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Abstract

Some governments have recently called for international accords restricting the use of preferential taxes targeted to attract mobile tax bases from abroad. Are such agreements likely to discourage tax competition or conversely cause it to spread? We study a general model of competition for multiple tax bases and establish conditions for a restriction on preferential regimes to increase or decrease tax revenues. Our results show that restrictions are most likely to be desirable when tax bases are on average highly responsive to a coordinated increase in tax rates by all governments, and when tax bases with large domestic elasticities are also more mobile internationally. Our analysis allows us to reconcile the apparently contradictory results, derived from analyzing special cases, of the previous literature.

JEL Classification: H21, H73.

Keywords: preferential taxation, tax competition, multiple tax bases.

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1 Introduction

Governments often appear to target business tax relief to attract investment from abroad, while maintaining higher taxes on immobile investment. These preferential tax arrangements take many forms, including sectoral differences in corporation income tax rates, selective investment tax credits and tax holidays, income tax measures that are "ring-fenced" (i.e. unavailable to domestic taxpayers), and so on. For example, Ireland's low corporate tax rate for manufacturing and financial services is often identified as a primary reason for its success in attracting foreign direct investment in the past decade. Similarly, recent proposals in Germany and elsewhere to cut corporate tax rates relative to top personal rates reflect in part the view that much corporate income is mobile internationally, while income of unincorporated businesses (subject to personal rates) is not.[1]

These tax measures have emerged in response to increased mobility of some forms of capital and increased international competition for these bases. Recently, international organizations have attempted to define international standards for capital taxation as a means to control tax competition. The OECD (1998, 2000), for example, has developed guidelines for eliminating "harmful tax competition" among member nations, and is directing its efforts as well at persuading non-member states that offer "tax havens" to reform their ways. The guidelines suggest zero-rating of some bases is to be discouraged; likewise, measures aimed at ring-fencing domestic tax base from more mobile international tax bases are strongly deprecated. In the Irish case, pressure from the European Union has led the government to replace its dual-rate structure (10 per cent for manufacturing and financial services, and 24 per cent for other sectors) with a general, lower rate of 12.5 per cent for most forms of corporate income. A similar philosophy pervades thinking about subnational tax competition in federal states. In Canada, the federal government has recently attempted to enforce a common definition of taxable income for the provinces, in an effort to end zero-rating of some income items that are viewed as mobile across provincial boundaries. The goal of this paper is to evaluate the effects of such restrictions on equilibrium tax rates within a general theoretical model of competition among governments for several tax bases.

At first glance, the move to restrict tax preferences appears perfectly sensible. By linking tax policies applied to internationally mobile bases to those applied to less mobile ones, governments would create a "brake" on the tendency to compete tax rates on mobile bases to inefficiently low levels. Tax rates levied on mobile bases would tend to rise, raising

[1] Under the German reform, the corporate tax rate will fall to 25 from 40 per cent, while the top personal rate will be 42 per cent.

equilibrium revenues. On the other hand, tax rates on immobile bases would fall, as the restriction caused the effects of tax competition to spread through the economy. Whether such a restriction would lead to higher revenues overall, therefore, depends the nature of strategic interactions for more and less mobile bases and on the elasticities of the bases. Put differently, it is possible that restrictions on tax competition would simply lead governments to compete through other, less efficient means. In this paper we explore this trade-off and provide a comprehensive analysis of factors which lead restrictions either to increase or decrease revenues.

In so doing, we also seek to reconcile apparently conflicting conclusions of earlier research. Janeba and Peters (1999) study an example in which each of two governments may levy a tax on a domestic base that is immobile internationally and on a base that is perfectly mobile between the two jurisdictions. They show that a complete ban on tax policies that differentiate between the two bases (but which does not restrict the tax rates imposed in either country) raises the equilibrium level of revenue in both countries. On the other hand, Keen (2000) argues that international restrictions on preferential tax regimes may reduce revenues in all countries party to the agreement. Keen studies another example, in which both bases are imperfectly mobile, but the size of each tax base is fixed in the aggregate. In stark contrast to the results of Janeba and Peters, Keen shows in this environment that a prohibition on tax preferences can never increase revenues.[2]

An important contribution of our formal analysis is to derive a general condition that allows us to assess when restrictions on tax preferences are desirable and when they are not. Our general condition is appealing because it depends on very few elasticities: the elasticity of a tax base with respect to a single country's tax rate, with respect to a coordinated tax change, and the derivative of the first elasticity. The condition provides several important insights and has interesting policy implications. First, we show that the results of the previous literature emerge as special cases of our more general model. Secondly, we demonstrate that the case both for and against the restriction of tax preferences is in some sense more general than the previous literature suggests.

In particular, using our approach we are able to show that a restriction of tax preferences can increase revenues even if the difference in international mobility of tax bases is not as extreme as in Janeba and Peters (1999). Some degree of restriction is always desirable if

[2] Our analysis is closely related to the literature on third-degree price discrimination in the theory of industrial organization. Holmes (1989) and Winter (1997) study the effects on profits and consumer welfare of a restriction on price discrimination in a duopoly. Some of our results (in particular Propositions 2 and 4) have close analogues in their work.

the tax base with the lower rate in the uncoordinated equilibrium is sufficiently more mobile internationally than the base with the higher uncoordinated tax rate (Proposition 2). On the other hand, we show that any restriction of tax preferences is harmful if the aggregate tax base does not respond to a coordinated tax change (Proposition 1). This generalizes the finding of Keen (2000). The result however appears not to be particularly robust when aggregate tax bases are elastic. For the central case in which both bases are equally elastic with respect to coordinated tax rate changes, our results suggest some restriction on tax preferences is desirable whenever coordinated elasticities are sufficiently large (Proposition 4). Nevertheless, a complete ban on tax preferences remains undesirable (Proposition 3).

Which of these cases is the most plausible empirically? Certainly, it is reasonable to expect that aggregate tax bases are elastic. In the theoretical literature on tax competition, it is often assumed that aggregate capital supply is fixed and hence aggregate tax bases are perfectly inelastic. But an increase in the overall level of taxation lowers the net return on savings and so may decrease aggregate saving. As well, restrictions on tax preferences are typically contemplated among only a small group of countries. Consequently, an increase in tax rates by parties to the agreement gives investors the option to move their capital elsewhere, reducing the aggregate tax base of member countries. If this leakage effect is strong enough, our results suggest that some restriction on tax preferences to be beneficial. To say more than this requires estimates of the three elasticities, a point which we will discuss in the concluding section.

While our approach is more general than previous ones, we maintain a number of important assumptions from the existing literature. For example, we assume that countries are symmetric and governments maximize tax revenues (like in Keen). The symmetry assumption is made for analytical convenience and represents a good starting point. The revenue maximization assumption, while often used in tax competition models, appears quite restrictive. In an appendix, we show that results under revenue maximization are similar to results under the more standard welfare maximization objective if there is large underprovision of public goods. Another important assumption is that we assume no spillover effects between tax bases. This seems to be a reasonable approximation if we think of tax bases as capital income in different sectors or industries, where effective tax rates may differ due to different depreciation rules or other sector-specific tax provisions. Spillovers are likely to play a bigger role when tax bases represent real and financial capital in one sector, or capital and labor income more generally.

The remainder of the paper has the following structure. Section 2 introduces our model of tax competition with two tax bases and two jurisdictions, and it describes equilibrium tax policies when tax preferences for mobile bases are unrestricted. Section 3 studies the effects of international restrictions on tax preferences, modelled as a parametric limit on the difference in tax rates applied to the two bases. We relate the effects of such restrictions to the elasticities of tax bases with respect to coordinated and unilateral increases in tax rates. We then provide various conditions that are sufficient for restrictions on tax preferences to increase or decrease revenues. Section 4 concludes the paper.

2 Model

Consider a model of two identical countries, labelled "home" and "foreign", which compete for two tax bases. Let $x_i(t_i, T_i)$ denote tax base $i = 1, 2$ for the home country when home and foreign country levy tax rates t_i and T_i respectively; let $X_i(t_i, T_i)$ be the analogous base for the foreign country. Assume that $(t_i, T_i) \in [0, 1]^2$ and tax bases are almost everywhere twice continuously differentiable in tax rates. For each tax base in the home country x_i, we define two elasticities. The elasticity with respect to a unilateral increase in the tax rate of the home country is

$$\epsilon_i^a(t_i) = -\frac{t_i x_{it}(t_i, t_i)}{x_i(t_i, t_i)} \tag{1}$$

while that for a coordinated increase in the tax rates of both countries is

$$\epsilon_i^b(t_i) = -\frac{t_i(x_{it}(t_i, t_i) + x_{iT}(t_i, t_i))}{x_i(t_i, t_i)} \tag{2}$$

(The symbols a and b are intended as mnemonics for "alone" and "both" respectively.) For notational convenience, the elasticities have been defined when both countries set the same tax rate t_i; this will suffice for our purposes since we examine symmetric equilibria below. Note also the convention that elasticities are measured as positive numbers.

We make the following assumptions about tax bases $i = 1, 2$:

A1. $x_i(t_i, T_i) = X_i(T_i, t_i)$ for all (t_i, T_i).

A2. $\epsilon_i^a(t)$ is an increasing function of t (i.e. $\epsilon_i^{a\prime} > 0$), and $\epsilon_1^a(t) > \epsilon_2^a(t)$ for all $t > 0$.

A3. $\epsilon_i^a(t) \geq \epsilon_i^b(t) \geq 0$ for all t.

A1 states that tax bases of the home and foreign countries are symmetric. The first part of A2 states that bases become more elastic as tax rates increase. This is a regularity condition which guarantees governments respond to a restriction on tax preferences by raising the lower tax rate and decreasing the higher one.[3] The second part of A2 states that tax base 1 is unambiguously more elastic with respect to a country's tax rate than is tax base 2. A3 states that bases are less elastic with respect to a coordinated change in both countries' tax rates than a unilateral one; thus the "cross elasticity" of tax bases is non-negative, as

$$\epsilon_i^c(t) \equiv \epsilon_i^a(t) - \epsilon_i^b(t) = \frac{tx_{iT}}{x_i} \geq 0 \tag{3}$$

We will consider below various special cases by assigning values to the three elasticities $\epsilon_i^a(t)$, $\epsilon_i^b(t)$, and $\epsilon_i^c(t)$. For example, the case of an internationally immobile tax base is characterized by $\epsilon_i^c(t) = 0$. When the aggregate amount of a tax base is fixed, $\epsilon_i^b(t) = 0$, we deal with with the framework assumed by Keen (2000). Note that $\epsilon_i^b > 0$ may capture the effects of tax-base flight to third-party countries, or a tax that has distortionary effects on the base in each country.

Governments in the two countries are of the "Leviathan" type, setting tax rates to maximize revenues derived from the two bases. This assumption is consistent with maximizing welfare of domestic residents if all capital is owned by non-residents and investment does not increase the productivity of other, domestic factors of production. As well, results for welfare-maximizing governments is more generally similar, as long as the marginal benefit of public spending is high relative to the marginal benefit of private goods. We show this in an appendix. The Leviathan hypothesis allows us also to compare results to previous research.

In the absence of any coordinating mechanism for the two governments, the home country sets its tax rate t_i on each base to maximize revenue $t_i x_i(t_i, T_i)$ given T_i. In a symmetric Nash equilibrium,[4] the tax rates $t_i = T_i \equiv t_i^p$ satisfy the first-order conditions $\epsilon_i^a(t_i^p) = 1$ for $i = 1, 2$. In view of A2, $t_1^p < t_2^p$: both countries offer a "tax preference" to tax base 1, which is more elastic with respect to unilateral tax changes. Let $\delta = t_2^p - t_1^p$ denote the difference in rates in the tax preference régime.

If the two governments harmonized tax policies and maximized joint revenues, rates would be set on each base to $\max t_i(x_i + X_i)$, and optimal rates would satisfy the first-order condition $\epsilon_i^b(t_i^c) = 1$. Note that tax rates would still be differentiated for the two bases, although it might be reasonable to expect that the difference in rates is smaller than for the

[3] It is possible to show this is a minimal sufficient condition to guarantee stability of the unrestricted Nash equilibrium when countries' tax rates are strategic complements. To see this, note that the slope of the reaction function follows from differentiating the first-order condition $\epsilon_i^a = 1$ (see below) to obtain $dt_i^*/dT_i = -(\partial\epsilon_i^a/\partial T_i)/(\partial\epsilon_i^a/\partial t_i)$, and the stability condition in the strategic complements case is $dt_i^*/dT_i < 1$ in a neighbourhood of the equilibrium. This in turn implies $\epsilon_i^{a\prime} > 0$.

[4] We analyze existence and uniqueness of symmetric equilibrium below in Lemma 1..

uncoordinated equilibrium tax rates (t_1^p, t_2^p).[5] However, when $\epsilon_1^b(t) = \epsilon_2^b(t)$ for all t, it follows that optimal tax rates are uniform for the two bases: $t_1^c = t_2^c$. We discuss this possibility further below.

3 Restrictions on tax preferences

If governments were able to coordinate tax policies, they could impose the rates (t_1^c, t_2^c) that maximize joint revenues. For a variety of reasons, however, such an arrangement may not be implementable. For political reasons, governments may regard it an unacceptable loss of sovereignty to cede taxation powers to another government or a supranational agency. As well, when nations differ in their preferred tax policies, other governments may lack sufficient information to implement optimal taxes. This idea is formalized in Dhillon et al. (1999). A similar idea is discussed, although not formally modeled, in Janeba and Peters (1999) by arguing that tax bases are stochastic at the time of tax coordination and therefore state-dependent agreements are hard to implement.

Governments may therefore prefer to implement arrangements that limit the extent of tax preferences offered to mobile tax bases, without restricting the average level of taxation that may be chosen. This is clearly a second-best instrument for eliminating tax competition since, as we noted above, jointly optimal tax rates will generally still involve differentiated rates for the two bases. But if tax preferences serve mainly to attract mobile bases from abroad, rather than to raise joint revenue, then such restrictions clearly have the potential to raise total revenues. To consider such restrictions, suppose that the two governments agree *ex ante* to restrict themselves to tax schedules such that $t_2 - t_1 \leq \theta$ for the home country, and $T_2 - T_1 \leq \theta$ for the foreign country, for some parameter θ. When this constraint is binding (i.e. $\theta \leq \delta$), the home country's problem is then to choose t_1 given T_1 to maximize total home revenue[6]

$$R(t_1, T_1, \theta) \equiv t_1 x_1(t_1, T_1) + (t_1 + \theta) x_2(t_1 + \theta, T_1 + \theta)$$

Let $t_1^*(T_1, \theta) = \arg\max R(t_1, T_1, \theta)$ be the reaction function of the home country. A Nash

[5] It follows from A2 that $t_i^c > t_i^p$ for $i = 1, 2$ when $x_{iT} > 0$. Note that the difference in tax rates need not be smaller under coordination. For example, suppose that the two tax bases have similar own elasticity, i.e. $t_2^p - t_1^p$ is small, but they differ in their aggregate elasticity, i.e. $\epsilon_1^b > \epsilon_2^b$ or vice versa.

[6] Note the constraint must bind at the optimum. To see this, suppose revenues are maximized when $t_2 < t_1 + \theta$ and denote the solution $\tilde{t}_1, \tilde{t}_2'$. If $\tilde{t}_1 < t_1^p$, then second tax rate $\tilde{t}_2 < t_2^p$ must be less than the rate in the unrestricted preference equilibrium. However, $t_2 x_2$ is increasing in t_2 for $t_2 \leq t_2^p$, a contradiction. A similar argument holds when $\tilde{t}_1 > t_1^p$.

equilibrium is then a fixed point of the two countries' reaction functions.

Naturally, it would be reassuring if we could guarantee that a well-behaved solution to the governments' problems exists, and that a symmetric fixed point of the reaction functions exists and perhaps is even unique. It turns out that the first desideratum, existence of a Nash equilibrium for all θ can be guaranteed if the two revenue functions are concave in the home country's tax rate. Admittedly, this is a strong restriction, at least for tax base functions that have the property that a country's base falls to zero before the maximum feasible tax rate is reached. A related case was studied by Janeba and Peters (1999), where one of the bases is perfectly mobile, so that a country's share of the base falls to zero whenever it imposes a tax rate higher than its competitor. It is shown there that, when tax preferences are abolished, pure-strategy Nash equilibrium tax rates may not exist.[7] In this case, revenue functions are discontinuous, so that existence problems are not surprising. But similar problems arise whenever there is a "choke tax rate" above which a country's base falls to zero, leading to a non-convexity at the associated kink in the revenue function. The second desideratum, uniqueness of a symmetric Nash equilibrium, requires a related but stronger restriction on the two revenue functions. We say that the Hessian matrices of the tax base functions

$$D^2 x_i = \begin{pmatrix} x_{itt} & x_{itT} \\ x_{itT} & x_{iTT} \end{pmatrix}$$

satisfy the *Hadamard property* if $\min\{|x_{itt}|, |x_{iTT}|\} > |x_{itT}|$. (This is sometimes also called the dominant-diagonal property.) This condition, which is clearly related to the stability of reaction functions, proves to be sufficient for uniqueness of Nash equilibrium. We note that, while the restrictions are strong, none of our results below rely explicitly on these assumptions, as long as a symmetric Nash equilibrium exists.

Lemma 1 *Assume A1–A3, and that revenue functions $t_i x_i(t_i, T_i)$ are concave in t_i. Then, for all θ, there exists a Nash equilibrium which is symmetric: both countries choose the tax rate $\hat{t}_1(\theta)$ that solves $\hat{t}_1 = t_1^*(\hat{t}_1, \theta)$. Moreover, assume that the Hessian matrices of the base functions satisfy the Hadamard property. Then this equilibrium is unique and stable: i.e. $t_{1T}^*(\hat{t}_1, \theta) < 1$ for all θ.*

Proof. See appendix.

Let us denote the equilibrium tax rate for base 2 by $\hat{t}_2(\theta) = \hat{t}_1(\theta) + \theta$ and define the

[7] The problem is that revenue functions are not concave, and each country may wish to impose a high tax rate on the immobile base when the other country sets a low rate, but impose a low rate to attract the mobile when the other country sets a high rate.

associated equilibrium level of revenues by

$$V(\theta) = \sum_i \hat{t}_i(\theta) x_i(\hat{t}_i(\theta), \hat{t}_i(\theta)).$$

Our chief interest is in determining when the equilibrium in which tax preferences are banned yields greater revenue than the equilibrium with unrestricted tax preferences, i.e. whether $V^{np} = V(0) \geq V(\delta) = V^p$. However, we will also investigate the the impact on revenues of "small" restrictions on tax preferences $-d\theta$. To this end, note that

$$V'(\theta) = \sum_i x_i(1 - \epsilon_i^b)\hat{t}_i'(\theta). \tag{4}$$

The following gives a more useful characterization of V'. We additionally assume $\epsilon_i^b < 1$ for all $\theta \leq \delta$. That is, tax rates remain below the levels that maximize joint revenue of the two countries, no matter how binding are constraints on tax preferences. This allows us to focus on the interesting case in which evaluating a restriction on preferential arrangements involves a real trade-off between revenue gains from a low-tax base and revenue losses from a high-tax base. When $\epsilon_i^b \geq 1$ for one base or the other, in contrast, further restrictions on tax preferences create an unambiguous gain or loss in total revenues.

Lemma 2 *Assume* $\epsilon_i^b(\hat{t}_i(\theta)) < 1$. *Then*

$$V'(\theta) = \alpha(\theta)\left[\phi_1(\hat{t}_1(\theta)) - \phi_2(\hat{t}_2(\theta))\right] \tag{5}$$

where

$$\phi_i(t_i) = \frac{\epsilon_i^b}{t_i}\frac{1-\epsilon_i^a}{1-\epsilon_i^b} + \frac{\epsilon_i^{a\prime}}{1-\epsilon_i^b}$$

$$\alpha(\theta) = -\frac{x_1 x_2 (1-\epsilon_1^b)(1-\epsilon_2^b)}{R_{tt} + R_{tT}} > 0$$

Proof. See appendix.

The proof consists of showing that, when restrictions on tax preferences are tightened, revenues from base 1 increase by an amount inversely proportional to ϕ_1, while revenues from base 2 decrease in inverse proportion to ϕ_2. On balance, the first effect is smaller, so that $V'(\theta) > 0$ and total revenues of each country fall, when $\phi_1 > \phi_2$, or

$$\frac{\epsilon_1^b}{t_1}\frac{1-\epsilon_1^a}{1-\epsilon_1^b} + \frac{\epsilon_1^{a\prime}}{1-\epsilon_1^b} > \frac{\epsilon_2^b}{t_2}\frac{1-\epsilon_2^a}{1-\epsilon_2^b} + \frac{\epsilon_2^{a\prime}}{1-\epsilon_2^b} \tag{6}$$

The first term on each side of the expression represents the *base effect* of the restrictions on revenues from each base. When, in the absence of restrictions, governments offer excessive tax preferences in order to attract the mobile base from abroad, a restriction on tax preferences increases revenues through the base effect. To see this, observe that, in view of A2, $\epsilon_1^a \geq 1 \geq \epsilon_2^a$ for all $\theta \leq \delta$. Thus the first term on the left-hand side of (6) is negative, whereas the first term on the right-hand side is positive. In the absence of the second term on each side of (6), therefore, we would have $\phi_1 < \phi_2$ for all θ; that is, restrictions on tax preferences tend to increase equilibrium revenues through the base effect *per se*. The exception to this is the case studied by Keen (2000), in which $\epsilon_i^b = 0$, so that the base effect is entirely absent. We analyze this case further below.

The second term on each side of the inequality is what Winter (1997) has called the *strategic effect* of the restriction. The strategic effect captures the impact the restriction has on the intensity of competition between the two governments and therefore on the level of taxes for each base. For base i, $\epsilon_i^{a\prime} > 0$ reflects the impact of a coordinated increase in t_i on each government's marginal incentive to raise its own tax rate for that base. A restriction on tax preferences increases t_1 and decreases t_2. As t_1 rises, competition for the first base intensifies, which tends to limit the tax increase. Conversely, the fall in t_2 has a dampening effect on competition for the second base, which works to reduce the tax cut that is offered in equilibrium. Each of these effects on tax rates is scaled in (6) by $1 - \epsilon_i^b$, which measures the impact of a proportional tax increase on revenues from the relevant base. If the net effect $1/\phi_i$ captured by the two terms is smaller for base 1 than for base 2, then total revenues fall with the restriction.

3.1 The role of base effects

To understand how the base effect influences desirability of restrictions, suppose that the aggregate amount of each base in the two countries is fixed. This implies, because of the symmetry assumption, that

$$x_i(t, T) + x_i(T, t) = \text{constant}$$

for all (t, T). Then the base in each country is a function of the difference in tax rates alone, say $x_i(t, T) = B_i(T - t)$, where $B_i' > 0$. This case was analyzed by Keen (2000), who showed that a complete abolition of tax preferences necessarily reduces revenues. With our different approach, it can further be shown that V is increasing in θ: any restriction on tax preferences reduces revenues. Since $x_i(t, T) = B_i(T - t)$, $\epsilon_i^b(t) = 0$ and $\epsilon_i^a(t) = tB_i'(0)/B_i(0)$.

Since $\epsilon_i^{a\prime}(t) = B_i'(0)/B_i(0)$, A2 implies $\epsilon_1^{a\prime} > \epsilon_2^{a\prime}$, so that

$$\phi_1(\hat{t}_1) = \epsilon_1^{a\prime}(\hat{t}_1) > \epsilon_2^{a\prime}(\hat{t}_2) = \phi_2(\hat{t}_2)$$

and $V' > 0$, which establishes the following corollary to Lemma 2.

Proposition 1 *Suppose that aggregate bases are independent of tax rates ($\epsilon_i^b \equiv 0$). Then any degree of restrictions on tax preferences reduces equilibrium revenues.*

The case of fixed aggregate bases is evidently a very special one, although it has hitherto received a great deal of attention in the literature on capital tax competition. But a similar logic may be applied to show how aggregate base elasticities influence the sign of V' more generally. Differentiating the unilateral elasticity in (1), we can express the marginal revenue effects of a restriction ϕ_i as

$$\phi_i(t_i) = \frac{\epsilon_i^a + \epsilon_i^b}{t_i(1-\epsilon_i^b)} - \frac{t_i(x_{itt} + x_{itT})}{x_i(1-\epsilon_i^b)} \tag{7}$$

As long as the latter second-order terms are small, therefore, we will have $\phi_1(t_1) > \phi_2(t_2)$, and a restriction on tax preferences is undesirable, when ϵ_2^b is small or ϵ_1^b is large. This is as expected. When base 2 is relatively unresponsive to a coordinated decrease in tax rates, the revenue losses of the restriction are large; similarly, when base 1 is highly elastic, the corresponding revenue gains of the restriction are small. The converse is true when the relative magnitudes of the elasticities of the elasticities are reversed.

This suggests it is important to assess the impact of a restriction in the central case in which both bases are equally responsive to a coordinated rate change, i.e. $\epsilon_1^b(t) = \epsilon_2^b(t)$. (This will generalize Proposition 1, in which $\epsilon_1^b = \epsilon_2^b = 0$.) When this is the case, the effects of a restriction depend on the more subtle issue of how governments adjust tax rates in response to the restriction, rather than simply the magnitude of spillover effects. We return to this case in Propositions 3 and 4 below.

3.2 Small restrictions on tax preferences

One may ask whether, beginning from an initial equilibrium with unlimited tax preferences, a small restriction increases or decreases revenues. At the initial equilibrium (t_1^p, t_2^p), the first-order conditions are $\epsilon_i^a = 1$, so that $1 - \epsilon_i^b = \epsilon_i^a - \epsilon_i^b = \epsilon_i^c$. Evaluating (5) with these substitutions implies $V'(\delta) > 0$, so that a small restriction decreases revenues, if and only if $\epsilon_1^{a\prime}/\epsilon_1^c > \epsilon_2^{a\prime}/\epsilon_2^c$. This condition is stated more usefully in the following proposition.

Proposition 2 *A small restriction on tax preferences reduces equilibrium revenues if and only if*

$$\frac{\epsilon_2^c}{\epsilon_1^c} > \frac{\epsilon_2^{a\prime}}{\epsilon_1^{a\prime}} \tag{8}$$

i.e. if and only if the proportional difference in cross-country spillovers exceeds the proportional difference in strategic effects.

To understand the implications of the result, suppose first that $\epsilon_1^{a\prime} = \epsilon_2^{a\prime}$, so that strategic effects on the two bases are exactly offsetting. Then the proposition states that a small restriction on tax preferences increases revenue when $\epsilon_2^c < \epsilon_1^c$. This is the case that receives most attention in the policy literature, in which the tax base that has the lower tax rate in the unrestricted equilibrium (called henceforth the "low-tax base") is the more mobile internationally, so that a small restriction on tax preferences creates positive net spillovers in revenues for both countries. Conversely, however, it is possible that $\epsilon_2^c > \epsilon_1^c$, so that $V' > 0$. When this is so, the high-tax base has stronger cross-country spillover effects than the low-tax base. Consequently, there is in fact too *little* differentiation in tax rates at the unregulated equilibrium, and revenues would fall further if the difference in tax rates were constrained by international agreement. Similarly, when $\epsilon_1^c = \epsilon_2^c$, the spillover effects for the two revenue sources are exactly offsetting, and the net impact of the restriction depends only on the strategic effect discussed above. When $\epsilon_1^{a\prime} > \epsilon_2^{a\prime}$, competition for the first tax base intensifies with the restriction more than competition for the second base diminishes, so that the average tax rate and total revenues fall. The opposite is true when $\epsilon_1^{a\prime} < \epsilon_2^{a\prime}$.

In the limiting cases where one of the two bases is immobile internationally ($\epsilon_i^c \to 0$), the effects of a restriction can be determined from (8) regardless of the sign or magnitude of the strategic effect.[8] When $\epsilon_2^c = 0$, the high-tax base is internationally immobile, and (8) shows that a small restriction must increase revenues. Since there are no international spillovers in base 2, joint revenues from this base are maximized at the unrestricted equilibrium, and the reduction in t_2 caused by the restriction creates a negligible loss in revenues. The result is in spirit of Janeba and Peters (1999), who show that, when one base is perfectly mobile internationally and the other perfectly immobile, a complete abolition of tax preferences increases revenues. In contrast, our result applies also when the low-tax base is imperfectly mobile internationally, but only for small restrictions on tax preferences. Conversely, when $\epsilon_1^c = 0$ the low-tax base is internationally immobile, and a small restriction must decrease

[8] Formally, the decomposition in (6) is invalid when $\epsilon_i^c = 0$, since it would involve division by zero. But in these cases we can use (4) to establish the results directly.

revenues because the first-order loss in revenues from base 2 creates a negligible increase in revenues from base 1. Taken together, these two results suggest that immobility of one tax base has very strong implications for the effects of tax preferences. The important point is that it is crucial which of the two bases is immobile.

A result which applies only locally may be deemed to be of little value, since real-world agreements to restrict tax preferences involves discrete jumps in tax policies. When V is a quasi-concave function, however, $V'(\delta) \geq 0$ implies $V(\theta) \leq V(\delta)$ for all $\theta \leq \delta$, so that any degree of restriction on tax preferences would reduce revenues. It appears difficult to find economically meaningful conditions on tax base functions that guarantee V is quasi-concave. We show below that V is quasi-concave when tax bases are linear functions of tax rates. Thus the assumption is not vacuous.

Corollary *Suppose that $V(\theta)$ is quasi-concave. Then a sufficient condition for any degree of restrictions on tax preferences to reduce equilibrium revenues is that* (8) *holds at the unregulated equilibrium $\theta = \delta$.*

3.3 Optimally uniform tax rates

Our preceding results suggest that restrictions on preferential tax arrangements aimed at limiting tax competition may quite frequently have the perverse effect of reducing revenues. Loosely speaking, this occurs in a broad set of circumstances because a restriction on tax preferences causes equilibrium tax rates on less mobile, high-tax bases to fall more than proportionately to increases in tax rates on more mobile, low-tax bases. It might be felt that this result reflects the "second-best" nature of the reforms we consider: our restrictions move in the direction of a uniform tax on both bases (i.e. $t_1 = t_2$ when $\theta = 0$), although a uniform tax system does not in general maximize joint revenues of the two countries. In fact, our results do not depend on the sub-optimality of uniform taxes. To see this, suppose that $\epsilon_1^b(t) = \epsilon_2^b(t) \equiv \epsilon^b(t)$ for all t: in this case, a uniform tax rate for the two bases (that for which $\epsilon^b(t) = 1$) does indeed maximize joint revenues. In this case, a complete ban on tax preferences will force governments to adopt a uniform tax system, but at a tax rate that is below the optimal level, as they continue to compete to attract tax bases through the limited means available.

In what follows, we show that introducing a small permissible degree of tax preferences is likely to increase total revenues, i.e. $V'(0) > 0$. Moreover, a small tightening of restrictions at $\theta = \delta$ is likely to reduce revenues. For both these results, we assume that the strategic effects of restrictions are "similar" for the two bases, in the sense that differences in second derivatives of the two bases are small when a common tax rate is levied on both bases. That is, we assume

$$\Delta \equiv \left| \frac{t(x_{1tt} + x_{1tT})}{x_1} - \frac{t(x_{2tt} + x_{2tT})}{x_2} \right| \quad \text{is small} \tag{9}$$

when the functions are evaluated at any *common* tax rate t. Note (9) holds trivially when tax bases are linear.

Evaluating ϕ_i at $\theta = 0$ for $\epsilon_i^b = \epsilon^b$ gives

$$\phi_1 - \phi_2 = \frac{(\epsilon_1^a - \epsilon_2^a)/t + \Delta}{1 - \epsilon^b}$$

so that $\epsilon_1^a > \epsilon_2^a$ and (9) imply $V'(0) > 0$. This establishes the following result.

Proposition 3 *Suppose that aggregate base effects are identical for the two bases, i.e.* $\epsilon_1^b(t) = \epsilon_2^b(t)$ *for all* t*, and that second-order effects are similar for the two bases, i.e.* (9) *holds. Then a small increase in permissible tax preferences, beginning from the point of uniformity, increases equilibrium revenues; i.e.* $V'(0) > 0$.

Since effects of coordinated tax changes on revenues are identical for the two bases when $\epsilon_1^b = \epsilon_2^b$, a small restriction reduces total revenues if and only if it causes t_2 to fall more in percentage terms than t_1 increases. As long as differences in the curvature of the two revenue functions (and so in strategic effects) is negligible, the proposition implies this will be the case beginning from an initial point of uniform taxation.

It might be useful to compare our results from this section with those of Keen (2000) and Proposition 1. When $\epsilon_1^b = \epsilon_2^b \equiv 0$, the base effect of restricting tax preferences is zero. Revenues monotonically increase in θ because the dampening of competition for tax base 2 outweighs the intensified competition for the first tax base. When the aggregate elasticities are the same for both tax bases, but non-zero, the base and the strategic effect work in opposite direction and that makes it difficult to prove a general result.

3.4 Linear tax bases

The preceding result applies when second-order effects in tax base functions are similar for the two bases. Evidently, this property must obtain when tax bases are linear function of rates, so that second-order effects are identically zero for both bases. The linear case proves to be instructive: as we will show, it implies that the "strategic effects" of restrictions, discussed above, are proportional to initial elasticities. Examination of this case, as well as being more straightforward computationally, will allow us to elucidate the role of aggregate base elasticities in determining whether restrictions are desirable.

Accordingly, we restrict attention to tax bases that are linear, i.e.

$$x_i(t,T) = 1 + (a_i - b_i)T - a_i t \tag{10}$$

for $a_i > b_i > 0$, $i = 1, 2$. Assume further that $b_i < 1$ to ensure that tax bases are positive for all feasible tax rates. Since the second derivatives of tax base functions are zero, the "strategic" effects of restrictions take a far simpler form: $\epsilon_i^{a\prime} = \epsilon_i^a(1+\epsilon_i^b)/t_i$. The marginal revenue effects of a restriction are

$$\phi_i(t_i) = \frac{\epsilon_i^a + \epsilon_i^b}{t_i(1-\epsilon_i^b)} = \frac{a_i + b_i}{1 - 2b_i t_i} \tag{11}$$

When tax preferences are unrestricted, equilibrium tax rates are $t_i^p = 1/(a_i + b_i)$. In order for $t_1^p < t_2^p$ to hold, we assume $a_1 + b_1 > a_2 + b_2$.[9] For any binding restriction θ on tax preferences, the corresponding equilibrium rates are

$$\begin{aligned}\hat{t}_1(\theta) &= \frac{2}{\sum_i(a_i+b_i)} - \frac{a_2+b_2}{\sum_i(a_i+b_i)}\theta \\ \hat{t}_2(\theta) &= \frac{2}{\sum_i(a_i+b_i)} + \frac{a_1+b_1}{\sum_i(a_i+b_i)}\theta\end{aligned}$$

Evaluating (11) at unrestricted tax rates (t_1^p, t_2^p) implies that $\phi_1 > \phi_2$ and $V' > 0$ if and only if

$$\frac{(a_1+b_1)^2}{a_1-b_1} > \frac{(a_2+b_2)^2}{a_2-b_2}$$

A sufficient condition for small restrictions to reduce revenues is therefore that the cross-country spillover $a_i - b_i$ is smaller for base 1 than for base 2. The tightening of the restriction leads to an increase in the first tax rate and a decrease in the second tax rate. The gain from tax base 1 is smaller than the loss from tax base 2. Intuitively, when the spillover effect is very small for base 1, an increase in tax rate 1 at the unrestricted equilibrium has a small impact on revenues, while a decrease in tax rate 2 reduces revenues from that tax base more. The condition $a_1 - b_1 < a_2 - b_2$ is not necessary, however, since $a_1 + b_1 > a_2 + b_2$. Thus, even when cross-country spillovers are stronger for base 2 than base 1 (in contrast to

[9] In fact, this restriction is weaker than the requirement in Assumption A2 that $\epsilon_1^a > \epsilon_2^a$ for all $t > 0$, but it is sufficient in the linear case to guarantee $\hat{t}_1 \leq \hat{t}_2$ for all $\theta \leq \delta$, as required. Additional assumptions on the parameters would however be enough to ensure that A2 holds. For instance, $\epsilon_1^a(t) > \epsilon_2^a(t)$ for all $t > 0$ when $a_1 = a_2 > b_1 > b_2$.

our discussion following Proposition 2), the strategic effect of the restriction may be strong enough to cause aggregate revenues to fall, despite the positive base effect.

Indeed, the condition is sufficient for *any* restriction to reduce revenues, since V is quasi-concave in the linear case. To establish this, we need only show that $V' = 0$ implies $V'' \leq 0$. But, when $V' = 0$, $V''(\theta) = \alpha(\phi_1' \hat{t}_1' - \phi_2' \hat{t}_2')$. Since $\phi_i' = 2b_i \phi_i^2/(a_i + b_i) > 0$ and $\hat{t}_1' < 0 < \hat{t}_2'$, it follows that $V'' \leq 0$; hence V is quasi-concave in the linear case. Together with Corollary 3.2, this establishes the following.

Proposition 4 *Suppose that tax bases are linear functions of tax rates, i.e.* (10) *holds. Then any restriction on tax preferences reduces equilibrium revenues if*

$$\frac{(a_1 + b_1)^2}{a_1 - b_1} > \frac{(a_2 + b_2)^2}{a_2 - b_2}. \tag{12}$$

Further insight into the condition can be gained by examining the case in which the two bases respond the same way to coordinated increases in the tax rates, i.e. $b_1 = b_2 = b$. In this case, base 1 is more elastic with respect to a unilateral change in a country's own tax rate simply because it is more mobile internationally. When $b_1 = b_2 = b$, (12) holds if and only if

$$a_1 a_2 - (a_1 + a_2)b - b^2 > 0 \tag{13}$$

When b is small then the base effect is small, and the strategic effect of a restriction on preferences leads to a lower average tax rate. (When $b = 0$, moreover, the result is a special case of Proposition 1.) When b is large, in contrast, the positive base effect of the restriction on revenues dominates, so that restrictions on tax preferences are desirable. (In the limiting case of $b = a_2$, tax base 2 is internationally immobile, and a small restriction again must increase revenues.)

Our analysis of (12) can be extended by analyzing the roles of a_1 and a_2. Note that in general a change in a_1 or a_2 alone has an ambiguous effect. Interestingly, however, for the case $a_1 = a_2 = a$, condition (12) does hold. In this case we need $b_1 > b_2$ for $t_1^p < t_2^2$ in the unrestricted equilibrium. This implies also that A2 holds because $\epsilon_1^a = at/(1 - b_1 t) > \epsilon_2^a = at/(1 - b_2 t)$. It is easy to see that (12) holds. The intuition follows the one given above: Restricting preferences leads to a gain in revenues from tax base 1 that is smaller than the loss from base 2 because the former is more elastic than the latter.

4 Conclusion

Policy makers in some governments and international organizations have recently expressed concern about the increasing use of tax preferences to attract internationally mobile tax bases: Allowing tax preferences leads to intense competition for mobile tax bases and hence to an erosion of government revenues. The purpose of this paper was to shed light on this claim. This is important because an appealing counter-argument can be made: Restricting tax preferences is harmful because competition for one tax base may spill over to other tax bases and therefore revenues fall. In effect, a restriction on the form of tax competition may simply induce governments to compete in another, less efficient way, leading to lower total revenues for all. The two conflicting views have found support in the previous literature.

An important contribution of our formal analysis was to derive a general condition that allows us to assess when restrictions on tax preferences are desirable or not. Thereby we are able to show how, in analyzing special cases, the previous literature has arrived at opposing conclusions. Our analysis allowed us to decompose the impact of a restriction into its "base effect" and "strategic effect". Arriving at definitive welfare prescriptions is difficult in general, since the two effects tend to work in opposite directions. Our general condition is appealing nevertheless since it depends on very few, empirically observable elasticities: the elasticity of a tax base with respect to a single country's tax rate, the elasticity of a tax base with respect to a coordinated tax change, and the derivative of the first elasticity.

The general condition leads to a number of more practical insights. First, when bases do not respond to a coordinated change in tax rates, then the base effect is absent, and any restriction on tax preferences will reduce revenues. This generalizes a result of Keen (2000). More realistically, however, tax bases grow when all governments cut tax rates, and further investigation suggests this result is not particularly robust. Restrictions on tax preferences tend to be revenue increasing when the tax base that has the higher tax rate in the uncoordinated equilibrium (i.e. the high-tax base) is less internationally mobile, and the more mobile is the low-tax base. Moreover, even if the elasticities with respect to coordinated tax changes are the same for both bases, but not zero as in Keen, (small) restrictions tend to be revenue increasing if both tax bases are highly responsive. In these cases, a restriction on tax preferences leads to small revenue losses from the high-tax base and more than offsetting revenue gains from increasing the tax on the low-tax base.

On the other hand, we identified several cases under which revenues may fall when restrictions are tightened. In particular, we show this for the case when the joint revenue maximizing tax rates are the same for both bases. If tax preferences are initially prohibited entirely, then a loosening of the restriction increases revenues. We showed also that results under welfare maximization are qualitatively similar to those derived here if there is large underprovision of public goods.

Our research could be extended in a variety of ways in the future. On the empirical side, it would be useful to get estimates for the various elasticities that we identified in our formal analysis. We expect that the elasticities are quite different across sectors or industries. There is likely to be a large difference in terms of international mobility between real capital and financial capital. The OECD has been concerned largely about the latter. Yet Ireland's case suggests that policymakers are also concerned about tax preferences for real investment.

Applying our results to evaluate actual agreements to restrict tax preferences requires robust estimates of tax base elasticities and effective tax rates, and naturally conclusions are apt to be specific to the case being studied. At the broadest level, however, our results suggest agreements to restrict competition for corporate tax bases may be desirable. In most OECD countries, statutory corporate tax rates have declined substantially in the last decade relative to top personal income tax rates. As well, average effective tax rates on capital income are now less than those on labour income, the result of a substantial change in relative burdens since the late 1980s Sorensen (2000). It is common to argue for parity between corporate and top personal rates in domestic policy debates in order to reduce the possibility of tax avoidance through the incorporation decision. Our analysis however suggests another, international argument for parity: international agreements linking corporate tax rates to top personal tax rates are likely to limit corporate tax competition and increase revenues overall. The case for such restrictions will be enhanced in the future if the downward trend in effective corporate tax rates continues. We note here again that this conclusion rests on the assumption that there are no significant spillover effects between tax bases.

We made several important assumptions in our theoretical model whose relaxation would be desirable. For example, we assumed that countries are symmetric. While this assumption makes our analysis much more tractable, many countries that engage heavily in tax preferences are small (e.g. Luxembourg, Ireland, Bahamas, etc.). It is therefore desirable to learn more about the effects of tax preferences when countries are asymmetric. Another useful extension would allow for heterogeneity of citizens. Individuals may differ in terms of the level of incomes and the sources of income. Some individuals may receive a disproportionate share of their income from internationally mobile tax bases and hence favor tax preferences. Allowing for heterogeneity would also require the modeling of how governments make decisions in the presence of political conflict.

Appendix

Proof of Lemma 1. Since the revenue functions are concave in t_i, $R(t,T,\theta)$ is concave in t. It follows that $t_1^*(T_1,\theta)$ is single-valued and, in view of A2, continuous in T_1. Thus a fixed point of t_1^*, $\hat{t}_1 = t_1^*(\hat{t}_1,\theta)$, exists.

Next we show $t_{1T}^*(t_1,\theta) < 1$ when $t_1^* = t_1$ and the Hessian matrices have the Hadamard property. Differentiating the first-order condition $R_t = 0$ gives

$$t_{1T}^* - 1 = -\frac{R_{tt} + R_{tT}}{R_{tt}}$$

and

$$\begin{aligned} R_{tt} + R_{tT} &= \sum_i \left[2x_{it} + x_{iT} + t_i(x_{itt} + x_{itT})\right] \\ &= -\sum_i x_i \left[\frac{\epsilon_i^a + \epsilon_i^b}{t_i} - \frac{t_i(x_{itt} + x_{itT})}{x_i}\right] \end{aligned}$$

Since the base functions are concave, $x_{itt} < 0$, and the Hadamard property implies $x_{itt} + x_{itT} < 0$. Thus $t_{1T}^* - 1 < 0$. It follows that t_1^* has a unique fixed point.

Lastly, suppose there exists an asymmetric equilibrium, in which the two countries choose distinct tax rates $(\tilde{t}_1, \tilde{T}_1)$. The first-order condition for the home country is

$$R_t(\tilde{t}_1, \tilde{T}_1, \theta) = 0$$

and, using the symmetry assumption A1, the first-order condition for the foreign country is

$$R_t(\tilde{T}_1, \tilde{t}_1, \theta) = 0$$

where R_t is the derivative of the function with respect to the first argument. Since R is quasi-concave, this is a contradiction. Hence $(\hat{t}_1, \hat{t}_1)$ is the unique equilibrium.

Proof of Lemma 2: Recall $\hat{t}_1(\theta)$ is implicitly defined by the first-order condition $R_t(\hat{t}_1, \hat{t}_1, \theta) = 0$, so that

$$\begin{aligned} \hat{t}_1'(\theta) &= -\frac{R_{t\theta}}{R_{tt} + R_{tT}} \\ \hat{t}_2'(\theta) &= \frac{R_{tt} + R_{tT} - R_{t\theta}}{R_{tt} + R_{tT}} \end{aligned}$$

Since

$$R_{t\theta} = 2x_{2t} + x_{2T} + t_2(x_{2tt} + x_{2tT})$$
$$R_{tt} + R_{tT} = \sum_{i=1,2} [2x_{it} + x_{iT} + t_i(x_{itt} + x_{itT})] < 0$$

these expressions become

$$\hat{t}_1' = -\frac{2x_{2t} + x_{2T} + t_2(x_{2tt} + x_{2tT})}{R_{tt} + R_{tT}} < 0$$
$$\hat{t}_2' = \frac{2x_{1t} + x_{1T} + t_1(x_{1tt} + x_{1tT})}{R_{tt} + R_{tT}} > 0$$

where the signs of the derivatives are guaranteed by the Hadamard property and Assumption A3.[10] Substituting the definitions of elasticities (1) and (2) implies

$$\hat{t}_1'(\theta) = \frac{x_2}{R_{tt} + R_{tT}} \left[\frac{\epsilon_2^b}{t_2}(1 - \epsilon_2^a) + \epsilon_2^{a\prime} \right]$$
$$\hat{t}_2'(\theta) = -\frac{x_1}{R_{tt} + R_{tT}} \left[\frac{\epsilon_1^b}{t_1}(1 - \epsilon_1^a) + \epsilon_1^{a\prime} \right]$$

where the derivative of the elasticity ϵ_i^a is

$$\epsilon_i^{a\prime} = \frac{\epsilon_i^a(1 + \epsilon_i^b)}{t_i} - \frac{t_i(x_{itt} + x_{itT})}{x_i} > 0 \tag{14}$$

by A2. Collecting terms then gives the expressions stated in the lemma. Finally, recall from the proof of Lemma 1 that stability (i.e. $t_{1T}^*(\hat{t}_1, \theta) < 1$) implies $R_{tt} + R_{tT} < 0$, which in turn implies $\alpha > 0$.

A Comparison of revenue and welfare maximization

Consider the basic model with the same notation. To analyze the case of welfare maximization, we introduce a representative household in each country. The household in home has preferences over the two decisions y_1, y_2 and a public good g. Let utility be $u(y_1, y_2, g)$. This is maximized subject to a budget constraint that can be written in the form $f(y_1, y_2; t_1, t_2, T_1, T_2) = 0$. As in the base model, we assume no links between tax bases, so that the solution to the utility maximization problem can be written as $y_1 = y_1(t_1, T_1)$ and $y_2 = y_2(t_2, T_2)$. The decision problem in foreign is similar with utility $U(Y_1, Y_2, G)$.

There are two tax bases, which we denote x_i for home and X_i for foreign. We assume

[10] Note that if the Hadamard property did not hold here, then both tax rates would either increase or decrease together, and effect on total revenue would be unambiguous (see (4)). In this sense, the assumptions here allow us to focus on the interesting case.

that the private decisions give rise to these tax bases such that

$$y_i + Y_i = x_i + X_i \qquad i = 1, 2.$$

For example, the left hand side of this equation could stand for the sum of home and foreign savings, while the right hand side represents the capital employed in each country. Home's tax base depends on the tax rates in both countries. Let $x_i = x_i(t_i - T_i, z_i(t_i, T_i))$, where $t_i - T_i$ determines the split between countries of a total tax base of $z_i = y_i + Y_i$ such that with symmetric countries $x_i(0, z_i) = z_i/2 = y_i$. For notational convenience we write the tax base x_i more compactly as $x_i = x_i(t_i, T_i)$ and similar for foreign. Government revenue is

$$g = h(x_1(t_1, T_1), x_2(t_2, T_2), t_1, t_2), \tag{15}$$

where the function h captures the possibility that tax rates are ad valorem (so that the function is not linear in x_i).

Revenue maximization. Under revenue maximization the government maximizes (15) subject to the constraint $t_2 = t_1 + \theta$. In a Nash equilibrium tax rates are functions of θ, so that $t_1(\theta), t_2(\theta), T_1(\theta)$, and $T_2(\theta)$. Government revenue can now be written $V_R(\theta) = h(x_1(t_1(\theta), T_1(\theta)), x_2(t_2(\theta), T_2(\theta)), t_1(\theta), t_2(\theta))$, where the subscript indicates revenue maximization. We are interested in the shape of this function in order to compare it with the one under welfare maximization. Differentiating with respect to θ and using the first-order conditions from the government maximization problem, we obtain the following

$$V_R'(\theta) = h_{x_1} \frac{dx_1}{dT_1} \frac{dT_1}{d\theta} + h_{x_2} \left(\frac{dx_2}{dt_2} + \frac{dx_2}{dT_2} \frac{dT_2}{d\theta} \right) + h_{t_2}, \tag{16}$$

where we used the partial derivative $\partial t_2 / \partial \theta = 1$.

Welfare Maximization. In this case the government maximizes utility of the representative individual subject to the behavioural responses and the constraint (15). Again, the Nash equilibrium can be defined as a function of θ and we can write welfare as $V_W(\theta)$. Differentiating and using the envelope conditions, we get

$$\begin{aligned} V_W'(\theta) &= u_1 \frac{dy_1}{dT_1} \frac{dT_1}{d\theta} + u_2 \left(\frac{dy_2}{dt_2} + \frac{dy_2}{dT_2} \frac{dT_2}{d\theta} \right) + u_g \left[h_{x_1} \frac{dx_1}{dT_1} \frac{dT_1}{d\theta} + h_{x_2} \left(\frac{dx_2}{dt_2} + \frac{dx_2}{dT_2} \frac{dT_2}{d\theta} \right) + h_{t_2} \right]. \\ &= u_g \cdot \left\{ \left[\frac{u_1}{u_g} + h_{x_1} \right] \frac{dx_1}{dT_1} \frac{dT_1}{d\theta} + \left[\frac{u_2}{u_g} + h_{x_2} \right] \cdot \left(\frac{dx_2}{dt_2} + \frac{dx_2}{dT_2} \frac{dT_2}{d\theta} \right) + h_{t_2} \right\}, \end{aligned} \tag{17}$$

where the second equality follows from the fact that in a symmetric equilibrium $x_i = y_i$.

It is now clear that (16) and (17) are proportional if u_i/u_g becomes very small, that is, there is large underprovision of public goods.

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