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Fiscal Federalism

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FISCAL EQUALIZATION UNDER POLITICAL PRESSURES *

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ABSTRACT: We examine the design of fiscal equalization transfers aimed at inter-regional redistribution in a setting in which special interest groups distort the fiscal policies of local governments. Equity always calls for tax-base equalization while efficiency calls for tax-base equalization of fiscal capacities backed by strong lobby groups and for tax-revenue equalization of those backed by weak lobby groups. Hence, it is optimal to rely only on tax-base equalization if the special interest groups are similar in terms of lobbying power, whereas a mixed system is optimal if they are highly heterogeneous. Tax competition reinforces the role of tax-base, while tax exporting that of tax-revenue, fiscal equalization.

JEL Codes: H77, D72, H21

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1 Introduction

Fiscal equalization programs represent an important feature of public sector finance in many states with multiple levels of government (Blöchliger and Charbit, 2008, Blöchliger, 2013). Since, generally, the local tax bases and the local public expenditure needs are not uniformly distributed over the territories of the state, fiscal equalization aims at reducing such gaps, thereby limiting the disparities in terms of net fiscal benefits for similar individuals living in different regions. However, the gains in terms of equity stemming from fiscal equalization must be confronted with its costs in terms of efficiency, since the transfer mechanism can distort the local governments' tax and expenditure decisions, as well as the locational choices of individuals and firms.

The literature on fiscal equalization can be divided into two main strands. The first examines, at a general level, under either a positive or a normative perspective, the assignment of the allocative and distributive functions between the central and the sub-national governments, and the role of inter-governmental transfer programs. This literature can be traced back to the works of Buchanan and Goetz (1972), Flatters *et al.* (1974), Boadway and Flatters (1982), where emphasis is given to inefficiencies in the allocation of the population as a consequence of fiscal externalities in the presence of perfect mobility of the population. In this setting, the role of transfers is to internalize the fiscal externalities. More recent contributions, e.g. Dahlby (1996), Sato (2000) and Albouy (2012), extend the previous models by assuming imperfect mobility of the population and distortionary taxation. The analysis of the optimal design of grant schemes based on the equalization of the social marginal cost of raising tax revenue across jurisdictions is due to Dahlby and Wilson (1994), while Gordon and Cullen (2011) examine the interplay between redistribution policies at the central and at the local level.

The second strand of the literature is more policy-oriented and examines the functioning of particular forms of fiscal equalization schemes that are used in practice. Among these, the grants aimed at fiscal-capacity equalization receive a great deal of attention, since programs of this kind are implemented both in federal (e.g., Canada and Germany) and unitary (e.g., Norway and Italy) states. Fiscal capacity equalization can be based either on *standard* tax revenues (tax-base equalization) or on *effective* tax revenues (tax-revenue equalization). Focusing on the representative tax system (RTS) equalization scheme for the Canadian Provinces, Smart (1998) offers a clear theoretical analysis of the incentive effects of tax-base equalization, by which a receiving local jurisdiction is entitled to a grant that depends on the difference between the national-average and its own per capita standard tax revenues. Since the latter, which depend on the effective tax bases, are a decreasing function of the effective tax rates, the equalization program gives the local governments an incentive to obtain more grants by raising their tax rates. Of the opposite sign are the incentives provided by tax-revenue equalization, since when a local government reduces its own tax rates, by reducing its own tax revenues it increases the equalization grant, which is based on the gap between average and own effective tax revenues. The empirical works by Esteller-Moré and Solé-Ollé (2002) and Smart (2007) for Canada, and Buettner (2006) for Germany, generally confirm the relevance of the incentives that tax-base equalization gives to set excessively high tax rates at the local level, while Baretti *et al.* (2002) show that the German interstate transfer system, based on tax revenues, discourages fiscal effort.

Following this line of research, some authors (see, e.g., Koethenbuerger, 2002; Bucovetsky and Smart, 2006; Rizzo, 2008), have observed that the distorting incentives of fiscal equalization should be confronted with those arising from horizontal tax competition among local governments. Hence, the focus of these studies is to characterize the conditions under which fiscal equalization programs aimed at inter-regional redistribution can bring about also some efficiency gains, by mitigating the adverse effects of tax competition.

A common hypothesis of this literature is that policy makers are benevolent social welfare maximizers. Sub-optimality of local fiscal policies, and hence the corrective role, if any, of fiscal equalization, is due to the failure by local governments to internalize various types of fiscal externalities. In the present work, instead, we contribute to the second strand of the literature by taking a political economy perspective. In particular, our premise is that fiscal policies at the local level can be influenced and distorted by special interest groups competing for preferential treatment, and accordingly examine how these distortions affect the design of fiscal capacity equalization programs, based either on tax bases or on tax revenues, that pursue equity and efficiency objectives.

We set up a simple public finance model, in which a large number of small local authorities finance their local public expenditure by taxing incomes accruing to two types of production factors that, being the expression of different socio-economic groups, also engage in lobbying activities in the attempt to bend the policy choices to their advantage. We examine first the case in which production factors are immobile and then extend the analysis to factors' mobility. We abstract from differences in fiscal needs or service-cost provision at the local level, while we allow for differential fiscal capacities. In defining the transfer program, we assume that the central authority is guided by the maxi-min criteria of maximizing the per capita social welfare of the less well-off local jurisdictions.[1]

[1] The literature on fiscal capacity equalization (see, e.g., the review by Boadway, 2006) usually

We frame the activities of the special interest groups by means of the common agency approach developed by Bernheim and Whinston (1986a, 1986b). However, we stress that the scope of our results extends to other forms of citizens' influence on fiscal choices (e.g., Brusco *et al.*, 2014), as well as to situations in which fiscal policy is driven by electoral concerns, like in probabilistic voting settings (e.g., Hettich and Winer, 1988, Dixit and Londregan, 1998).

We find that it is important to account for politically induced distortions in the design of fiscal equalization transfers. In particular, if the two lobby groups are not highly heterogeneous in terms of lobbying power, then it is optimal to rely exclusively on tax-base equalization. Ceteris paribus, the degree of equalization on the tax base backed by the stronger lobby group is higher than that on the tax base backed by the weaker group. If, instead, the special interest groups are highly heterogeneous in terms of lobbying power, then it is optimal to employ a mixed system: tax-base equalization on the tax base backed by the strong lobby group and tax-revenue on that backed by the weak one.

The explanation is simple. From the equity perspective, tax-base equalization is superior to tax-revenue equalization. If local governments are on the increasing side of their Laffer curve, tax-base equalization, by fostering tax rates and local tax revenues, increases inter-regional redistribution. On the contrary, tax-revenue equalization, by depressing tax rates and revenues, reduces the amount of inter-regional redistribution. From the efficiency perspective, each one of the fiscal equalization mechanisms works on a different side of the same coin. Since lobbying distorts taxation downward on the more powerful group and upward on the less powerful one, tax-base equalization on the former tax base, by stimulating fiscal effort, and tax-revenue equalization on the latter, by hindering fiscal effort, can help to redirect taxation toward its efficient structure. Taking together equity and efficiency considerations, we obtain the normative prescriptions described above.

Inter-regional mobility of production factors determines two contrasting incentives on local governments' tax setting. One is tax competition, putting a downward pressure on taxation. The other one is tax exporting, giving incentives of the opposite sign. While tax competition reinforces the role of tax-base equalization, tax exporting reinforces that of tax-revenue equalization. Ceteris paribus, factors' mobility reduces the gap between the fiscal equalization rates of the strong and the weak lobby groups.

defines the equity objective in terms of horizontal equity, by which otherwise identical individuals should bear equal tax burdens, irrespective of their place of residence. Since our main goal is to analyze the equity-efficiency tradeoff in the design of fiscal equalization schemes under lobbying and tax competition distortions, we define the objective function in terms of a social welfare functional.

The equity-efficiency trade-off facing inter-regional redistribution programs, as well as some aspects of the political determinants of the transfer policies, have already been examined in the literature on fiscal federalism, but never jointly, as we do in this paper, and however with a focus on issues that different from ours. Lockwood (1999) and Bordignon *et al.* (2001) focus on redistribution among regions in a setting of asymmetric information in which, because of moral hazard and adverse selection, the optimal equalization transfers are second best. Kotsogiannis and Schwager (2008) examine how fiscal capacity equalization impacts on the accountability of local politicians. The importance of political incentives on the allocation of grants is stressed by a line of empirical research: Dahlberg and Johansson (2002) focus on electoral incentives, while Levitt and Snyder (1995), Larcinese *et al.* (2006), and Solé-Ollé and Sorribas-Navarro (2008), focus on the partisan alignment hypothesis.

The rest of the paper is organized as follows. Section 2 presents the theoretical framework. Section 3 examines the normative aspects of fiscal equalization in a setting with immobile tax bases. Section 4 extends the analysis to the case of mobile tax bases. Section 5 concludes and an Appendix contains some of the technical details.

2 The model

Consider a federation composed of two types of local jurisdictions, or regions, indexed by $j = 1, 2$, and assume that there is an equal, and large, number, $J > 1$, of jurisdictions of each type.

In both types of regions, a private good is produced by means of a linear technology that uses two types of inputs, labelled $i = a, b$, each one supplied by a different type of agent. All agents of a given type i have identical preferences and endowments; instead, their productivity can be different in the two types of regions. We start our analysis by assuming that the regions are inhabited by immobile agents, i.e., by individuals supplying their own production factor only in their region of residence. We then consider the implications of factors' mobility in Section 4.

In both types of regions, the local government provides a public good (namely, a publicly provided private good) using a technology that transforms one unit of the private good into one unit of the public good. The private good serves also the role of consumption good and that of *numeraire* good. All markets are perfectly competitive.

2.1 Factors' supplies

All agents are endowed with an exogenous amount, normalized to unity, of a good that can be either directly consumed or supplied as a production factor. For a type-i agent resident in a type-j region, the endowment constraint is $h_{ij} + x_{ij} = 1$, where $h_{ij} \geq 0$ is the quantity directly consumed and $x_{ij} \geq 0$ is the quantity supplied for production. Let p_{ij} be the gross market price of production factor i in a type-j region. Since markets are perfectly competitive, by linearity of the production function, p_{ij} is constant and equal to the (exogenously given) marginal productivity of production factor i in a type-j region. Gross income, $y_{ij} = p_{ij}x_{ij}$, is taxed at source at a proportional rate $t_{ij} \in [0, 1]$. The individual budget constraint is then equal to $c_{ij} = (1 - t_{ij})y_{ij}$, where c_{ij} is the consumption good purchased in the market (the output, and *numeraire*, good, defined above).

Preferences of a type-i agent for consumption bundles (c_{ij}, h_{ij}) are represented by the utility function:

$$u^i(c_{ij}, h_{ij}) = c_{ij} + \phi^i(h_{ij}), \tag{1}$$

where the strictly concave function $\phi^i(.)$ represents the utility of direct consumption of the endowment. Quasi linearity of the utility function (1) implies that all income effects fall on the demand for market consumption.[2]

Taking t_{ij} and p_{ij} as given, the representative type-i individual solves:

$$\max_{x_{ij}} \; (1 - t_{ij})p_{ij}x_{ij} + \phi^i(1 - x_{ij}). \tag{2}$$

Denote with ϕ^i_h and ϕ^i_{hh} the first- and the second-order derivatives of ϕ^i, respectively. The equilibrium factor supply, $\tilde{x}_{ij}(p_{ij}, t_{ij})$, that solves problem (2) is defined by the first order condition:

$$(1 - t_{ij})p_{ij} = \phi^i_h(1 - x_{ij}). \tag{3}$$

To ensure an interior solution, $\tilde{x}_{ij} \in (0, 1)$, assume that $\lim_{x_{ij}\to 1} \phi^i_h(1 - x_{ij}) = +\infty$, $\phi^i_h(1) = 0$. Factor's supply is increasing in p_{ij}, $\partial\tilde{x}_{ij}/\partial p_{ij} = -(1 - t_{ij})/\phi^i_{hh}(\tilde{h}_{ij}) > 0$, and decreasing in t_{ij}, $\partial\tilde{x}_{ij}/\partial t_{ij} = p_{ij}/\phi^i_{hh}(\tilde{h}_{ij}) < 0$. To simplify the analysis, we assume that the elasticity of factors' supply, $\varepsilon_i > 0$, is constant. Then:

$$\frac{\partial\tilde{x}_{ij}}{\partial t_{ij}} = -\frac{\tilde{x}_{ij}\varepsilon_i}{1 - t_{ij}} < 0. \tag{4}$$

By inserting the equilibrium quantities into Eq. (1), the indirect utility function of a type-i agent resident in a type-j region is:

$$v_{ij}(t_{ij}) = (1 - t_{ij})p_{ij}\tilde{x}_{ij} + \phi^i\left(1 - \tilde{x}_{ij}\right), \tag{5}$$

[2] The quasi-linearity assumption is made for analytical convenience and can be relaxed. For some types of production factors, the empirical estimates of the impact of income taxes on their supply find weak income effects (see, e.g., Gruber and Saez, 2002, for the case of labor supply).

where, by applying the envelope theorem, it is:

$$\frac{\partial v_{ij}}{\partial t_{ij}} = -p_{ij}\tilde{x}_{ij} < 0. \tag{6}$$

The supply of production factors modelled above can be interpreted in familiar ways. If the endowment is expressed in units of time, and x_{ij} is labor time, h_{ij} is leisure time, and p_{ij} is the wage rate, then one obtains the standard neoclassical model of labor supply. As another example, consider a two-period framework with an endowment that in the first period can be allocated to consumption, h_{ij}, and investment, x_{ij}. Let p_{ij} be the second-period return of investment (including the principal). Then, in the absence of second-period bequests, c_{ij} is second-period consumption, and the model can be interpreted as one of capital supply.

Note that, strictly speaking, the use of distortionary income taxes is unjustified in the present setup. Since taxpayers are divided into two distinct, and observable, groups of identical agents, the efficient instrument would be a uniform lump sum tax — if the only objective is public good financing, or a pair of group-specific lump sum taxes — if also some degree of between-groups redistribution is deemed as desirable. However, the aim of this paper is not that of justifying the use of second-best distortionary taxes in place of first-best lump sum instruments, which is usually the focus of optimal tax models. Instead, the objective is the analysis of the efficiency and equity properties of transfer programs that are based on the equalization of fiscal capacities of local governments financing their own public services with distortionary taxes; to this end, and to avoid unnecessary analytical complications, we use a simple two-group, identical-agents, setup.[3]

Note, finally, that in the economy described above, in which there are two production factors and a single private good produced, the use of group-specific income taxes makes redundant the use of any other tax instrument. In fact, a proportional sales tax levied on producers, or a proportional consumption tax, is equivalent to a uniform income tax (i.e., $t_a = t_b$) on the suppliers of production factors. Thus, output and consumption taxes are embedded as special cases of production factors' income taxation.[4]

[3] Also Smart (1998) uses distortionary taxes in a setting in which lump sum taxes are feasible.

[4] The equivalence between consumption and income taxation requires somewhat strong conditions if there is tax competition among local governments. Income taxes collected at source are equivalent commodity taxes under the origin principle if factors' mobility induced by differentials in regional income tax rates bear the same impact on local tax revenues as consumers' cross border shopping in response to differentials in regional commodity tax rates.

2.2 Tax revenues and equalization grants

Let $n_{ij} > 0$ be the number of type-i agents supplying their own production factor in a type-j region. Let $\mathbf{t}_j = (t_{aj}, t_{bj})$. Let

$$\bar{z}_{kj} = \frac{n_{kj} p_{kj} \tilde{x}_{kj}}{n_{aj} + n_{bj}}, \tag{7}$$

be the per capita tax base of production factor k in a type-j jurisdiction, and let

$$\bar{z}_k = \frac{\sum_{r=1}^{2} n_{kr} p_{kr} \tilde{x}_{kr}}{\sum_{r=1}^{2} (n_{ar} + n_{br})}, \tag{8}$$

be the national per capita tax base of production factor k.

In a type-j jurisdiction, the per capita tax revenues are equal to:

$$T_j(\mathbf{t}_j) = \sum_{k \in \{a,b\}} t_{kj} \bar{z}_{kj}, \tag{9}$$

and the per capita equalization grant takes the following form:

$$E_j(\mathbf{t}_j) = \sum_{k \in \{a,b\}} \theta_k^{\mathrm{B}} \bar{t}_k \left(\bar{z}_k - \bar{z}_{kj} \right) + \sum_{k \in \{a,b\}} \theta_k^{\mathrm{R}} \left(\bar{t}_k \bar{z}_k - t_{kj} \bar{z}_{kj} \right), \tag{10}$$

where

$$\bar{t}_k = \frac{\sum_{r=1}^{2} t_{kr} n_{kr} p_{kr} \tilde{x}_{kr}}{\sum_{r=1}^{2} n_{kr} p_{kr} \tilde{x}_{kr}}, \tag{11}$$

is the national average tax rate on production factor k's income.

The transfer mechanism defined in Eq. (10) is based on the equalization of fiscal capacities. The parameters $\boldsymbol{\theta}^{\mathrm{S}} = (\theta_a^{\mathrm{S}}, \theta_b^{\mathrm{S}})$, $\theta_k^{\mathrm{S}} \in [0, 1]$, $\theta_k^{\mathrm{B}} \theta_k^{\mathrm{R}} = 0$, $\mathrm{S} = \mathrm{B}, \mathrm{R}$, $k = a, b$, express the degree of equalization of the fiscal capacity system. In particular, for each tax source, either one of two fiscal capacity measures are used: tax-base (B) or tax-revenue (R). Note that while we do not allow for a mixed mechanism for any single tax source, we do allow for a different mechanism on the two tax sources.

The grant formula shows that, for production factor k, given the national per capita tax base, $\bar{z}_k$, and the national average tax rate, $\bar{t}_k$, under tax-base equalization (TBE) the grant covers the share θ_k^{B} of the gap between the standardized national per capita tax revenue, $\bar{t}_k \bar{z}_k$, and the standardized per capita tax revenue, $\bar{t}_k \bar{z}_{kj}$, of the given type-j jurisdiction. Alternatively, under tax-revenue equalization (TRE), the grant covers the share θ_k^{R} of the gap between the standardized national per capita tax revenue, $\bar{t}_k \bar{z}_k$, and the effective per capita tax revenue, $t_{kj} \bar{z}_{kj}$, of the given type-j jurisdiction. Both equalization systems are of the 'net' type, since the transfers cashed by the 'recipient' jurisdictions (those with below-the-average fiscal capacities) are financed by the 'donor' jurisdictions (those with above-the-average fiscal capacities), and in the aggregate total transfers sum up to zero (in contrast, the Canadian RTS system is of the 'gross' type, by which only positive transfers are paid to some Provinces).

The two types of transfer mechanism have opposite effects on the tax-setting incentives of local governments. Under TBE, from the point of view of a single jurisdiction, an increase in its own tax rate t_{kj} determines, *coeteris paribus*, an increase in the grant, since the per capita tax base $\bar{z}_{kj}$ is decreasing in t_{kj}. That is, the equalization program gives incentives to local governments to expand taxation, an issue clearly exposed by Smart (1998). On the contrary, under TRE, an increase in its own tax rate t_{kj} determines, *coeteris paribus*, a reduction in the grant, since the per capita effective tax revenues $t_{kj}\bar{z}_{kj}$ are increasing in t_{kj}, provided that, of course, taxation is on the increasing side of the Laffer curve.

Note also that, in principle, the transfers depend not only on the tax rates set by the receiving jurisdiction, but also on those set by all other jurisdictions, since the latter affect the national per capita tax bases, $\bar{z}_k$, and the national average tax rates, $\bar{t}_k$, $k = a, b$. However, recall that we are focusing the analysis on a large number of local jurisdictions of each type. This means that any single jurisdiction is 'small' with respect to the federation to which it belongs, and thus it takes the average values $(\bar{z}_k, \bar{t}_k)$ as exogenously given when setting its own fiscal policy. That is, any given type-j jurisdiction perceives the impact of a change in its own tax rate t_{ij} on the equalization transfer as being equal to:

$$\frac{\partial E_j}{\partial t_{ij}} = \bar{z}_{ij}\theta_i^{\mathrm{B}} \left(\frac{\bar{t}_i \varepsilon_i}{1 - t_{ij}} \right) - \bar{z}_{ij}\theta_i^{\mathrm{R}} \left(1 - \frac{t_{ij}\varepsilon_i}{1 - t_{ij}} \right). \tag{12}$$

In a type-j jurisdiction, per capita public good supply is equal to its per capita public resources, $T_j(.) + E_j(.)$. By differentiating Eq. (9), and combining with Eq. (12), we obtain:

$$\frac{\partial T_j}{\partial t_{ij}} + \frac{\partial E_j}{\partial t_{ij}} = \bar{z}_{ij} \left(1 - \theta_i^{\mathrm{R}} - \frac{\left(1 - \theta_i^{\mathrm{R}}\right) t_{ij} - \theta_i^{\mathrm{B}} \bar{t}_i}{1 - t_{ij}} \varepsilon_i \right). \tag{13}$$

2.3 Social welfare

The welfare of a type-i agent supplying its own production factor in a type-j region is:

$$w_{ij}(\mathbf{t}_j) = v_{ij}(t_{ij}) + \gamma \left[T_j(\mathbf{t}_j) + E_j(\mathbf{t}_j) \right], \tag{14}$$

where $v_{ij}(.)$ is the utility of private consumption, defined in Eq. (5), and $\gamma > 1$ is the marginal utility of public expenditure, which is assumed to be constant and exogenously given.[5] Recall also that we have assumed that local public services take the form of a publicly provided private good; hence, individual welfare depends on per capita local public expenditure, $T_j + E_j$.

Using a Utilitarian criteria to aggregate the individual utilities, social welfare in a type-j jurisdiction is defined as:

$$W_j(\mathbf{t}_j) = \sum_{k \in \{a,b\}} n_{kj} w_{kj}(\mathbf{t}_j). \tag{15}$$

2.4 Taxpayers' lobbying

At the local level, we frame taxpayers' lobbying activities within the conventional 'buying influence' approach, originally conceived by Bernheim and Whinston (1986a, 1986b) and then further developed by Grossman and Helpman (1994, 2001) and Dixit *et al.* (1997). We setup a perfect-information common-agency game with three players: two principals (the lobbyists, each one representing the interests of one group of taxpayers) and one agent (the local policy maker). Interest groups compete to sway tax policy to their advantage by openly offering legal monetary rewards (in the form, for instance, of campaign contributions) to the policy maker.

Formally, the game presents two stages. In the first, the taxpayers' lobbyists announce to the policy maker a menu of monetary offers which are contingent on fiscal policies. Following acceptance of the offers, in the second stage the policy maker takes her preferred choice under the influence of the incentives provided by lobbyists. The game can be solved backward using the notion of subgame perfection.

Following Dixit *et al.* (1997), we assume that the contribution function presented by a lobbyist to the policy maker is of the *truthful*, or *compensating*, type. A truthful contribution is a continuous function of the policy instruments that is defined along an indifference curve of the lobbyist; hence, a change in a policy instrument determines a change in the contribution offered to the policy maker that reflects one-to-one the impact of the policy change on the lobbyist's welfare. Truthful contributions are a helpful device for solving this class of common agency games, since the set of the best responses of each principal to the contribution functions (not necessarily truthful) of the other principals always contains a truthful contribution schedule (Dixit *et al.*, 1997, Proposition 2). Hence, there is no loss of generality in using this type of contribution functions. Moreover, with truthful contributions the equilibrium of the game is often unique, while in general common agency games admit multiple equilibria.

[5] The analysis can be easily generalized, albeit at the cost of some analytical complexity, to the case in which the marginal benefits of the public good are a decreasing function of public expenditure.

In a type-j jurisdiction, the truthful contribution function offered by group i lobbyist is, in per capita terms:

$$c_{ij}(\mathbf{t}_j; \lambda_{ij}, \hat{\pi}_{ij}) = \lambda_{ij} \max\{0, w_{ij}(\mathbf{t}_j) - \hat{\pi}_{ij}\}, \tag{16}$$

where $\hat{\pi}_{ij} \geq 0$ is a scalar representing the per capita net payoff of the lobby group. The parameter $\lambda_{ij} \in [0,1]$ represents a measure of the effectiveness of group i in its lobbying activity in a type-j region: the group is fully powerful if $\lambda_{ij} = 1$; it is completely ineffective if $\lambda_{ij} = 0$. Following the literature quoted above, we do not model how a group organizes its lobbying activity in order to provide its members with the incentives to pursue the common interest and to overcome free riding behavior. We simply assume the existence of a lobbyist for each group of taxpayers, with an exogenously given 'capacity' to influence policy making, as represented by the parameter λ_{ij}.

The local policy maker cares both for social welfare, defined in Eq. (15), and for political contributions, defined in Eq. (16). Her objective function is assumed to be linearly additive, with uniform weights, in the two components. Ignoring the non-negativity constraint on the contribution functions, the objective function of the local policy maker in the second stage of the lobby game can be written as:[6]

$$\Omega_j(\mathbf{t}_j) = \sum_{k \in \{a,b\}} n_{kj}(1 + \lambda_{kj}) w_{kj}(\mathbf{t}_j). \tag{17}$$

By looking at Eq. (17), we immediately note that political pressures impact on fiscal policy only if groups a and b are not equally effective in lobbying (i.e., if $\lambda_{aj} \neq \lambda_{bj}$), so that the policy maker ends up maximizing a 'distorted' social welfare function. Instead, if the two groups are equally effective in lobbying (i.e., if $\lambda_{aj} = \lambda_{bj}$), then lobbying does not impact on fiscal policy.

Note also that the objective function (17) is compatible with a political setting in which tax policy is driven by electoral competition instead of by special interest groups. In particular, an objective function similar to that shown in Eq. (17) can be obtained within a standard probabilistic voting model in which two parties run for election with the aim of maximizing their vote share, with voters of groups a and b ideologically dispersed in favor of one of the two parties. In this setting, the weight λ_{kj} represents a

[6] The lobby game can be solved by first computing the equilibrium in the policy variables at the second stage by maximizing Eq. (17), which ignores the non-negativity constraints on political contributions. The latter can then be checked ex-post, after having computed the equilibrium net payoffs of the lobby groups, $(\hat{\pi}^*_{aj}, \hat{\pi}^*_{bj})$, at the first stage of the game. However, in the present work we do not solve for the first stage of the game, since we are not interested in the distributional effects of lobbying due to the monetary transfers from the lobby groups to the policy maker. We focus only on the second stage of the game, where lobbying impacts on fiscal policy.

measure of the 'political clout' of group k in region j, as a function of the mass of swing voters (see Persson and Tabellini, 2000, for a textbook exposition of the probabilistic voting model, and Dixit and Londregan, 1996, for an application to redistributive tax policy).

3 Fiscal equalization with immobile factors

In this section, we characterize the fiscal policies set by local governments under the influence of taxpayers' lobbying, and then examine inter-regional redistribution by means of fiscal equalization.

3.1 Equilibrium local fiscal policies

Consider a type-j jurisdiction. The local policy maker maximizes the objective function defined in Eq. (17) with respect to the own tax rates $\mathbf{t}_j$, taking as given the other jurisdictions' tax rates and the average tax rates, and tax bases, at the national level. The first order conditions are:[7]

$$\frac{\partial \Omega_j}{\partial t_{ij}} = -n_{ij}(1+\lambda_{ij})p_{ij}\tilde{x}_{ij} + \gamma \left(\frac{\partial T_j}{\partial t_{ij}} + \frac{\partial E_j}{\partial t_{ij}} \right) \sum_{k \in \{a,b\}} n_{kj}(1+\lambda_{kj}) = 0, \quad i = a, b. \quad (18)$$

Defining:

$$\bar{\lambda}_j = \frac{n_{aj}\lambda_{aj} + n_{bj}\lambda_{bj}}{n_{aj} + n_{bj}},$$

and using Eq. (13), Eq. (18) can be manipulated to obtain:

$$\frac{\left(1-\theta_i^{\mathrm{R}}\right) t_{ij} - \theta_i^{\mathrm{B}} \bar{t}_i}{1 - t_{ij}} = \frac{\gamma \left(1-\theta_i^{\mathrm{R}}\right) - (1+\lambda_{ij})/(1+\bar{\lambda}_j)}{\gamma \varepsilon_i}, \quad j = 1, 2, \quad i = a, b. \quad (19)$$

In principle, the equilibrium local fiscal policies of the federation are defined by a system of $4J$ equations in the $4J$ tax rates set by the $2J$ jurisdictions. However, since the J jurisdictions of type j, $j = 1, 2$, are identical, we can focus on the symmetric equilibria in which all jurisdictions of the same type set the same fiscal policy. This reduces the $4J$-equation system to a four-equation system. However, note that since the average tax rate $\bar{t}_i$ is a (non-linear) function of the tax rates (t_{i1}, t_{i2}), the equilibrium tax rates (t_{i1}^*, t_{i2}^*), for given i, are implicitly defined by a two-equation system. Note also that the equilibrium tax rate t_{ij}^* depends on the entire vector, $\boldsymbol{\lambda}$, of the lobby

[7] We assume that the second order condition for a maximum holds at the equilibrium tax rates defined below in Eq. (19). Second order conditions are satisfied in the numerical simulations presented in Table 2 Section 3.3, below.

weights, $\boldsymbol{\lambda} = (\lambda_{a1}, \lambda_{b1}, \lambda_{a2}, \lambda_{b2})$, but it depends only on the equalization coefficients, θ_i^{B} and θ_i^{R}, of the corresponding tax base i.

Eqs. (19) highlight, on a *coeteris paribus* basis, the factors driving tax choices. First, taxation on factor i is lower the higher is its elasticity of (compensated) supply ε_i. This is a Ramsey-type efficiency argument, by which the minimization of the excess burden of taxation requires a taxation level which is inversely related to the elasticity of the tax base. Second, the higher the marginal benefits γ of public expenditure, the higher the tax rates are. Note that, absent lobbying activities and fiscal equalization, local taxation is second-best efficient, with tax rates set at a level below the bliss point of the Laffer curve:

$$\frac{t_{ij}}{1-t_{ij}} = \frac{\gamma-1}{\gamma\varepsilon_i}. \tag{20}$$

The other two factors bearing on taxation are lobbying and fiscal equalization. If, say, group b is more powerful than group a in lobbying, i.e., if $\lambda_{bj} > \bar{\lambda}_j > \lambda_{aj}$, then lobbying distorts taxation downward on group b and upward on group a; the opposite otherwise, if it is group a the more capable in lobbying. Finally, the higher the degree θ_i^{B} of fiscal equalization on tax base i, the higher its equilibrium tax rate is, since TBE gives incentives to local governments to expand taxation. On the contrary, the higher the degree θ_i^{R} of fiscal equalization on tax revenues i, the lower its equilibrium tax rate is, since TRE gives incentives to local governments to reduce taxation.

Note that, in the absence of lobbying, type-1 and type-2 regions apply in equilibrium the same tax rate on tax base i, since $\lambda_{ij} = 0$, $i = a, b$, $j = 1, 2$, implies that the r.h.s. of Eq. (19) is independent of jurisdictions' type j. Instead, in the presence of lobbying, type-1 and type-2 jurisdictions apply in general different tax rates on the same type of production factor, unless the lobbying power is 'uniformly distributed' in the federation between groups a and b. The latter condition is formally defined in the following assumption.

Assumption 1 (Uniform distribution of lobbying power across regions) *The absolute lobbying power, and the relative size, of groups a and b are the same in type-1 and type-2 jurisdictions. That is:*

$$\lambda_{aj} = \lambda_a, \quad \lambda_{bj} = \lambda_b, \quad \frac{n_{aj}}{n_{bj}} = \nu, \quad j = 1, 2. \tag{21}$$

The following proposition derives the equilibrium tax rates under Assumption 1.

Proposition 1 *If lobbying power is uniformly distributed across regions, then the equilibrium tax rate on type-i production factor is the same in type-1 and type-2 jurisdictions. That is, $t_{ij}^* = t_i^*$, $j = 1, 2$, where:*

$$\frac{t_i^*}{1-t_i^*} = \frac{\gamma\left(1-\theta_i^{\mathrm{R}}\right) - (1+\lambda_i)/(1+\bar{\lambda})}{\gamma(1-\theta_i^{\mathrm{B}}-\theta_i^{\mathrm{R}})\varepsilon_i}, \quad i = a, b, \quad \bar{\lambda} = \frac{\nu\lambda_a + \lambda_b}{\nu+1}. \tag{22}$$

Proof. By the conditions given in Eq. (21), the r.h.s. of Eq. (19) is independent of j and therefore also t_{ij} on the l.h.s. is independent of j. Thus $t_{i1} = t_{i2} = \bar{t}_i = t_i$ and Eq. (19) reduces to Eq. (22). ■

A situation with uniform lobbying greatly simplifies the normative analysis on optimal equalization, since the equilibrium tax rates defined in Eq. (22) are explicitly expressed in terms of the model's parameters. Moreover, it is not a too restrictive assumption, since it requires only that groups a and b are equally effective in lobbying across regions, and that their relative size is the same, in both types of regions. Assumption 1 admits, instead, situations in which type-1 and type-2 regions are heterogeneous in terms of total population and production factors' productivity. Hence, we maintain the uniform lobbying assumption throughout the analysis.

We denote with $\mathbf{t}^* = (t_a^*, t_b^*)$ the vector of the equilibrium tax rates defined by Eq. (22), and we use 'starred' variables to denote their corresponding values after substitution for the equilibrium tax rates. Hence, for instance, $x_{ij}^* = \tilde{x}_{ij}(p_{ij}, t_i^*)$ denotes the equilibrium supply of type-i factor in type-j regions, and $T_j^* = T_j(\mathbf{t}^*)$ denotes the equilibrium tax revenues in type-j regions.

A final restriction we introduce into the analysis concerns the size of the marginal benefits of public expenditure.

Assumption 2 $\gamma\left(1-\theta_i^{\mathrm{R}}\right) > (1+\lambda_i)/(1+\bar{\lambda})$, $i = a, b$.

Recall that, in Section 2.3, we assumed $\gamma > 1$; otherwise, it is inefficient to provide public goods, since the marginal utility of private consumption is equal to unity by assumption. In the absence of lobbying distortions and of TRE, $\gamma > 1$ ensures that both tax rates are positive, see Eq. (22). However, either one or both tax rates can be negative if $\theta_i^{\mathrm{R}} > 0$ or if $\lambda_a \neq \lambda_b$. Since equalizing subsidies means redistribution from low to high fiscal capacity regions, we appeal to Assumption 2 to ensure that taxation is positive on both tax bases. In fact, the condition is not too restrictive, since, as we show below, it can be optimal to use TRE, i.e., to set $\theta_i^{\mathrm{R}} > 0$, only on the less powerful lobby group, i.e., that for which $(1+\lambda_i)/(1+\bar{\lambda}) < 1$.

3.2 Regional heterogeneity and social welfare

By inserting the equilibrium tax rates, $\mathbf{t}_j^* = \mathbf{t}^*$, into Eq. (15), social welfare in a type-j region, as a function of the equalization parameters, is equal to:

$$W_j^*(\boldsymbol{\theta}) = \sum_{k \in \{a,b\}} n_{kj} \left\{ v_{kj}(t_k^*) + \gamma \left[T_j(\mathbf{t}^*) + E_j(\mathbf{t}^*) \right] \right\}, \quad j = 1, 2, \tag{23}$$

where $\boldsymbol{\theta} = \left(\theta_a^{\mathrm{B}}, \theta_b^{\mathrm{B}}, \theta_a^{\mathrm{R}}, \theta_b^{\mathrm{R}}\right)$ is the vector of the equalization parameters.

Recall that all agents of a given type i have identical preferences and endowments, no matter their region of residence. However, their productivity can be different in type-1 and type-2 regions. Hence, in per capita terms, any gap in the per capita regional social welfare levels can be due only to differences in production factors' productivity. And since there are two types of production factors and two types of regions, there are only two possible cases. Either both types of production factors are more productive in one type of regions than in the other one, or each type of production factor is more productive in one type of regions and less productive in the other, and vice versa. Our choice is to focus the analysis on the first case only, since it implies a non-ambiguous rank between type-1 and type-2 regions in terms of per capita social welfare, hence delivering clear-cut results, while there is no value added in examining also the second case. To simplify the exposition, we assume, without loss of generality, that the more productive regions are type-2.

Assumption 3 *Both types of production factors are more productive in type-*2 *than in type-*1 *regions. That is,* $p_{i1} < p_{i2}$*,* $i = a, b$*.*

An implication of the hypothesis introduced so far is that in the absence of central government intervention the per capita social welfare in type-2 regions is higher than that in type-1 regions. Fiscal equalization redistributes from rich to poor regions. However, it can never determine re-ranking between high and low productivity regions, in terms of either per capita fiscal capacity, individual welfare and per capita regional welfare. These properties are stated formally in the following lemma (see Appendix A.1 for the proof).

Lemma 1 *Assume A.1, A.2 and A.3. Then, for any degree,* $\theta_i^{\mathrm{S}} \in [0, 1)$*, of fiscal equalization,* $\mathrm{S} = \mathrm{B}, \mathrm{R}$*, the per capita tax base on production factor* i*, the welfare of type-*i *agents, and the per capita regional social welfare, are strictly higher in type-*2 *than in type-*1 *regions. That is:*

$$\bar{z}_{i1}^* < \bar{z}_{i2}^*, \quad w_{i1}^* < w_{i2}^*, \quad i = a, b; \qquad \frac{W_1^*}{n_{a1} + n_{b1}} < \frac{W_2^*}{n_{a2} + n_{b2}}.$$

By aggregating over type-1 and type-2 regions (recall that there is an equal number of regions of each type), and taking into account that the equalization transfers sum up to zero in the aggregate, i.e.,

$$\sum_{j=1}^{2}(n_{aj}+n_{bj})E_j(\mathbf{t}^*)=0,$$

the national social welfare, $W^* = \sum_{j=1}^{2} W_j^*$, is expressed as:

$$W^*(\boldsymbol{\theta}) = \sum_{j=1}^{2}\sum_{k\in\{a,b\}} n_{kj}\left[v_{kj}(t_{kj}^*)+\gamma T_j(\mathbf{t}^*)\right]. \tag{24}$$

Given that (i) the marginal utility of private consumption is constant and uniform for all types of agents in all regions, and (ii) the marginal utility of local public expenditure is also constant and uniform in all regions, the national social welfare function (24) shows no preference for redistribution, neither at the individual nor at the regional level; indeed, it is invariant to any kind of balanced-budget lump sum transfers among individuals or regions. It is, instead, sensitive to tax distortions. Hence, Eq. (24) represents an appropriate measure of the impact of fiscal equalization on efficiency.

3.3 Fiscal equalization: efficiency and equity

We are now ready to examine the choice of the fiscal equalization system, and the determination of its parameters, by the central government. We assume that, when setting the equalization program, the central policy maker accounts for the influence (if any) of the lobby groups on local fiscal policies. On the other hand, taxpayers do not attempt to influence the policy choices at the central level.

In particular, we assume that the central authority takes a Rawlsian view in terms of per capita social welfare at the regional level. Within our framework, the maxi-min criterion amounts to maximizing social welfare of type-1 regions, since fiscal equalization can never determine, by Lemma 1, re-ranking between type-1 and type-2 regions in terms of per capita social welfare.

To ease the presentation of the results, we also assume, without loss of generality, that one of the two groups is always (weakly) more powerful than the other one in lobbying.

Assumption 4 *Group a is always less powerful, at most equally powerful, than group b in lobbying. That is, $\lambda_a \leq \lambda_b$.*

To compute the impact on a type-j region's social welfare of an increase in fiscal equalization, we differentiate Eq. (23) with respect to θ_i^{S}, obtaining:

$$\frac{\partial W_j^*}{\partial \theta_i^{\mathrm{S}}} = -n_{ij} p_{ij} x_{ij}^* \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{S}}} + \gamma (n_{aj} + n_{bj}) \left(\frac{\partial T_j^*}{\partial \theta_i^{\mathrm{S}}} + \frac{\partial E_j^*}{\partial \theta_i^{\mathrm{S}}} \right), \quad \mathrm{S} = \mathrm{B}, \mathrm{R}. \tag{25}$$

Recall that, under the conditions of Proposition 1, $t_{ij}^* = t_i^* = \bar{t}_i^*$, $j = 1, 2$. Hence, in equilibrium, tax revenues and equalization grants are equal to:

$$T_j^*(\mathbf{t}_j^*) = \sum_{k \in \{a,b\}} t_k^* \bar{z}_{kj}^*, \qquad E_j^*(\mathbf{t}_j^*) = \sum_{k \in \{a,b\}} \left(\theta_k^{\mathrm{B}} + \theta_k^{\mathrm{R}} \right) t_k^* \left(\bar{z}_k^* - \bar{z}_{kj}^* \right),$$

with derivatives

$$\frac{\partial T_j^*}{\partial \theta_i^{\mathrm{S}}} = \bar{z}_{ij}^* \left(1 - \frac{t_i^* \varepsilon_i}{1 - t_i^*} \right) \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{S}}}, \quad \mathrm{S} = \mathrm{B}, \mathrm{R}, \tag{26}$$

$$\frac{\partial E_j^*}{\partial \theta_i^{\mathrm{S}}} = t_i^* \left(\bar{z}_i^* - \bar{z}_{ij}^* \right) + \left(\theta_i^{\mathrm{B}} + \theta_i^{\mathrm{R}} \right) \left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \left(1 - \frac{t_i^* \varepsilon_i}{1 - t_i^*} \right) \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{S}}}, \quad \mathrm{S} = \mathrm{B}, \mathrm{R}. \tag{27}$$

Using the fact that, by Eq. (22),

$$\frac{t_i^* \varepsilon_i}{1 - t_i^*} = \frac{\gamma \left(1 - \theta_i^{\mathrm{R}} \right) - \Lambda_i}{\gamma \left(1 - \theta_i^{\mathrm{B}} - \theta_i^{\mathrm{R}} \right)}, \qquad \Lambda_i = \frac{1 + \lambda_i}{1 + \bar{\lambda}},$$

and using Eqs. (26)-(27), Eq. (25) can be finally written as:

$$\frac{\partial W_j^* / \partial \theta_i^{\mathrm{S}}}{n_{aj} + n_{bj}} = \gamma t_i^* \left(\bar{z}_i^* - \bar{z}_{ij}^* \right) + \left(\theta_i^{\mathrm{B}} + \theta_i^{\mathrm{R}} \right) \left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \frac{\Lambda_i - \gamma \theta_i^{\mathrm{B}}}{1 - \theta_i^{\mathrm{B}} - \theta_i^{\mathrm{R}}} \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{S}}} + \\ + \bar{z}_{ij}^* \left(\frac{\Lambda_i - 1 - (\gamma - 1)\theta_i^{\mathrm{B}} + \theta_i^{\mathrm{R}}}{1 - \theta_i^{\mathrm{B}} - \theta_i^{\mathrm{R}}} \right) \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{S}}}, \quad \mathrm{S} = \mathrm{B}, \mathrm{R}. \tag{28}$$

Recall that, for each tax base i, only one type of equalization system is employed, either tax-base (B) or tax-revenue (R). Hence, Eq. (28) can be specified for each equalization system as follows:

$$\left. \frac{\partial W_j^* / \partial \theta_i^{\mathrm{B}}}{n_{aj} + n_{bj}} \right|_{\theta_i^{\mathrm{R}} = 0} = \underbrace{\left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \gamma t_i^*}_{\substack{\text{mechanical effect} \\ \text{(equity)}}} + \underbrace{\left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \frac{\theta_i^{\mathrm{B}} \left(\Lambda_i - \gamma \theta_i^{\mathrm{B}} \right)}{1 - \theta_i^{\mathrm{B}}} \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{B}}}}_{\text{behavioral effect (equity)}} + \\ + \underbrace{\bar{z}_{ij}^* \left(\frac{\Lambda_i - 1 - (\gamma - 1)\theta_i^{\mathrm{B}}}{1 - \theta_i^{\mathrm{B}}} \right) \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{B}}}}_{\text{behavioral effect (efficiency)}}, \tag{29}$$

$$\left. \frac{\partial W_j^* / \partial \theta_i^{\mathrm{R}}}{n_{aj} + n_{bj}} \right|_{\theta_i^{\mathrm{B}} = 0} = \underbrace{\left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \gamma t_i^*}_{\substack{\text{mechanical effect} \\ \text{(equity)}}} + \underbrace{\left(\bar{z}_i^* - \bar{z}_{ij}^* \right) \frac{\theta_i^{\mathrm{R}} \Lambda_i}{1 - \theta_i^{\mathrm{R}}} \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{R}}}}_{\text{behavioral effect (equity)}} + \\ + \underbrace{\bar{z}_{ij}^* \left(\frac{\Lambda_i - 1 + \theta_i^{\mathrm{R}}}{1 - \theta_i^{\mathrm{R}}} \right) \frac{\partial t_i^*}{\partial \theta_i^{\mathrm{R}}}}_{\text{behavioral effect (efficiency)}}. \tag{30}$$

	tax base $i = a$				tax base $i = b$			
	TBE regions		TRE regions		TBE regions		TRE regions	
	$j = 1$	$j = 2$	$j = 1$	$j = 2$	$j = 1$	$j = 2$	$j = 1$	$j = 2$
mechanical effect: equity	$+$	$-$	$+$	$-$	$+$	$-$	$+$	$-$
behavioral effect: equity	$+$ (*)	$-$ (*)	$-$	$+$	$+$ (*)	$-$ (*)	$-$	$+$
behavioral effect: efficiency (°)	$-$		$+$ if $\theta_a^{\mathrm{R}} < \alpha^{\mathrm{R}}$ $-$ if $\theta_a^{\mathrm{R}} > \alpha^{\mathrm{R}}$		$+$ if $\theta_b^{\mathrm{B}} < \beta^{\mathrm{R}}$ $-$ if $\theta_b^{\mathrm{B}} > \beta^{\mathrm{R}}$		$-$	

(*) if $\theta_i^{\mathrm{B}} < \Lambda_i/\gamma$. (°) $\theta_a^{\mathrm{R.Eff.}}$ and $\theta_b^{\mathrm{B.Eff}}$ are defined in Eq. (33)

Table 1: Fiscal equalization: equity and efficiency.

Provided that the second order conditions hold,[8] and that the solution is unique, the optimal equalization parameters, $\theta_i^{\mathrm{B}*}$, $\theta_i^{\mathrm{R}*}$, are obtained by solving:

$$\left.\frac{\partial W_j^*/\partial\theta_i^{\mathrm{B}}}{n_{aj}+n_{bj}}\right|_{\theta_i^{\mathrm{R}}=0} = 0 \Rightarrow \theta_i^{\mathrm{B}*}, \qquad \left.\frac{\partial W_j^*/\partial\theta_i^{\mathrm{R}}}{n_{aj}+n_{bj}}\right|_{\theta_i^{\mathrm{B}}=0} = 0 \Rightarrow \theta_i^{\mathrm{R}*}.$$

For each tax base i, either $\theta_i^{\mathrm{B}*}$ or $\theta_i^{\mathrm{R}*}$ is chosen, depending on which equalization system gives higher social welfare for type-1 regions.[9]

Derivatives (29) and (30) highlight the key factors driving the choice of the fiscal equalization system, by showing that an increase in the degree of fiscal equalization, of either types, bears three effects on social welfare, which are summarized in Table 1. The first effect is mechanical, expressing the marginal transfer of resources from rich to poor regions of a marginal increase in fiscal equalization, for given levels of local tax revenues. Under Assumption 3, these terms are positive for type-1, and negative for type-2, regions, since $\bar{z}_i^* > \bar{z}_{i1}^*$, $\bar{z}_i^* < \bar{z}_{i2}^*$. The other two effects are behavioral, for they are due to the impact of a marginal change in the degree of fiscal equalization on local tax rates and tax bases. One effect impacts on equity, the other one on efficiency. For

[8] We do not state formally the conditions for the optimal equalization problem to be concave. The numerical model presented in Table 2, for instance, is well-behaved.

[9] Note that, given the structure of our model, by which taxation on type-a agents impacts on the welfare of type-b agents only through the supply of public goods (and viceversa), the choice of the best equalization system can be done independently on each tax base i.

both, the sign of their impact on social welfare crucially depends on the sign of the impact of fiscal equalization on the equilibrium tax rates, $\partial t_i^*/\partial\theta_i^{\mathrm{S}}$, which is positive for TBE and negative for TRE.

We examine the roles of fiscal equalization by considering cases of increasing order of complexity. We start by focusing on efficiency, that is by abstracting from the redistributive impact of the equalization transfers. This amounts to maximizing the national social welfare function, defined in Eq. (24), or, equivalently, the aggregate of Eqs. (29)-(30) over $j = 1, 2$, giving first order conditions that depend only the behavioral efficiency term:

$$\left.\frac{\partial W^*}{\partial\theta_i^{\mathrm{B}}}\right|_{\theta_i^{\mathrm{R}}=0} = \bar{z}_i^* \left(\frac{\Lambda_i - 1 - (\gamma-1)\theta_i^{\mathrm{B}}}{1-\theta_i^{\mathrm{B}}}\right)\frac{\partial t_i^*}{\partial\theta_i^{\mathrm{B}}} = 0, \tag{31}$$

$$\left.\frac{\partial W^*}{\partial\theta_i^{\mathrm{R}}}\right|_{\theta_i^{\mathrm{B}}=0} = \bar{z}_i^* \left(\frac{\Lambda_i - 1 + \theta_i^{\mathrm{R}}}{1-\theta_i^{\mathrm{R}}}\right)\frac{\partial t_i^*}{\partial\theta_i^{\mathrm{R}}} = 0. \tag{32}$$

From these equations, it is immediate to see that, if lobbying does not distort local tax rates (since groups a and b are equally powerful in lobbying, so that $\Lambda_a = \Lambda_b = 1$), then the solution is $\theta_i^{\mathrm{B}} = \theta_i^{\mathrm{R}} = 0$. The reason is obvious. Absent lobbying distortions, local taxes are optimally set, and fiscal equalization would introduce a distortion that is costly in terms of efficiency.

The incentives provided by fiscal equalization on tax setting are instead useful to reap efficiency gains when taxation is distorted by lobbying. Since, by Assumption 4, group b is a more powerful lobbyist than a, so that $\Lambda_a < 1 < \Lambda_b$, then taxation is distorted downward on tax base b and upward on a. Fiscal equalization can then be used to provide adequate incentives for bringing tax rates to their efficient level, by employing TBE on tax base b and TRE on a. By solving Eq. (31) for $i = b$ and Eq. (32) for $i = a$, the optimal equalization parameters that bring tax rates at their efficient levels defined in Eq. (20) are equal to:[10]

$$\theta_b^{\mathrm{B.Eff.}} = \frac{\Lambda_b - 1}{\gamma - 1} > 0, \qquad \theta_a^{\mathrm{R.Eff.}} = 1 - \Lambda_a > 0. \tag{33}$$

Now consider inter-regional redistribution. In the absence of lobbying distortions, it is clear that TBE is superior to TRE in terms of equity. Indeed, under TBE both the mechanical and the behavioral effect are positive for type-1 regions, whereas under TRE the former is positive but the latter is negative. The explanation is simple. Local taxes are on the increasing side of their Laffer curve. Hence, while TBE, by stimulating

[10] Clearly, efficiency can be obtained also with negative TBE on tax base a, at rate $(\Lambda_a - 1)/(\gamma - 1) < 0$, and with negative TRE on tax base b, at rate $1 - \Lambda_b < 0$. However, we discard these solutions since they redistribute in the wrong direction, from poor to rich regions.

an increase in tax rates and local tax revenues, increases inter-regional redistribution, TRE, by reducing tax rates and revenues, reduces it.[11] Since, as noted above, both equalization systems are costly in term of efficiency (absent lobbying distortions), overall TBE is a better redistributive device than TRE. Note also that, in this situation in which the initial allocation without central government intervention is efficient, fiscal equalization faces a standard equity-efficiency tradeoff, since the gains in terms of transfers to the poor regions must be balanced against the efficiency costs in terms of tax distortions.

Finally, we reintroduce lobbying into the picture. As illustrated above, we know that efficiency calls for TBE on the tax base backed by the more powerful group b and for TRE on that backed by the less powerful group a. We also know that TBE is preferable on equity grounds. By combining these elements, we obtain the following optimality conditions. If lobbying distortions are not very important, because group b is not much more powerful than a, then TBE should be used on both tax bases, since the main driver of fiscal equalization is equity. For given level of productivity gap, $p_{i2} - p_{i1}$, between the two types of regions, the optimal degree of fiscal equalization depends on the measure, $\lambda_b - \lambda_a$, of the distance between groups in terms of lobbying power: if the latter increases, it is optimal to increase the degree of TBE on tax base b and reduce it on tax base a, since it is necessary to counteract a stronger pressure for low tax rates on tax base b, that in turn induces local governments to increase taxation on tax base a. Note also that equity and efficiency do not conflict when TBE is increased on tax base b, while they do when TBE is reduced on a. This means that there exists a threshold of the lobby-power-gap, $\lambda_b - \lambda_a$, above which it becomes optimal, for tax base a, to shift from TBE to TRE, since the latter serves well both efficiency and equity objectives.[12] Note finally that, when lobbying distortions are important, fiscal equalization does not face an equity-efficiency tradeoff, since the optimal policy can improve both equity (i.e., per capita social welfare in the poor regions) and efficiency (i.e., national social welfare), or even obtain a Pareto improvement (i.e., an increase in

[11] That local tax revenues are on the increasing side of their Laffer curve is clearly a condition for optimality, both at the local and at the central level of government. In particular, taxation is always on the increasing side of the Laffer curve under TRE, since the latter lowers taxation. Instead, under TBE, taxation is on the increasing side of the Laffer curve provided that the degree of equalization is below a given threshold, since TBE increases taxation. Namely, the condition is $\Lambda_i - \gamma\theta_i^{\mathrm{B}} > 0$, ensuring that the behavioral effect (equity) in Eq. (29) is positive for type-1 regions and negative for type-2.

[12] The conditions for optimality can be stated also as follows: for given level, $\lambda_b - \lambda_a$, of lobby-power gap, there exists a threshold level of the productivity gap, $p_{i2} - p_{i1}$, such that TBE should be used on tax base b and TRE on a if the productivity gap is below the threshold level, while TBE should be used on both tax bases if it is above it.

per capita social welfare for both types of regions).[13]

The rules governing the design of the fiscal equalization scheme in the presence of lobbying are summarized in Proposition 2 (its proof is omitted, since the arguments have been given above). An illustration of the results by means of a numerical example is given in Table 2.

Proposition 2 *Assume A.1, A.2, A.3, A.4, and that fiscal equalization aims at maximizing the per capita social welfare of type-*1 *regions. Then, for a given level of productivity gap between type-*1 *and type-*2 *regions, the optimal fiscal equalization policy is governed by the following rules.*

- *If groups a and b heterogeneity in terms of lobbying power, as measured by $\lambda_b - \lambda_a$, is below a given threshold, then TBE should be employed on both tax bases. The degree of equalization of tax base b is increasing, while that of tax base a is decreasing, in $\lambda_b - \lambda_a$.*
- *If groups a and b heterogeneity in terms of lobbying power is above a given threshold, then TBE should be employed on tax base b while TRE should be employed on tax base a. Both equalization coefficients are increasing in $\lambda_b - \lambda_a$.*

Row 1 in Table 2 shows the equilibrium tax rates and social welfare, in the absence of fiscal equalization, in a situation in which lobbying does not distort fiscal policy, since the two groups are equally powerful ($\lambda_b = \lambda_a = .2$). In order to highlight the impact of lobbying, the simulation assumes the same elasticity of supply for factors a and b ($\varepsilon_b = \varepsilon_a = .2$). Row 2 shows that TBE maximizes social welfare of type-1 regions with a 51% equalization rate on both tax bases. This, however, distorts taxation upward from 37 to 54%, hence there is a reduction in national social welfare. Row 3 shows that TBE at 51% on tax base b and TRE at 6% on tax base a is not as good, in equity terms, as TBE on both tax bases. The reason is that TRE distorts taxes downward and also redistributes less than TBE.

Rows 4-6 show what happens if group b is a more powerful lobbyist than a. With no equalization (row 4), taxation is distorted by lobbying upward on group a, from 37 to 44%, and downward, from 37 to 27%, on b. Row 5 shows that TBE at 39% on tax base a and TBE at 66% on b reduces the gap between tax rates from 17 to 5 percentage points, thus partially counteracting the lobbying distortion; however, at the same time both tax rates increase because of TBE. Row 6 shows that, in terms of type-1 regions

[13] A Pareto improvement at a regional level does not imply, in general, a Pareto improvement at the individual level. Typically, fiscal equalization, by lowering taxation on the less powerful lobby group a and by increasing it on the more powerful one b, favors the former and penalizes the latter.

Immobile production factors

	λ_a	λ_b	θ_a^{B*}	θ_b^{B*}	θ_a^{R*}	t_{a1}^*	t_{a2}^*	t_{b1}^*	t_{b2}^*	W_1^*	W_2^*	W^*	T_1^*	T_2^*	$\lvert E_i^*\rvert$
1	.2	.2	.00	.00	.00	.37	.37	.37	.37	2.813	3.111	5.924	.160	.219	.000
2	.2	.2	.51	.51	.00	.54	.54	.54	.54	2.844	3.033	5.877	.209	.285	.020
3	.2	.2	.00	.51	.06	.31	.31	.54	.54	2.830	3.069	5.899	.175	.239	.011
4	.2	.5	.00	.00	.00	.44	.44	.27	.27	2.809	3.105	5.914	.154	.210	.000
5	.2	.5	.39	.66	.00	.57	.57	.52	.52	2.845	3.031	5.876	.208	.284	.020
6	.2	.5	.00	.66	.15	.33	.33	.52	.52	2.843	3.064	5.906	.175	.239	.014
7	.2	.8	.00	.00	.00	.49	.49	.16	.16	2.798	3.090	5.888	.138	.188	.000
8	.2	.8	.31	.80	.00	.58	.58	.49	.49	2.846	3.029	5.875	.207	.283	.021
9	.2	.8	.00	.80	.22	.34	.34	.49	.49	2.854	3.058	5.912	.175	.239	.018

Mobile production factors

	λ_a	λ_b	θ_a^{B*}	θ_b^{B*}	θ_a^{R*}	t_{a1}^*	t_{a2}^*	t_{b1}^*	t_{b2}^*	W_1^*	W_2^*	W^*	T_1^*	T_2^*	$\lvert E_i^*\rvert$
10	.2	.2	.00	.00	.00	.30	.26	.30	.26	2.851	3.143	5.994	.137	.166	.000
11	.2	.2	.53	.53	.00	.52	.50	.52	.50	2.892	3.083	5.974	.204	.272	.021
12	.2	.2	.00	.53	.00	.30	.26	.52	.50	2.871	3.113	5.984	.170	.219	.010
13	.2	.5	.00	.00	.00	.36	.32	.23	.20	2.848	3.141	5.989	.134	.164	.000
14	.2	.5	.43	.64	.00	.53	.51	.51	.49	2.892	3.082	5.974	.204	.272	.021
15	.2	.5	.00	.64	.09	.32	.28	.51	.49	2.879	3.109	5.988	.172	.221	.013
16	.2	.8	.00	.00	.00	.41	.36	.17	.15	2.843	3.135	5.978	.129	.159	.000
17	.2	.8	.36	.73	.00	.55	.52	.50	.48	2.892	3.081	5.973	.204	.272	.021
18	.2	.8	.00	.73	.16	.33	.29	.50	.48	2.886	3.105	5.991	.173	.223	.015

Model's parameters: $n_{a1} = n_{b1} = n_{a2} = n_{b2} = 1$, $p_{a1} = p_{b1} = 1$, $p_{a2} = p_{b2} = 1.25$, $\gamma = 1.3$, $\varepsilon_a = \varepsilon_b = .4$, $F_a(0) = F_b(0) = .1$, $f_a(0) = f_b(0) = .5$, $\int_{-\infty}^{0} \mu \mathrm{d}F_a = \int_{-\infty}^{0} \mu \mathrm{d}F_b = .02$.

Model's specification: $\phi^i = 1 - 5\frac{\varepsilon_i}{1+\varepsilon_i} x_{ij}^{(1+\varepsilon_i)/\varepsilon_i}$, $\tilde{x}_{ij} = \frac{1}{5}((1-t_{ij})p_{ij})^{\varepsilon_i}$

Table 2: Optimal fiscal equalization: some numerical examples.

social welfare, a mixed system TBE-TRE is equivalent to one based only on TBE. Indeed, the mixed system is superior to a pure TBE system in terms of efficiency, since national social welfare is higher. Note, however, that the mixed system overturn the structure of taxation, with the more powerful lobby group being taxed more heavily than the less powerful one.

Finally, rows 7-9 show that when there is high heterogeneity in terms of lobbying power, the best equalization system is the mixed one, both on equity and efficiency grounds. TRE at 22% on tax base a and TBE at 80% on base b performs better than TBE at 31% on base a and at 80% on b.

The remaining part of Table 2 refers to the model with factors' mobility, to which we turn now.

4 Tax competition and tax exporting

In this section, the analysis is extended by allowing for mobility of production factors. In particular, while we continue to assume that the place of residence is fixed for all agents, we allow them to choose the place where to earn their income.

4.1 Mobility of production factors

We model factors' mobility in a simple way, by assuming that each region is 'connected' with a region of the same type, so that the agents who are resident in a given type-j region have the opportunity to supply their own production factor either at 'home' or 'abroad', in another, and only one, region of the same kind.

An agent supplying her own production factor in the 'foreign' region connected to her place of residence sustains a lump sum cost μ, with μ distributed within the group of type-i agents according to the density function $f_i(\mu) \geq 0$ on the support $\mu = (-\infty, +\infty)$, with cumulative distribution denoted by $F_i(\mu)$. On the one hand, a positive μ can be interpreted as the mobility cost sustained for supplying abroad instead of at home. On the other hand, a negative μ can be interpreted as a net opportunity cost for *not* supplying abroad; an instance of a negative μ is when the agent can enjoy a better workplace environment abroad than at home, by an amount that more than compensates for the costs of commuting. Obviously, a reasonable restriction to impose on the distribution of μ is $F_i(0) < .5$. That is, mobility costs are positive for more than 50% of the residents in the region; otherwise, it is hard to sustain the hypothesis of fixed residence (i.e., no migration). Note, however, that none of the results hinges on specific restrictions on the distribution of mobility costs.

Consider a type-(i, μ) agent who is resident in a type-j region. To illustrate, and with a slight abuse of notation, j denotes the 'home' region and ι the connected 'foreign' region. The agent chooses to supply at home if $v_{ij}(t_{ij}) \geq v_{i\iota}(t_{i\iota}) - \mu$, and abroad otherwise, where v_{ir}, $r = j, \iota$, is the indirect utility function defined in Eq. (5). The number of type-i agents supplying at home is thus equal to:

$$\tilde{n}_{ijj}(t_{ij}, t_{i\iota}) = n_{ij} \left[1 - F_i(v_{i\iota} - v_{ij})\right],$$

while that of those supplying abroad is equal to $\tilde{n}_{ij\iota}(t_{ij}, t_{i\iota}) = n_{ij} - \tilde{n}_{ijj}(t_{ij}, t_{i\iota})$.

Specularly, the number of type-i agents resident in region ι that supply in region j is equal to:

$$\tilde{n}_{i\iota j}(t_{i\iota}, t_{ij}) = n_{i\iota} F_i(v_{ij} - v_{i\iota}).$$

Hence, the total number of type-i agents supplying in region j is equal to:

$$\tilde{n}_{ij}(t_{ij}, t_{i\iota}) = \tilde{n}_{ijj}(t_{ij}, t_{i\iota}) + \tilde{n}_{i\iota j}(t_{i\iota}, t_{ij}). \tag{34}$$

An increase in the home tax rate t_{ij} causes an outflow of production factors from region j to region ι that is equal to:

$$\frac{\partial \tilde{n}_{ij}}{\partial t_{ij}} = -p_{ij}\tilde{x}_{ij} \left[n_{ij} f_i(v_{i\iota} - v_{ij}) + n_{i\iota} f_i(v_{ij} - v_{i\iota})\right] \leq 0. \tag{35}$$

Per capita tax revenues and equalization grants are defined as in Eqs. (9)-(10), respectively, with $\tilde{n}_{ij}$, defined in Eq. (34), that substitutes n_{ij} in the Eqs. (7), (8) and (11), defining the average tax bases and tax rates, $\bar{z}_{kj}$, $\bar{z}_k$ and $\bar{t}_k$, respectively.

For a type-j region, an increase in its own tax rate t_{ij} impacts on tax tax revenues and equalization grants as follows:

$$\frac{\partial T_j}{\partial t_{ij}} + \frac{\partial E_j}{\partial t_{ij}} = \bar{z}_{ij} \left(1 - \theta_i^{\mathrm{R}} - \left[\left(1 - \theta_i^{\mathrm{R}}\right) t_{ij} - \theta_i^{\mathrm{B}} \bar{t}_i\right] \left(\frac{\varepsilon_i}{1 - t_{ij}} - \frac{\partial \tilde{n}_{ij} / \partial t_{ij}}{\tilde{n}_{ij}}\right)\right). \tag{36}$$

The type-i agents that are resident in a type-j region are divided into two groups: that of those supplying at home, in number $\tilde{n}_{ijj}$, with welfare $v_{ij} + \gamma\,(T_j + E_j)$, and that of those supplying abroad, in number $\tilde{n}_{ij\iota}$, with welfare $v_{i\iota} + \gamma\,(T_j + E_j) - \mu$. Note that, while income can be earned in the foreign region, public goods are always enjoyed in the home region. Hence, although $\tilde{n}_{ijj}$ agents supply at home and $\tilde{n}_{ij\iota}$ abroad, the number those benefitting from public goods is always equal to the number of residents, n_{ij}. Aggregate social welfare is thus equal to:

$$\tilde{W}_j(\mathbf{t}_j) = \sum_{k \in \{a,b\}} \left(\tilde{n}_{kjj} v_{kj} + \tilde{n}_{kj\iota} v_{k\iota} - n_{kj} \int_{-\infty}^{v_{k\iota} - v_{kj}} \mu \, \mathrm{d}F_i + n_{kj} \gamma\,(T_j + E_j)\right).$$

4.2 Fiscal equalization under tax competition and lobbying

We assume that only the resident agents lobby their own local policy maker. That is, agents supplying abroad lobby at home but not abroad. Hence, following the same steps described in Section 2.4, the objective function of a type-j local policy maker is:

$$\tilde{\Omega}_j(\mathbf{t}_j) = \sum_{k\in\{a,b\}} (1+\lambda_k) \left(\tilde{n}_{kjj} v_{kj} + \tilde{n}_{kj\iota} v_{k\iota} - n_{kj} \int_{-\infty}^{v_{k\iota}-v_{kj}} \mu \, \mathrm{d}F_i + n_{kj}\gamma \left(T_j + E_j\right) \right). \tag{37}$$

By maximizing Eq. (37) with respect to the own tax rates, taking as given the tax rates set in the other jurisdictions, the equilibrium local fiscal policies are obtained. Note that, since each region is connected with an identical region of the same type, the equilibrium is always a symmetric one, with $t^*_{ij} = t^*_{k\iota}$, $v^*_{ij} = v^*_{k\iota}$, $\tilde{n}^*_{ijj} = n_{ij}\left[1 - F_i(0)\right]$, $\tilde{n}_{ij\iota} = n_{ij}F_i(0)$, $\tilde{n}^*_{ij} = n_{ij}$. In general, however, regions of different types set different tax policies. Formally, the equilibrium tax rates on tax base i are defined by the following two-equation system in (t_{i1}, t_{i2}) (the derivation is in Appendix A.2):

$$\frac{\left(1-\theta_i^{\mathrm{R}}\right) t_{ij} - \theta_i^{\mathrm{B}} \bar{t}_i}{1 - t_{ij}} = \frac{\gamma\left(1-\theta_i^{\mathrm{R}}\right) - \left[1 - F_i(0)\right](1+\lambda_i)/(1+\bar{\lambda})}{\gamma\left[\varepsilon_i + 2(1-t_{ij}) p_{ij} \tilde{x}_{ij} f_i(0)\right]}, \quad j = 1, 2. \tag{38}$$

Eq. (38) represents a generalization of Eq. (19) to the case of mobile production factors. It shows that mobility produces two contrasting incentives on tax setting by local governments. On the one hand, it determines incentives to lower taxation, in the attempt to prevent the resident production factors to supply abroad and to attract factors from abroad, thereby augmenting the tax base. This effect, which is present in the denominator of the r.h.s. of Eq. (38), is proportional to the after-tax income, $(1 - t_{ij})p_{ij}\tilde{x}_{ij}$, multiplied by the density, $f_i(0)$, of the agents that in equilibrium are indifferent between supplying at home and abroad. Clearly, the higher the density $f_i(0)$, the higher is the elasticity of the tax base depending on mobility, and hence the lower is the tax rate in equilibrium. On the other hand, mobility determines incentives to higher taxation, since local governments can export part of their tax burden by taxing non-resident agents. This effect, which is present in the numerator of the r.h.s. of Eq. (38), is proportional to the mass, $F_i(0)$, of agents supplying abroad in equilibrium. The higher the mass of agents supplying abroad, the higher is taxation in the attempt to export taxation on non-residents.

Note that, although Eq. (38) is derived under Assumption 1 of uniform lobbying power across the federation, in equilibrium, under factors' mobility type-1 and type-2 regions set different tax rates on the same tax base i, since, in general, $p_{i1}\tilde{x}_{i1} < p_{i2}\tilde{x}_{i2}$ under Assumption 3. This means that fiscal equalization, differently from the case of immobile production factors (see Eq. 33), cannot restore efficiency if taxation is distorted by tax competition, tax exporting, or lobbying.[14]

We conclude by looking at the results of the numerical example in Table 2. Rows 10 to 18 introduce factors' mobility into the corresponding rows 1 to 9 in which factors are immobile. By comparing the two parts of the Table, we see that in the absence of fiscal equalization taxation is in general lower under mobility (rows 10, 13, 16) than under no-mobility (rows 1, 4, 7). Of course, this is not a general result, since it depends on the chosen parametrization of the example, in which tax competition dominates over tax exporting. Under fiscal equalization, however, tax rates under mobility and under no-mobility are more similar. Because of tax competition, TBE on both tax bases is the best equalization policy even when groups a and b are highly heterogeneous in terms of lobbying power (rows 17-18). Intuitively, since tax competition tends to lower taxation, TBE is the best instrument to reap efficiency gains. Obviously, by giving more weight to tax exporting, it is possible to construct examples in which a mixed system TBE-TRE, or even a pure TRE system, is the best option, since in this case efficiency calls for giving incentives to lower taxation, which is inflated by tax exporting.

5 Concluding remarks

In this paper, we set up a simple public finance model to examine whether and how political pressures by special interest groups on local governments affect their fiscal choices and the design of optimal fiscal equalization schemes by the central authority. Our main results show that it is optimal to rely exclusively on tax-base equalization if the lobby groups are similar in terms of lobbying power. A mixed system is instead optimal if the special interest groups are highly heterogeneous in terms of lobbying power, with tax-base equalization on the tax base backed by the strong lobby group and tax-revenue on that backed by the weak one.

The analysis was conducted under several assumptions, some of which could be relaxed in future work to test the theoretical robustness of the results. The hypothesis of perfect substitutability between production factors can be relaxed by allowing for imperfect substitutability, or to analyze the opposite polar case of perfect complementarity. In both cases, taxation would bear general equilibrium effects on the before-tax market returns of production factors, thus determining tax shifting between sectors.

Fiscal equalization focused on fiscal capacity, with regions that are homogeneous

[14] Of course, fiscal equalization can restore efficiency if all regions are identical. However, this is not an interesting case, since fiscal equalization is motivated in the first place by the fact that regions are heterogeneous.

with respect to expenditure needs and service cost provision. The analysis can be extended to account for these relevant factors of regional heterogeneity.

Finally, lobbying was confined only at the local level. For some production factors, especially those that are highly mobile, it is probably a better strategy to lobby at the central level of government than at the local one. Moreover, it is also possible that local authorities lobby the central one to bend the equalization scheme towards their interests.

Appendix

A.1 Proof of Lemma 1

Recall that, by Assumptions 1 and 2, type-1 and type-2 regions set identical and positive tax rates t_i^*. Hence, by Assumption 3, $(1-t_i^*)p_{i1} < (1-t_i^*)p_{i2}$. Since factors' supplies are upward sloping, the latter inequality implies $y_{i1}^* < y_{i2}^*$, $v_{i1}^* < v_{i2}^*$. Assumption 1 (namely, type-a and type-b agents are in the same proportion in both types of regions) then implies $\bar{z}_{i1}^* < \bar{z}_{i2}^*$. For $\theta_i < 1$, per capita public expenditure, $(T_j^* + E_j^*)/(n_{aj} + n_{bj})$, is higher in type-2 than in type-1 regions, since tax revenues are higher while the equalization mechanism does not fully equalizes total resources. Higher welfare from private consumption ($v_{i1}^* < v_{i2}^*$) and higher benefits from public goods imply that all agents of a given type resident in type-2 regions are better off than those of the same type resident in type-1 regions. That is, $w_{i1}^* < w_{i2}^*$. This also implies that the per capita social welfare is higher in type-2 than in type-1 regions.

A.2 Derivation of Eq. (38)

By differentiating Eq. (37) with respect to t_{ij}, we get the first order condition:

$$\begin{aligned} \frac{\partial \tilde{\Omega}_j}{\partial t_{ij}} &= -(1+\lambda_i)\left(\tilde{n}_{ijj}p_{ij}\tilde{x}_{ij} + v_{ij}\frac{\partial \tilde{n}_{ijj}}{\partial t_{ij}} + v_{i\iota}\frac{\partial \tilde{n}_{ij\iota}}{\partial t_{ij}} + n_{ij}(v_{i\iota}-v_{ij})f(v_{i\iota}-v_{ij})p_{ij}\tilde{x}_{ij}\right) + \\ &\quad + \sum_{k\in\{a,b\}}(1+\lambda_k)n_{kj}\gamma\left(\frac{\partial T_j}{\partial t_{ij}} + \frac{\partial E_j}{\partial t_{ij}}\right). \qquad \text{(A.1)} \end{aligned}$$

Since the Nash equilibrium between the two identical connected regions, j and ι, is symmetric, it is: $v_{i\iota} = v_{ij}$, $\frac{\partial \tilde{n}_{ij\iota}}{\partial t_{ij}} = \frac{\partial \tilde{n}_{ijj}}{\partial t_{ij}}$, $\tilde{n}_{ijj} = n_{ij}\left[1-F_i(0)\right]$. Hence, Eq. (A.1) can be written as:

$$-(1+\lambda_i)n_{ij}\left[1-F_i(0)\right]p_{ij}\tilde{x}_{ij} + \sum_{k\in\{a,b\}}(1+\lambda_k)n_{kj}\gamma\left(\frac{\partial T_j}{\partial t_{ij}} + \frac{\partial E_j}{\partial t_{ij}}\right) = 0. \qquad \text{(A.2)}$$

Dividing by $n_{aj}+n_{bj}$, using Eq. (36), and dividing by $\bar{z}_{ij}$, we get:

$$\left(1-\theta_i^{\mathrm{R}} - \left[\left(1-\theta_i^{\mathrm{R}}\right)t_{ij} - \theta_i^{\mathrm{B}}\bar{t}_i\right]\left(\frac{\varepsilon_i}{1-t_{ij}} - \frac{\partial \tilde{n}_{ij}/\partial t_{ij}}{\tilde{n}_{ij}}\right)\right) - \frac{1+\lambda_i}{1+\bar{\lambda}}\left[1-F_i(0)\right] = 0. \qquad \text{(A.3)}$$

In a symmetric equilibrium, it is: $(\partial \tilde{n}_{ij}/\partial t_{ij})/n_{ij} = -2p_{ij}\tilde{x}_{ij}f_i(0)$. Substituting the latter expression into Eq. (A.3), and rearranging, we finally obtain Eq. (38).

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