International tax competition: do public good spillovers matter?

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Abstract We study the impact of public good spillovers on tax competition between two imperfectly integrated countries with different levels of productivity. We show that international public good spillovers, by reducing the tax gap between countries, strengthen the agglomeration of firms in the most productive country. Then we carry on a welfare analysis. We first assume that governments are engaged in a redistributive tax policy. At the non-cooperative equilibrium, the tax level in the high-productivity country is inefficiently high while it is inefficiently low in the other country. A different conclusion emerges when tax revenues are recycled in a public good provision: taxes are inefficiently low in both countries and public good spillovers increase the global welfare. Finally, for a given amount of total tax revenues, public good provision in the high-productivity country is inefficiently high compared to its level in the low-productivity country.

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1 Introduction

The relevance of economic decisions on a national level is challenged by the existence of spillovers across countries arising from transnational public goods. This may be a major concern for European member states, since deeper economic integration and spatial proximity could facilitate spillovers from public spending. Indeed, the last two decades have seen the recognition of the global effects of environmental problems such as ozone depletion, climate changes and marine pollution. Other examples suggest that the European member states are faced with international spillovers in a number of policy areas. The important national public investments in transport infrastructures, coordinated by the Trans-European transport network, have generated significant spillovers by improving the accessibility of all the European member states and promoting international trade. European integration has also significantly improved dissemination on a European scale of the new knowledge produced by publicly sponsored research and development efforts of the members.

Being aware of all these spillovers, we can expect that governments will adapt their tax policies. This paper investigates this point in the context of tax competition for mobile firms between imperfectly integrated countries. More precisely, it aims to answer the question of whether international public good spillovers could affect tax competition and the resulting international allocation of firms.

The issues of public good spillovers and international tax competition have often been analyzed separately. According to the seminal contribution of Zodrow and Mieszkowski (1986), tax competition could result in inefficiently low capital taxes and the underprovision of public goods because of a fiscal externality (see Wilson 1999, for a survey). Moreover, when countries have different sizes, tax competition could induce a mis-allocation of capital between countries (Bucovetsky 1991; Wilson 1991). Nevertheless, these early models do not take into account two main characteristics of major industrialized countries. Firstly, countries are imperfectly integrated economic spaces. National borders still matter despite significant improvements in trade liberalization (Zodrow 2003; Head and Mayer 2000). Secondly, economic activities are far from being dispersed and evenly distributed among countries (see Combes and Overman 2005, for the European Union). This last point suggests that some agglomeration externalities due to increasing returns are at work and that they influence the location choice of firms. New economic geography models have recently challenged the main results of the basic tax competition model by taking into account such characteristics. Combining increasing returns with positive trade costs and asymmetric market sizes, Ottaviano and van Ypersele (2005) (OvY, hereafter), among others, show that the mobile factor benefits from an agglomeration rent in the larger country allowing its government to set a higher tax and be a net-importer of capital.[1] Moreover, they carry on a detailed welfare analysis with interesting results. When trade costs are large enough to make it inefficient for all firms to cluster in the larger country, tax competition for mobile firms is efficiency-enhancing with respect to the free market outcome, but leads to an excessive dispersion of firms compared with the second-best optimum. Thus, a second-best planner can improve the overall

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[1] See Ludema and Wooton (2000), Kind et al. (2000) and Baldwin and Krugman (2004) for similar results.

welfare by setting a tax wedge smaller than at the Nash equilibrium. Nevertheless, OvY assume that taxes exist only to redistribute income between factors. Thus, the externality from the public good provision and the incidence of public good spillovers on tax competition are not analyzed.

The literature on public good spillovers was initiated by Oates (1972).[2] Assuming that residents are immobile between jurisdictions, his main result is that public good spillovers lead to an underprovision of public goods, because each government ignores the positive effects of its public good provision on the welfare of residents in other jurisdictions. By considering that households are mobile between jurisdictions, Bloch and Zenginobuz (2006) show that spillovers act as a dispersion force with respect to the spatial distribution of population. A common feature of these models is their assumption that residents are both the only recipients of and contributors to public spending. By contrast, the tax competition literature assumes that the funding of the public sector partly rests on mobile capital, which does not benefit from public good provision.[3]

Only few papers deal with the coexistence of tax competition and public good spillovers. Using a standard tax competition model between two identical countries, Bjorvatn and Schjelderup (2002) show that international public good spillovers mitigate tax competition but that public goods are still under provided because of a well-known free-rider problem (see also Kobayashi et al. 2003). Nevertheless, this paper assumes symmetric countries and is based on a standard tax competition framework which abstracts from imperfect competition and trade barriers.

To summarize, the literature on the relationship between public good spillovers and tax competition ignores imperfectly competitive firms and trade costs, while the literature on international tax competition based on a new economic geography framework takes into account these two characteristics but abstracts from the issue of public good provision and its spillovers. This is the gap we want to fill with this paper.

Our model is based on a framework à la OvY, except that we assume that countries differ with respect to their level of productivity. Each government is benevolent and provides a public good to its immobile residents after taxation of mobile firms. Moreover, public good provision is at the origin of international spillovers. Our main results are as follows. Both public good provision and international public good spillovers imply that governments set higher taxes than when their policy consists of redistributing tax revenues between firms and households. Moreover, the tax wedge between countries decreases with the degree of international spillovers, giving rise to more agglomeration of firms in the high-productivity country. Thus, public good spillovers have the same impact on the tax wedge as trade integration in OvY's model, but different mechanisms are at work. Moreover, we investigate the inefficiencies of the non-cooperative equilibrium: how could a second-best central planner

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[2]The effects of public good spillovers can also be related to the literature on the private provision of public goods dealing with the free-riding problem (Warr 1983; Bergstrom et al. 1986).

[3]Nevertheless, this literature has been recently extended by taking into account the coexistence of two kinds of public expenditures: public good provision which benefits exclusively immobile residents and public input provision (see Keen and Marchand 1997; Matsumoto 2000).

intervene to improve the overall welfare? As in OvY, the tax is inefficiently high in the high-tax country and inefficiently low in the low-tax one when we consider that taxes serve only to redistribute income between firms and households. The introduction of public good provision has significant implications in terms of welfare, since the taxes of both countries become inefficiently low at the non-cooperative equilibrium. Moreover, for a given amount of total tax revenues, public good provision in the high-productivity country is too high compared to its level in the low-productivity country. Finally, a better diffusion of public good spillovers improves the global welfare at the non-cooperative equilibrium.

The rest of our paper is organized as follows. In Sect. 2, we present our framework. We assume an economy made of two countries, whose governments engage in tax competition in an environment of imperfect competition with trade costs. Section 3 describes the location equilibrium for given tax policies. In Sect. 4, we describe the non-cooperative outcome and discuss the effect of public good spillovers on this outcome. In Sect. 5, we carry on a welfare analysis by emphasizing the role played by public good provision and their potential spillovers when governments adopt a non-cooperative behavior. The last section concludes.

2 The model

We consider an economy made of two large countries, labelled $r = 1, 2$. This economy is endowed with n firms and $2l$ workers equally distributed across countries ($l_r = l_s = l$). There are two sectors: a public sector and a private one.

The private sector consists of a modern industry (M) and a traditional one (T). The M-industry produces a continuum of varieties of a horizontally differentiated product under increasing returns to scale, using workers as the only input.[4] The T-industry produces a homogenous good (the numéraire) under constant returns to scale, also using workers as the only input. Firms of the M-industry are perfectly mobile between countries. Their location is governed by the international difference in net profits. Thus, the location equilibrium is reached when no firm can get a higher level of net profit by changing location, so that the net profits made by firms at the location equilibrium is the same everywhere and equal to $\bar{\pi}$. By contrast, workers are not mobile between countries but are mobile between industries.

The public sector of country r is represented by a benevolent government levying a per unit tax t_r on profits made by mobile firms of the M-industry. This tax is levied on the source principle, which means that governments only tax firms located in their country. The resulting tax revenues are recycled in a public good provision for domestic households using the numéraire as the only input so that the marginal rate of transformation between the public good and the numéraire is unity. Because public good provision can generate international spillovers, the individual public good

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[4]Note that the choice of an oligopolistic structure with Cournot competitors does not qualitatively change our results. The trade structure is then simply a generalization of the "reciprocal dumping" model of Brander and Krugman (1983). See Haufler and Wooton (2007) and Ludema and Wooton (2000) for an application of this framework to the international taxation problem.

consumption in country r is given by

$$G_r = g_r + \rho g_s, \tag{1}$$

where $\rho \in (0; 1)$ measures the degree of international spillovers that enable a resident in country r to benefit from the public good provided in country s (g_s). Hence, in the absence of public good spillovers, public good provision in country r boils to $G_r = g_r$.

Finally, the utility derived from the consumption of these private and public goods by a consumer living in country r is given by the following quasi-linear function:

$$U_r\big(G_r; q_O; q(i), i \in [0, n]\big) = u_r\big(q_O; q(i), i \in [0, n]\big) + G_r, \tag{2}$$

where $q(i)$ is the quantity of each variety $i \in [0, n]$ of the M-industry and q_O the quantity of the numéraire.

2.1 Sequence of events

There are three types of actors (firms, governments, and consumers/workers) and three sequential stages in which they are involved. In the first stage, each government simultaneously chooses its level of taxation on firms, taking as given the decision of the other government and anticipating the private sector outcome and the resulting location choices of firms. In stage 2, given the taxes announced by the two governments, firms choose their place of production. In the last stage, production and consumption in the private sector take place.

Information of players is common knowledge and the game is solved by a sub-game perfect Nash equilibrium involving backward induction beginning with the last stage. In order to solve the first and second stages where tax competition takes place and firms choose their place of production (long-run equilibrium), we first have to solve the last stage. Thus, we describe in the two next subsections the consumption and production outcomes in the private sector for a given spatial distribution of firms and for given tax policies in each country (short-run equilibrium).

2.2 Consumption

Preferences for the goods produced in the private sector are identical across workers. Following Ottaviano et al. (2002), they are captured by a quasi-linear utility function, which is symmetric as well as quadratic in a continuum of horizontally differentiated varieties and linear in the homogenous good T:

$$u_r\big(q_O; q(i), i \in [0, n]\big) = \alpha \int_0^n q(i)\, di - \frac{\beta - \gamma}{2} \int_0^n \big[q(i)\big]^2 di$$

$$- \frac{\gamma}{2}\left[\int_0^n q(i)\, di\right]^2 + q_O$$

with $\alpha > 0$ and $\beta > \gamma > 0$. This quadratic utility with respect to the differentiated varieties of the M-industry is standard in industrial organization (Dixit 1979;

Vives [1990]). In this expression, α measures the intensity of preferences for the differentiated product with respect to the numéraire, while γ expresses the substitutability between varieties. Thus, the condition $\beta > \gamma$ implies that workers have a preference toward a dispersed consumption of varieties.[5]

Each consumer/worker is endowed with one unit of labor and $\bar{q}_O$ units of the numéraire. As we want to focus on a unique source of asymmetry given by the productivity wedge, we assume that each resident owns an equal share of the total number of firms so that all the profits are equally distributed to households among countries.[6] Thus, his/her budget constraint can then be written as follows:

$$\int_0^n p(i)q(i)\,di + q_O = y_r + \bar{q}_O, \tag{3}$$

where $p(i)$ is the price of variety i, and the individual income y_r is the sum of the labor income (w_r) and the income from firm ownership ($\bar{\pi}n/2l$):

$$y_r = w_r + \frac{\bar{\pi}n}{2l}.$$

Given the assumption of symmetry between varieties, solving the consumption problem yields the amount of a variety produced in r that is demanded by a resident living in r (q_{rr}) and in s with $s \neq r$ (q_{rs}):

$$q_{rr}^* = a - (b+cn)p_{rr} + cP_r, \qquad q_{rs}^* = a - (b+cn)p_{rs} + cP_s, \tag{4}$$

where

$$a \equiv \alpha/\big[\beta+(n-1)\gamma\big], \qquad b \equiv 1/\big[\beta+(n-1)\gamma\big], \qquad c \equiv \gamma/(\beta-\gamma)\big[\beta+(n-1)\gamma\big]$$

and p_{rr} (resp., p_{rs}) is the price of a variety produced in country r for consumers living in country r (resp., s). These prices give the following price indices (i.e., n times the average price) of varieties in country r and in country s, respectively:

$$P_r = n_r p_{rr} + n_s p_{sr}, \qquad P_s = n_r p_{rs} + n_s p_{ss}, \tag{5}$$

with n_r and n_s the number of varieties/firms located in r and s.

Finally, the initial endowment in numéraire is supposed to be large enough for his/her consumption to be strictly positive at the market outcome. Hence, workers allocate their residual incomes to the consumption of the numéraire.

Thus, we can write the indirect utility derived from the consumption of private goods by a resident of country r as follows:

$$V_r\big(y_r, p(i), i \in [0,n]\big) = -a\int_0^n p(i)\,d(i) + \frac{b+cn}{2}\int_0^n \big[p(i)\big]^2 d(i)$$

$$- \frac{c}{2}\bigg[\int_0^n p(i)\,d(i)\bigg]^2 + \frac{a^2 n}{2b} + \bar{q}_O + y_r. \tag{6}$$

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[5]When $\beta \to \gamma$, the utility function boils to a standard quadratic utility for a homogenous good.

[6]In Appendix of a previous version, we addressed this point and assumed an asymmetric distribution of capital endowment among countries. The results are available upon request.

2.3 Production

The traditional industry produces a homogeneous good under perfect competition and constant returns to scale. One unit of output requires one unit of labor. The T-good is costlessly traded between countries so that its price is the same everywhere. This makes that good a natural choice for the numéraire, which implies that the price of the T-good and the wage in this industry are equal to 1. Moreover, since labor is mobile between industries, the wage rate is also equal to 1 in the M-industry. However, this will be verified only if the T-industry is always active in both countries. Then we have to ensure that a single location alone cannot supply the world demand for the homogeneous good. The condition is $1 < 2q_O$.[7]

The modern industry supplies varieties under increasing returns to scale and monopolistic competition. For simplicity, the marginal cost of production is assumed to be constant and equal to zero without loss of generality. For a firm located in country r, the production of any variety requires a fixed amount ϕ_r of labor with

$$\phi_2 > \phi_1.$$

Put differently, we assume that country 1 benefits from higher increasing returns and then has a productivity advantage. We define $\theta = \phi_2 - \phi_1 > 0$ as the productivity wedge between countries. This wedge allows us to investigate the role of public good spillovers on tax competition among asymmetric countries.

A one-to-one correspondence exists between firms and varieties. Firms of the M-industry compete within a large group of firms. The total mass of firms in this industry is fixed and is equal to n.[8] In other words, we consider a market structure with monopolistic competition in which entry is restricted instead of being free. Thus, firms have a market power and will earn positive profits which will be taxed by governments.

Varieties of M-industry are traded at a cost of τ units of the numeraire per unit shipped between the two countries.[9] Thus, firms will segment markets, by setting a price specific to the market in which its product is sold. As firms bear trade costs, the net profits of a representative firm in country r are as follows:

$$\pi_r = p_{rr}q_{rr}l + (p_{rs} - \tau)q_{rs}l - \phi_r - t_r \quad \text{with } r \neq s. \tag{7}$$

When producers maximize net profits, they take the price indices as given. Nevertheless, the market as a whole has a non-negligible impact on each firm's choice in that each firm must account for the distribution of all firms' prices through aggregate statistics (the price index) in order to find its equilibrium price. Thus, the market solution is given by a Nash equilibrium with a continuum of players in which prices are

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[7]Another condition indicates that the full agglomeration of the modern industry in one country is not sufficient to promote equilibrium in the labor market of this country, that is $L > 2\phi_r n$ where $\phi_r n$ is the number of workers employed in the modern industry when a core-periphery configuration emerges.

[8]Picard et al. (2004) have the same assumption in a spatial version of the Dixit–Stiglitz model.

[9]The term "trade costs" must be understood in the most general sense, as including tariffs, non-tariffs barriers, and transportation costs.

interdependent. As in Ottaviano et al. (2002), the profit-maximizing prices are given by

$$p_{rr}^* = \frac{1}{2}\frac{2a + \tau c(n - n_r)}{cn + 2b}, \qquad p_{rs}^* = p_{ss}^* + \frac{\tau}{2}. \tag{8}$$

First notice that domestic prices depend on the spatial distribution of firms. The relocation of firms in a country decreases the domestic prices in this country while increasing them in the source country. This is the *price-competition effect*: as n_r increases, the market in country r becomes more crowded, thus pushing down local prices while the opposite effect occurs in the other country (because the total number of firms is supposed to be fixed). This *price-competition effect* is important, since it will act as a dispersion force when firms choose their place of production, thus eliminating the possibility of catastrophic spatial agglomeration. Nonetheless, as the *price-competition effect* is attenuated by the fall of barriers to trade ($\partial^2 p_{rr}/\partial n_r \partial \tau < 0$), this dispersion force will vanish with trade integration.

Besides, the equilibrium prices depend on trade costs. By inspection, it is readily verified that p_{rr}^* is increasing in τ because the local firms are more protected against foreign competition. By contrast, $p_{rs}^* - \tau$ is decreasing in τ because it is now more difficult for firms to sell on the foreign market. As firms' prices net of trade costs have to be positive for any distribution of firms, we assume throughout this paper that

$$\tau < \tau_{\text{trade}} \equiv \frac{2a}{2b + cn}. \tag{9}$$

This condition guarantees that it is always profitable for a firm to export to the other country.

Having described the price and demand equilibrium, we can deduce the consumer's surplus in country r:

$$S_r(\lambda_r) = \frac{n(b + cn)}{8b(2b + cn)^2}\Big[\big(-b(\lambda_r - 1)\big(n^2c^2\lambda_r + 4b(b + cn)\big)\big)\tau^2$$
$$+ \big(8ab(\lambda_r - 1)(b + cn)\big)\tau + 4a^2(b + cn)\Big],$$

where λ_r denotes the share of firms located in country r, so that $n_r = \lambda_r n$. Because of the *price-competition effect*, observe that the consumer surplus in country r is an increasing function of λ_r.[10]

3 Location equilibrium for given taxes

In the long run, the location of firms is driven by the international difference in net profits. By introducing (4), (5), and (8) in (7), we get the level of net profit that a firm

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[10]Nonetheless, the increase in the consumer's surplus following an inflow of firms is attenuated by trade integration ($\partial^2 S_r/\partial \lambda_r \partial \tau > 0$), because the fall in trade costs attenuates the *price-competition effect*.

would earn by locating in country r:

$$\pi_r(\lambda_r, t_r) = \frac{l(b+cn)}{2(cn+2b)^2}\left[-cn\tau^2(1-\lambda_r)\left(-cn(1-\lambda_r)-2b\right)\right.$$
$$\left. +4a(a-\tau b)+2\tau^2 b^2\right] - \phi_r - t_r.$$

From this expression, we conclude that two main location forces emerge from the private sector. Firms have a natural incentive to locate in the country with the highest level of increasing returns or productivity (*productivity effect*). Nonetheless, the agglomeration of firms in a country implies that the prices of all varieties sold in this country decrease. Therefore, gross profits in a country decreases with the share of local firms and firms have an incentive to disperse in order to avoid price competition (*price competition effect*). Finally, the fact that governments finance public good provision by taxing mobile firms introduces a third location force: firms are incited to locate in the country where taxation is the lowest to get higher net profits (*taxation effect*).

The location equilibrium is such that these opposite forces balance. Formally, a spatial equilibrium is such that, in each country, no firm has an incentive to change its location, provided that the product markets clear at the equilibrium prices. Thus, by denoting λ the share of modern firms in country 1 (that is n_1/n), a *spatial equilibrium* arises at

$$\lambda \in (0, 1) \quad \text{when } \Delta\pi(\lambda, t_1, t_2) = \pi_1(\lambda, t_1) - \pi_2(\lambda, t_2) = 0$$

$$\text{or at} \quad \lambda = 0 \quad \text{if } \Delta\pi(0, t_1, t_2) \leq 0,$$

$$\text{or at} \quad \lambda = 1 \quad \text{if } \Delta\pi(1, t_1, t_2) \geq 0.$$

To begin, consider the location of firms without taxation ($t_1 = t_2 = 0$). Solving $\Delta\pi(\lambda) = 0$ with respect to λ gives the location equilibrium at the free market:

$$\lambda^M = \frac{1}{2} + \frac{cn+2b}{ncl\tau^2(b+cn)}\theta. \tag{10}$$

Observe that $d\lambda^M/d\theta > 0$. Put differently, the attractiveness of country 1 increases with its productivity advantage. Moreover, for a given productivity advantage, this attractiveness increases with the level of trade integration. Indeed, recall that the *price-competition effect* is attenuated by the fall of barriers to trade because it becomes less costly for firms to serve the foreign market. Thus, firms are more and more incited to locate on the market with the lowest production costs.[11]

Now, assuming the existence of a public sector financed by governments through the taxation of mobile firms gives rise to the following location equilibrium:

$$\lambda(t_1, t_2) = \frac{1}{2} + (cn+2b)\frac{t_2 - t_1 + \theta}{ncl\tau^2(b+cn)}. \tag{11}$$

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[11] This result is similar to the one obtained with a *home market effect*: the attractiveness effect of the country having the largest market size increases with the degree of trade integration (see Ottaviano and Thisse 2004).

In what follows, we focus on the most realistic case of an interior outcome where mobile activities are not fully agglomerated in a country. For this reason, we will assume throughout this paper that

$$\theta < \theta^T_{\text{agglo}} = (t_1 - t_2) + \frac{\tau^2 nlc(b + cn)}{2(2b + cn)},$$

which excludes the possibility of a core-periphery configuration.

Clearly, taxation acts as a dispersion force, since we have $\partial\lambda/\partial t_1 < 0$ and this is true for the other country. Interestingly, the strength of this dispersion force is tightly related to the level of trade integration. Indeed, let

$$\varepsilon_r = -\frac{d\lambda_r}{dt_r}\frac{t_r}{\lambda_r} > 0 \quad r = 1, 2$$

denote the tax base elasticity to the tax rate in country r. We can show that the sensitivity to tax rate variations increases when trade integration is favored:

$$\frac{d\varepsilon_r}{d\tau} < 0 \quad \forall r = 1, 2.$$

4 Non-cooperative equilibrium

In what follows, we solve the first-stage of the sequential game where tax competition takes place and compare it with respect to the outcome resulting from a policy redistributing tax revenues between firms and residents. We first analyze how the Nash tax equilibrium is influenced by public good provision and by a rise in the degree of public good spillovers. Then we discuss their influence on the location of firms.

4.1 Nash tax equilibrium

Each government behaves non-cooperatively and chooses the level of unit tax t_r which maximizes the aggregate welfare of residents living in its country evaluated at the price and location equilibrium. More precisely, we can break down the aggregate welfare into four components: the aggregate income from profits made by modern firms $((\bar{\pi}n)/2)$, the aggregate consumer surplus (lS_r), the aggregate utility from public good consumption $(l(g_r + \rho g_s))$, and a constant which is the sum of the labor income and the endowment in numéraire $(l + l\bar{q}_O)$.

Thus, the maximization program of a government in country r is

$$\underset{t_r}{\text{Max}} \quad W_r = lS_r + \frac{\bar{\pi}n}{2} + l(g_r + \rho g_s) + \text{constant}$$

$$\text{s.t} \quad \begin{cases} g_r = t_r\lambda_r n, \\ g_s = t_s\lambda_s n \end{cases} \tag{12}$$

with $\bar{\pi}n/2 = (\pi_r(\lambda(t_1, t_2))n)/2$ the aggregate income from profits made by firms evaluated at the location equilibrium for given tax policies (11).

Inserting the budget constraints in the welfare function and maximizing the resulting objective function with respect to t_r, we get the following first-order condition:

$$\underbrace{l\frac{dS_r}{d\lambda_r}\frac{d\lambda_r}{dt_r}}_{\text{surplus effect}} + \underbrace{\frac{n}{2}\left[\frac{d\Pi_r}{d\lambda_r}\frac{d\lambda_r}{dt_r} - 1\right]}_{\text{profit effect}} + \underbrace{l\left[\frac{d\lambda_r}{dt_r}t_r n + \lambda_r n\right]}_{\text{tax revenues effect}} + \underbrace{\rho l\left[\frac{d\lambda_s}{dt_r}t_s n\right]}_{\text{public good spillovers effect}} = 0,$$

where $\Pi_r = p_{rr}^* q_{rr}^* l + (p_{rs}^* - \tau) q_{rs}^* l$ denotes the gross profits earned by a firm located in country r.

Let us first assume that the public good provided in a country exclusively benefits its residents ($\rho = 0$). Each country has an incentive to reduce its tax rate in order to increase the consumer surplus ($dS_r/dt_r < 0$) *via* a rise in λ_r (*surplus effect*). The two other effects on the global welfare are more ambiguous. Following a tax rise, the *profit effect* goes in two opposite directions. The first term in brackets gives the firm movement effect of a higher taxation on the operating profits. This firm movement effect is always positive because $d\lambda_r/dt_r < 0$ and $d\Pi_r/d\lambda_r < 0$. Less firms in a country relaxes the price competition and raises the operating profits. Nevertheless, this is attenuated by the direct negative effect of taxation on the equilibrium level of net profits. Finally, raising the tax implies a positive effect on tax revenues provided that the tax base elasticity is less than one in absolute value (*tax revenues effect*).[12]

Let us now assume that public good spillovers emerge between countries, so that non-residents benefit from a share $\rho > 0$ of public goods provided in the foreign country. Observe that $(d\lambda_s/dt_r)t_s$ describes a new incentive in the tax setting coming from public good spillovers (*public good spillovers effect*). This term is identical to the Pigouvian grant system proposed by Wildasin (1989) and can also be found in equalization schemes (see Köthenbürger 2002; Gaigné and Riou 2007). Indeed, it partly internalizes the traditional fiscal externality coming from the fact that when a government taxes mobile factors, it neglects the effect on the tax bases located in the other countries. Since $(d\lambda_s/dt_r)t_s > 0$, we can expect that this incentive will push governments to set higher taxation. In other words, the harmful tax base erosion effect would be partially counteracted. Indeed, thanks to public good spillovers, the potential gain of attracting firms by lower taxes is partly offset by the loss from a reduction in the supply of public goods in the other country.

Solving the system of first-order conditions yields the following Nash tax equilibrium:

$$t_1^{\rho>0} = \tau\frac{\Lambda}{1-\rho} + \Psi\theta \quad \text{and} \quad t_2^{\rho>0} = \tau\frac{\Lambda}{1-\rho} - \Psi\theta, \tag{13}$$

with

$$\Psi = \frac{1}{2}\frac{4l(cn+2b)-cn}{2l(\rho+3)(cn+2b)-cn} \in \left[\frac{1}{4}, \frac{1}{2}\right[$$

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[12]In what follows, we make this standard assumption that the elasticity of capital with respect to the tax rate is less than one in absolute value.

and

$$\Lambda = \frac{(cn + b)((2b^2 - c^2n^2 + 2cnl(cn + 2b))\tau - 4a(cn + b))}{4(cn + 2b)^2}.$$

Since we focus on public good spillovers, we have to ensure that a positive supply of public goods emerges at the Nash tax equilibrium. Therefore, we have to restrict our analysis to the case where both governments levy positive taxation on mobile firms. Appendix A.1 gives the conditions to ensure that it will be the case. We will assume throughout the paper that these conditions are met. Under these conditions, decreasing barriers to trade reduce taxation in both countries:

$$\frac{dt_r^{\rho>0}}{d\tau} > 0 \quad \forall r = 1, 2.$$

This result partly arises from the fact that trade integration increases the tax base elasticity ($d\varepsilon_r/d\tau < 0$). This strengthens the race to the bottom in taxation and countries have to engage more vigorously in tax competition in order to attract firms.

Now, evaluating the tax gap we get:

$$\Delta^{\rho>0} = t_1^{\rho>0} - t_2^{\rho>0} = 2\theta\Psi > 0.$$

The ability of country 1 to levy higher taxation on the mobile factor increases with its cost advantage. This result is consistent with the empirical evidence for OECD countries and especially in the EU where the old member states enjoy a higher labor productivity and generally set the highest corporate tax rates while the new member states set lower corporate tax rates but have a lower labor productivity.

Having described the tax competition outcome, we now evaluate how public good provision and public good spillovers affect the incentives to tax. To evaluate the effect of public good provision, consider the tax competition outcome when taxes serve only to redistribute income between firms and households. Assuming that governments are engaged in such policy as in OvY, we show that corporate taxes in each country and the tax gap (Δ^R) are lower than if governments were engaged in a public good provision with $\rho = 0$ (see Appendix A.2). The intuition for this result is simply related to the strength of the *tax revenues effect* that appears in the first-order condition. Indeed, when taxes serve to redistribute income between firms and workers, the *tax revenues effect* is lower (up to a multiplicative constant l) than when governments provide a public good with $\rho = 0$. Hence, public good provision provides governments with an incentive to set higher taxes and this incentive is more important for the most productive country because of its initial attractiveness.

Now we can focus on the specific impact of public good spillovers on governments' tax choices. Given that $\Lambda/(1 - \rho) > \Lambda$ and $d\Psi/d\rho < 0$, it follows from (13) that public good spillovers unambiguously play as a force mitigating the tendency of the low-productivity country to engage in a race to the bottom in taxation, that is,

$$\frac{dt_2^{\rho>0}}{d\rho} > 0.$$

Still, it seems to be more ambiguous for the high-productivity country. The magnitude of the productivity wedge effect on taxation is lowered with positive spillovers, since $d\Psi/d\rho < 0$. The reason can be found in the relation between the productivity wedge and the amount of public good spillovers that the high-productivity country will benefit from the low productivity one. To be more precise, the incentive to set a higher taxation when spillovers emerge among countries is positively related to the magnitude of spillovers a country expects from the other one. This positively depends on the level of tax chosen by the country generating spillovers and the number of firms it hosts. In our case, the larger the productivity wedge, the lower the level of tax and the number of firms in the low-productivity country will be. Because this productivity advantage will reduce the amount of spillovers received in the leader country, its government will be less prompted to promote higher taxation. This means that the presence of spillovers erodes the ability given by the productivity advantage to the leader country to set a higher level of tax. Nevertheless, we show in Appendix A.3 that

$$t_1^{\rho>0} > t_1^{\rho=0}.$$

Because of the asymmetric incentives to tax described above, it is not surprising to observe that an increase in the degree of public good spillovers reduces the tax wedge between the high-productivity country and the low-productivity one:[13]

$$\frac{d\Delta^{\rho>0}}{d\rho} < 0.$$

Finally, above a given threshold level of public good spillovers $\bar{\rho}$, we show in Appendix A.2 that the tax wedge with spillovers becomes lower than the tax wedge resulting from a policy redistributing tax revenues between firms and workers. We sum up with the following proposition.

Proposition 1 *A higher degree of public good spillovers results in an increase in corporate taxes and a decrease in the tax wedge between countries.*

4.2 Location at the Nash tax equilibrium

Let us now evaluate the location equilibrium at the Nash taxes. Inserting (13) into (11), we get

$$\lambda^T = \frac{1}{2} - \frac{(cn+2b)}{l\tau^2 cn(b+cn)}(2\Psi - 1)\theta \tag{14}$$

which is higher than 1/2 and increases with the level of trade integration. Thus, even though the tax burden is higher in the high-productivity country, it will host a more than proportionate share of mobile firms because higher increasing returns more than compensate for the tax disadvantage.[14] In other words, the high-productivity country

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[13]These results are robust for asymmetric market sizes. Proofs are available upon request.

[14]This result can also be obtained in an economic geography linear model with monopolistic competition and two countries with asymmetric sizes in terms of immobile population (see Ottaviano and van Ypersele 2005; Gaigné and Riou 2007).

is a kind of *"net-importer" of firms*. This result contrasts with Bucovetsky (1991) and Wilson (1991) showing that if two countries differ only in size, then the smaller country levies the lowest capital tax rate and becomes a "net-importer" of capital.

Nonetheless, because asymmetric tax competition gives a tax attractiveness to the low-productivity country, it acts as a dispersion force and we have

$$\lambda^T < \lambda^M. \tag{15}$$

Finally, since public good provision and public good spillovers affect the tax differential, they are not without consequences on the spatial distribution of firms. Firstly, as the tax gap increases when governments finance a public good without spillovers ($\Delta^{\rho=0} > \Delta^R$), the resulting agglomeration of firms in the most productive country will be lower. That is to say, public good provision acts as a centripetal force. Notwithstanding, since $d\Psi/d\rho < 0$, an increase in the degree of public good spillovers reinforces the agglomeration of firms in the high-productivity country:

$$\frac{d\lambda^T}{d\rho} > 0. \tag{16}$$

Thus, the dispersion force induced by asymmetric tax competition and public good provision is mitigated by positive public good spillovers. The origin of this force can be found in the decreasing tax wedge arising from public good spillovers, which moderates the relative tax attractiveness of the low-productivity country. Hence, all the factors promoting public good spillovers between countries will reinforce the position of "net-importer" of firms of the high-productivity country. We summarize in the following proposition.

Proposition 2 *A higher degree of public good spillovers increases the firm-labor ratio in the high-productivity country.*

5 Welfare analysis

This section studies the welfare implications of tax competition. How would a second-best planner intervene to improve the overall welfare? More specifically, we are interested in the role played by public good provision and their potential international spillovers on the inefficiencies due to the non-cooperative behavior of governments. To isolate these effects, we assume as a benchmark case that public expenditures are equal to zero because governments only use taxes to redistribute incomes between firms and households, as in OvY. In this case, after rearrangements the total welfare is given by

$$W_T^R = \left[l(S_1 + S_2)\right] + \left[n\lambda(\Pi_1 - \phi_1) + n(1 - \lambda)(\Pi_2 - \phi_2)\right] + \text{constant} \tag{17}$$

which is the sum of the total consumers' surplus, the total gross income from profits and a constant. Given that the first two terms depend on the spatial distribution of firms and not on the absolute levels of taxation, the total welfare can be expressed

exclusively as a function of the tax gap $\triangle = t_1 - t_2$. Hence, we can define the optimal tax gap that would be set by a second-best planner by solving $dW_T^R/d\triangle = 0$:

$$\triangle^O = \theta \frac{cn + 4b}{3cn + 8b}. \tag{18}$$

$\triangle^O$ is smaller than the tax wedge of the tax competitive outcome $\triangle^R$. To understand this result, we distinguish between the tax gap maximizing the total consumers' surplus and the one that maximizes the total gross income from profits. In Appendix A.4, we show that $\triangle^R$ is inefficiently low to maximize the total consumers' surplus while it is inefficiently high to maximize the gross income from profits. Since $\triangle^O < \triangle^R$, the effect of the tax gap on the gross income from profits does more than compensate the first one. Thus, improving the total welfare would require a lower tax wedge and then more agglomeration in the high-productivity country.

Following OvY, we now ask how a second-best planner could intervene to promote this optimal tax gap. More precisely, we analyze if a second-best planner could raise overall welfare by deciding marginal deviations of each national tax and we get

$$\frac{dW_T^R}{dt_1} = -\frac{dW_T^R}{dt_2} \gtreqless 0 \quad \text{iif } \triangle \lesseqgtr \triangle^O. \tag{19}$$

Thus, the optimal tax policy is tightly related to the size of the tax gap as compared to the optimal one $\triangle^O$. First, consider that the tax gap is below the optimal one ($\triangle < \triangle^O$). In such a case, a policy improving the total welfare requires a marginal increase in t_1 or a marginal decrease in t_2, and thus an increase in the tax gap favoring a more even spatial distribution of firms. By contrast, when the tax gap is higher than the optimal one ($\triangle > \triangle^O$), a social planner would decrease t_1 or raise t_2, so as to induce more firms to agglomerate in the most productive country. As the tax gap at the Nash equilibrium ($\triangle^R$) is higher than $\triangle^O$, a social planner would raise the overall welfare by requiring the government of the high-productivity (resp. low-productivity) country to decrease (resp. increase) its tax. This result is qualitatively identical to OvY's result with countries of different sizes.

Now assume that governments provide a public good that may generate international spillovers ($\rho \geq 0$). A second-best central planner has to maximize the overall welfare that can be rewritten as follows:

$$W_T^{PG} = l(S_1 + S_2) + \bar{\pi}n + lg^T(\rho + 1) + \text{constant}, \tag{20}$$

where $g^T = g_1 + g_2$ and $\bar{\pi}n$ stands for the total net profits redistributed in the economy as a whole. One important implication is that we can no longer define a second-best optimal tax wedge as the total welfare now also depends on the absolute levels of taxation through the second and third terms of the expression (20).

To analyze how public goods and their spillovers affect the welfare analysis, we first focus on the impact of the non-cooperative behavior of governments on the total public good consumption $lg^T(\rho + 1)$. When a government unilaterally changes its taxation, it does not take into account: (i) the impact on the tax base in the foreign country and the resulting adjustment of its public good supply; (ii) the effect on its

own public good supply which is transmitted to the welfare of foreign residents by public good spillovers. In Appendix A.5, we show that the final effect of taxation on the total public good consumption tightly depends on the tax gap since we have

$$\frac{d(l(\rho+1)g^T)}{dt_1} \gtreqless 0 \quad \text{iif } \Delta \lesseqgtr \Delta_{t_1}^{g^T},$$

$$\frac{d(l(\rho+1)g^T)}{dt_2} \gtreqless 0 \quad \text{iif } \Delta \gtreqless \Delta_{t_2}^{g^T}$$

with $\Delta_{t_2}^{g^T} < \Delta_{t_1}^{g^T}$. By comparing the tax gap at the Nash equilibrium with these two thresholds, we get

$$\Delta^{\rho>0} < \Delta_{t_1}^{g^T} \quad \text{and} \quad \Delta^{\rho>0} > \Delta_{t_2}^{g^T}.$$

Therefore, starting at the Nash tax equilibrium, a marginal and unilateral rise in t_1 or in t_2 would raise total tax revenues, and thus increase total public good consumption.

Given these elements, we can expect that recommendations arising from the overall welfare analysis will be different than when governments are engaged in a purely redistributive tax policy. Indeed, we have

$$\frac{dW_T^{PG}}{dt_1} \gtreqless 0 \quad \text{iif } \Delta \lesseqgtr \Delta_{t_1}^{PG} > 0, \tag{21}$$

$$\frac{dW_T^{PG}}{dt_2} \gtreqless 0 \quad \text{iif } \Delta \gtreqless \Delta_{t_2}^{PG} \gtreqless 0, \tag{22}$$

where the thresholds $\Delta_{t_r}^{PG}$ are increasing with the productivity wedge and $\Delta_{t_2}^{PG} < \Delta_{t_1}^{PG}$ (see Appendix A.6). Thus, the optimal tax policy is tightly related to the size of the tax gap. In Appendix A.6, we show that the Nash tax gap is such that $\Delta_{t_2}^{PG} < \Delta^{\rho>0} < \Delta_{t_1}^{PG}$, so that

$$\left.\frac{dW_T^{PG}}{dt_r}\right|^{\text{Nash}} > 0 \quad \forall r = 1, 2. \tag{23}$$

Hence, contrary to OvY, both taxes are inefficiently low at the non-cooperative equilibrium when tax revenues are recycled in a public good provision. In other words, introducing public good provision changes the sign of the externality arising from the tax policy of the high-productivity country. We summarize in the following proposition.

Proposition 3 *When governments provide a public good, Nash taxes in both countries are inefficiently low from the point of view of a second-best planner.*

Having analyzed the inefficiency of the taxes in each country, we now turn to the efficiency properties of the allocation of government spending across countries.

Recall that both countries are equally populated and residents share the same preferences with respect to the public good. Still, at the Nash tax equilibrium, public good

provision (and thus public good consumption) is higher in the most productive country.[15] We can wonder if this difference in public good provision is optimal from the second-best planner point of view. Thus, we analyze the impact on the total welfare of a reallocation of public funds from country 1 to country 2, by holding total public expenditures constant. As public good provision is funded through the taxation of firms and the tax base elasticity is supposed to be less than unity, this reallocation amounts to evaluating the impact on the total welfare of a policy increasing revenue by a dollar through a tax increase in country 2 ($dt_2 > 0$) while reducing revenue by a dollar through a tax decrease in country 1 ($-dt_1 < 0$). Formally, by perturbing total welfare $W_T^{PG}(t_1, t_2)$ and rearranging (20), the effect of switching between g_1 and g_2 is given by

$$dW_T^{PG} = -\frac{dW_T^R}{dt_1} dt_1 + \frac{dW_T^R}{dt_2} dt_2 + \left(l(\rho + 1) - 1\right)\left(-\frac{dg_T}{dt_1} dt_1 + \frac{dg_T}{dt_2} dt_2\right),$$

where

$$-\frac{dg_T}{dt_1} dt_1 + \frac{dg_T}{dt_2} dt_2 = 0$$

since we consider a reallocation of public funds which is neutral with respect to total public good provision. Given the inequality (19), it is straightforward that

$$dW_T^{PG} \gtrless 0 \quad \text{iif } \Delta \gtrless \Delta^O.$$

Thus, for a total revenue-neutral reallocation of public expenditures from the high-productivity country to the low-productivity one to be welfare-improving, the tax gap has to be higher than the optimal tax gap calculated for a purely redistributive taxation scheme (that is, $\Delta > \Delta^O$). As $\Delta^{\rho>0} > \Delta^O$, it comes that a too big share of the financing of total public good provision relies on firms located in the high-productivity country at the Nash tax equilibrium. Hence, a planner could raise the welfare by reallocating public good provision from the high-productivity country to the low-productivity one. Even if this reallocation implies more agglomeration in the high-productivity country—as it involves a decrease in t_1 and an increase in t_2—this agglomeration effect raises the total welfare thanks to its positive impact on total gross income from firm ownership (see Appendix A.4).

We summarize with the following proposition.

Proposition 4 *At the Nash tax equilibrium and for a given amount of total tax revenues, public good provision in the high-productivity country is inefficiently high compared to its level in the low-productivity country from the point of view of a second-best planner.*

Finally, it's worth noting that public good spillovers are not without consequences for the total welfare, even if Proposition 3 and 4 hold whatever their level of diffusion.

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[15] At the Nash tax equilibrium, because country 1 sets a higher tax and is a net importer of firms, both public good provision and public good consumption is higher in this country.

Indeed, by inserting $t_1^{\rho>0}$ and $t_2^{\rho>0}$ in (20) and differentiating the resulting expression W_T^* with respect to ρ, we get

$$\frac{dW_T^*}{d\rho} = \frac{2\theta^2(\rho+1)\Phi}{[2l(2b+cn)\rho+(12bl+cn(6l-1))]^3} - \frac{n\tau(b+cn)(2l-1)\Omega}{4(\rho-1)^2}$$

with

$$\Phi = \frac{l(2b+cn)^2(8bl+cn(4l-1))(16bl+cn(8l-1))}{c\tau^2(b+cn)},$$

$$\Omega = \frac{4a(b+cn)-\tau(cn(4bl+cn(2l-1))+2b^2)}{(2b+cn)^2}.$$

This expression is positive for all admissible values of parameters. Therefore, the global welfare increases with the degree of public good spillovers because this latter raises the levels of Nash taxes and promotes a better transmission of the public goods benefits between countries. Thus, the efforts made by EU member states to better take into account the international spillovers in various policy areas (research and development, transport and telecommunication infrastructures, environment, etc.) could be welfare-enhancing in a context of tax competition.

6 Conclusion

By promoting more mobility of firms and developing various common policies, the European economic integration can simultaneously strengthen tax competition and public good spillovers.

We show that public good spillovers can have significant impacts on tax policies and the resulting distribution of activities. They tend to strengthen the agglomeration of firms in the high-productivity country by reducing the tax gap. Moreover, when countries adopt non-cooperative tax policies which result in inefficiently low taxes, the global welfare is increasing in the degree of public good spillovers.

Both public good spillovers and tax competition call for more international coordination. European countries make an effort to adopt common policies not only with respect to environment or research and development expenditures, but also with respect to corporate taxation with the adoption by the European Commission of the Code of Conduct for business taxation in 1998 and the project of introducing a common consolidated corporate tax base. Our paper suggests that these two types of coordination policies should be tightly related. More accurately, the debate on tax competition and on the opportunity for more coordination among European countries should pay more attention to public good spillovers which could affect tax distortions.

Appendix

A.1 Conditions for positive public good provision

The level of taxation is higher in country 1 than in country 2. Moreover, we show in Appendix A.3 that the level of taxation in each country will be higher when public goods generate spillovers ($\rho > 0$) than without public good spillovers ($\rho = 0$). Thus, we only have to study the conditions ensuring that, in the absence of public good spillovers, the level of corporate taxation in country 2 ($t_2^{\rho=0}$) is positive to be sure that both levels of taxation are also positive. That is, the tax rate in the low-productivity country is positive when

$$\theta < \theta_{t>0}^{\rho=0} = \frac{\tau \Lambda}{\Psi}. \tag{24}$$

Thus, the productivity gap must be low enough to allow a positive taxation in the low-productivity country. Indeed, the larger its disadvantage, the higher the incentive to allocate subsidies to attract firms in this country. θ being positive, the inequality $\theta < \theta_{t>0}^{\rho=0}$ is possible under the necessary condition that trade costs are not too low so that Λ takes a positive value, that is when

$$\tau > \bar{\tau} = 4a \frac{b + cn}{2b^2 + cn(cn(2l - 1) + 4lb)}. \tag{25}$$

We will assume throughout the paper that these conditions (24) and (25) are met, in order to ensure that a positive supply of public goods emerges at the Nash tax equilibrium. Finally, we check that (24) ensures that there is no full agglomeration in the high-productivity country at the Nash equilibrium (that is, $\theta_{t>0}^{\rho=0} < \theta_{\mathrm{agglo}}^T|^{\mathrm{Nash}}$), whatever the degree of public good spillovers.

A.2 Public good provision VS redistributive tax policy

Assume that taxes exist only to redistribute income, as in Persson and Tabellini (1992), Ottaviano and van Ypersele (2005), Kind et al. (2000), Ludema and Wooton (2000). The government's budget constraint is given by

$$\sigma_r l = t_r \lambda_r n$$

with σ_r the unit tax on workers. Inserting this budget constraint in the national welfare function, we get the objective function for the government of country r:

$$W_r^R = l S_r + \frac{\bar{\pi} n}{2} + t_r \lambda_r n + \text{constant}.$$

Maximizing this expression with respect to t_r, we get the following Nash tax equilibrium:

$$t_1^R = \frac{1}{2} \frac{3cn + 8b}{5cn + 12b} \theta - \frac{1}{4}(b + cn)l\tau \frac{4a(cn + b) - \tau(c^2 n^2 + 2b^2 + 4ncb)}{(2b + cn)^2},$$

$$t_2^R = -\frac{1}{2}\frac{3cn + 8b}{5cn + 12b}\theta + \frac{1}{4}(b + cn)\tau l\frac{\tau(c^2n^2 + 2b^2 + 4ncb) - 4a(cn + b)}{(2b + cn)^2}$$

while the resulting tax gap is given by

$$\triangle^R = \frac{3cn + 8b}{5cn + 12b}\theta.$$

We can show that

$$t_r^R < t_r^{\rho=0} \quad \forall r = 1, 2.$$

Moreover, we have

$$\triangle^{\rho>0} \gtrless \triangle^R \quad \text{for all } \rho \lessgtr \bar{\rho} = \frac{l-1}{l}\frac{cn}{3cn + 8b} < \frac{1}{3}$$

provided that $l > 1$.

A.3 Comparing $t_1^{\rho>0}$ with $t_1^{\rho=0}$

We can show that $t_1^{\rho>0} - t_1^{\rho=0} > 0$ if and only if

$$\theta < \Lambda\tau\frac{\rho}{(\rho - 1)(\Psi^{\rho>0} - \Psi^{\rho=0})}.$$

This condition is always fulfilled for positive taxation, since

$$\Lambda\tau\frac{\rho}{(\rho - 1)(\Psi^{\rho>0} - \Psi^{\rho=0})} > \theta_{t>0}^{\rho=0}$$

and we have assumed that $\theta < \theta_{t>0}^{\rho=0}$ to ensure positive taxation at the Nash tax equilibrium.

A.4 Optimal tax gap

The tax gap maximizing total gross profits ($\Pi^T = n\lambda(\Pi_1 - \phi_1) + n(1 - \lambda)(\Pi_2 - \phi_2)$) is $\triangle^{O,\Pi^T} = (2b\theta)/(cn + 4b)$, with

$$\triangle^{O,\Pi^T} < \triangle^R \quad \text{and} \quad \triangle^{O,\Pi^T} < \triangle^{\rho>0}$$

while the tax gap maximizing total consumers' surplus ($S^T = l(S_1 + S_2)$) is $\triangle^{O,S^T} = \theta$, with:

$$\triangle^{O,S^T} > \triangle^R \quad \text{and} \quad \triangle^{O,S^T} > \triangle^{\rho>0}.$$

A.5 Inefficiency of Nash taxes with respect to total public good consumption

After calculations, we get

$$\frac{d(l(\rho+1)g^T)}{dt_1} \gtreqless 0 \quad \text{iif } \Delta \lesseqgtr \frac{1}{4} \frac{\tau^2 ncl(b+cn) + 2\theta(2b+cn)}{cn+2b} = \Delta_{t_1}^{g^T},$$

$$\frac{d(l(\rho+1)g^T)}{dt_2} \gtreqless 0 \quad \text{iif } \Delta \gtreqless -\frac{1}{4} \frac{\tau^2 ncl(b+cn) - 2\theta(2b+cn)}{cn+2b} = \Delta_{t_2}^{g^T}.$$

We then compare the tax gap at the Nash equilibrium with these thresholds. We can easily check that $\Delta_{t_1}^{g^T} > \Delta^{\rho>0}$ and $\Delta_{t_2}^{g^T} < \Delta^{\rho>0}$. Hence, at the Nash tax equilibrium, these derivatives are positive:

$$\frac{d(l(\rho+1)g^T)}{dt_r}\bigg|^{\text{Nash}} > 0 \quad \forall r = 1, 2.$$

A.6 Global analysis

The sign of the derivatives of W_T^{PG} with respect to t_r is given by the following inequalities:

$$\frac{dW_T^{PG}}{dt_1} \gtreqless 0 \quad \text{iif } \Delta \lesseqgtr \Delta_{t_1}^{PG}, \tag{26}$$

$$\frac{dW_T^{PG}}{dt_2} \gtreqless 0 \quad \text{iif } \Delta \gtreqless \Delta_{t_2}^{PG}$$

with

$$\Delta_{t_1}^{PG} = \frac{(2l(\rho+1)(2b+cn) - cn)\theta + n(l-1+l\rho)cl\tau^2(cn+b)}{(4l(\rho+1)(2b+cn) - cn)},$$

$$\Delta_{t_2}^{PG} = \frac{(2l(1+\rho)(2b+cn) - cn)\theta - n(l-1+\rho l)cl\tau^2(b+cn)}{(4l(1+\rho)(2b+cn) - cn)}.$$

We show that $\Delta^{\rho>0}$ is always higher than $\Delta_{t_2}^{PG}$, while $\Delta^{\rho>0} > \Delta_{t_1}^{PG}$ if and only if

$$\theta > \frac{1}{4}n(l-1+l\rho)c\tau^2(cn+b)\frac{2l(2b+cn)(\rho+3) - cn}{l(1-\rho)(\rho+1)(2b+cn)^2} = \hat{\theta}$$

and we check that $\hat{\theta} > \theta_{t>0}^{\rho=0}$. Thus, $\theta < \hat{\theta}$ is the only inequality compatible with $\theta_{t>0}^{\rho=0} > \theta$, and we can conclude that $\Delta^{\rho>0} < \Delta_{t_1}^{PG}$. As a consequence, evaluating the derivatives dW_T^{PG}/dt_r at the Nash tax equilibrium, we get

$$\frac{dW_T^{PG}}{dt_r}\bigg|^{\text{Nash}} > 0.$$

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