hold, making sure that the change in global revenues (conditional on the tax-harmonizing reforms) take the appropriate direction, conferring a positive welfare gain. To emphasize:

Corollary 1 *Under the conditions of Proposition 2, the tax-harmonizing reforms in (12) and (13) deliver a potential Pareto improvement when public goods are local in nature.*

We turn now to the case in which products are taxed in the country of origin.

5 Origin principle of taxation

The analysis in the case of origin-based taxation parallels that of the destination-based taxation. To economize on space, we briefly state the necessary modifications of the

[25] This is easily seen from noticing that the slope of the Laffer curve in the home country is given by $d(t_d D)/dt_d = (Q/e + t_d)(De/Q)$. With $De/Q < 0$, $d(t_d D)/dt_d > 0$ (implying that the home country is on the left-hand-side of the Laffer curve) if and only $Q/e + t_d > 0$. (Similarly for the foreign country). For an example that demostrates transparently the existence of potential Pareto improvements under the conditions of Proposition 2 see Appendix C. Examples for Proposition 1 and Corollary 1 are available upon request.

model to deal with this case.

Origin-based taxes are levied by (and revenues accrue to) the country in which the commodity is produced. International arbitrage then dictates that consumer prices across countries are equalized. Denoting the international price of the good by Q and the specific tax in the home (foreign) by t_o (t_o^*), firms maximize

$$\Pi = (Q - t_o)X - C(X) \quad ; \quad \Pi^* = (Q - t_o^*)X^* - C^*(X^*) \; . \tag{22}$$

Making use of (1) and (3) gives the aggregate inverse demand given by

$$Q(X + X^*) \; , \tag{23}$$

with, following from (3),

$$Q' = 1/(D' + D^{*\prime}) < 0 \; . \tag{24}$$

Profits maximization requires

$$Q + Q'X = C' + t_o \quad ; \quad Q + Q'X^* = C^{*\prime} + t_o^* \; . \tag{25}$$

Revenues are used to provide public goods

$$G = t_o X \quad ; \quad G^* = t_o^* X^* \; . \tag{26}$$

Indirect utility is still given by (11). We turn now to a discussion of origin-based tax-harmonizing reforms and to a search of potential Pareto improvements.

Origin-based tax-harmonizing reforms

Under the origin principle the tax-harmonizing reform is

$$\left[\begin{array}{c} dt_o \\ dt_o^* \end{array} \right] = \delta \left[\begin{array}{c} \psi \left(H_o - t_o \right) \\ \psi^* \left(H_o - t_o^* \right) \end{array} \right] \; , \tag{27}$$

where δ is a small positive number, ψ, ψ^* are arbitrary positive numbers and H_o—the common target for the taxes—is given by

$$H_o = \left[\frac{\psi A^*}{\psi A^* + \psi^* A} \right] t_o + \left[\frac{\psi^* A}{\psi A^* + \psi^* A} \right] t_o^* \; , \tag{28}$$

where

$$A = Q' - C'' < 0 \quad ; \quad A^* = Q' - C^{*\prime\prime} < 0 \; , \tag{29}$$

with the inequality sign following from the fact that $Q' < 0, C'', C^{*\prime\prime} \geq 0$. Interestingly, the (strictly positive) weights attached to the origin-based taxes in (28) depend upon both demand, through (24), and supply responses. Following from (27) and (28), it is the case that

$$dt_o = \frac{\delta\psi\psi^* A}{\psi A^* + \psi^* A}(t_o^* - t_o) \quad ; \quad dt_o^* = -\frac{\delta\psi\psi^* A^*}{\psi A^* + \psi^* A}(t_o^* - t_o) \; , \tag{30}$$

and so[26]

$$\frac{1}{A}dt_o = -\frac{1}{A^*}dt_o^* \; . \tag{31}$$

Notice that (a claim shown in Appendix B) the implication of (31) is that world-consumer price, Q, is unaffected, and as a consequence both countries' demands are unaffected, too.

Perturbing now (11) and adding to its foreign analogue—after using (30)—one obtains

$$\begin{aligned} dV + dV^* \;\; = \;\; & \left[\left(\Gamma_G + \Gamma_G^* - 1\right)\left(t_o + AX\right) - \left(\Gamma_{G^*}^* + \Gamma_{G^*} - 1\right)\left(t_o^* + A^* X^*\right) + \left(C^{*\prime} - C'\right)\right] \\ & \frac{\delta\psi\psi^*}{\psi A^* + \psi^* A}(t_o^* - t_o) \; . \end{aligned} \tag{32}$$

The level of generality of (32)—as was the case under the destination principle of taxation—posses a significant problem in the attempt to evaluate the welfare consequences of the origin-based tax-harmonizing reforms in (27) and (28). In this case too, however, there are instances in which the reforms, starting from any tax-distorting equilibrium $t_o^* \neq t_o$, attain a potential Pareto improvement.

One such instance is when global public good provision follows the (modified) Samuelson rule in both countries (in the sense that $\Gamma_G + \Gamma_G^* = 1$ and also $\Gamma_{G^*}^* + \Gamma_{G^*} = 1$). In this case (32) reduces to

$$dV + dV^* = \left(C^{*\prime} - C'\right)\frac{\delta\psi\psi^*}{\psi A^* + \psi^* A}(t_o^* - t_o) \; . \tag{33}$$

Inspection of (33) reveals that the origin-based tax-harmonizing reform is potentially Pareto improving whenever $C^{*\prime} - C'$ has the opposite sign of $t_o^* - t_o$ that is, if and only if the high tax country is also the country with the lower marginal cost of producing the tradeable good. There is some straightforward intuition behind this. Notice that, as

[26]This is in contrast to the linear demand and constant marginal cost case analyzed in Kotsogiannis and Lopez-Garcia (2007) where the weights A and A^* in (31) vanish leaving $dt_o = -dt_o^*$.

already noted, the tax-harmonizing reforms ensure that the world consumer price remains at the pre-reform level and as a consequence the demands in both countries remain unchanged. What changes, as a consequence of tax harmonization, is the production pattern of the tradeable good across the two countries. Suppose, that, without loss of generality, $t_o^* > t_o$ and so it is the foreign country that is the high tax one. In this case, following (33), $dV + dV^* > 0$ if and only if the foreign country is the country that produces the tradeable good more efficiently, in the sense that $C' > C^{*\prime}$. Since tax harmonization calls for a reduction in t_o^* (and an increase in t_o), what effectively the tax reform does is to reallocate production from the home country (the inefficient one) to the foreign country (the efficient one). To emphasize:

Proposition 3 *With taxes being levied under the origin principle and public goods being global, starting from any tax-distorting equilibrium in which $t_o^* \neq t_o$, the tax-harmonizing reforms in (27) and (28) deliver a potential Pareto improvement if both countries follow the (modified for the case of global public goods) Samuelson rule of global public good provision and sign$[C^{*\prime} - C'] =$sign$[t_o - t_o^*]$ (that is, if the country with the inefficient firm is also the low tax country).*

Outside the case emphasized by Proposition 3 (and the more general cases identified shortly below) inefficiencies from global public good provision will still linger making the welfare effects of tax harmonization indeterminate. A policy that improves this, as noted earlier for the destination case, is the use of unrequited transfers that can be optimally set—implying that $\Gamma_G + \Gamma_G^* = \Gamma_{G^*} + \Gamma_{G^*}^* \equiv E_o$—but also the tax-harmonizing reforms to satisfy a condition on global revenue change whose sign is in accordance with the under-provision/over-provision of global public goods, relative to the Samuelson rule. To identify these rewrite (32) as

$$dV + dV^* = (E_o - 1)\, d\,(G + G^*) + (C^{*\prime} - C')\, \frac{\delta\psi\psi^*}{\psi A^* + \psi^* A}(t_o^* - t_o)\ , \tag{34}$$

where

$$d\,(G + G^*) = [(t_o + AX) - (t_o^* + A^* X^*)]\, \frac{\delta\psi\psi^*}{\psi A^* + \psi^* A}(t_o^* - t_o)\ . \tag{35}$$

Thus, it is the case that $dV + dV^* > 0$ if the change in global tax revenues (conditional on the reforms) $d\,(G + G^*)$ takes the sign of $E_o - 1$ but also $C^{*\prime} - C'$ takes the opposite sign of $t_o^* - t_o$. Summarizing:

Proposition 4 *With taxes being levied under the origin principle and public goods being global, starting from any tax-distorting equilibrium in which the country with the inefficient firm is also the low tax country, the tax-harmonizing reforms in (27) and (28) deliver a potential Pareto improvement if there exist unrequited transfers that can be optimally set, and the tax-harmonizing reforms are conditional revenue increasing (decreasing) when the global public goods are under-provided (over-provided) relative to the Samuelson rule.*

Outside the cases emphasized in Propositions 3 and 4, it is still possible (as with the destination principle) to identify situations in which the tax-harmonizing reform delivers a potential Pareto improvement even *without* recourse to unrequited transfers. To see this, suppose that $t_o^* > t_o$ and $C^{*\prime} < C^{\prime}$—that is it is the foreign country that is both the high tax and the most efficient one—and both countries under-provide the global public good—with respect to the Samuelson rule of Proposition 3—in the sense that $\Gamma_G + \Gamma_G^* > 1$ and $\Gamma_{G^*} + \Gamma_{G^*}^* > 1$. Then, the tax-harmonizing reforms in (27) and (28) deliver a potential Pareto improvement whenever $(t_o + AX) - (t_o^* + A^*X^*) < 0$, a condition that, as before, relates to the relative positions of the two countries on own Laffer curve. The implication of the tax-harmonizing reform, then, is that it decreases (increases) the tax rate of the high (low) tax country, which is also the country for which the marginal effect on revenue is sufficiently large. This implies that both countries gain in revenues and, therefore, in global public good provision.[27]

Tax harmonization is also desirable—again starting from *any* tax-distorting equilibrium—even if governments provide *local* public goods. The reason is as before: Unrequited transfers between governments are needed in order to equalize the marginal valuations from local public good consumption (and not internalize global externalities as in the case of global public goods), replacing (19) with $\Gamma_G = \Gamma_{G^*}^* \equiv E_o$. With equalized marginal valuations, the conditions on global revenues identified previously still hold, making sure that the change in global revenues (conditional on the tax-harmonizing reforms) takes the appropriate direction, conferring a positive welfare gain. It is, thus, the case that:

Corollary 2 *Under the conditions of Proposition 4, the tax-harmonizing reforms in (27)*

[27]Appendix C develops and an example that demostrates the existence of potential Pareto improvements under the conditions of Proposition 4. Examples for Proposition 3 and Corollary 2 exist and are available upon request.

and (28) deliver a potential Pareto improvement when public goods are local in nature.

The results established emphasize that, interestingly, tax harmonization in the presence of public goods deserves more attention than it has typically received. There is certainly pause for thought in the simple fact that a combination of tax harmonization and a proper role for a way to allocate global revenues can increase aggregate welfare.

6 Concluding remarks

This paper has introduced *global* public goods in an imperfectly competitive framework and identified reasonably plausible conditions under which, starting from any tax-distorting equilibrium, destination- and origin-based tax-harmonizing reforms are potentially Pareto improving. The first condition (unrequited transfers between governments) requires that transfers are designed in such a way that the overall gains from the provision of global public goods are distributed among countries, whereas the second one (conditional revenue changes) ensures that any excess revenue gain (or loss) to be had is distributed in accordance with the extent of under-provision/over-provision of global public goods, relative to the Samuelson rule. Under these conditions, tax harmonization results in a potential Pareto improvement. And, interestingly, this is true independently of the tax principle in place (destination or origin).

One can certainly question the feasibility of optimal unrequited transfers (more than the requirement for conditional revenue changes) that redistributes the gains of tax harmonization.[28] Though this appears certainly to be an unwanted additional fiscal instrument that works independently of tax harmonization, it is something that multi-country fiscal systems (like the European Union) cannot dispense with. For, given the tax base asymmetries that exist between the coordinating countries, there is always a need for allocating resources between them efficiently. In fiscal federal systems—like, for example, Canada—such reallocation of revenues takes place via intergovernmental transfers between governments that accounts for the deviation of a jurisdictional unit's tax base from the national tax base. The system of allocation of revenues between governments adopted here is the simplest one that one can think of, thereby increasing the attractiveness of tax-harmonization.

[28]It is nevertheless—as noted in the introductory section—used widely in the literature.

What is, thus, important, is that one does not take a negative view of tax harmonization. To the contrary, as the analysis has shown here, careful fiscal policy can harness the strengths of tax harmonization for the social good.

Appendices

Appendix A

Proof of the statement that the reform in (12) and (13) implies that $dP = dX = dX^* = 0$.

Re-write, for convenience, the market clearing condition in (3) and the first order conditions in (9) and (10) given by, respectively,

$$D + D^* = X + X^* , \tag{A.1}$$

$$P'X + P = C' , \tag{A.2}$$

$$P'X^* + P = C^{*\prime} . \tag{A.3}$$

Equations (A.1)-(A.3) define the equilibrium of output and the world producer price of the tradeable good. Notice that sufficiency for the choice of X and X^* requires, respectively, that

$$\Pi_{XX} \equiv \alpha_d = 2P' + XP'' - C'' < 0 , \tag{A.4}$$

and

$$\Pi^*_{X^*X^*} \equiv \alpha^*_d = 2P' + X^*P'' - C^{*\prime\prime} < 0 . \tag{A.5}$$

It is also assumed that

$$\Pi_{XX^*} \equiv \beta_d = P' + XP'' < 0 , \tag{A.6}$$

$$\Pi^*_{X^*X} \equiv \beta^*_d = P' + X^*P'' < 0 , \tag{A.7}$$

and so the firms' best response functions are downward sloping in quantity space. Stability of equilibrium (in the Cournot stage) requires that

$$\Delta_d = \alpha_d\alpha^*_d - \beta_d\beta^*_d > 0 . \tag{A.8}$$

Perturbation (abusing notation somewhat) of (A.1)-(A.3)—after using the fact that, following from the demand functions, $dD = D'\left(dP + dt_d\right)$ $\left(dD^* = D^{*\prime}(dP + dt^*_d)\right)$, but also that $P' = \left(D' + D^{*\prime}\right)^{-1}$—gives in matrix form

$$\begin{bmatrix} 1 & -P' & -P' \\ 1 & \alpha_d - P' & \beta_d - P' \\ 1 & \beta^*_d - P' & \alpha^*_d - P' \end{bmatrix} \begin{bmatrix} dP \\ dX \\ dX^* \end{bmatrix} = \begin{bmatrix} -P'D'dt_d - P'D^{*\prime}dt^*_d \\ 0 \\ 0 \end{bmatrix} . \tag{A.9}$$

It can be easily verified that the determinant of the left-hand-side matrix is given by (A.8). As is typically the case, without further restrictions on the structure of the model the comparative statics are indeterminate. This, in the present context, is not

problematic: All that is required here is that the comparative statics are 'well defined' in the sense that the coefficients of the components of $D'dt_d + D^{*\prime}dt_d^*$, are non-zero. It is assumed this to be the case. Solving the system of equations in (A.9) for dP, dX and dX^* one obtains

$$dP = -P' \frac{\Delta_d - P' \left[(\alpha_d + \alpha_d^*) - (\beta_d + \beta_d^*) \right]}{\Delta_d} \left(D'dt_d + D^{*\prime}dt_d^* \right) , \tag{A.10}$$

$$dX = \frac{(\alpha_d^* - \beta_d) P'}{\Delta_d} \left(D'dt_d + D^{*\prime}dt_d^* \right) , \tag{A.11}$$

$$dX^* = \frac{(\alpha_d - \beta_d^*) P'}{\Delta_d} \left(D'dt_d + D^{*\prime}dt_d^* \right) . \tag{A.12}$$

Close inspection of (A.10) reveals that if $D'dt_d + D^{*\prime}dt_d^* = 0$, then, $dP = dX = dX^* = 0$. □

Appendix B

Proof of the statement that the reform in (27) and (28) implies that $dQ = 0$.

Re-write, for convenience, the market clearing condition in (3) and the first order conditions in (25)

$$D + D^* = X + X^* , \tag{B.1}$$

$$Q + Q'X = C' + t_o , \tag{B.2}$$

$$Q + Q'X^* = C^{*\prime} + t_o^* . \tag{B.3}$$

Equations (B.1)-(B.3) define the equilibrium of output and the world consumer price of the tradeable good. Notice that sufficiency for the choice of X and X^* requires, respectively, that

$$\Pi_{XX} \equiv \alpha_o = 2Q' + XQ'' - C'' < 0 , \tag{B.4}$$

and

$$\Pi_{X^*X^*}^* \equiv \alpha_o^* = 2Q' + X^*Q'' - C^{*\prime\prime} < 0 . \tag{B.5}$$

It is also assumed that

$$\Pi_{XX^*} \equiv \beta_o = Q' + XQ'' < 0 , \tag{B.6}$$

$$\Pi_{X^*X}^* \equiv \beta_o^* = Q' + X^*Q'' < 0 , \tag{B.7}$$

and so the firms' best response function are downward sloping in quantity space. Stability of equilibrium (in the Cournot stage) requires that

$$\Delta_o = \alpha_o\alpha_o^* - \beta_o\beta_o^* > 0 . \tag{B.8}$$

Perturbing now (B.1)-(B.3) gives (again abusing notation somewhat) in matrix form

$$\begin{bmatrix} 1 & -Q' & -Q' \\ 1 & \alpha_o - Q' & \beta_o - Q' \\ 1 & \beta_o^* - Q' & \alpha_o^* - Q' \end{bmatrix} \begin{bmatrix} dQ \\ dX \\ dX^* \end{bmatrix} = \begin{bmatrix} 0 \\ dt_o \\ dt_o^* \end{bmatrix} . \tag{B.9}$$

Solving the system of equations in (B.9) for dQ, dX and dX^* one obtains

$$dQ = \frac{Q'}{\Delta_o} \left[(\alpha_o^* - \beta_o^*)\, dt_o + (\alpha_o - \beta_o)\, dt_o^* \right] , \tag{B.10}$$

$$dX = \frac{1}{\Delta_o} \left(\alpha_o^* dt_o - \beta_o dt_o^* \right) , \tag{B.11}$$

$$dX^* = -\frac{1}{\Delta_o} \left(\beta_o^* dt_o - \alpha_o dt_o^* \right) . \tag{B.12}$$

Since

$$\alpha_o^* - \beta_o^* = Q' - C^{*\prime\prime} \equiv A^* , \tag{B.13}$$

and

$$\alpha_o - \beta_o = Q' - C'' \equiv A , \tag{B.14}$$

it is the case that, following from (31), the origin-based tax-harmonizing reforms imply that $dQ = 0$. □

Appendix C

Destination principle: Numerical example based on Proposition 2.

To simplify matters, suppose that both demands and costs functions are linear and given, respectively, by

$$D = a - \beta Q \quad ; \quad D^* = a^* - \beta^* Q^* \,, \tag{C.1}$$

$$C = cX \quad ; \quad C^* = c^* X^* \tag{C.2}$$

and so

$$P' = -\left(\beta + \beta^*\right)^{-1}, \tag{C.3}$$

and the utility the consumer derives from global public goods in the home (foreign) country is $\Gamma(G, G^*)$ ($\Gamma^*(G^*, G)$). It can be easily shown, in this case, that (A.10)-(A.12) reduce to, respectively,

$$dP = -(b/3)\left(\beta dt_d + \beta^* dt_d^*\right) \,, \tag{C.4}$$

$$dX = dX^* = -(1/3)\left(\beta dt_d + \beta^* dt_d^*\right) \,, \tag{C.5}$$

and that, by making use of,

$$dD = -\beta\left(dP + dt_d\right) \quad ; \quad dD^* = -\beta^*\left(dP + dt_d^*\right), \tag{C.6}$$

perturbation of the home country utility function in (11) gives

$$\begin{aligned} dV = {} & \frac{b\beta}{3}\left[D - 2X + \frac{3}{b\beta} D\left(\Gamma_G - 1\right) - \left(2\beta + 3\beta^*\right)\Gamma_G t_d + \beta^* \Gamma_{G^*} t_d^*\right] dt_d \\ & + \frac{b\beta^*}{3}\left[D - 2X + \beta \Gamma_G t_d + \frac{3}{b\beta^*}\Gamma_{G^*} D^* - \left(2\beta^* + 3\beta\right)\Gamma_{G^*} t_d^*\right] dt_d^* \,. \end{aligned} \tag{C.7}$$

(An analogous condition applies to the foreign country). Non-cooperative taxes (denoted by the subscript N) are given by setting the derivative of (C.7) with respect to t_d equal to zero, that is

$$t_d^N = \frac{\left[\left(2\beta^* + 3\beta\right)\Gamma_{G^*}^* \left[b\beta\left(D - 2X\right) + 3D\left(\Gamma_G - 1\right)\right] + \beta\Gamma_{G^*}\left[b\beta^*\left(D^* - 2X^*\right) + 3D^*\left(\Gamma_{G^*}^* - 1\right)\right]\right]}{\beta b\left[\left(2\beta^* + 3\beta\right)\Gamma_{G^*}^*\left(2\beta + 3\beta^*\right)\Gamma_G - \beta^*\Gamma_{G^*}\beta\Gamma_G^*\right]} \,, \tag{C.8}$$

(a similar expression holds for t_d^*).

Suppose now that the demand parameters are $a = 10$ $a^* = 9$, $\beta = 1.2$, $\beta^* = 1.3$, the marginal utilities of the public goods are $\Gamma_G = 1.9$, $\Gamma_{G^*} = 1.2$, $\Gamma_G^* = 1.1$, $\Gamma_{G^*}^* = 1.8$— implying that $\Gamma_G + \Gamma_G^* = 3 = \Gamma_{G^*} + \Gamma_{G^*}^* > 1$ (and so global public goods are under-

provided with respect to the Samuelson rule)—the costs are $c = 5 > c^* = 4$, and the reform parameters are given by $\psi = 1 = \psi^*$ and $\delta = 1$.

It is the case that (computation performed with MAPLE v12—and all numbers have been rounded to two decimal points) $D = 2.25$, $D^* = 1.63$, $P = 5.28$, $X = 0.69$, $X^* = 3.19$ and $t_d^N = 1.18$, $t_d^{*N} = 0.39$ (and so it is the home country that is the high tax country). Adding (C.7) and its foreign counterpart gives $dV + dV^* = 0.56 > 0$ and so tax harmonization is welfare improving. It is easy also to verify that (following (21)) $d(G + G^*) = 0.09$ (with $(Q/e + t_d) - (Q^*/e^* + t_d^*) = 0.17 > 0$).

Origin principle: Numerical example based on Proposition 4.

Following the same steps as above it is the case that

$$dQ = (1/3)(dt_o + dt_o^*) , \tag{C.9}$$

$$dX = (1/3b)(dt_o^* - 2dt_o) , \tag{C.10}$$

$$dX^j = (1/3b)(dt_o - 2dt_o^*) . \tag{C.11}$$

Perturbing (11) the non-cooperative origin-based tax in the home country is given by

$$t_o^N = \frac{1}{(4\Gamma_G\Gamma_{G^*}^* - \Gamma_{G^*}\Gamma_G^*)}\left[2\Gamma_{G^*}^* b\left[(-4X - D) + 3\Gamma_G X\right] + b\Gamma_{G^*}\left[(-4X^* - D^*) + 3\Gamma_{G^*}^* X^*\right]\right] , \tag{C.12}$$

(an analogous condition holds for the foreign country).

Suppose now that demand parameters are $a = 20$, $a^* = 14$, $\beta = 1.8$, $\beta^* = 1.9$, the marginal utilities of the public goods are $\Gamma_G = 1.7$, $\Gamma_{G^*} = 1.6$, $\Gamma_G^* = 1.8$, $\Gamma_{G^*}^* = 1.9$, whereas the costs are $c = 2 > c^* = 1$, and the reform parameters $\psi = 1, \psi^* = 1, \delta = 1$. Then it is the case that $D = 12.11$, $D^* = 5.67$, $Q = 4.38$, $X = 8.28$, $X^* = 9.50$, and $t_o^{*N} = 0.81 > t_o^N = 0.14$ (so the foreign country is the high tax one). Then, in this case, $dV + dV^* = 2.29 > 0$, (with $dG + dG^* = 0.42$, and $(t_o + AX) - (t_o^* + A^*X^*) = -0.34 < 0$). □

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