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I WANT TO FREE-RIDE. AN OPPORTUNISTIC VIEW ON DECENTRALIZATION VERSUS CENTRALIZATION PROBLEM

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I Want to Free-Ride.
An Opportunistic View on Decentralization versus Centralization Problem

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Abstract

The aim of the paper is to analyze a model of local public good provision with positive interjurisdictional spillovers comparing decentralized and centralized system. As in the recent *Second Generation Theory* (SGT) of fiscal federalism (Seabright 1996; Lockwood 2002; Besley and Coate 2003; Oates 2005; Weingast 2009), we also adopt a political economy approach, assuming different behaviours of political leaders (*Leviathan* and *non-Leviathan*). The main contribution of the paper is to consider two relevant aspects neglected by the political economy models: the size of local jurisdictions and the explicit definition of the rent-seeking behaviour. Moreover, modelling interregional externalities as a mechanism contributing to lowering the production cost of the public good in each region, a quite different trade-off - from the traditional and new theory of fiscal federalism - is proposed in order to compare decentralized versus centralized solution: the gains from *internalizing externalities* and the losses of *free-riding advantages*, which may differ with regional size and preferences for the public good. Given this general framework, the convenience of decentralization versus centralization mainly depends on the interaction among these factors: *i)* the free-riding gains exploiting positive externalities; *ii)* the gains of internalizing externalities; *iii)* the degree of preferences heterogeneity; *iv)* the implicit transfers ("*cross subsidization*") across different regions. To summarize, from a positive viewpoint, decentralization should not be necessarily pursued only in the absence of externalities, but also with high spillovers. The key insight of this result is represented by different size of regions, which may determine an asymmetry among citizens' responses concerning the best institutional setting.

JEL classification: *H73, H77, H41, D72*

Keywords: *Decentralization; Spillovers; Free-riding; Rent-seeking behaviour; Local public goods*

1. Introduction

According to the traditional theory of fiscal federalism (Tiebout 1956; Buchanan 1965; Oates 1972), decentralized tiers of government found their primary role in the provision of efficient levels of "local" public goods – that is, public goods whose consumption was limited primarily to their own constituencies. Where spillovers benefits across jurisdictions accompanied outputs of local public goods, appropriate unit subsides would encourage decentralized authorities to extend outputs to efficient levels. Indeed, under the *First Generation Theory* (FGT) of fiscal federalism, the trade-off between centralization and decentralization of certain public activities concerns, on the one hand, the inefficiencies under centralized provision of public services stemming from more uniform outputs that fail to reflect divergences in local tastes and conditions versus, on the other hand, inefficiencies in local provision resulting from the failure to internalize interjurisdictional externalities (Oates 2005). In the latter case, the solution for decentralized provision is stronger only whether spillovers effects across local jurisdictions are relatively small and the variation in efficient levels of local outputs is relatively large.

More recently, new insights have emerged from the *Second Generation Theory* (SGT) of fiscal federalism (Seabright 1996; Qian and Weingast 1997; Lockwood 2002; Besley and Coate 2003; Weingast 2009),[1] which focuses on a quite different - with respect to the one crucial for the FGT - trade-off: the centralization versus decentralization issue is now based on the comparison between the higher degree of policies coordination under centralization (which should guarantee the internalization of externalities), and the higher degree of accountability and control of local politicians by citizens under decentralization (which should guarantee more sensitivity of outcomes to local preferences). Thus, improved accountability - as a result of decentralization - must be set against any externalities which arise from spillovers between localities (Seabright 1996). Actually, this trade-off is in a somewhat similar spirit to their earlier counterparts since, as Besley and Coate (2003) pointed out, "the key insight remains that heterogeneity and spillovers are correctly at the heart of the debate about the gains from centralization", but for different reasons than those suggested in the existing literature.

In general, to address the choice between centralized and decentralized provision of public goods, political economy studies model - explicitly or implicitly - the government behaviour, where differentiated (and possibly conflicting) objective functions between decision makers and citizens are usually assumed.[2] In Edwards and Keen (1996) and Seabright (1996), for example, government is modelled as a *Leviathan*.[3] In this case, politicians aim at applying taxes (or at having financing sources) that best maximize their rents, obtaining all potential benefits that arise from providing services whose value (in aggregate) is less than the amount of taxes received by their communities (Liberati 2010).

Following this line of research, we also adopt a political economy approach[4] assuming different behaviours of political leaders to look at the trade-off between centralized and decentralized provision of local public goods with spillovers linked thereto. In detail, two

[1] See Oates (2005) for a survey.

[2] A central tenet of the *Public Choice* approach is the view that public decision makers are utility maximizers with their own objective functions. Budget maximization is taken here to serve as a proxy for a variety of objectives including enhancement of power and influence, large staffs, and higher salaries.

[3] See also Alesina and Spolaore (1997); Bolton and Roland (1997); Cremer and Palfrey (1996).

[4] As argued by Lockwood (2006), "By a political economy approach, I mean a systematic attempt to model the behaviour of government - whether at the national or local level - taking into account institutions and processes, such as elections and legislatures, which determine the choice of fiscal policy in practice".

specifications of politicians' behaviour are studied: one adopting a "*full recovery costs"* (FRC) strategy, setting taxation equal to the cost of providing the public good, without any additional gains; one implementing a "*Leviathan"* strategy, charging a higher tax than the production cost in order to get an extra-rent. To some extent, the former is quite similar to the standard benevolent government; while, the latter exploits their residents, imposing taxes above the benefits they get. From an analytical point of view, the innovation of the paper is to describe the detail of the representatives' opportunistic behaviour in the legislature through an alternative specification concerning the budget constraint definition which includes an extra-rent when the decision maker is Leviathan. Thus, we directly model a "rent equation" to represent the additional gain of rent-seeking politicians.

The second contribution of the paper is to model positive external spillovers linked to the provision of local public goods in a different way as usual (Gilbert and Picard 1996; Conley and Dix 1999; Lockwood 2002; Besley and Coate 2003; Dur and Staal 2008). Indeed, positive externalities are treated as a mechanism contributing to lowering the production cost of the public good in each region. In this vein, we introduce them into the unitary cost of the public good production, which negatively depends on the amount of the public good provided in all regions. In general, the cost of local public good provision is assumed to be decreasing if intergiurisdictional externalities are large and positive, since their total effect is over the whole national territory and independent of the number of regions in which the territory is divided. The main point remains, as suggested by Seabright (1996), that the "choice between centralized and decentralized forms of government need not always be made once and for all, but can sometimes be undertaken on a case-by-case basis if it is possible to estimate some of the relevant variables (such as the size of the spillovers)".

Given this general framework, we propose a different trade-off to compare centralized with decentralized solution: it is between the gains from internalizing externalities and the losses of free-riding advantages, which may vary with *size* and *preferences* of local jurisdictions. Indeed, the issue of size[5] is relevant since it allows a range of different public policies under decentralization or centralization, given the degree of intergiurisdictional externalities and the policy makers' behaviour.

Disparity in size may be a source of inefficiency itself, exacerbating the loss that each region suffers as a consequence of non-cooperative behaviour. Surprisingly, the role of size in strategic tax and spending design has received little explicit attention.[6] The Kanbur and Keen's (1993) contribution represents an exception as it particularly focuses on the role of country size to capture some of the central features of the interaction between national tax systems in an integrated world. The crucial point of the KK's model is that the form of the home country's best-response correspondence critically depends on its relative size. In other words, there is a fundamental asymmetry between the responses - in choosing their own level of taxation - of small and large countries. Markusen and Wigle (1989) also focus on the role of size, showing that optimal tariffs vary with the country size (in particular, the optimal tariff is smaller when the country is smaller). In their turn, Dur and Staal (2008) assume heterogeneous regions - where each one consists of two districts that differ in size: a city and a village - to analyze local public good provision characterized by positive spillovers and find

[5] The preliminary issue here is to identify the meaning of size. Indeed, size can be measured in terms of land or population (King 1984), and also considering the public budget of government. We define size in terms of population, as in most of the literature of fiscal federalism (Buchanan 1965; Oates 1972).

[6] Besley and Coate (2003) consider regions only different in preferences - not in size - assuming a continuum of citizens with a mass of unity. Analogously, Lockwood (2002) describes regions populated by a number of identical individuals with a population size normalized to unity; Gilbert and Picard (1996) assume a geographical space divided into m jurisdictions of equal size, with local governments.

that the optimal lump-sum tax, as well as the optimal earmarked transfer, crucially depend on the exact distribution of relative population sizes and spillovers effects over regions.

We stress the matter of local jurisdictions size and its influence on the choice between decentralized and centralized public goods provision, particularly in the case of *FRC policy*. Considering size, we achieve different results from those of the SGT. In general, increasing differences in population size across regions would lead towards the centralized solution. Intuitively, high variability in size leads to high variability in costs to provide the public good; hence, to avoid disparities in costs among regions, the centralized system appears the best. This result is mainly due to the "*cross subsidization*" effect, which implies an implicit transfer across different regions in line with the Boadway and Hobson's model (1993). Yet, introducing spillovers, it emerges that from a positive viewpoint decentralization should not be necessarily pursued only in the absence of externalities, but it depends on the relative size of regions. In particular, the net gain between the potential benefit of free-riding behaviour and the effect of internalizing spillovers among different jurisdictions should be taken into account, as it is likely to be different for large and small local units. Indeed, decentralization becomes more attractive at high spillovers levels for small regions (and those with high preferences for the public good), which have a larger incentive to free-ride on each other's policies and production costs. At the same time, large regions (and those with low preferences for the public good) gain more through internalizing spillovers - hence, they prefer centralization - instead of remaining autonomous and acting as a free-rider, *ceteris paribus*.

In reference to the heterogeneity of preferences, the traditional argument according to which decentralization yields a higher level of surplus than does centralization if regions are relatively heterogeneous is substantially confirmed (Tiebout 1956; Buchanan 1965; Oates 1972), considering both kinds of policy maker (Leviathan and FRC). Yet, as in Lockwood (2002), we find that while conditions can be found under which this statement is true in both cases, there are some important qualifications - also considering the interaction with spillovers. Indeed, decentralization appears to be preferable for controlling the rent-seeking behaviour of Leviathans not in absence of externalities - as the "*competitive federalism*" theory suggests - but when spillovers are present (at intermediate levels), given high preference heterogeneity. In addition, when the overall preferences heterogeneity increases, the range of spillovers values favouring decentralization becomes wider and further regions with increasing preferences for the public good start to decentralize.

The remainder of the paper is organized as follows. Section 2 outlines the general framework of the model. In Section 3, results emerging from the political decision-making process are presented. Section 4 derives conditions under which centralization or decentralization is the more efficient. Finally, Section 5 offers some concluding remarks.

2. The model

2.1 The economic framework

We propose a many-regions model where the economy is divided into J geographically distinct districts indexed by $j = 1,...,J$, each populated by a different number of individuals ($i = 1,....,L_j$), who are heterogeneous and immobile.[7] The total population of the country is

[7] As Besley and Coate (2003), and Dur and Staal (2008), we ignore issues of mobility in this analysis. While such considerations are obviously important, incorporating them is sufficiently difficult that they are best left for a separate paper.

represented by L (with $L = \sum_{j=1}^{J} L_j$). Each citizen living in a local jurisdiction derives utility from the private good (x_j^i) and the local pure public good (G_j) provided by his/her region, in relation to his/her public good preference parameter: $0 \leq \lambda_j^i \leq 1$. Thus, the utility function of an inhabitant i in region j is:[8]

$$U_j^i = x_j^i + \lambda_j^i \ln G_j \qquad (\mathbf{1})$$

Under a *decentralized system*, the budget constraint of the *generic individual* is as follows:

$$x_j^i + t_j G_j = 1 \qquad (\mathbf{2})$$

where the private good is the numerary, while t_j represents the individual contribution - or price - paid by each citizens to finance local public good provision. Hence, public expenditures are financed by a uniform head tax on local residents - as in Besley and Coate, (2003) - represented by $t_j G_j$, according to the Lindahl (1919/1958) tax-price mechanism.[9] Actually, the Lindahl price allows different willingness to pay of everyone, say different t_j^i in our case. Hence, in order to avoid the individual free-riding problem - since individuals are characterized by different willingness to pay for the public good - the level of taxation is assumed to be unique and identical into the same region (but different across region).

In the case of a *centralized system*, a government representing all districts decides different level of public goods in each region,[10] but sets a uniform head tax on all citizens (tG_j). In this vein, we assume a partially different budget constrain for the *generic individual*, where the same taxation level is again considered in aggregate, to solve the individual free-riding tendency:

$$x_j^i + tG_j = 1 \qquad (\mathbf{2.a})$$

[8] Following Besley and Coate (2003) and Dur and Staal (2008), the utility function is assumed quasi-linear. In this way, we can omit the private good consumption (x_j^i).

[9] The Lindahl tax-price is the optimal price that a consumer is willing to pay to participate in the public good consumption. If each person pays a customized tax-price, the sum of all these can cover the marginal cost of providing the public good. Unfortunately, Lindahl taxation requires knowledge of the demand functions for each individual for all private and public goods. Hence, the main problem of this mechanism is the possibility of the free-riding behaviour.

[10] Following Lockwood (2002) and Besley and Coate (2003), it is quite unclear - from a theoretical point of view - why a government charged with providing public goods in a centralized system cannot differentiate the levels according to the heterogeneous tastes in each district. This assumption seems to be not satisfactory also on the empirical front. Indeed, there are many examples of goods provided unequally by a central government in a federal system. The case of federal highway spending in the United States illustrates this well: a significant fraction of funds in the *Federal Highway Aid Program* are earmarked by legislators for specific projects in their districts.

The unitary cost of the public good (α_j) is different among regions. It is a function of the amount of the public good provided in all regions and the degree of intergiurisdictional spillovers ($0 \leq \gamma \leq 1$)[11] linked thereto:

$$\alpha_j = \beta\left(\prod_{k=1}^{J} G_k\right)^{-\frac{\gamma}{J}} + \frac{F}{G_j} \qquad (\mathbf{3})$$

where β is a positive parameter[12] and F is the fixed cost. When positive externalities are large (γ is high), the production cost is lower. When positive externalities are small (γ is low), the opposite situation takes place. As explained before, we treat external spillovers as a mechanism allowing to reducing production costs of the public good provided.[13] This has a positive indirect effect on the individual welfare, since each person will pay less to finance the total cost of public good provision.

Moreover, the price fixed by the *decentralized* policy maker for the public good in jurisdiction j is the sum of all contributions collected into the region ($t_j L_j$), and it is assumed to be equal to the unitary cost of the public good (α_j), increased by a percentage ($R_j \geq 0$), which represents an extra-rent for each local politician:

$$t_j L_j = (1 + R_j)\alpha_j \qquad (\mathbf{4})$$

The idea is that politicians can adopt a "*full recovery costs*" (FRC) strategy, setting the price equal to the cost of providing the public good, without any additional gains ($R_j = 0$). Hence, we have leaders fixing: $t_j L_j = \alpha_j$. Otherwise, he/she can adopt a "*Leviathan*" strategy, charging a higher price than the production cost in order to get an extra-rent ($R_j > 0$), exploiting local residents. Shortly, the price for the public good may change depending on the politician's attitude.

In addition, it is supposed to be different in the case of a *centralized* policy maker, who chooses to not differentiate inhabitants in terms of unitary price ($t_j = t$). In this case, politicians of all regions cooperate[14] in setting a unique tax (t) in order to cover all the costs and to gain an extra-rent over them.

$$t\sum_{j=1}^{J} L_j G_j = (1 + R)\sum_{j=1}^{J} \alpha_j G_j \qquad (\mathbf{4.a})$$

[11] In our model, γ is a measure of the average spillovers effect coming from the mix of public goods provided by local governments. In reference to the externalities, we adopt a similar simplification to that proposed by Boadway and Hobson (1993) for describing the index of "publicness" of goods. Moreover, our parameter can give further policy intuition as different values of γ can be associated to different kinds of public goods. Hence, our results on γ give different implications depending on the nature of public goods provided.

[12] For simplicity, we set $\beta = 1$.

[13] Since the overall size of the economy is fixed, the total effect of spillovers - which is over the whole national territory - on costs should not depend on the number of local jurisdictions in which the territory is divided. Equation (**3**) captures this idea.

[14] Under centralization, we only focus on the cooperative solution among local politicians. Yet, we do not analyze the non-cooperative case as Besley and Coate (2003) do.

Assumptions on the extra-rent remain unchanged, with the only difference that, in this case, R is unique, by definition. Thus, under centralization and *FRC policy*, the price is assumed to be equal to the cost of providing the public good ($R = 0$); with *Leviathan* politician, R is greater than zero and the price is higher than the cost. In general, the price for the public good varies with the institutional system - centralization versus decentralization - and the government behaviour.

To take into account the different effects of the extra-rent linked to the representative's attitude, we propose an alternative specification of the budget constraint - than equation (**2**) and (**2.a**) - when the generic individual coincides with the *rent-seeking decision maker* (the index i becomes d). Under a *decentralized system*, we have:

$$x_j^d + t_j G_j = 1 + R_j \alpha_j G_j \qquad (\mathbf{5})$$

where the second term on the right hand side ($R_j \alpha_j G_j$) represents the additional gain of the opportunistic politician. On the other hand, in the case of a *FRC policy*, no additional gains ($R_j = 0$) are supposed and his/her budget constraint is the same as that of equation (**2**). Analogously, under *centralization* the budget constraint of no-Leviathan decision maker is expressed by equation (**2.a**); for the *opportunistic politician*, the only differences are about taxation and rent, which are uniform across regions:

$$x_j^d + tG_j = 1 + R\alpha_j G_j \qquad (\mathbf{5.a})$$

2.2 The political decision-making process

The political decision-making process consists of four stages. First, citizens in each region vote on the institutional system - say, on whether to decentralize or centralize local public goods provision. Next, under decentralization (centralization) residents choose a single representative among citizens living in their own jurisdiction.[15] Voters elect candidates whose policy preferences yield outcomes they like, according to the citizens-candidate approach (Besley and Coate 2003). Candidates will be evaluated comparing their proposals on taxes, which should be the lowest as possible for citizens. We assume that these proposals coincide with those setting by the policy makers in order to maximize their own utility function in the third stage. Tax setting depends on politicians' different behaviour: FRC or Leviathan. Finally, in the fourth stage there is a vote on the amount(s) of public goods which should be provided by the decision maker in each region, according to the median-voter theorem.

This decision-making structure forms a game to be solved for *backward induction*. Therefore, we first derive the optimal level of local public goods according to the median-voter theorem under both decentralized and centralized systems. Next, assuming different behaviours - "benevolent" and rent-seeking - of the elected representatives, we analyze their influence in determining the individual tax burden to finance local public goods. Turning to the voting stage, we solve the citizens' selection problem of representatives, particularly when

[15] As in Besley and Coate (2003), the assumption according to which a single representative makes decisions in a decentralized system is a simplification trying to capture the reality that there will be a greater commonality of interest across sub-districts than across district, even if in the real decentralized system decisions are typically made by legislatures consisting of elected representatives of each of the sub-districts of the district.

he/she is a Leviathan. Lastly, we compare decentralized versus centralized solution in order to determine which is preferred by citizens from a welfare viewpoint.

3. Solutions

3.1 The level of public goods provision

The optimal level of public goods is the outcome of the median-voter theorem which always provides the politically accepted solution. In general, it is assumed that each politician - under both decentralization and centralization - would to get a majority voting over the alternatives to implement the public policy. This means that the problem solution is to choose a level of G_j corresponding to that preferred by the median-voter in each region, given *single-peaked* individual preferences.[16] As in Lockwood (2002), the only difference between decentralization and centralization is that: in the former, public goods provision is funded by a regional head tax (t_j); in the latter, decisions about the setting of a tax (t) to finance different amounts of public goods across regions are made by a single legislature. This may represent a kind of "partial centralization", in particular the "centralized funding" (Lockwood 1998),[17] where projects and policies are decided upon regionally - which implies not uniform public goods provision across jurisdictions but different levels according to the heterogeneous tastes in each district (Besley and Coate 2003) - but funded through a national tax, that is a uniform head tax on all citizens.

Proposition 1: *Whatever the level of taxation, the amount of public good provided is that required by the median-voter in each region.*

Proof: If each citizen in region j could express his/her individual demand for the amount of the public good to be provided, he/she will maximize his/her utility function, subject to the budget constraint, for a single value: $\hat{G}_j^i = \frac{\lambda_j^i}{t_j}$ under decentralization, and $\hat{G}_j^i = \frac{\lambda_j^i}{t}$ under centralization.[18] Thus, the preferences are single-peaked and the median-voter theorem is satisfied. ■

Defining m_j equal to λ_j^m, which is the preference of the median-voter living in jurisdiction j for the public good, the outcome in region j when the institutional system is *decentralized* is

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[16] As in Besley and Coate (2003), for simplicity we assume that G_j is a generic public good. By this way, we can easily study if the conditions of the median-voter theorem hold.

[17] Centralization is usually when both the decisions about which projects to fund, and the setting of a tax to fund them, are made by a legislature that comprised of delegates from all regions. This is the traditional way to define centralization (Lockwood 2002). However, there are two alternative types of *partial centralization*: the first is "centralized expenditure", where projects are decided upon by central government, but are funded by regions; the second "centralized funding" above explained and adopted, to some extent, in this paper.

[18] Indeed, each citizen maximizes his/her utility function for $\hat{G}_j^i = \frac{\lambda_j^i}{t_j}$ since we have: $\frac{\partial U_j^i}{\partial \hat{G}_j^i} \geq 0$ for $\hat{G}_j^i \leq \frac{\lambda_j^i}{t_j}$ and $\frac{\partial U_j^i}{\partial \hat{G}_j^i} < 0$, otherwise. Thus, preferences are *single-peaked*.

found by maximizing equation (**1**) with respect to G_j subject to the budget constraint (**2**). The equilibrium level of the public good emerging from the median-voter theorem is:

$$G_j = \frac{m_j}{t_j} \qquad (\mathbf{6})$$

Each regional spending is higher the stronger is the public good preference of the median-voter and lower the higher is its "price", represented by the taxation level (upon locally decided).

Under *centralization*, the policy outcome emerges from the maximization of equation (**1**) with respect to G_j subject to the budget constraint (**2.a**). Solving that yields:

$$G_j = \frac{m_j}{t} \qquad (\mathbf{6.a})$$

where the meaning of m_j is the same as before. The amount of public good provided in each local unit negatively depends on national taxation and positively on the local median-voter preference for it.[19]

3.2 Tax setting

We focus on different policy makers' attitude - FRC and Leviathan - when they are in office, and on different consequences in terms of setting taxation to finance local public goods. Indeed, different behaviours of politicians determine different taxation choices. In this vein, we analyze how individual taxes - representing the required contributions to finance the median-voter's amount of the public good in each region - are determined under both decentralized and centralized systems. The general approach is to find the taxation level which maximizes the elected representative's welfare.

Under a *decentralized system*, the policy maker wants to maximize the constrained utility function calculating by substituting equation (**5**) into equation (**1**):

$$\begin{aligned} &\underset{t_j}{Max} \;\; U_j^d = 1 - t_j G_j + R_j \alpha_j G_j + d_j \ln G_j \\ &s.t. \quad R_j \alpha_j = t_j L_j - \left(\prod_{k=1}^{J} G_k \right)^{-\frac{\gamma}{J}} - \frac{F}{G_j} \\ &\alpha_j = \left(\prod_{k=1}^{J} G_k \right)^{-\frac{\gamma}{J}} + \frac{F}{G_j} \leq t_j L_j \end{aligned} \qquad (\mathbf{7})$$

[19] As equation (**6**), equation (**6.a**) represents a maximum point for the individual welfare. Moreover, both results $tG_j = m_j \leq 1$ and $t_j G_j = m_j \leq 1$ are consistent with the previous hypotheses: the individual income is normalized to 1; m_j represents the median value of λ_j^i such that $0 \leq \lambda_j^i \leq 1$.

where d_j is the policy maker's preference for the public good. When the decision maker follows a *FRC strategy*, $R_j = 0$, and the last constraint is binding. Otherwise, when he/she is a *Leviathan*, the last constraint is not binding.

Analogously, the maximization problem of politicians who cooperate under a *centralized system* is:

$$\begin{aligned} &\underset{t}{Max}\ \ W = \sum_{j=1}^{J} U_j^d = \sum_{j=1}^{J}\left(1 - tG_j + R\alpha_j G_j + d_j \ln G_j\right) \\ &s.t.\quad R\sum_{j=1}^{J}\alpha_j G_j = \sum_{j=1}^{J}\left[tL_j G_j - G_j\left(\prod_{k=1}^{J} G_k\right)^{-\frac{\gamma}{J}} - F\right] \\ &\qquad \sum_{j=1}^{J}\alpha_j G_j = \sum_{j=1}^{J}\left[G_j\left(\prod_{k=1}^{J} G_k\right)^{-\frac{\gamma}{J}} + F\right] \le t\sum_{j=1}^{J} L_j G_j \end{aligned} \qquad \textbf{(7.a)}$$

where d_j's are the public good preferences of the leaders of each region. As described above, when politicians adopt a *FRC policy*, $R = 0$, and the second constraint is binding; while with a *Leviathan behaviour*, $R > 0$, and the second constraint is not binding.
Considering results of Proposition 1, the maximization processes of systems (**7**) and (**7.a**) yield the following tax solutions (Table 1).[20] In all cases, taxes negatively depend on the degree of externalities in public goods provision (γ).

Proposition 2: *The policy maker cannot act as a Leviathan - setting a higher taxation level - for high levels of spillovers.*

Proof: The proof strategy is to check the value of externalities for which the constraints become binding. In the Appendix, we demonstrate there exist critical thresholds for γ, over which the rent-seeking solution collapse to that where costs are fully recovered. ■

Table 1 - *Tax solutions*

Politician attitude / Institutional system	***Decentralization***	***Centralization***
Full recovery costs	$t_j^{FRC} = \left(\frac{m_j}{m_j L_j - F}\right)\left[\prod_{n=1}^{J}\left(m_n L_n - F\right)\right]^{-\frac{\gamma}{J(1-\gamma)}}$	$t^{FRC} = \left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J(1-\gamma)}}\left[\frac{\sum_{n=1}^{J} m_n}{\sum_{n=1}^{J}\left(m_n L_n - F\right)}\right]^{\frac{1}{1-\gamma}}$
Leviathan	$t_j^{LEV} = \frac{m_j}{d_j}\left(1-\frac{\gamma}{J}\right)^{\frac{1}{1-\gamma}}\left(\prod_{n=1}^{J} d_n\right)^{-\frac{\gamma}{J(1-\gamma)}}$	$t^{LEV} = (1-\gamma)^{\frac{1}{1-\gamma}}\left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J(1-\gamma)}}\left(\frac{\sum_{n=1}^{J} m_n}{\sum_{n=1}^{J} d_n}\right)^{\frac{1}{1-\gamma}}$

[20] See the Appendix for the algebra of getting solutions of Table 1.

3.3 Optimal voting

According to the citizen-candidate approach, policy makers are elected citizens who follow their policy preferences when in office. Voters elect candidates whose policy preferences satisfy their utility functions. In other words, each candidate proposes the taxation level which maximizes his/her own utility function (see Table 1); in their turn, individuals select the candidate characterized by the public good preference (d_j), which maximizes their welfare. Starting from the previous results, the maximization problem of the generic individual is:

$$\underset{d_j}{Max} \;\; U_j^i = 1 - m_j + \lambda_j^i \ln m_j - \lambda_j^i \ln\left[t^*\left(d_j\right)\right] \qquad (9)$$

where $t^*\left(d_j\right)$ is one of those in Table 1.

Proposition 3: *With FRC candidates, the result of voting is indifferent for citizens since whoever is elected, he/she will have to respect the constraints on G_j and taxation level. This is true under both centralization and decentralization.*

Proof: Looking at FRC taxation in Table 1, it is easy to note that t_j and t do not depend on d_j. ■

With politician of FRC type the outcome election is not so relevant, as the elected representative will provide a "predetermined" public policy mix: the amount of G_j preferred by the median-voter and the level of taxation required by the full recovery costs condition. To some extent, this kind of policy maker does not really decide, but he/she only implements policies.

When candidates are of Leviathan type, the election process is not indifferent. Indeed, any potential decision maker, characterized by his/her public good preferences (d_j), proposes different taxes to finance the local public good in order to maximize his/her welfare function - which also means to extract a rent from citizens. In their turn, residents choose the politician considering the announced level of taxation.

Proposition 4: *With Leviathan candidates, citizens unanimously vote for the candidate with the highest preference for the public good ($d_j = 1$).*

Proof: See the Appendix. ■

Intuitively, the way to moderate the rent-seeking behaviour is to elect candidates with the highest preference for the public good. Indeed, they should reduce taxes in order to win the election - that is to make the median-voter willing to accept a bigger amount of the public good.

4. The choice of institutional system: decentralization versus centralization

The final stage of the political decision-making process is the choice between decentralization and centralization. In each region, there is a vote on whether to coordinate each other and to consolidate decisions into one single authority - a centralized system - or to remain autonomous and favour decentralized local public goods provision. In other words, given the outcome of the policy makers emerging from the previous steps, citizens have to assess the relative efficiency of both systems selecting one which provides a higher level of utility.

As we demonstrated before, the individual utility function is decreasing with the level of taxation defined by the politician. Thus, each person will compare different "tax rate" and vote for the institutional setting where he/she pays less. The politician behaviour - which determines the level of taxation - and the degree of external spillovers represent key elements to compare the convenience of either institutional system. In reference to the last issue, the tradition theory (i.e., Oates 1972) suggests that, with identical districts and policy uniformity, decentralization dominates when interregional spillovers are small; centralization, when spillovers are large. However, Besley and Coate (2003) show that, with identical and non-identical districts under a cooperative legislature, decentralization is still better when externalities are small, but what happens when spillovers are high is less clear: "The only nuance here is that we cannot show that there exists a critical level of spillovers in the case of heterogeneous district". This reflects the fact that the gain in surplus from centralization is not necessarily everywhere increasing in the size of externality (Lockwood 2002).

In our model - where "policy uniformity" is not exogenously assumed - the following elements can be identified and should be taken into account to compare centralized versus decentralized solution, given different policy makers behaviours (Leviathan or FRC):

i) the implicit transfers ("*cross subsidization*") across different regions;
ii) the free-riding gains in receiving positive externalities;
iii) the gains of internalizing externalities;
iv) the degree of preferences heterogeneity.

4.1 The Leviathan behaviour: decentralization versus centralization

When the policy makers are rent-seeking, they try to extract an extra-rent from taxation unless the externalities are high, as we have proved in Proposition 2. In this case, the taxes proposed by the elected politicians (Table 2) can be redefined from those reported in Table 1, assuming $d_j = 1$ according to Proposition 4.

Table 2 - *Leviathan taxation*

Institutional system	***Decentralization***	***Centralization***
	$t_j^{LEV} = m_j \left(1 - \frac{\gamma}{J}\right)^{\frac{1}{1-\gamma}}$	$t^{LEV} = M(1-\gamma)^{\frac{1}{1-\gamma}} \left(\frac{M}{\Theta}\right)^{\frac{1}{1-\gamma}}$

where $M = \frac{\sum_{j=1}^{J} m_j}{J}$ and $\Theta = \left(\prod_{j=1}^{J} m_j \right)^{\frac{1}{J}}$ are the arithmetic and geometric mean of the regional preferences of the median-voters, respectively. The ratio $\frac{M}{\Theta}$ is an index which increases with the overall heterogeneity of preferences.

From Table 2, we can note that both kinds of taxation are dependent on the preferences parameter (m_j and M). In general, we can anticipate that the choice of the institutional system is determined by the relationship among regional preferences, the degree of preferences heterogeneity and an index of internalization. Indeed, we can capture the effect of the internalization of externalities under centralization through the ratio $\frac{1-\gamma}{1-\frac{\gamma}{J}}$, which is less than 1 and decreasing in γ. This means that the per capita cost under centralization decreases faster than under decentralization because of the presence of spillovers. In addition, the centralized tax also depends on $\left(\frac{M}{\Theta}\right)^{\frac{\gamma}{1-\gamma}}$, which is greater than 1 and increasing in γ. Given a certain degree of preferences heterogeneity, when externalities increase politicians can exploit the benefits of spillovers in order to rise up their extra-rent instead of reducing the per capita cost.

Comparing the two taxation levels - in logarithmic form - we have that the region j prefers decentralization ($t_j^{LEV} < t^{LEV}$) if the following holds:

$$\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] < HM \qquad \textbf{(10)}$$

where $HM = \ln\frac{M}{\Theta} > 0$ (since $\frac{M}{\Theta} > 1$) is an index of the overall preferences heterogeneity. The condition is likely to be true - say, citizens of region j prefer decentralization - when the relative preference of region j for the public good ($\ln m_j - \ln M$) is low; when the gain from internalization $\left(\frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right]\right)$ is low, and when the overall preference heterogeneity (HM) is high. From equation (**10**), we have the following:

Proposition 5:

- **a)** *When the median-voter's preference for the public good is lower than the average, there exists a threshold for externalities, which changes the convenience of decentralization versus centralization. When spillovers are lower than the threshold, regions prefer decentralization. Otherwise, centralization.*
- **b)** *When the median-voter's preference for the public good is higher than the average, three cases may appear:*

1. *Regions always prefer centralization when the overall preferences heterogeneity (HM) is low.*
2. *When the overall preferences heterogeneity is high, regions prefer decentralization only for intermediate levels of externalities. Otherwise, for very low and very high degree of spillovers, regions prefer centralization.*
3. *When the overall preferences heterogeneity increases, the range of spillovers values favouring decentralization becomes wider. In addition, further regions with increasing preferences for the public good start to decentralize.*

Proof: See the Appendix. ■

Intuitively, for regions with preferences lower than the average, the centralized solution implies higher taxation - and higher costs - when externalities are low or absent. Indeed, for γ equal to zero, the centralized tax represents the average of those decentralized. Thus, in a centralized system these regions should pay more for providing the public good to regions with higher preferences. When externalities are absent, following this logic, regions with preferences higher than the average vote for centralization. This means that there is an implicit transfer (*"cross subsidization")* from regions with low preferences for the public good to regions with high ones. On the other hand, when externalities are very high the gain from internalization overcome the benefits of decentralization. These results appear to be quite standard.

New findings emerge from part (b) - point 2 and 3 - of Proposition 5. Indeed, decentralization can be suitable for controlling the rent-seeking behaviour of Leviathans not in absence of externalities - as the *"competitive federalism"* theory suggests (Salmon 1987; Breton 1987) - but when spillovers are present (at intermediate levels) since the centralized politician partially exploits the gain of internalization in order to rise up his/her extra-rent instead of reducing taxation.

4.2 The FRC policy: decentralization versus centralization

When politicians adopt the FRC strategy, the taxes proposed (Table 3) can be redefined from those reported in Table 1 after some algebra:

Table 3 - *Full recovery costs taxation*

Institutional system	***Decentralization***	***Centralization***
	$t_j^{FRC} = \frac{m_j}{M\hat{L}}\omega_j\left(\frac{\Gamma}{M\hat{L}}\right)^{\frac{\gamma}{1-\gamma}}$	$t^{FRC} = \frac{\Omega}{\hat{L}}\left(\frac{\Omega}{\Theta\hat{L}}\right)^{\frac{\gamma}{1-\gamma}}$

where $\hat{L} = \frac{\sum_{j=1}^{J} L_j}{J}$ is the average size of regions, while M and Θ are the same as before. We define a new parameter: $\omega_j = \frac{M\hat{L}}{m_j L_j - F}$. It represents the gross mark-up on variable costs ($m_j L_j - F$) in the region j necessary to perform public expenditure - say, financing the

public good - equal to the average spending of all regions ($M\hat{L}$).[21] The higher the average expenditure and fixed costs, the higher the mark-up; while the higher the expenditure in the region j ($m_j L_j$) - say, high values of m_j and L_j - the lower the mark-up required. Given ω_j, $\Omega = \dfrac{J}{\sum_{j=1}^{J}\left(\dfrac{1}{\omega_j}\right)}$ and $\Gamma = \left(\prod_{j=1}^{J}\omega_j\right)^{\frac{1}{J}}$ are the harmonic and geometric mean of the gross mark-up, respectively.[22] Both taxation levels inversely depend on summary measures of regional preferences (M for t_j^{FRC} and Θ for t^{FRC}, respectively) and directly on those of the gross mark-up (Γ for t_j^{FRC} and Ω for t^{FRC}, respectively).

In this vein, we introduce two indicators of heterogeneity in order to easily compare the FRC taxation under decentralization and centralization. The former concerns preferences heterogeneity, $\dfrac{M}{\Theta}$, which increases with the variance in preferences; the latter describes the heterogeneity in mark-up, $\dfrac{\Gamma}{\Omega}$, which increases with the variance in preferences and with the variability of local size (L_j). Hence, the choice between centralization and decentralization is mainly determined by these two indexes of heterogeneity, given different values of externalities (γ).

Considering the logarithmic form of solutions of Table 3, region j prefers decentralization ($t_j^{FRC} < t^{FRC}$) if the following is verified:

$$\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] < HM - H\omega \qquad \textbf{(11)}$$

where HM is the same as before (see Section 4.1) and $H\omega = \ln\left(\dfrac{\Gamma}{\Omega}\right)$,[23] maintaining the same properties above described.

Starting from the right hand term, we have the following:

Proposition 6: *Increasing differences in population size across regions would lead towards the centralized solution; while with increasing heterogeneity of preferences, regions prefer decentralization.*

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[21] The mark-up ω_j is equal to the mark-up on variable costs of region j to cover the total costs of public good provision times the ratio between the average expenditure of all regions and the expenditure of region j: $\omega_j = \dfrac{M\hat{L}}{m_j L_j - F} = \dfrac{m_j L_j}{m_j L_j - F}\dfrac{M\hat{L}}{m_j L_j}$.

[22] Since the harmonic mean is always lower than the geometric mean, the ratio $\dfrac{\Omega}{\Gamma} < 1$ and it is decreasing with the heterogeneity of the gross mark-up. This index will be useful to compare the two institutional systems.

[23] The index $H\omega$ is greater than 0, since $\dfrac{\Gamma}{\Omega} > 1$.

Proof: The proof is straightforward. ■

Equation (**11**) is likely to be false when the variability of regional size grows up, contributing to increase the $H\omega$ indicator, *ceteris paribus*. Following this logic, centralization is preferred when regions are quite different in size. Intuitively, high variability in size leads to high variability in costs to provide the public good, where smaller jurisdictions suffer higher costs and mark-up. Hence, to avoid disparities in costs among regions, the centralized system appears to be the best solution ("*cross subsidization"*).[24]

In reference to preferences heterogeneity, it is easy to show that the increasing variability in preferences has two effects: a direct effect, implying an increase of the *HM* index which contributes to verify equation (**11**) and confirm the traditional argument according to which with a high degree of preferences heterogeneity the chance of decentralizing is likely to increase. Yet, the indirect effect concerns the increase of mark-up heterogeneity ($H\omega \uparrow$) due to the high variability in preferences. This favours the convenience of centralization than decentralization. Consistently with the mainstream, we can assume that the direct effect prevails over the indirect one, promoting decentralization. In this sense, the traditional findings (Tiebout 1956; Buchanan 1965; Oates 1972), according to which with benevolent policy makers - similar, to some extent, to our politicians implementing the FRC strategy - the decentralized solution dominates when individuals' preferences are heterogeneous across local jurisdictions, are confirmed.

Observing the left hand side, we have the following:

Proposition 7: *The centralized system is preferred by smaller regions and those with preferences for the public good higher than the average.*

Proof: Equation (**11**) is likely to be false - citizens of region j prefer centralization - when regions are small which means their relative mark-up ($\ln\frac{\omega_j}{\Omega}$) is high. Indeed, smaller regions have to pay higher per capita costs, so they prefer centralization (*"cross subsidization"* argument). When the preference for the public good is higher than the average ($\ln\frac{m_j}{M}$ is high), two effects occur: a direct effect which leads towards centralization; an indirect one according to which higher preferences imply lower mark-up, and thus decentralization. We assume that the direct effect is stronger than the indirect one, favouring so centralization. As in the Leviathan case, under centralization regions characterized by higher preferences for the public good receive implicit transfers from regions with lower preferences. ■

Moreover, looking at the externalities we have the following:

Proposition 8: *Suppose that median-voter's preference for the public good is lower than the average and regions are large - their mark-up is lower than the average -* $\left(\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)<0\right)$*. Then:*

[24] This result is consistent with that of Boadway and Hobson (1993).

a) *Regions always prefer decentralization when the right hand term is positive* ($HM - H\omega > 0$).
b) *When the right hand term is negative* ($HM - H\omega < 0$), *there exists a threshold level for externalities: below the threshold, regions prefer decentralization; over, centralization.*

Proof: see the Appendix. ■

The quite standard result here obtained is not general. Large jurisdictions and those with low preferences for the public good would like decentralization. The crucial point is that, in this case, the effect of "*cross subsidization*" is negative; hence, these regions have to pay implicit transfers when taxation is centralized. Under decentralization, large municipalities can self-finance, even without any external spillovers to exploit. To some extent, we may conclude that public goods provision may be efficiently *decentralized* only if regions are *large* enough, *ceteris paribus*. When spillovers increase, those regions internalize spillovers instead of remaining autonomous. That is to say they prefer to gain form internalization, losing the advantages of free-riding. This is true when disparities in size are very high ($HM - H\omega < 0$).

Proposition 9: *Suppose that median-voter's preference for the public good is higher than the average and regions are small - their mark-up is higher than the average -* ($\ln\left(\frac{m_j}{M}\right) + \ln\left(\frac{\omega_j}{\Omega}\right) > 0$). *Then:*

a) *Regions always prefer centralization when the right hand term is negative* ($HM - H\omega < 0$).
b) *When the right hand term is positive* ($HM - H\omega > 0$), *there exists a threshold level for externalities: below the threshold, regions prefer centralization; over, decentralization.*

Proof: See the Appendix. ■

To summarize, the advantages of free-riding may be asymmetric for regions differing in preferences and size - as in Kanbur and Keen's (1993) - and also offset the benefits of the internalization of externalities, favouring unexpected solutions in terms of centralized versus decentralized provision of local public goods. The intuition behind this result is as follows. Smaller regions and those with high preferences for the public good would prefer the centralized solution, because through it they try to charge other regions for some costs of production. In a broad sense, this result could justify that such municipalities would prefer monetary transfers from the State, rather than autonomously deciding their fiscal policy. When beneficial spillovers increase, these regions may find more suitable a decentralized system since they can exploit - without costs - positive externalities provided by other regions as a free rider. The free-riding behaviour can be convenient when preferences heterogeneity is high ($HM - H\omega > 0$).

In general, we may conclude that when the politician does *not* act as a *Leviathan* - that is, he/she exactly sets taxes to cover the cost of providing public goods - the argument of whether decentralization or centralization is more suitable also depends on the size of local jurisdictions, not only on regional preferences and the extent of spillovers. *Neither* the institutional systems appear to *be universally valid*.

Our propositions suggest that some regions "move" from centralization to decentralization when externalities increase, challenging the traditional results (i.e., Oates 1972), according to which the centralized solution is the best when spillovers are maximal, while decentralization is better when there are no inter-jurisdictional externalities. Even Besley and Coate (2003) show that (with a cooperative legislature) for both - identical and heterogeneous - districts, decentralization dominates centralization for low levels of spillovers, while centralization dominates for high levels of spillovers. However, they cannot demonstrate that there exists a critical value of externalities in the case of heterogeneous districts, confirming that there is no general presumption that the relative performance of centralization is always increasing in spillovers. Lockwood (2002) also affirms that the gain in surplus from centralization is not necessarily everywhere increasing in the size of externality.[25]

The key insight of our results is represented by different size of regions, which may determine an asymmetry among citizens' responses about the best institutional setting. Thus, we obtain findings partially consistent with Besley and Coate's (2003), but we propose the trade-off between free-riding and internalization - not considering in the previous literature - to compare centralized versus decentralized system. From a positive viewpoint, decentralization should not be necessarily pursued only in the absence of externalities, but also with high spillovers. This is true only for small regions and those with higher preferences for the public good, where the free-riding gains overcome the benefits of internalizing spillovers.

5. Concluding remark

We have developed a model to study local public goods provision characterized by positive spillovers, adopting a political economy approach. In general, the standard result suggests that decentralization is not efficient when there are positive spillovers (Tiebout 1956; Buchanan 1965; Oates 1972). However, recent contributions (Lockwood 2002; Besley and Coate 2003) show that, under certain political conditions - for example, with a cooperative legislature - the familiar presumption that centralization emerges only with higher spillovers is not confirmed since it can be chosen also for low spillovers degree.

Starting from these findings, we propose a partially different framework where modelling the detail of political decision-making is important to understand the trade-off between centralization and decentralization. One key feature of the paper is to focus on two relevant aspects neglected by the political economy models: *the size of local jurisdictions* (which is relevant for the scale effect in the financing mechanism of non-rival public goods) and the explicit definition of the rent-seeking behaviour, representing the additional gain of Leviathan politicians through the *"extra-rent" equation*. Moreover, modelling interregional externalities as a mechanism contributing to lowering the production cost of the public good in each region, a quite different trade-off - from the FGT and the SGT of fiscal federalism - is proposed in order to compare decentralized versus centralized solution: the gains from *internalizing externalities* and the losses of *free-riding advantages*, which may differ with the size of regions and their preferences for the public good.

In short, the relative performance of centralized and decentralized systems depends upon spillovers extent and differences in tastes for public spending, but for different reasons than those suggested in the existing literature. In addition, a key insight is represented by disparities in regional size and the index of heterogeneity linked thereto. In detail, without

[25] In particular, he shows that this is related to the non-monotonicity of project funding as net spillovers increase.

assuming *policy uniformity* (as Lockwood 2002, and Besley and Coate 2003), we identify the following factors, which interact to determine the choice between decentralization and centralization, when policy makers are Leviathan and FRC type, respectively:

i) the free-riding gains exploiting positive externalities;
ii) the gains of internalizing externalities;
iii) the degree of preferences heterogeneity;
iv) the "*cross subsidization*" across different regions

where the net benefit of the first two items is substantially different for large and small regions.

In general, we can affirm that increasing differences in population size across regions would lead towards the centralized solution; while increasing heterogeneity of preferences to decentralization. This is especially true when politicians adopt a FRC strategy. To some extent, the last finding is quite consistent with the tradition theory of fiscal federalism according to which "the welfare gain from the decentralized provision of particular local public good becomes greater as the diversity of individual demands within the country as a whole increases" (Oates, 1972).

However, considering spillovers effects and different size of local jurisdictions allow better qualifying these results. Indeed, neither the institutional systems appear to be universally valid: for small regions and those with higher preferences for the public good, for example, the free-riding gains overcome the benefits of internalizing spillovers, favouring decentralization, when beneficial spillovers increase. In other words, from a positive viewpoint, decentralization should not be necessarily pursued only in the absence of externalities, but also with high spillovers and some regions "move" from centralization to decentralization when externalities increase. At the same time, large jurisdictions and those with low preferences for the public good would like decentralization only without any external spillovers to exploit; while, when spillovers increase, they internalize spillovers - centralization - getting more from internalization than from free-riding.

Finally, new results also emerge with Leviathan decision makers. In this case, the "dimension" of public good preferences plays a crucial role. Indeed, decentralization seems to be suitable for regions with higher preferences for the public good to control the rent-seeking behaviour of Leviathans not in absence of externalities but when spillovers are present - at intermediate levels - and preferences heterogeneity is high. Under centralization, citizens would pay more since the centralized opportunistic politician would partially exploit the gain of internalization to rise up his/her extra-rent instead of reducing taxation. Following this logic, when the overall preferences heterogeneity increases, the range of spillovers values favouring decentralization becomes wider, and further regions (with increasing preferences for the public good) start to decentralize.

Appendix

The algebra of tax solutions (Table 1)

Each policy maker, who provides $G_j = \frac{m_j}{t_j}$ (where t_j is equal to t under centralization), sets taxation in order to maximize his/her utility function subject to the budget constraint which depends on his/her opportunistic behaviour. Thus:

- *Decentralization*

We solve the system described in equation (**7**). Substituting $G_j = \frac{m_j}{t_j}$ and simplifying, we have:

$$\underset{t_j}{Max} \quad U_j^d = 1 - m_j + m_j L_j - F - \left(\prod_{n=1}^{J} \frac{m_n}{t_n} \right)^{-\frac{\gamma}{J}} \frac{m_j}{t_j} + d_j \ln m_j - d_j \ln t_j$$

$$s.t. \quad \alpha_j = \left(\prod_{n=1}^{J} \frac{m_n}{t_n} \right)^{-\frac{\gamma}{J}} + \frac{F t_j}{m_j} \leq t_j L_j$$

When the constraint is binding, we have the FRC solutions solving the constraint. Otherwise, we have the Leviathan solutions maximizing the utility function.

a) *FRC taxation*

Solving the constraint, we have:

$$t_j \left(\frac{m_j L_j - F}{m_j} \right) = \left(\prod_{n=1}^{J} \frac{m_n}{t_n} \right)^{-\frac{\gamma}{J}}$$

This equation is the taxation reaction function of the elected policy maker of jurisdiction j with respect to the taxation policy of other regions. Obviously, the taxation reaction function of region k is:

$$t_k \left(\frac{m_k L_k - F}{m_k} \right) = \left(\prod_{n=1}^{J} \frac{m_n}{t_n} \right)^{-\frac{\gamma}{J}}$$

Comparing the two, we have the ratio between taxes of two different regions. Then, substituting this ratio in the first reaction function we have:

$$t_j = \frac{m_j}{m_j L_j - F} \left(\prod_{n=1}^{J} \frac{m_n}{t_j \frac{m_j L_j - F}{m_j} \frac{m_n}{m_n L_n - F}} \right)^{-\frac{\gamma}{J}}$$

Simplifying, we have:

$$t_j = \frac{m_j}{m_j L_j - F}\left(t_j \frac{m_j L_j - F}{m_j}\right)^{\gamma}\left(\prod_{n=1}^{J} m_n L_n - F\right)^{-\frac{\gamma}{J}}$$

Finally:

$$\underline{t_j^{FRC} = \left(\frac{m_j}{m_j L_j - F}\right)\left[\prod_{n=1}^{J}\left(m_n L_n - F\right)\right]^{-\frac{\gamma}{J(1-\gamma)}}}$$

b) *Leviathan taxation*

Maximizing the utility function, we have:

$$\text{FOC} \qquad \frac{\partial U_j^d}{\partial t_j} = \left(1-\frac{\gamma}{J}\right)\left[\left(\sum_{n\neq j}^{J}\frac{m_n}{t_n}\right)^{-\frac{\gamma}{J}}\left(\frac{m_j}{t_j}\right)^{1-\frac{\gamma}{J}}\right]\frac{1}{t_j} - \frac{d_j}{t_j} = 0$$

$$\text{SOC} \qquad \frac{\partial^2 U_j^d}{\partial {t_j}^2} = \left(1-\frac{\gamma}{J}\right)\left(\frac{\gamma}{J}-2\right)\left[\left(\sum_{n\neq j}^{J}\frac{m_n}{t_n}\right)^{-\frac{\gamma}{J}}\left(\frac{m_j}{t_j}\right)^{1-\frac{\gamma}{J}}\right]\frac{1}{{t_j}^2} + \frac{d_j}{{t_j}^2}$$

FOC holds for: $$\left(1-\frac{\gamma}{J}\right)\left[\left(\sum_{n\neq j}^{J}\frac{m_n}{t_n}\right)^{-\frac{\gamma}{J}}\left(\frac{m_j}{t_j}\right)^{1-\frac{\gamma}{J}}\right] = d_j$$

When FOC holds, SOC is negative:

$$\frac{\partial^2 U_j^d}{\partial {t_j}^2} = \left(\frac{\gamma}{J}-2\right)\frac{d_j}{{t_j}^2} + \frac{d_j}{{t_j}^2} = \left(\frac{\gamma}{J}-1\right)\frac{d_j}{{t_j}^2} < 0$$

Thus, when the constraint is not binding we have a maximum solving FOC, which also represents the taxation reaction function of region j. Taking the taxation reaction function of region n and making the ratio, we find: $t_n = \frac{m_n}{d_n}\frac{d_j}{m_j}t_j$. Substituting into the reaction function of region j, we have:

$$\left(1-\frac{\gamma}{J}\right)\left[\left(\sum_{n=1}^{J}\frac{m_n}{\frac{m_n}{d_n}\frac{d_j}{m_j}t_j}\right)^{-\frac{\gamma}{J}}\left(\frac{m_j}{t_j}\right)\right] = d_j$$

Simplifying, we have:

$$t_j^{LEV} = \frac{m_j}{d_j}\left(1-\frac{\gamma}{J}\right)^{\frac{1}{1-\gamma}}\left(\prod_{n=1}^{J} d_n\right)^{-\frac{\gamma}{J(1-\gamma)}}$$

- *Centralization*

We solve the system described in equation (**7.a**). Substituting $G_j = \frac{m_j}{t}$ and simplifying, we have:

$$\underset{t}{Max} \quad W = \sum_{n=1}^{J}\left[1 - m_n + m_n L_n - F - \left(\prod_{k=1}^{J}\frac{m_k}{t}\right)^{-\frac{\gamma}{J}}\frac{m_n}{t} + d_n \ln m_n - d_n \ln t\right]$$

$$s.t. \quad \sum_{n=1}^{J}\alpha_n G_n = \sum_{n=1}^{J}\left[\frac{m_n}{t}\left(\prod_{k=1}^{J}\frac{m_k}{t}\right)^{-\frac{\gamma}{J}} + F\right] \le \sum_{n=1}^{J} m_n L_n$$

When the constraint is binding, we have the FRC solutions solving the constraint. Otherwise, we have the Leviathan solutions maximizing the joint utility function.

a) *FRC taxation*

Solving the constraint, we have:

$$t^{\gamma-1}\sum_{n=1}^{J}\left[m_n\left(\prod_{k=1}^{J} m_k\right)^{-\frac{\gamma}{J}}\right] = \sum_{n=1}^{J}\left(m_n L_n - F\right)$$

Finally:

$$t^{FRC} = \left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J(1-\gamma)}}\left[\frac{\sum_{n=1}^{J} m_n}{\sum_{n=1}^{J}\left(m_n L_n - F\right)}\right]^{\frac{1}{1-\gamma}}$$

b) *Leviathan taxation*

Maximizing the joint utility function, we have:

$$\text{FOC} \qquad \frac{\partial W}{\partial t} = (1-\gamma)t^{\gamma-2}\left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J}}\sum_{j=1}^{J} m_j - \frac{\sum_{j=1}^{J} d_j}{t} = 0$$

SOC $$\frac{\partial^2 W}{\partial t^2} = (1-\gamma)(\gamma-2)t^{\gamma-3}\left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J}} \sum_{j=1}^{J} m_j + \frac{\sum_{j=1}^{J} d_j}{t^2}$$

FOC holds for: $$(1-\gamma)t^{\gamma-1}\left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J}} \sum_{j=1}^{J} m_j = \sum_{j=1}^{J} d_j$$

When FOC holds, SOC is negative:

$$\frac{\partial^2 W}{\partial t^2} = (\gamma-2)\frac{\sum_{j=1}^{J} d_j}{t_j^{\,2}} + \frac{\sum_{j=1}^{J} d_j}{t_j^{\,2}} = (\gamma-1)\frac{\sum_{j=1}^{J} d_j}{t_j^{\,2}} < 0$$

Thus, when the constraint is not binding we have a maximum solving FOC:

$$t^{LEV} = (1-\gamma)^{\frac{1}{1-\gamma}}\left(\prod_{n=1}^{J} m_n\right)^{-\frac{\gamma}{J(1-\gamma)}}\left(\frac{\sum_{n=1}^{J} m_n}{\sum_{n=1}^{J} d_n}\right)^{\frac{1}{1-\gamma}}$$

Proof of Proposition 2

Let us consider the decentralized taxation of Leviathan. Substituting this solution into the constraint, it should be not binding. We verify if it is true for all values of γ.

$$G_j\alpha_j = \frac{m_j}{t_j}\left(\prod_{n=1}^{J}\frac{m_n}{t_n}\right)^{-\frac{\gamma}{J}} + F < m_j L_j$$

Substituting t_n, we have:

$$\frac{m_j}{t_j}\left(\prod_{n=1}^{J}\frac{m_n}{\frac{m_n}{d_n}\left(1-\frac{\gamma}{J}\right)^{\frac{1}{1-\gamma}}\left(\prod_{k=1}^{J} d_k\right)^{-\frac{\gamma}{J(1-\gamma)}}}\right)^{-\frac{\gamma}{J}} + F < m_j L_j$$

$$\frac{m_j}{t_j}\left(1-\frac{\gamma}{J}\right)^{\frac{\gamma}{1-\gamma}}\left(\prod_{k=1}^{J} d_k\right)^{-\frac{\gamma}{J}\left(\frac{\gamma}{1-\gamma}\right)}\left(\prod_{n=1}^{J} d_n\right)^{-\frac{\gamma}{J}} + F < m_j L_j$$

$$\frac{m_j}{t_j}\left(1-\frac{\gamma}{J}\right)^{\frac{\gamma}{1-\gamma}}\left(\prod_{n=1}^{J} d_n\right)^{-\frac{\gamma}{J}\left(\frac{1}{1-\gamma}\right)} < m_j L_j - F$$

Substituting t_j, we have:

$$\frac{d_j}{m_j L_j - F} < \left(1-\frac{\gamma}{J}\right)$$

Setting F small enough, so that $m_j L_j - F > 1$, it is a sufficient condition to have $\frac{d_j}{m_j L_j - F} < 1$. Thus, this equation cannot hold when γ increases. The analytical steps for the centralized taxation of Leviathan are similar. In detail, the condition to have a not binding constraint is:

$$\frac{\sum_{j=1}^{J} d_j}{\sum_{j=1}^{J}\left(m_j L_j - F\right)} < (1-\gamma)$$

Also in this case, this equation cannot hold when γ increases.
In other words, when externalities increase, the constraints may become binding and Proposition 2 is proved. ■

Proof of Proposition 4

Substituting the Leviathan taxation into the maximization problem of the generic citizen, we obtain the following FOCs:

For decentralized Leviathan: $$\frac{\partial U_j^i}{\partial d_j} = \lambda_j^i\left(1+\frac{\gamma}{J}\frac{1}{1-\gamma}\right)\frac{1}{d_j} > 0$$

For centralized Leviathan: $$\frac{\partial U_j^i}{\partial d_j} = \lambda_j^i\left(\frac{1}{1-\gamma}\right)\frac{1}{\sum_{j=1}^{J} d_j} > 0$$

That is to say the individual utility is always increasing in d_j. The corner solution is $d_j = 1$ in both cases.
Hence, Proposition 4 is proved. ■

Proof of Proposition 5

$$\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] < HM \qquad \textbf{(10)}$$

- **Case a):**

The term $\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] < 0$ and increases in γ. Moreover:

$\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] = -\infty$ and $\lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] = 0$

The term $\frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] > 0$ and increases in γ. Moreover, using L'Hopital:

$\lim_{\gamma\to 0}\frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = 1-\frac{1}{J}$ and $\lim_{\gamma\to 1}\frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = +\infty$

Since, $\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = -\infty$, equation (10) is true.

Since, $\lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = +\infty$, equation (10) is false.

For continuity, Proposition 5, case a) is proved. ■

- **Case b):**

The term $\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] > 0$ and decreases in γ. Moreover:

$\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] = +\infty$ and $\lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] = 0$

Thus:

$\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = +\infty$, equation (10) is false.

$\lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln m_j - \ln M\right] + \frac{1}{\gamma}\left[\ln\left(1-\frac{\gamma}{J}\right) - \ln(1-\gamma)\right] = +\infty$, equation (10) is false.

Hence, the left hand side has a minimum.
If HM is lower than the minimum value, case b.1) holds. Otherwise, case b.2) and b.3) hold.
Hence, Proposition 5, case b) is proved. ■

Proof of Proposition 8

$$\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] < HM - H\omega \qquad \textbf{(11)}$$

- The proof of case a) is straightforward.
- In the case b), the left hand side is increasing in γ and:

$$\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] = -\infty \qquad \text{and} \qquad \lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] = 0$$

This proves the case b).

Hence, Proposition 8 is proved. ■

Proof of Proposition 9

$$\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] < HM - H\omega \qquad \textbf{(11)}$$

- The proof of case a) is straightforward.
- In the case b), the left hand side is decreasing in γ and:

$$\lim_{\gamma\to 0}\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] = +\infty \qquad \text{and} \qquad \lim_{\gamma\to 1}\frac{1-\gamma}{\gamma}\left[\ln\left(\frac{m_j}{M}\right)+\ln\left(\frac{\omega_j}{\Omega}\right)\right] = 0$$

This proves the case b).

Hence, Proposition 9 is proved. ■

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