



Vertical transfers and tax competition: does trade integration matter?

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Received: 11 October 2018 / Accepted: 10 March 2020 / Published online: 23 March 2020
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Abstract

Our paper presents a model of decentralized leadership with fiscal equalization and imperfect trade liberalization. The degree of trade integration (reflected by trade costs) turns out to have an effect on both state corporate taxes and ex-post vertical equalization transfers. Our main results are the following: when public goods are highly valued by the citizens of the federation, ex post equalization transfers are welfare enhancing compared to tax competition, whatever the degree of trade integration. However, when citizens do not have strong preferences for the public good, ex post vertical transfers turn out to be welfare deteriorating for low levels of trade integration while they are welfare improving compared to tax competition when trade integration is sufficiently deep.

1 Introduction

There is a growing literature dealing with the effects of decentralized leadership on the efficiency of public good provision in federations (representative papers are those by Caplan et al 2000; Köthenbürger 2004, 2007; Silva 2014, 2015; Silva et al 2016). Decentralized leadership refers to a situation where self-interested state governments act as first movers and anticipate how the federal government will react to their fiscal policies. The underlying assumption is that state governments are able to pre-commit vis-à-vis the federal government.¹ Examples of decentralized leadership arrangements include the relationships between European member states and

¹ The decentralized leadership assumption leads of course to a radical change of perspective with respect to the “top-down” literature (Dahlby 1996; Boadway and Keen 1996; Boadway et al 1998) which implicitly assumes that the federal government can commit itself towards sub-national governments and that well-designed federal transfers are able to internalize inter-jurisdictional externalities, which is generally welfare-improving.

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the European Union (Nitsch 2000), the Russian Oblasts and the federal government of Russia and the Canadian provinces of British Columbia and Alberta vis-à-vis the Canadian federal government (see Köthenbürger 2007 for more details). More generally, federations assembled for historical reasons in a bottom-up process involve decentralized leadership.

All theoretical papers about decentralized leadership focus on inter-jurisdictional spill-overs and fiscal externalities arising from factor mobility but ignore the effects of trade integration on the efficiency of (ex-post) federal policies. Nevertheless, progress has been made towards more trade liberalization as shown by the border effect literature, even if “borders still matter”, not only between countries that are members of a highly integrated area such as the European Union (Millimet and Osang 2007) but also within countries in both developed countries (Millimet and Osang 2007 for the US states) and emerging countries (Poncet 2005 for Chinese provinces).

We argue that globalization, and its two main driving forces—namely trade liberalization and capital mobility—are likely to affect the relationships between subnational governments (states) and the federal one. More precisely, the literature on new fiscal federalism and the literature on political secessions both support the idea that the deepening of trade liberalization is likely to strengthen the role of states vis-à-vis the federal government, which makes our decentralized leadership assumption even more credible. There are at least three arguments that support this idea. First, capital (or firm) mobility exerts pressure to diminish the role of the federal governments while enhancing the role of states in attracting new investments and promoting economic development. In other words, as argued by Weingast (2008, 2009) among others, factor mobility reinforces fiscal autonomy of subnational governments and makes them more accountable. Second, factor mobility makes states more strategic with respect to the upper layer of government given that they seek to draw as much benefit as possible while transferring the costs onto the rest of the federation (Garrett and Rodden 2000).

Finally, the theory of secessions shows that trade liberalization affects the desire of some (small) regions to separate from the rest of their country because the domestic market is less and less important and because they can readily access international markets (Alesina and Spolaore 1997). This in turn leads the federal (or central) governments to provide subnational governments with more autonomy and, then, strengthens the role of secessionist regions vis-à-vis the federal government.

However, the decentralization process is rarely without difficulty since central governments oftentimes struggle to retain some of their power and even try to re-centralize a proportion of tax revenues (Porto et al 2014). The case of China since mid-2000 is emblematic of such a situation. One way for federal governments to retain control over subnational governments is to increase the importance of vertical transfers in states’ revenues, and more specifically vertical fiscal equalization transfers. Indeed, governments can both reduce regional inequalities in terms of public good provision and at the same time keep control of subnational resources.

Our paper aims to analyze the effects of a deepening of trade integration on the sustainability of vertical fiscal transfers when subnational governments (states) enjoy a strategic advantage vis-à-vis the federal government. Indeed, one may expect trade liberalization not only to intensify tax competition but also to strengthen the

strategic behavior of states to secure additional vertical transfers because fiercer tax competition across states translates into scarcer tax revenues. A problem that arises is that vertical equalization schemes are subject to a “common pool” problem, which is particularly salient when sub-national governments are in a position of strength and enjoy a strategic advantage with respect to the central government (Köthenbürger 2004). Thus, one can expect trade liberalization and firm mobility to affect states’ tax policy differently depending on whether the latter play a Nash game with the federal government or behave as Stackelberg leaders.

Our model analyses tax competition among a set of regions (states) that are part of an imperfectly integrated two-tier federation. Regional governments provide a public good, anticipating the ex-post fiscal equalization transfers that the federal government will grant to promote equal access to public services across the federation (Boadway 2004)². As shown by Köthenbürger (2004), ex post transfers in a decentralized leadership setting lead to two effects which go in opposite directions: On the one hand, ex-post vertical transfers allow tax externalities arising from tax-induced capital mobility to be internalized (Pigouvian effect), which is welfare improving compared to a situation of tax competition; on the other hand, ex-post transfers create a “tax revenue sharing” effect, which can be welfare deteriorating because the latter reduces the incentives for governments to tax capital. In Köthenbürger’s model, the net effect on global welfare depends mostly on the number of competing decentralized states.

Our paper departs from the standard decentralization literature in two main aspects: Most of the literature including Köthenbürger (2004, 2007) uses a standard model of tax competition à la Zodrow and Mieszkowski (1986) and Wildasin (1988) assuming that capital is perfectly mobile across regions and ignoring both interregional trade and agglomeration effects. Instead, we set up a model of generalized oligopoly à la Haufler and Wooton (2010) where a set of N identical states (not just two) compete with each other over corporate income tax to attract internationally mobile firms operating in an oligopolistic industry and owned by residents living outside the federation. The model allows for rents that can be taxed away by governments to finance a regional public good, which enters the utility function of representative individuals in each region. This is an important difference with Haufler and Wooton (2010), who assume that corporate tax incomes are evenly redistributed in a lump-sum way to the consumers in each state. We also depart from their paper in that we account for a federal framework and assume that there are two layers of governments, with the federal government aiming to equalize the provision of public good across the federation through ex-post vertical transfers. In our setting, the state governments first set the levels of corporate taxes and then, the federal government chooses the amount of transfers to be allocated between states.

More specifically, in each state, there are two industries in operation: a perfectly competitive industry that produces a numeraire good and an oligopolistic industry that is subject to trade costs when goods are exported to foreign markets. Our model

² Silva (2017) shows that if the federal government can implement both fiscal equalization and revenue equalization, the subgame perfect decentralized leadership equilibrium is socially optimal.

shows that the degree of trade integration (reflected by trade costs) affects both the equilibrium corporate tax levels between regions (states) and the ex-post vertical equalization transfers. High trade costs insulate domestic markets from foreign firm competition while low trade costs intensify price competition. In our framework, the intensity of price competition impacts the sensitivity of firms to corporate taxes and, eventually, the tax revenues of state governments. This turns out to have effects on both the Pigouvian tax effect and the tax revenue sharing effect. More precisely, the strengths of both effects turn out to depend on the level of trade costs and the extent to which public goods are valued by the citizens of the federation. Our main result is the following: First, when public goods are highly valued by the citizens of the federation, ex post transfers are always welfare enhancing with respect to tax competition (Nash equilibrium). Second, when public goods are less valued, ex post vertical transfers are welfare deteriorating for low levels of trade integration and welfare improving for high levels of trade integration. The intuition is the following: When trade costs are sufficiently high, this lowers tax competition for firms and thus the downward pressure on corporate taxes is less severe. As a result, the role of vertical transfers in internalizing tax externalities is less important and is more than offset by the distortion from fiscal equalization in the decentralized leadership equilibrium. In contrast, when trade costs are lower, vertical transfers play a more important role because there is a greater need to internalize tax externalities. Moreover, the inefficiency arising from fiscal equalization is less severe. Finally, when trade liberalization goes hand-in-hand with a high level of preference for the public good, ex post transfers are always welfare improving because the internalization of tax externalities is all the more valuable for states that their citizens have a high preference for public goods.

Our paper develops as follows: Sect. 2 presents the setup of the model. Section 3 derives taxes and vertical transfers in three different settings: For the central planner, and for Nash and decentralized leadership. Section 4 compares welfares between the Nash and decentralized leadership equilibria. Section 5 presents a numerical exercise and Sect. 6 concludes.

2 The model

We use a model à la Haufler and Wooton (2010), that we extend in order to consider a federation composed of N identical states and an overarching (federal) government. States compete over corporate taxes to attract mobile firms and offer a residential public good to a representative household residing in their state.

2.1 Consumers

The households consume two private goods and a public good. A private good labeled x is produced and sold by the firms in an oligopolistic industry at price p .

The numeraire commodity labeled z is produced and sold in a perfectly competitive market. Finally, g stands for a publicly-provided good that is financed out of corporate taxes paid by mobile firms operating in the oligopolistic industry.

Consumers in each state have the same preferences, which are given by:

$$u_i = \alpha x_i - \frac{\beta}{2} x_i^2 + z_i + \gamma v(g_i) \quad \forall i = 1, \dots, N \quad \text{and} \quad g_i > 0. \quad (1)$$

The public good is assumed to enter the preferences of the households as a concave function with $v'(g_i) > 0$, $\lim_{g \rightarrow 0} v' = +\infty$ and $v''(g_i) < 0$. The sub-utility function $v(g_i)$ measures the benefit of the public good and γ is a parameter that captures the (relative) preference of the consumers for the public good. This utility function is similar to those of Markusen et al (1995), Bernhofen (2001) and Haufler and Wooton (2010) for the two private goods. In addition, we include the consumption of a public good, in line with the fiscal federalism literature.

Each consumer supplies one unit of labor. The budget constraint for the representative consumer in each state is:

$$w_i = z_i + p_i x_i \quad \forall i = 1, \dots, N \quad (2)$$

where p_i is the price of good x in state i , x_i is the consumption of good x in state i and w_i is the wage in i . The profit incomes are assumed to accrue to capital owners outside the federation and do not enter the budget constraint. The households maximise their utility function (1) with respect to x_i taking into account their budget constraint (2), which leads to:

$$x_i = \frac{\alpha - p_i}{\beta} \quad \forall i. \quad (3)$$

2.2 Firms

There are two sectors in the economy, the numeraire industry and the oligopolistic industry. The numeraire good is produced under conditions of perfect competition and constant returns to scale with labor as the only input. Free trade in this industry determines the wage rate, which equalizes between states and is denoted by w .

There are k firms operating in the oligopolistic industry with $k \geq N$. They are located inside the federation and can invest in any of the N states in the federation. Firms bear sunk costs that are assumed to be high enough to ensure that each firm can only set up one production plant in the federation. Firms can serve both their domestic market and the $N - 1$ foreign markets. Exporting firms are subject to trade costs labeled τ on each unit of exported output. Firms compete with each other in both their domestic and foreign markets. Labour is assumed to be the only variable input in the production of each unit of output, which requires the effort of m

workers. Therefore, the marginal cost of production is $\omega = mw$ so that the cost of exporting the x good is equal to $\omega + \tau$.

Given oligopolistic competition, firms exhibit positive profits. The total profit of a given firm in state i amounts to:

$$\pi_i = (p_i - \omega)x_{ii} + \sum_{j \neq i} (p_j - \omega - \tau)x_{ji} \quad (4)$$

where x_{ji} stands for sales in state j by a firm located in state i . Profits are taxed by states so that the net-of-tax profits of firms located in state i are $\pi_i - t_i$.

The aggregated demand in state i is given by

$$x_i = \sum k_j x_{ij} \quad (5)$$

where k_j is the number of firms located in j . Firms maximise their profit (4) taking into account (5) and the fact that $\sum k_j = k$. This yields the following output levels per firm:

$$x_{ii} = \frac{\alpha - \omega + \tau \sum_{j \neq i} k_j}{\beta(k+1)} \quad \text{and} \quad x_{ji} = \frac{\alpha - \omega - \tau(1 + k_j)}{\beta(k+1)} \quad (6)$$

and the prices for consumers in each state i :

$$p_i = \frac{\alpha + k\omega + \tau \sum_{j \neq i} k_j}{k+1}. \quad (7)$$

For symmetric states, ensuring that $x_{ij} > 0$ and $x_{ji} > 0$ implies:

$$\alpha - \omega - \tau \left(1 + \frac{k}{N}\right) > 0 \iff \tau < (\alpha - \omega) \frac{N}{N+k} = \bar{\tau}. \quad (8)$$

From now, let us assume that $\tau < \bar{\tau}$. The special case of $\tau > \bar{\tau}$ (which implies no trade) will be discussed in Sect. 4. Plugging Eqs. (6) and (7) into (4) leads to:

$$\pi_i = \frac{\left(\alpha - \omega + \tau \sum_{j \neq i} k_j\right)^2}{\beta(k+1)^2} + \sum_{j \neq i} \frac{\left(\alpha - \omega - (1 + k_j)\tau\right)^2}{\beta(k+1)^2}. \quad (9)$$

Given that firms are mobile between states, net-of-tax profits equalize at the location equilibrium: $\pi_i - t_i = \pi_j - t_j \forall i, j$ and $i \neq j$. This determines the number of firms k_i in each state (see Appendix 1):

$$k_i = \frac{k}{N} - \frac{\beta(k+1)}{2\tau^2 N} \sum_{l \neq i} (t_i - t_l) = \frac{1}{N} \left(k - \frac{\beta(k+1)}{2\tau^2} \sum_{l \neq i} (t_i - t_l) \right)$$

and

$$\begin{aligned}\frac{\partial k_i}{\partial t_i} &= -\frac{\beta}{2\tau^2}(k+1)\left(1 - \frac{1}{N}\right) < 0 \quad \text{and} \\ \frac{\partial k_j}{\partial t_i} &= \frac{\beta(k+1)}{2\tau^2 N} > 0 \quad \text{for } i \neq j.\end{aligned}\tag{10}$$

Combining the two above expressions, we obtain:

$$\frac{\partial k_i}{\partial t_i} = -(N-1)\frac{\partial k_j}{\partial t_i}$$

An increase in t_i leads to an outflow of mobile firms which relocate to other states $j \neq i$. Moreover, it is straightforward to check that:

$$\frac{\partial}{\partial N}\left(-\frac{\partial k_i}{\partial t_i}\right) > 0; \quad \frac{\partial}{\partial N}\left(\frac{\partial k_j}{\partial t_i}\right) < 0$$

and

$$\frac{\partial}{\partial \tau}\left(-\frac{\partial k_i}{\partial t_i}\right) < 0; \quad \frac{\partial}{\partial \tau}\left(\frac{\partial k_j}{\partial t_i}\right) < 0$$

The comparative statics show that the larger N is, the greater the number of firms is that relocate to foreign states if t_i diminishes. In addition, an increase in the trade cost makes price competition less fierce on the domestic market and mitigates the magnitude of firm relocations. Put differently, firms are less responsive to a shift in corporate tax when trade costs are high. Indeed, the latter insulate the domestic market from competition by foreign firms.

2.3 Governments

As already mentioned, the federation is composed of two layers of benevolent governments.

The federal government aims to maximize the agents of the federation's total utility $\sum_{i=1}^N u_i(\cdot)$ and implements a horizontal equalization scheme which comes down to granting a positive or negative lump sum transfer s_i to each state with $\sum_{i=1}^N s_i = 0$.

Each state government maximises the welfare of its representative household and sets a source-based corporate tax t_i on each firm in a lump sum fashion in order to finance its local public good g_i . Note that governments are constrained in their ability to tax since after tax profits have to be non negative ($\pi_i - t_i \geq 0$), such that $t^{\max} = \min\{\pi_1, \dots, \pi_N\}$. Each state i 's budget constraint is given by $g_i = t_i k_i + s_i \forall i = 1, \dots, N$. By plugging the consumer's budget constraint (2) into the utility function (1) and using the state aggregated demand (5), the output of the firms (6) and the expression for the consumer price equilibrium (7), we can rewrite state i 's representative agent utility as follows:

$$u_i = S_i + w + \gamma v(g_i) \quad (11)$$

with state i 's total consumer surplus S_i in market x being:

$$S_i = \frac{\left(k(\alpha - \omega) - \tau \sum_{j \neq i} k_j\right)^2}{2\beta(k+1)^2} = \frac{\left(k(\alpha - \omega - \tau) + \tau k_i\right)^2}{2\beta(k+1)^2}$$

Combining with (10), we deduce that

$$\frac{\partial S_i}{\partial t_i} = -\frac{N-1}{N} \frac{k(\alpha - \omega - \tau) + \tau k_i}{2\tau(k+1)} < 0$$

Any increase (decrease) in the corporate tax set by state i leads to an outflow (inflow) of firms which in turn makes price competition on the domestic market less fierce (fiercer). As a result, prices are higher (lower) and the consumer surplus is lower (higher).

3 State corporate taxes and vertical transfers

3.1 The central planner

The central planner chooses $\{s_i\}_{i=1,\dots,N}$ and $\{t_i\}_{i=1,\dots,N}$ in order to maximise the aggregated welfare $U = \sum_i u_i$:

$$\max_{\substack{\{s_i\}_{i=1,\dots,N} \\ \{t_i\}_{i=1,\dots,N}}} U \equiv \sum_i S_i + Nw + \sum_i \gamma v(g_i)$$

s.t.

$$\sum_i s_i = 0 \quad (12)$$

$$\sum_i g_i = \sum_i t_i k_i + \sum_i s_i \quad (13)$$

$$\sum_i k_i = k \quad (14)$$

$$\sum_i z_i = Nw - \sum_i (\alpha - \beta x_i) x_i$$

and (5) for all i .

The first order condition with respect to s_i boils down to equalizing the marginal benefit of public goods across states: $v'(g_i) = v'(g_j) \quad \forall i, j$. This directly implies that:

$$t_i k_i + s_i = t_j k_j + s_j \quad \forall i, j \quad (15)$$

The first order condition with respect to t_i is:

$$\frac{\partial U}{\partial t_i} = \frac{\partial S_i}{\partial t_i} + \sum_{j \neq i} \frac{\partial S_j}{\partial t_i} + \gamma v'(g_i) \left(k_i + t_i \frac{\partial k_i}{\partial t_i} \right) + \sum_{j \neq i} \gamma v'(g_j) \left(t_j \frac{\partial k_j}{\partial t_i} \right) \quad (16)$$

For identical states, $t_i = t_j$ and $k_i = k_j = \frac{k}{N}$, such that $s_i = s_j = 0$. Moreover, $\frac{\partial k_i}{\partial t_i} = - \sum_{j \neq i} \frac{\partial k_j}{\partial t_i}$ and $\frac{\partial S_i}{\partial t_i} = - \sum_{j \neq i} \frac{\partial S_j}{\partial t_i}$. Equation (16) reduces to $\frac{\partial U}{\partial t_i} = v'(g_i) \cdot k_i > 0$ and the optimal tax t^{SP} is the maximum level:³ $t^{SP} = t^{max}$. The explanation is straightforward: On the one hand, a higher t_i leads to lower consumer surplus because fewer firms are located in i , making price competition less intense. On the other hand, a higher tax leads to higher tax revenues and more public good provision. However, in the case of identical states, the impact of a change in the corporate tax on both the domestic consumer surplus and the number of firms is perfectly compensated by the opposite effect on foreign consumer surpluses and foreign firms. As a result, the only remaining effect is the direct tax revenue effect, which is positive. Hence, the central planner sets corporate taxes as high as possible.

3.2 Nash equilibrium

Both layers of government choose their fiscal instruments simultaneously and non-cooperatively, taking into account the effect on the location of the mobile firms. State governments maximise u_i s.t. $g_i = t_i k_i + s_i$. The first order condition can be written:

$$\frac{\partial S_i}{\partial t_i} + \gamma v'(g_i) \left(k_i + t_i \frac{\partial k_i}{\partial t_i} \right) = 0 \quad (17)$$

An interior solution exists if the elasticity of the number of firms with respect to the corporate tax is not too high in absolute value. From now on, we assume that $\epsilon_i = \left| \frac{t_i}{k_i} \frac{\partial k_i}{\partial t_i} \right| < 1$.

At the symmetric equilibrium there are no transfers ($s_i = s_j = 0$) and for positive net profits, \hat{t} is the corporate tax that solves the following equation:

$$\Phi(t) = t - \frac{\tau k}{\beta(k+1)} \left(\frac{2\tau}{N-1} - \frac{\alpha - \omega - \tau + \frac{\tau}{N}}{\gamma v'(\frac{tk}{N})(k+1)} \right) = 0 \quad (18)$$

which implies that

³ The level of t^{max} is determined by the level of t at which the net tax profit is zero.

$$\begin{aligned}\frac{\partial \hat{t}}{\partial \tau} &= -\frac{\partial \Phi / \partial \tau}{\partial \Phi / \partial t} > 0 \iff \gamma v' \left(\frac{\hat{t}k}{N} \right) > \frac{(N-1)(\alpha - \omega - 2\tau + \frac{2\tau}{N})}{(k+1)\alpha\tau} \\ \frac{\partial \hat{t}}{\partial \gamma} &= -\frac{\partial \Phi / \partial \gamma}{\partial \Phi / \partial t} > 0\end{aligned}$$

since

$$\begin{aligned}\frac{\partial \Phi}{\partial t} &= 1 - \frac{v''}{\gamma(v')^2} \frac{k^2\tau}{\beta(k+1)^2N} \left(\alpha - \omega - \tau + \frac{\tau}{N} \right) > 0 \\ \frac{\partial \Phi}{\partial \tau} &= -\frac{k}{\beta(k+1)} \left(\frac{4\tau}{N-1} - \frac{\alpha - \omega - 2\tau + \frac{2\tau}{N}}{\gamma v'(\frac{\hat{t}k}{N})(k+1)} \right) \\ &< 0 \iff \gamma v' \left(\frac{\hat{t}k}{N} \right) > \frac{(N-1)(\alpha - \omega - 2\tau + \frac{2\tau}{N})}{(k+1)4\tau} \\ \frac{\partial \Phi}{\partial \gamma} &= -\frac{\tau k}{(k+1)\beta} \left(\frac{1}{\gamma^2} \frac{\alpha - \omega - \tau + \frac{\tau}{N}}{(k+1)v'(\frac{\hat{t}k}{N})} \right) < 0\end{aligned}$$

At the symmetric Nash equilibrium, the corporate tax in each state is $t^N = \min\{\hat{t}, t^{max}\}$.

All things being equal, an increase in the preference for the public good γ unsurprisingly leads to a higher Nash equilibrium tax level. A marginal change in the level of trade costs impacts the Nash equilibrium corporate tax through two opposite effects: A location rent effect and a consumer price effect. On the one hand, the location rent effect [first term in brackets in equation (18)] pushes corporate taxes down when trade costs are low because low trade costs to some extent expose the domestic market to the competition of foreign firms. As a result, domestic firms are more sensitive to corporate taxes than when trade costs are higher. On the other hand, the consumer price effect [second term in brackets in Eq. (18)] drives corporate taxes up when trade costs are low since greater price competition translates into a lower prices and a higher consumer surplus. As a result, when trade costs decrease, both the location rent effect and the consumer price effect are strengthened. However, when the preference for the public good is high enough (compared to the consumption of the private good and the consumer's surplus), then the location rent effect outweighs the consumer surplus effect and a decrease in the level of trade costs leads to a diminution of Nash equilibrium tax levels.

3.3 Decentralized leadership

In the decentralized leadership setting, state governments behave as Stackelberg leaders vis à vis the federal government. In the first stage, state governments choose

their local corporate taxes taking into account the reaction function of the federal government. They still act as Nash competitors towards each other. In the second stage, the federal government chooses the grants provided to state governments taking the local corporate taxes as given. We solve the program by backward induction in order to obtain the subgame perfect equilibrium.

The federal government maximizes the aggregated welfare subject to constraint (12), which leads to Expression (15). Summing this expression for all $j \neq i$ and using (12) leads to

$$s_i = \frac{1}{N} \sum_{j \neq i} (t_j k_j - t_i k_i)$$

The program of each state government i becomes

$$\begin{aligned} \max_{t_i} \quad & u_i \equiv S_i + w + \gamma v(g_i) \\ \text{s.t.} \quad & g_i = t_i k_i + s_i \\ & s_i = \frac{1}{N} \sum_{j \neq i} (t_j k_j - t_i k_i) \end{aligned}$$

The first order condition for state i is

$$\frac{\partial S_i}{\partial t_i} + \gamma v'(g_i) \left(k_i + t_i \frac{\partial k_i}{\partial t_i} + \frac{\partial s_i}{\partial t_i} \right) = 0$$

with

$$\frac{\partial S_i}{\partial t_i} = \overbrace{\frac{1}{N} \sum_{j \neq i} t_j \frac{\partial k_j}{\partial t_i}}^{\text{Pigouvian tax effect}} - \overbrace{\frac{(N-1)}{N} \left(k_i + t_i \frac{\partial k_i}{\partial t_i} \right)}^{\text{tax revenue sharing effect}} \quad (19)$$

The reaction of the federal transfer with respect to a change in t_i consists of two effects. On the one hand, a Pigouvian tax effect which reflects the internalization by the federal government of the horizontal tax externalities arising from tax competition. On the other, a tax revenue sharing effect whereby any change in the tax revenues of state i is pooled and redistributed among the other states $j \neq i$ through the equalization scheme. The first effect is always positive while the second one is negative since we assumed that $\epsilon_i = \left| \frac{t_i}{k_i} \frac{\partial k_i}{\partial t_i} \right| < 1$.

$$\frac{\partial S_i}{\partial t_k} = \frac{\left(k_k + t_k \frac{\partial k_k}{\partial t_k} \right) + \sum_{j \neq k} t_j \frac{\partial k_j}{\partial t_k} - N t_i \frac{\partial k_i}{\partial t_k}}{N}$$

At the symmetric equilibrium, \tilde{t} is the tax that solves the following equation

$$\Psi(t) = \gamma v' \left(t \frac{k}{N} \right) - \frac{(N-1)N(\alpha - \omega - \tau + \frac{\tau}{N})}{2\tau(k+1)} = 0 \quad (20)$$

with

$$\frac{\partial \tilde{t}}{\partial \tau} = -\frac{\partial \Psi / \partial \tau}{\partial \Psi / \partial t} > 0 \quad \text{and} \quad \frac{\partial \tilde{t}}{\partial \gamma} = -\frac{\partial \Psi / \partial \gamma}{\partial \Psi / \partial t} > 0$$

since

$$\frac{\partial \Psi}{\partial t} = \gamma v'' \frac{k}{N} < 0, \quad \frac{\partial \Psi}{\partial \tau} = \frac{(N-1)N(\alpha - \omega)}{2(k+1)\tau^2} > 0 \quad \text{and} \quad \frac{\partial \Psi}{\partial \gamma} = v' > 0.$$

At the symmetric equilibrium, the corporate tax in each state is $t^{DL} = \min\{\tilde{t}, t^{max}\}$.

It is interesting to note that, in contrast with the tax competition (Nash) case, a marginal increase (decrease) in trade costs always leads to an increase (decrease) in the equilibrium tax levels, i.e. regardless of the preference of the households for the public good. The intuition is straightforward: The federal government allocates its transfers between the regional governments after the latter have chosen their taxes. As a result, the federal government internalizes all the effects related to the tax-induced mobility of firms between states and the only effect that remains is the impact of a change in the trade costs on the consumer surplus. A reduction of trade costs makes price competition more intense in the domestic market, which mitigates the upward effect of an increase in the corporate tax on prices. In other words, a change in trade costs affects the consumer surplus more strongly so that the downward effect on tax going through the consumer surplus is reinforced. Hence, in the case of trade liberalization (i.e. a reduction of trade costs), state governments tend to cut their taxes.

4 Comparisons of the equilibrium corporate taxes and levels of welfare

Note that the consumer surplus (S_i) does not depend on the corporate tax at the symmetric equilibrium. As a result, the comparison of the welfare defined by Eq. (11) reduces to a comparison of the corporate taxes. The comparison between the Nash setting (tax competition) and the decentralized leadership comes down to a trade-off between a pure tax competition effect which drives the taxes down at Nash equilibrium and a tax revenue sharing effect that dilutes the ability of state governments to increase their corporate taxes at the decentralized leadership equilibrium.

Proposition 1 Let $\hat{\gamma} = \frac{(N-1)N(\alpha - \omega - \tau + \frac{\tau}{N})}{2\tau(k+1)v'(\frac{2k^2\tau^2}{\beta(k+1)N^2})}$ and $\tau < \bar{\tau}$. For a finite number of firms k ,

$$\left. \frac{\partial S_i}{\partial t_i} \right|_{t^{NS}} > 0 \text{ and } t^{DL} > t^N \iff \gamma > \hat{\gamma}$$

Proof see Appendix 2. \square

Proposition 1 shows that the corporate tax set at the decentralized leadership equilibrium is higher than the corporate tax set at the Nash equilibrium when the level of preference for the public good is high (γ). In other words, ex post vertical transfers are welfare improving with respect to tax competition.

The reason is that the Pigouvian tax effect dominates the tax revenue sharing effect when the public good is highly valued by individuals. A high level of γ drives both the Nash and the decentralized leadership equilibrium taxes upward. At the symmetric equilibrium, this strengthens the Pigouvian tax effect and mitigates the tax revenue sharing effect as shown by Eq. (19). The former effect arises directly because the equilibrium corporate tax in any state $j \neq i$ is higher and thus so are the tax revenues in those states. The latter effect is explained by the fact that, for a high equilibrium corporate tax, the sensitivity of firm location to corporate tax (ε_i) is higher. As a result, both effects combine to increase vertical transfers granted by the central government ($\frac{\partial s_i}{\partial t_i} > 0$).

The threshold level of preference for the public good in Proposition 1 depends on trade costs τ . In order to focus on the impact of trade costs on both Nash and decentralized leadership equilibria, we henceforth assume that $v(g) = \log(g)$. Then, we are able to compute equilibrium corporate taxes:

$$\hat{t} = \frac{N}{N-1} \frac{2\gamma\tau^2(k+1)k}{k^2(\alpha - \omega - \tau)\tau + \frac{k^2}{N}\tau^2 + \gamma\beta(k+1)^2N} \quad (21)$$

which implies⁴

$$\frac{\partial \hat{t}}{\partial \tau} > 0 \quad \text{and} \quad \frac{\partial \hat{t}}{\partial N} < 0 \quad (22)$$

and

$$\tilde{t} = \frac{\gamma 2\tau(k+1)}{(N-1)k \left((\alpha - \omega - \tau) + \frac{\tau}{N} \right)}$$

It holds that

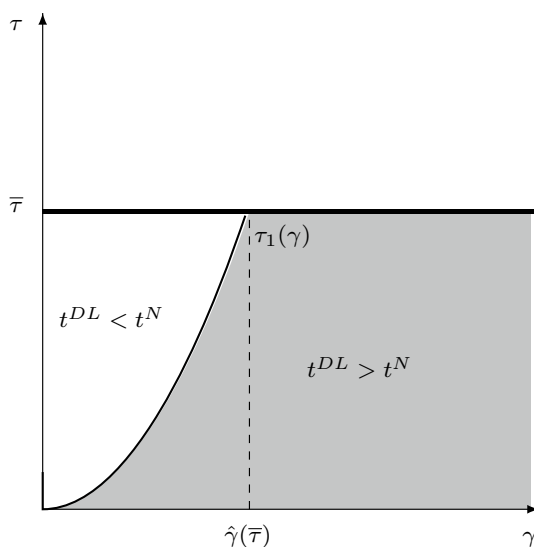
$$\frac{\partial \tilde{t}}{\partial N} = -\frac{\gamma 2(k+1)\tau}{(N-1)^2} \frac{(\alpha - \omega - \tau)N^2 + \tau}{k((\alpha - \omega - \tau)N + \tau k)^2} < 0$$

⁴ $\frac{\partial \hat{t}}{\partial \tau} = \frac{N}{N-1} \gamma 2(k+1)k\tau \frac{(k^2(\alpha - \omega)\tau + 2\gamma\beta(k+1)^2N)}{(k^2(\alpha - \omega - \tau)\tau + \frac{k^2}{N}\tau^2 + \gamma\beta(k+1)^2N)^2} > 0$

and

$\frac{\partial \hat{t}}{\partial N} = -\frac{N}{(N-1)^2} \gamma 2(k+1)k\tau^2 \frac{(k^2N(\alpha - \omega - 2\tau)\tau + 2k^2\tau^2 + \gamma\beta(k+1)^2N^3)}{(Nk^2(\alpha - \omega - \tau)\tau + k^2\tau^2 + \gamma\beta(k+1)^2N^2)^2} < 0$ for $\tau < \bar{\tau}$.

Fig. 1 Comparison of the equilibrium corporate taxes with trade



In our model, for a given number of firms k , a rise in the number of competitive regions makes competition fiercer and drives down both the Nash and the decentralized leadership equilibrium taxes.

Proposition 1 can be refined as follows under the assumption that $v(g) = \log(g)$:

Proposition 2 Let $\hat{\gamma}(\bar{\tau}) = \frac{(N-1)(\alpha-\omega)^2 k^2}{(N+k)^2 \beta(k+1)}$ and $\tau < \bar{\tau}$. For a finite number of firms k ,

- (i) if $\gamma > \hat{\gamma}(\bar{\tau})$, then $\left. \frac{\partial s_i}{\partial t_i} \right|_{t^{NS}} > 0$ and $t^{DL} \geq t^N \forall \tau$
- (ii) if $\gamma < \hat{\gamma}(\bar{\tau})$, then $\left. \frac{\partial s_i}{\partial t_i} \right|_{t^{NS}} \geq 0$ and $t^{DL} \geq t^N$ for $\tau \in [0, \tau_1]$ then $\left. \frac{\partial s_i}{\partial t_i} \right|_{t^{NS}} < 0$ and $t^{DL} \leq t^N$ for $\tau \in]\tau_1, \bar{\tau}]$,

with $\frac{\partial \tau_1}{\partial \gamma} > 0$ and $\frac{\partial \tau_1}{\partial k} < 0$.

Proof see Appendix 4. □

For $\gamma < \hat{\gamma}(\bar{\tau})$, which of the tax revenue sharing effect or the Pigouvian tax effect dominates depends on the level of trade costs (see Fig. 1).⁵ The decentralized equilibrium corporate tax is higher than the Nash equilibrium corporate tax for sufficiently low trade costs. Indeed, low trade costs make firms more sensitive to corporate taxes, resulting in more intense tax competition. As a result, Nash equilibrium corporate taxes decrease when trade is liberalized. At the decentralized equilibrium, low trade costs imply a high Pigouvian tax effect because tax externalities are more severe. However, low trade costs also imply a smaller tax revenue sharing effect

⁵ When $\gamma > \hat{\gamma}$, the threshold trade cost is higher than the maximum trade cost $\bar{\tau}$ and the decentralized leadership corporate tax is still higher than the Nash corporate tax.

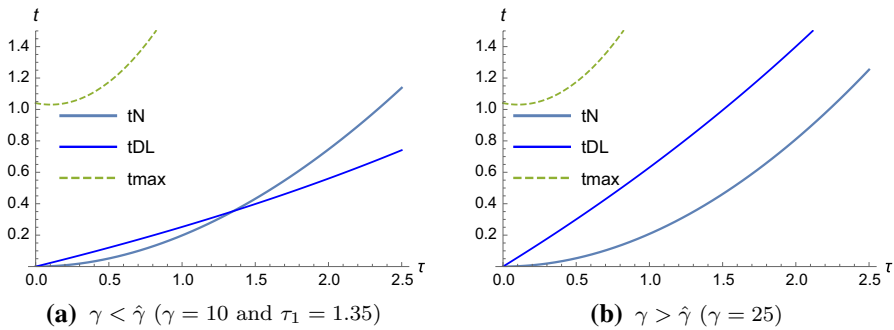


Fig. 2 For $N = 10$, $\bar{\tau} = 2.5$, $\hat{\gamma} = 16.33$

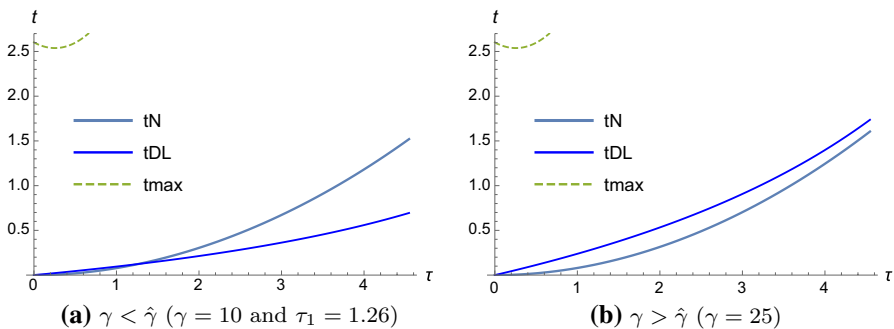


Fig. 3 For $N = 25$, $\bar{\tau} = 4.54$, $\hat{\gamma} = 23$

since a high firm mobility lowers the share of tax revenue “captured” by the federal government to be redistributed to the other states. Since the tax revenue sharing effect is dominated by the Pigouvian tax effect, the decentralized leadership corporate tax is higher than the Nash equilibrium corporate tax.

Proposition 2 compares tax levels when trade occurs because trade cost are not too high (lower than $\bar{\tau}$). If we now consider the case of prohibitive costs ($\tau > \bar{\tau}$), the comparison between the tax levels is entirely determined by the preferences of the citizens for the public good. Indeed, without trade, trade costs play no role in the calculation of equilibrium tax levels (see Appendix 4). Therefore, the welfare at the decentralized leadership equilibrium is higher than the welfare under tax competition (Nash equilibrium) for a sufficiently high level of public good preferences (the same argument as in Proposition 2 applies). In addition, we show in Appendix 4 that the threshold γ_{EC} beyond which vertical transfers are welfare-improving is higher in the absence of trade than when trade liberalization is taking place (i.e trade costs are lower). This means that vertical transfers are less likely to be welfare-improving when trade costs are a strong impediment to trade.⁶

⁶ The particular case of an infinite number of firms k induces no trade but requires a different comparison of the tax levels because since profits are null, positive tax levels are no longer possible (see Appendix 3).

5 Numerical example

To illustrate our results, we proceed to a numerical example, displayed in Figs. 2 and 3. The number of firms in the federation is set to $k = 30$. Here, k characterizes the average number of firms in a market. In line with the results derived in Proposition 2, we use a log function for the public good preferences. Following Haufler and Wooton (2010) we set $\beta = 1$. We fix $\alpha - \omega = 10$ in order to obtain a value for the price elasticity of demand for good x that lies between -1.5 and -3 , which are plausible empirical values. Finally, setting $\alpha = 40$, we obtain parameter values close to those of Gronberg et al (2012), i.e. $\frac{\beta}{2\alpha} = 0.0125$ and $\frac{\gamma}{\alpha}$ either equal to 0.25 (for $\gamma = 10$) or 0.625 (for $\gamma = 25$).

Figure 2 displays calculations for the case of 10 states, which is for example the number of Canadian provinces while Fig. 3 illustrates the case of 25 states, which is roughly the number of EU member states, German states and Swiss Cantons. Both cases satisfy the condition $k \geq N$. Figures 2a and 3a correspond to case (ii) of Proposition 2: when $\tau < \tau_1$, we observe that $t^{DL} > t^N$ while $t^{DL} < t^N$ for $\tau \in [\tau_1, \bar{\tau}]$. Figures 2b and 3b illustrate case (i) i.e. $t^{DL} > t^N \quad \forall \tau$ because of a high preference for public goods ($\gamma > \hat{\gamma}$).

Since the level of $\hat{\gamma}$ is the key element to rank the equilibrium tax levels, we observe that this threshold level is sensitive to the number of states. Where there are 25 states, the preference for the public good must be higher than when there are 10 states to ensure that the corporate tax in the decentralized leadership equilibrium is higher than in the Nash equilibrium for all levels of trade costs : $\frac{\hat{\gamma}}{\alpha} = 0.575$ for 25 states and $\frac{\hat{\gamma}}{\alpha} = 0.41$ for 10 states. Moreover, the threshold trade cost is almost twice as high for 25 states compared to the case with 10 states. Therefore, for a large number of states, the Nash corporate tax is the more likely to dominate the decentralized leadership corporate tax because the tax revenue sharing effect dominates the Pigouvian tax effect.

6 Conclusion

Decentralized leadership in federations has been extensively studied within the framework of the standard tax competition model characterized by perfect competition on markets for goods. Alternatively, we have argued that product markets are segmented and trade liberalization may affect the propensity of states (or sub-national governments) to extract vertical transfers from the federal government when the institutional features give them a first mover advantage. Furthermore, vertical transfers have mixed effects on welfare depending on the level of trade liberalization. From a public policy perspective, our results show that vertical transfers are always welfare improving compared to a situation of “laissez-faire” (tax competition without vertical transfers) when the citizens of the federation

exhibit high preferences for public goods. In other words, the common pool effect arising from vertical fiscal equalization, which is strengthened by decentralized leadership, does not prevent vertical transfers from being welfare enhancing. If households have preferences for the public good which are not too strong, then equalization transfers are welfare improving beyond a certain level of trade integration.

Our paper contributes to the fiscal federalism literature in the following way: In line with the more recent literature on decentralized leadership, we argue that central governments are less and less able to commit towards subnational governments. In contrast, the first generation of fiscal federalism generally assumes that central governments are able to commit to implementing top-down Pigouvian tax and transfers and lump sum transfers. As a result, the federal policy generally offsets inefficiencies arising from cross-border spillovers and externalities and total welfare is improved in the federation. We argue instead that this assumption is at odds with the deepening of international globalization, and especially with trade liberalization and increasing capital mobility. Indeed, those two driving forces of globalization go hand-in-hand with more fiscal autonomy for subnational governments (Stegarescu 2009). The latter are increasingly responsible for freely setting their tax rates and provide citizens and firms with public goods, which make them more likely to behave strategically vis-à-vis the federal layer of government. This is all the more the case that, as argued by the so-called “compensation theory” (Genschel and Seelkopf 2016), globalization requires those citizens who suffer the consequences of market deregulation to be “compensated” in the form of more social benefits and public services. It does not mean that there is no longer any role for federal governments but rather, that they have to make do with the fact that state governments are more jealous of their prerogatives and behave opportunistically. Furthermore, greater decentralization and greater autonomy for subnational governments strengthen the need for fiscal equalization as underlined among others by Boadway (2004). The question that arises is naturally whether the fact that subnational governments behave more and more as Stackelberg leaders makes fiscal equalization less and less efficient because of a resulting common pool effect. According to our model, there is still scope for vertical transfers in economies characterized both by trade liberalization and fiscal decentralization.

Appendix

Appendix 1: Determination of k_i

The level of k_i solves $\pi_i - t_i = \pi_j - t_j = \pi_l - t_l = \dots$.

Replacing the profit by its expression (9) for i and j and rearranging the resulting expression we obtain:

$$\frac{2\tau^2}{\beta(k+1)}(k_l - k_i) = (t_i - t_l) \quad (23)$$

The sum of this expression for any $l \neq i$ gives

$$\begin{aligned} \sum_{l \neq i} \frac{2\tau^2}{\beta(k+1)}(k_l - k_i) &= \sum_{l \neq i} (t_i - t_l) \\ 2\tau^2 \sum_{l \neq i} (k_l - k_i) &= \beta(k+1) \sum_{l \neq i} (t_i - t_l) \\ 2\tau^2(k - Nk_i) &= \beta(k+1) \left((N-1)t_i - \sum_{l \neq i} t_l \right) \end{aligned}$$

and we obtain

$$k_i = \frac{k}{N} - \frac{\beta(k+1)}{2\tau^2 N} \left((N-1)t_i - \sum_{l \neq i} t_l \right)$$

Appendix 2: Comparison of t^{NS} and t^{DL}

The FOC in the case of decentralized leadership is

$$\frac{\partial S_i}{\partial t_i} + \gamma v'(g_i) \left(k_i + t_i \frac{\partial k_i}{\partial t_i} + \frac{\partial s_i}{\partial t_i} \right) = 0$$

while for the Nash equilibrium,

$$\frac{\partial S_i}{\partial t_i} + \gamma v'(g_i) \left(k_i + t_i \frac{\partial k_i}{\partial t_i} \right) = 0$$

Evaluated at the Nash equilibrium, the FOC of the decentralized leadership maximizing program is

$$\begin{aligned} \gamma v'(g_i) \frac{\partial s_i}{\partial t_i} \Big|_{\hat{t}} > 0 &\iff \frac{\partial s_i}{\partial t_i} \Big|_{\hat{t}} > 0 \quad (\text{cf. lemma 3 Kothenburger}) \\ \text{and } \hat{t} < \tilde{t} &\iff \frac{\partial s_i}{\partial t_i} \Big|_{\hat{t}} > 0 \end{aligned}$$

which can be rewritten as

$$\begin{aligned} \frac{\partial s_i}{\partial t_i} \Big|_{\hat{t}} &= \frac{(N-1)}{N} \left(-\frac{k}{N} + \hat{t} \frac{\beta(k+1)}{2\tau^2 N} (N-1) \right) + \left(\frac{N-1}{N} \right) \hat{t} \frac{\beta(k+1)}{2\tau^2 N} > 0 \\ &\iff \\ \hat{t} &> \frac{k2\tau^2}{N\beta(k+1)} = t_1 \end{aligned}$$

Using (18), we have $\hat{t} > t_1 \iff \Phi(t_1) < 0$ since $\frac{\partial \Phi}{\partial t} > 0$. Replacing t by t_1 in expression (18) and rearranging yields:

$$\Phi(t_1) = \frac{\tau k}{\beta(k+1)} \left(\frac{-2\tau}{N(N-1)} + \frac{\alpha - \omega - \tau + \frac{\tau}{N}}{\gamma(k+1)v' \left(\frac{k^2 2\tau^2}{N^2 \beta(k+1)} \right)} \right)$$

$$\text{Then } \Phi(t_1) < 0 \iff \gamma v' \left(t_1 \frac{k}{N} \right) > \frac{N(N-1)}{k+1} \frac{\alpha - \omega - \tau + \frac{\tau}{N}}{2\tau}.$$

Appendix 3: Comparison of t^{NS} and t^{DL} with $v(g) = \log(g)$

With $v(g) = \log(g)$, $\hat{\gamma}$ can be rewritten

$$\hat{\gamma} = \frac{\tau(\alpha - \omega)(N-1) - \tau^2 \frac{(N-1)^2}{N}}{N\beta \left(\frac{k+1}{k} \right)^2} \quad (24)$$

with $\frac{\partial \hat{\gamma}}{\partial \tau} > 0$ for any $\tau < \bar{\tau}$ since

$$\begin{aligned} \frac{\partial \hat{\gamma}}{\partial \tau} &= \frac{(\alpha - \omega)(N-1) - 2\tau \frac{(N-1)}{N}}{N\beta \left(\frac{k+1}{k} \right)^2} > 0 \iff \tau < \frac{N(\alpha - \omega)}{2} \quad \text{and} \\ \bar{\tau} &= \frac{N(\alpha - \omega)}{N+k} < \frac{N(\alpha - \omega)}{2} \end{aligned} \quad (25)$$

since $k \geq N \geq 1$. We can determine $\hat{\gamma}(\bar{\tau})$:

$$\hat{\gamma}(\bar{\tau}) = \frac{(N-1)(\alpha - \omega)^2 k^2}{(N+k)^2 \beta(k+1)}$$

For any $\tau < \bar{\tau}$ if $\gamma > \hat{\gamma}(\bar{\tau})$ then $\Phi(t_1) < 0$.

For $\gamma < \bar{\tau}$, let us define $F(\tau) = N\beta \gamma \left(\frac{k+1}{k} \right)^2 - \tau(\alpha - \omega)(N-1) + \tau^2 \frac{(N-1)^2}{N}$

$$\begin{aligned} \Delta &= (N-1)^2 ((\alpha - \omega))^2 - 4\beta \gamma \left(\frac{k+1}{k} \right)^2 > 0 \\ &\iff \gamma < \frac{(\alpha - \omega)^2}{4\beta \left(\frac{k+1}{k} \right)^2} = \bar{\gamma} \end{aligned}$$

For $\Delta > 0$ there are two roots

$$\begin{aligned}\tau_1 &= N \frac{(\alpha - \omega) - \sqrt{(\alpha - \omega)^2 - 4\beta\gamma\left(\frac{k+1}{k}\right)^2}}{2(N-1)}; \\ \tau_2 &= N \frac{(\alpha - \omega) + \sqrt{(\alpha - \omega)^2 - 4\beta\gamma\left(\frac{k+1}{k}\right)^2}}{2(N-1)} \\ \tau_1 &= N \frac{(\alpha - \omega) - \sqrt{(\alpha - \omega)^2 - 4\beta\gamma\left(\frac{k+1}{k}\right)^2}}{2(N-1)} < \bar{\tau} \\ &\Leftrightarrow \gamma < \frac{(N-1)(\alpha - \omega)^2 k^2}{(N+k)^2 \beta(k+1)} = \hat{\gamma}\end{aligned}$$

and

$$\tau_2 = N \frac{(\alpha - \omega) + \sqrt{(\alpha - \omega)^2 - 4\beta\gamma\left(\frac{k+1}{k}\right)^2}}{2(N-1)} > \frac{N(\alpha - \omega)}{2N} > \bar{\tau} = (\alpha - \omega) \frac{N}{N+k}$$

because $k \geq N$.

Finally we can check that

$$\hat{\gamma} - \bar{\gamma} < 0 \Leftrightarrow (k+N)^2 - 4(1+k)(N-1) > 0$$

Which is always true for $N \in [2, k]$.

Furthermore, we obviously have

$$\frac{\partial \tau_1}{\partial N} > 0, \quad \frac{\partial \tau_1}{\partial \gamma} > 0 \quad \text{and} \quad \frac{\partial \tau_1}{\partial k} < 0$$

Finally, $t^N = \min\{\hat{t}, t^{\max}\}$ and $t^{DL} = \min\{\tilde{t}, t^{\max}\}$ complement the proof.

Appendix 4: Prohibitive trade costs

No trade implies $x_{ji} = 0$ and $x_i = k_i x_{ii}$. The profit of a given firm i reduces to $\pi_i = (p_i - \omega)x_{ii}$ with $p_i = \alpha - \beta k_i x_{ii}$. The profit-maximising output of firm i on its domestic market is:

$$x_{ii} = \frac{\alpha - \omega}{\beta(k_i + 1)} \quad (26)$$

while the price on the domestic market reduces to:

$$p_i = \frac{\alpha + k_i \omega}{k_i + 1}$$

Finally, the profit of the firm becomes

$$\pi_i = \frac{(\alpha - \omega)^2}{\beta(k_i + 1)^2} \quad (27)$$

so that the maximum tax level is given by $t_{EC}^{max} = \frac{(\alpha - \omega)^2}{\beta(\frac{k}{N} + 1)^2}$.⁷

The consumer surplus is

$$S_i = \frac{1}{2} \left(\frac{k_i}{k_i + 1} \right)^2 \frac{(\alpha - \omega)^2}{\beta}$$

Equalization of the after tax profit between countries allows us to derive the level of capital in each state:

$$k_i + 1 = \frac{k + N}{1 + \sum_{k \neq i} \left(1 - \left(\frac{\beta}{(\alpha - \omega)^2} (t_i - t_k) (1 + k_i)^2 \right)^{(-1/2)} \right)}$$

and the effect of taxes on the firm's location is:

$$\begin{aligned} \frac{\partial k_i}{\partial t_i} &= - \frac{1}{2} \frac{\beta(k_i + 1)^2}{(\alpha - \omega)^2} \frac{\sum_{k \neq i} \left(1 - \frac{\beta}{(\alpha - \omega)^2} (t_i - t_k) \right)^{(-3/2)}}{\frac{k+N}{(k_i+1)^2} + \sum_{k \neq i} \frac{\beta(k_i+1)(t_i-t_k)}{(\alpha-\omega)^2} \left(1 - \frac{\beta}{(\alpha-\omega)^2} (t_i - t_k) \right)^{(-3/2)}} \\ \frac{\partial k_i}{\partial t_j} &= \frac{1}{2} \frac{\beta(k_i + 1)^2}{(\alpha - \omega)^2} \frac{\left(1 - \frac{\beta}{(\alpha - \omega)^2} (t_i - t_k) \right)^{(-3/2)}}{\frac{k+N}{(k_i+1)^2} + \sum_{k \neq i} \frac{\beta(k_i+1)(t_i-t_k)}{(\alpha-\omega)^2} \left(1 - \frac{\beta}{(\alpha-\omega)^2} (t_i - t_k) \right)^{(-3/2)}} \end{aligned}$$

At the symmetric equilibrium, these expressions reduce to:

$$\frac{\partial k_i}{\partial t_i} = - \frac{1}{2} \frac{\beta}{(\alpha - \omega)^2} \frac{(k + N)^3 (N - 1)}{N^4} \quad (28)$$

$$\frac{\partial k_i}{\partial t_j} = \frac{1}{2} \frac{\beta}{(\alpha - \omega)^2} \frac{(k + N)^3}{N^4} \quad (29)$$

The Nash corporate tax solves Eq. (17) and we obtain:

$$\hat{t}_{EC} = \frac{2\gamma N^2}{(N - 1) \left(k + \frac{\gamma \beta (k + N)^3}{(\alpha - \omega)^2 k N} \right)} \quad (30)$$

and at the symmetric Nash equilibrium, the implemented corporate tax is $t^N = \min\{\hat{t}_{EC}, t_{EC}^{max}\}$. Similarly to Appendix 2, we can state that

⁷ t_{EC}^{max} is null for an infinite number of firms ($k \rightarrow \infty$).

$$\hat{t} < \tilde{t} \iff \left. \frac{\partial s_i}{\partial t_i} \right|_{\hat{t}} > 0 \quad (31)$$

which can be rewritten as

$$\begin{aligned} \left. \frac{\partial s_i}{\partial t_i} \right|_{\hat{t}_{EC}} &= -\frac{(N-1)\hat{t}_{EC}}{N} \frac{\beta}{(\alpha-\omega)^2} \frac{1}{2} \frac{(k+N)^3}{N^4} \\ &\quad - \frac{(N-1)}{N} \left(\frac{k}{N} - \frac{1}{2} \hat{t}_{EC} \frac{\beta}{(\alpha-\omega)^2} \frac{(k+N)^3(N-1)}{N^4} \right) > 0 \\ &\iff \\ \hat{t}_{EC} &> 2 \frac{(\alpha-\omega)^2}{\beta} \frac{kN^2}{(k+N)^3} \end{aligned}$$

Replacing \hat{t}_{EC} by its expression (30) and rearranging gives:

$$\gamma > \frac{(N-1)(\alpha-\omega)^2 k^2 N}{(N+k)^3 \beta} = \hat{\gamma}_{EC}$$

then $t^{DL} > t^N \iff \gamma > \hat{\gamma}_{EC}$ for $\tau > \bar{\tau}$.

$t_{EC}^N = \min\{\hat{t}_{EC}, t_{EC}^{\max}\}$ and $t_{EC}^{DL} = \min\{\tilde{t}_{EC}, t_{EC}^{\max}\}$ complement the proof.

Finally, Comparing $\hat{\gamma}_{EC}$ and $\hat{\gamma}$ gives

$$\hat{\gamma}_{EC} - \hat{\gamma} = \frac{(N-1)(\alpha-\omega)^2 k^2 N}{(N+k)^3 \beta} - \frac{(N-1)(\alpha-\omega)^2 k^2}{(N+k)^2 \beta (k+1)} \quad (32)$$

$$= \frac{(N-1)(\alpha-\omega)^2 k^2}{(N+k)^2 \beta} \left(\frac{Nk-k}{(k+N)(k+1)} \right) > 0 \quad (33)$$

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