Oates' Decentralization Theorem with Household Mobility*

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Abstract

This paper studies how Oates' trade-off between centralized and decentralized public good provision is affected by changes in households' mobility. We show that an increase in household mobility favors centralization, as it increases competition between jurisdictions in the decentralized régime and accelerates migration to the majority jurisdiction in the centralized régime. Our main result is obtained in a baseline model where jurisdictions first choose taxes, and households move in response to tax levels. We consider two variants of the model. If jurisdictions choose public goods rather than tax rates, the equilibrium level of public good provision is lower, and mobility again favors centralization. If jurisdictions maximize total utility rather than resident utility, the equilibrium level of public good provision again decreases, and mobility favors centralization when the size of the mobile population is bounded.

JEL Classification Codes: H77, H70, H41

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1 Introduction

Oates (1972) provided an insightful analysis of the trade-off between centralization and decentralization by contrasting efficient internalization of inter-jurisdictional spillovers through centralization and efficient matching of local policies to local tastes through decentralization. This analysis culminated in the celebrated "Oates' Decentralization Theorem", delineating conditions under which centralized or decentralized provision of public goods is efficient. Though reminiscent of Tiebout's (1956) notion of the alignment of local public goods to local tastes, Oates' framework did not allow for mobility of households across jurisdictions. The objective of this paper is to revisit Oates' theorem under mobility of households and to investigate how mobility affects the choice between centralization and decentralization in the presence of spillovers across jurisdictions.

Since Oates' original formulation, and particularly since the early 80's, there has been a worldwide trend towards fiscal decentralization. An increasing number of public service functions have been devolved to local governments. Arzaghi and Henderson (2005) provide a synthesis of the cross-country evidence between 1960 and 1995. For a sample of 48 countries with populations over 10 million in 1990, they construct a federalism index every 5 years from 1960 to 1995 and show that the decentralization index rises from a world average of 1.03 in 1975 to 1.94 by 1995. This global index covers wide regional disparities, but still shows a significant trend. Using more recent data on OECD countries, Rodríguez-Pose and Ezcurra (2011) show that the trend has continued between 1990 and 2005, even though some countries (like the Scandinavian countries) in fact re-centralized over the period.

Labor mobility has also shown an increasing trend over the last decades. The European Union is a case at point, since workers can freely move from one country to the other. Wildasin (2006) notes that several European nations (like Austria, Belgium, and Germany) have reached gross migration rates (measuring the sum of inflows and outflows as a percentage of the population) exceeding 1 percent in 2000 while most other European Union countries showed gross migration rates between 0.5 and 1 percent. Over the period 2000-2009, the gross migration rate in Europe has increased, with Austria, Belgium and Ireland exceeding 2 per cent, and sixteen members of the European union experiencing gross migration rates over 1%.[2]

In this paper, we analyze the interplay between household mobility and fiscal decentralization in a model that preserves the essential features of Oates' original formulation. However, following the reinterpretation of federal policies of Lockwood (2002) and Besley and Coate (2003), we allow

[2]Eurostat: *Migration and migrant population statistics*, October 2011.

for nonuniform public good provision in the centralized régime, and assume that the choice of public goods derives from a political process in the federal legislature. We consider a federation formed of two identical jurisdictions, each of which is initially inhabited by the same number of identical agents. A fraction of the residents in each jurisdiction are mobile and may move to the other jurisdiction in response to differences in the public good/taxation packages of the two jurisdictions, while the remainder are assumed to be immobile. The fraction of mobile agents is taken as an index of mobility, and is the first basic parameter of the model. Members of one jurisdiction benefit from the provision of public goods in the other jurisdiction; the extent of externalities across jurisdictions is measured by a spillover parameter, which forms the second basic parameter of the model.

The main result of our analysis shows that both higher mobility and higher spillovers favor centralization, so that one should observe more centralized provision of local public goods when households are more mobile, and externalities across jurisdictions increase. While the effect of higher spillovers on the choice between centralization and decentralization has been known since Oates (1972), the effect of higher mobility has hitherto not been emphasized in the literature on fiscal federalism. The intuition underlying this effect is easy to grasp. An increase in mobility increases competition between jurisdictions and results in lower public good provision and lower welfare in the decentralized régime.[3] In the centralized régime, an increase in mobility accelerates migration to the jurisdiction which holds the majority in the federal legislature, thereby increasing average welfare in society. Hence, an increase in the fraction of the mobile population results in higher welfare in the federal régime, and lower level in the decentralized régime. The recent trend towards greater household mobility and greater fiscal decentralization thus represents an empirical puzzle which does not fit the intuitions delivered by the theoretical model. In fact, we believe that this trend reflects a political move towards local governments rather than a careful consideration of the optimal level of government at which public goods should be provided.

In the baseline model, we consider jurisdictions which simultaneously select *tax rates*, after which households move, and the final level of public good is determined by the population of the two jurisdictions. In this taxation game, we prove existence of a unique pure strategy symmetric equilibrium. In the two polar cases of pure public goods and local public goods, surprisingly, mobility does not affect the equilibrium outcome. However, as soon as

[3]Notice however that this effect of mobility on public good provision only arises when jurisdictions take into account the effect of their choice of tax/public good packages on mobility. Hence, in order to capture this effect, we construct a sequential model where jurisdictions choose their tax/public good package in the first stage, and households move in the second stage.

spillovers are neither complete nor absent, the equilibrium level of taxation and utility in the two jurisdictions is decreasing in the mobility rate. In the taxation game, spillovers do not have a monotonic impact on equilibrium tax and public good provision. Public good provision is a U-shaped function of spillovers, highest in the case of pure and local public goods.[4] In the centralized régime, the optimal tax level chosen by the majority jurisdiction is independent of mobility, as taxes are uniformly levied on all agents irrespective of the jurisdiction in which they live. However, mobility affects the population distribution between the majority jurisdiction (in which public goods are provided) and the minority jurisdiction, and higher mobility accelerates migration from the minority to the majority jurisdiction, resulting in higher average social welfare. Hence, our analysis shows that decentralization dominates centralization only when mobility is low and spillovers not too high. Two examples, using quadratic and linear cost formulations, illustrate this result, by highlighting the existence of a decreasing curve linking spillover and mobility parameters, such that decentralization dominates centralization below this curve, and centralization dominates decentralization above.

We test the robustness of our intuitions by considering two variants of the baseline model. In the first variant, we suppose that jurisdictions choose public good levels rather than taxes, and that population movements affect taxes rather than public good levels. In this variant of the model, the existence of a pure strategy symmetric equilibrium is no longer guaranteed. However, when a pure strategy symmetric equilibrium exists, it results in *stronger competition and lower public good levels than in the taxation game.* Furthermore, the level of public good is decreasing in both the mobility and spillover parameters. As the outcome of the centralized régime is the same as in the baseline model, we obtain again that an increase in mobility favors centralization over decentralization. In the second variant, we assume that jurisdictions' objective is to maximize total utility rather than resident utility. When jurisdictions choose taxes, we again prove existence of a unique pure strategy symmetric equilibrium with *lower public good provision than when jurisdictions maximize resident utility.* Spillovers unambiguously reduce public good provision, as does an increase in the fraction of the mobile population. In the centralized régime, mobility affects the optimal tax level of the majority jurisdiction. As the majority jurisdiction cares about the size of its population, it will increase the tax rate in order to attract more immigrants. Hence, the effect of an increase in mobility on the welfare in the centralized régime is not as simple as in the case of resident utility. However, we show that when mobility is not too high, an increase in mobility

[4] See Lockwood (2008) for other examples where the relation between spillovers and the choice between centralization and decentralization is sometimes counterintuitive.

increases average welfare so that our basic intuition on the effect of mobility on the choice between centralization and decentralization remains valid.

There are a few papers like ours that incorporate mobility of households into analysis of decentralization versus centralization question in the presence of externalities. Following Tiebout's (1956) lead, there is a literature introducing household mobility into models of fiscal federalism, but those typically do not involve spillovers across jurisdictions; and there is a literature that incorporates spillovers, as Oates (1972) did in his original rendering of the decentralization theorem, that do not consider mobility. (See Epple and Nachyba (2004) and Boadway and Tremblay, (2011) for surveys of both strands of the literature.) Besley and Coate (2003) and Janeba and Wilson (2011) mention the study of Oates' theorem under household mobility as an important issue to be addressed. Closest to our analysis are a series of papers by Wellisch (1993, 1994, 1995) and Hoel and Shapiro (2003, 2004) and Hoel (2004). Wellisch (1993, 1994, 1995) considers a slightly different model of mobility, where agents have a linear attachment to their region of residence, as in de Palma and Papageorgiou (1988) and Mansoorian and Myers (1993), whereas we suppose that agents have heterogeneous migration costs. More importantly, Wellisch does not explicitly introduces spillovers in his analysis, so that his model does not enable him to study how changes in mobility affect the trade-off between centralization and decentralization. Hoel and Schapiro (2003, 2004) and Hoel (2004) also analyze the effect of mobility on local public good provision with spillovers, in a general model inspired by recent problems of transboundary pollution. Their main result, echoing earlier results by Boadway (1982) in the case of public goods without spillovers and Wellisch (1993) for perfectly mobile populations, is that, when agents are homogeneous, the outcome of the decentralized game of public provision is always efficient (when the unique equilibrium of the households' location game is interior). In our model, agents are heterogeneous (and our analysis is only valid if the support of the mobility cost distribution is large enough) so that their result does not apply. Hence, our model captures a situation where decentralized public good provision is *not efficient* so that the trade-off between decentralization and centralization of Oates' Theorem is meaningful.

The rest of the paper is organized as follows. Section 2 presents the model, including a description of decentralization, centralization and welfare measures for jurisdictions. Section 3 studies in detail the decentralized case for the two polar cases of pure public goods and local public goods as well as for arbitrary spillovers. Section 4 presents the centralized solution and states and proves the main result of the paper, extending Oates' theorem to a setting with household mobility. Section 5 looks at variations of the model for robustness. Section 6 provides a summary of the results and concludes.

2 The Model

2.1 Public goods, agents and jurisdictions

We consider a federation formed of two identical jurisdictions with a mass of 1 identical agents in each jurisdiction. All agents have an initial endowment of one unit of private good, which can be transformed into a public good with a constant returns to scale technology. Each jurisdiction i provides a public good g_i which is financed through a uniform tax τ_i levied on the agents. Members of one jurisdiction benefit from the provision of public goods in the other jurisdiction, through the following spillover mechanism.[5] Public goods provided in the two jurisdictions are perfect substitutes, and a member of jurisdiction i benefits from the public good provided in jurisdiction j at a rate $\alpha \in [0, 1]$. Hence, the effective amount of public good consumed by an agent in jurisdiction i is $g_i + \alpha g_j$. As α converges to zero, the public good becomes a local public good, and as α converges to one, a pure public good. The utility of an agent in jurisdiction i is thus given by:

$$U_i = U(g_i + \alpha g_j, 1 - \tau_i). \tag{1}$$

As in the classical model of Blume, Bergstrom and Varian (1986), we assume that the utility function U is strictly increasing and concave and that the public and private goods are normal goods. We denote the marginal utility with respect to the public good and private goods as U_g and U_e. We also assume that the public and private goods are complements so that $U_{ge} > 0$. Each jurisdiction initially comprises a mass of 1 residents. A fraction $\lambda \in [0, 1]$ of the residents are *mobile* and may move to the other jurisdiction in response to differences in the public good/taxation packages of the two jurisdictions. The remainder mass of $1 - \lambda$ are *immobile.* The parameter λ thus measures the degree of mobility of agents in society, and an increase in λ is interpreted as an increase in the geographical mobility of economic agents. In addition, we assume that mobile agents suffer a moving cost if they move to the other jurisdiction, and that moving costs are distributed according to a cumulative distribution function $F(\cdot)$ over a compact support $[0, K]$. After migration, the new jurisdiction sizes are given by (n_1, n_2) which may differ from the original sizes $(1, 1)$.

2.2 Decentralized public good provision

In the decentralized régime, the two jurisdictions independently choose their public good levels g_1 and g_2 and finance the public good by a tax levied only

[5] This is the same spillover model as the one studied in Bloch and Zenginobuz (2006) and (2007).

on the residents: $g_i = n_i\tau_i$, so that the utility of an agent in jurisdiction i is given by:

$$U_i = U(n_i\tau_i + \alpha n_j\tau_j, 1-\tau_i) = U(g_i + \alpha g_j, 1 - \frac{g_i}{n_i}). \tag{2}$$

In Tiebout (1956)'s original analysis, households' mobility decisions and jurisdictions' choices of public good and taxes are simultaneous: in our model a Tiebout equilibrium is defined as a vector (n_1, n_2, g_1, g_2) such that

1. No agent wants to move given (g_1, g_2)
2. Jurisdictions choose public goods in order to maximize the utility of the agents given (n_1, n_2)

In a symmetric equilibrium of the Tiebout model, $n_1 = n_2 = 1$ and jurisdictions choose public good levels g^* such that

$$U_g(g^*(1+\alpha), 1-g^*) = U_e(g^*(1+\alpha), 1-g^*) \tag{3}$$

Hence, because jurisdictions choose tax/public good levels *for a fixed jurisdiction structure*, equilibrium levels of public goods and utilities are independent of the agents' mobility, and an increase in the mobility parameter λ does not affect the equilibrium utility of households at a symmetric equilibrium.[6]

In order to capture the effect of changes in mobility on the equilibrium level of public goods and utilities, we thus consider a two-stage model, where jurisdictions choose a tax rate (or public good level) in the first stage, and households choose whether to move in the second stage. This two-stage model is naturally interpreted as a Stackelberg game where jurisdictions initially propose tax or public good levels and economic agents react by moving across jurisdictions. When agents are immobile, whether the jurisdiction chooses a public good level or a tax rate is irrelevant. With mobile agents, the instrument chosen by jurisdictions becomes important. A jurisdiction i can either choose the tax rate τ_i and let the quantity of public good g_i adjust according to the size of the jurisdiction, or fix the public good level g_i and adapt the tax rate to cover the cost of the public good. In the

[6]In our earlier work (Bloch and Zenginobuz (2006) and (2007)), we analyzed the Tiebout equilibria of the same model of public good provision with spillovers, but did not restrict attention to symmetric equilibria. Notice also that the same independence result obtains if, instead of considering a model of simultaneous mobility and taxation decisions, we analyzed a model of "slow" migration where agents choose their jurisdiction before jurisdictions choose taxation levels (Mitsui and Sato (2001) and Hoel (2004)). As in the Tiebout model, at a symmetric equilibrium, $n_1 = n_2 = 1$, and the equilibrium choice of jurisdictions g^* is independent of λ.

baseline analysis, in order to conform to real local government decision processes, we assume that jurisdictions select the tax rate and let the quantity of public good adjust. We thus solve the *taxation game* played by the two jurisdictions.

We also note that, in the mobility game of the second stage, as utilities depend on the sizes of jurisdictions, coordination failures may arise. Moving decisions involve coordination among agents of measure zero who individually have no impact on the outcome of the game. In order to select among equilibria, we focus attention on the equilibrium where the largest number of agents moves. This is the only equilibrium which is robust to deviations by groups of arbitrarily small sizes ϵ.[7] Finally, we will focus attention on *pure strategy symmetric equilibria* in the taxation game played by the two jurisdictions.

2.3 Centralized public good provision

In Oates (1972)' original analysis, a central government provides a uniform level of public goods across jurisdictions, so that the centralized outcome satisfied $g_i = g_j = g$ and $\tau_i = \tau_j = \tau$. This specification of centralized decision process imposes unrealistic constraints on the choice of the federation. Revisiting Oates original formulation, Lockwood (2002) and Besley and Coate (2003) have noted that the important aspect of centralized decision making is that decisions are made at a single level of government. However, these decisions may involve different levels of public good provision in different jurisdictions. Following this reinterpretation of centralized decision making, we assume that one jurisdiction (the "majority jurisdiction") chooses the levels of public good offered in both jurisdictions, g_i and g_j.[8] In the federal régime, all agents are subject to the same tax rate τ which is chosen to satisfy the budget constraint:

$$g_i + g_j = 2\tau \tag{4}$$

and the utility of an agent in jurisdiction i is thus given by:

$$U_i = U(g_i + \alpha g_j, 1 - \frac{g_i + g_j}{2}). \tag{5}$$

Mobile agents move in response to the public good levels in the two jurisdictions so that the final sizes of jurisdictions, (n_i, n_j) depend on the public good decisions made in the federation.

[7] Jéhiel and Scotchmer (2001) also adopt this refinement to abstract from coordination failures.

[8] When the two jurisdictions are of equal size, each one is chosen at random to hold the majority.

2.4 Welfare measures for jurisdictions

In order to compute the optimal decisions of jurisdictions in the decentralized and federal régimes, we need to specify the welfare indicator of the jurisdiction. Following Mansoorian and Myers (1997), we note that the result of the analysis crucially depends on the objective function of the jurisdictions. In general, we may write the welfare of jurisdiction i as a function of two criteria: the average utility of residents U_i, and the population size of the jurisdiction n_i:

$$W_i = W(U_i, n_i). \tag{6}$$

In the baseline analysis, we focus attention on a welfare criterion which only depends on *resident's utility*, $W_i = U_i$. Alternative specifications include *total utility* $W_i = U_i n_i$, and measures which take into account moving costs like *average utility*.[9]

2.5 Comparing decentralized and centralized provision

As in Oates (1972)'s original analysis, the central question we address is the following: Under which condition does centralization dominate decentralization? Given the political economy model of centralized decision making we consider, by a simple revealed preference argument, the welfare level of the majority jurisdiction is always higher under centralization than decentralization. In order to compare the two régimes we thus need to consider the welfare of residents in both jurisdictions. Assigning an equal weight to all agents in society, we compute the average resident utility of all agents in society. As the total population of society is fixed, we specify a social welfare criterion which only depends on average resident utility:

$$W = \frac{1}{2}(n_i U_i + n_j U_j). \tag{7}$$

3 Decentralized public good provision

In this Section, we analyze the outcome of the game played by the two jurisdictions choosing the tax rate. We start the analysis by considering two polar cases which have been extensively studied in the literature on fiscal federalism: pure public goods ($\alpha = 1$) and local public goods ($\alpha = 0$).

[9] In the average utility case, $W(U_i, n_i)$ is *decreasing* in population size n_i, as average utility includes moving costs which are increasing in immigration, and hence in the size of the population. In our view, this assumption is rather unrealistic, and it is hard to argue that a jurisdiction's objective should be decreasing in the population size.

3.1 Pure public goods

We solve the game by backward induction and consider first the choice of mobile agents. In the pure public good case, the effective public good level is the same in both jurisdictions, and agents only care about the tax rate. For any pair (τ_1, τ_2),

$$U_i \geq U_j \Leftrightarrow \tau_i \leq \tau_j \tag{8}$$

Without loss of generality, suppose that $\tau_1 \geq \tau_2$. Migration from jurisdiction 1 to jurisdiction 2 will be characterized by the index of the last agent to move where x is the solution to the equation:

$$\begin{aligned} U(\tau_1(1-\lambda F(x)) + \tau_2(1+\lambda F(x)), 1-\tau_1) &= \\ U(\tau_1(1-\lambda F(x)) + \tau_2(1+\lambda F(x)), 1-\tau_2) - x \end{aligned} \tag{9}$$

We may define similarly the migration flow of agents from jurisdiction 2 to jurisdiction 1 when $\tau_2 \geq \tau_1$. Anticipating the mobility of agents, the two jurisdictions simultaneously choose tax levels in order to maximize resident utility. Hence, for any τ_2, τ_1 is chosen to solve the maximization problem:

$$\begin{aligned} \max_{\tau_1} \quad & \mathbf{1}_{\tau_1 \geq \tau_2} U(\tau_1(1-\lambda F(x)) + \tau_2(1+\lambda F(x)), 1-\tau_1) \\ & + \mathbf{1}_{\tau_1 < \tau_2} U(\tau_1(1+\lambda F(x)) + \tau_2(1-\lambda F(x)), 1-\tau_1) \end{aligned} \tag{10}$$

Let τ^* denote the unique equilibrium level of the game played by the two jurisdictions when agents are immobile, i.e.

$$U_g(2\tau^*, 1-\tau^*) = U_e(2\tau^*, 1-\tau^*). \tag{11}$$

Proposition 1 *In the pure public goods model, the taxation game played by the two jurisdictions admits a unique symmetric equilibrium where* $\tau_1 = \tau_2 = \tau^*$.

Proposition 1 characterizes the unique symmetric equilibrium of the game of taxation. In the pure public good case, mobility has no impact on the provision of public good by the two jurisdictions. The equilibrium level of taxation τ^* is independent of λ, and an increase in agents' geographic mobility does not affect the provision of public good and the utility level of the agents. In order to compare the case of pure public goods with other situations, we illustrate in Figure 1 the equilibrium level τ^* and the utility levels to indicate the direction of migration of agents across jurisdictions for any possible choice (τ_1, τ_2).

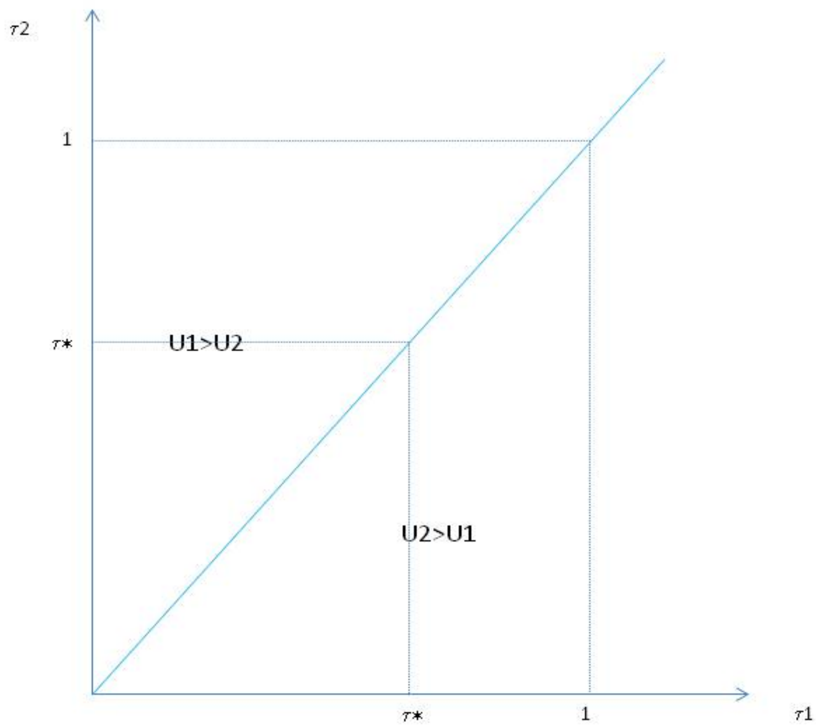

Figure 1: Pure public goods

3.2 Local public goods

When the public good does not produce any externality on the other jurisdiction, the utility of a member of jurisdiction i is given by

$$U_i(\tau_i n_i, 1 - \tau_i).$$

When agents are immobile, the optimal taxation level for any jurisdiction is given by τ^*, the solution to the equation

$$U_g(\tau^*, 1 - \tau^*) = U_e(\tau^*, 1 - \tau^*). \tag{12}$$

Agents' incentives to move across jurisdictions depends on the deviation between the optimal tax level τ^* and the effective tax level τ_i in the two jurisdictions. As illustrated in Figure 2, we can describe a locus of distinct tax rates (τ_1, τ_2) such that

$$U(\tau_1, 1-\tau_1) = U(\tau_2, 1-\tau_2).$$

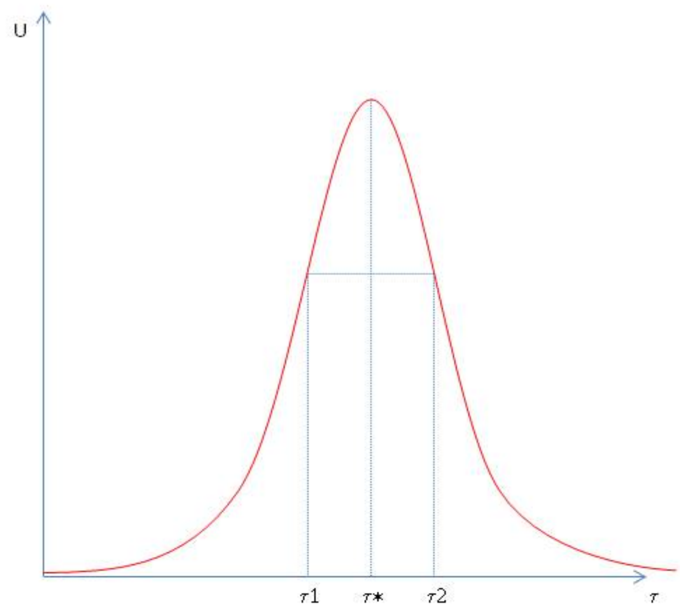

Figure 2: Local public goods: comparison of utilities

Furthermore this equation implicitly defines a decreasing function in the plane (τ_1, τ_2). Hence, as illustrated in Figure 3, the plane (τ_1, τ_2) can be divided into four regions, according to the direction of the migration flow.

For low levels of τ_j and moderate levels of τ_i, and for high values of τ_j and moderate values of τ_i, migration flows from jurisdiction j to jurisdiction i. In particular, along the diagonal, we see that $U_1 > U_2$ if $\tau_1 > \tau_2$ when $\tau_1 < \tau^*$ and $U_2 > U_1$ if $\tau_1 > \tau_2$ when $\tau_1 > \tau^*$.

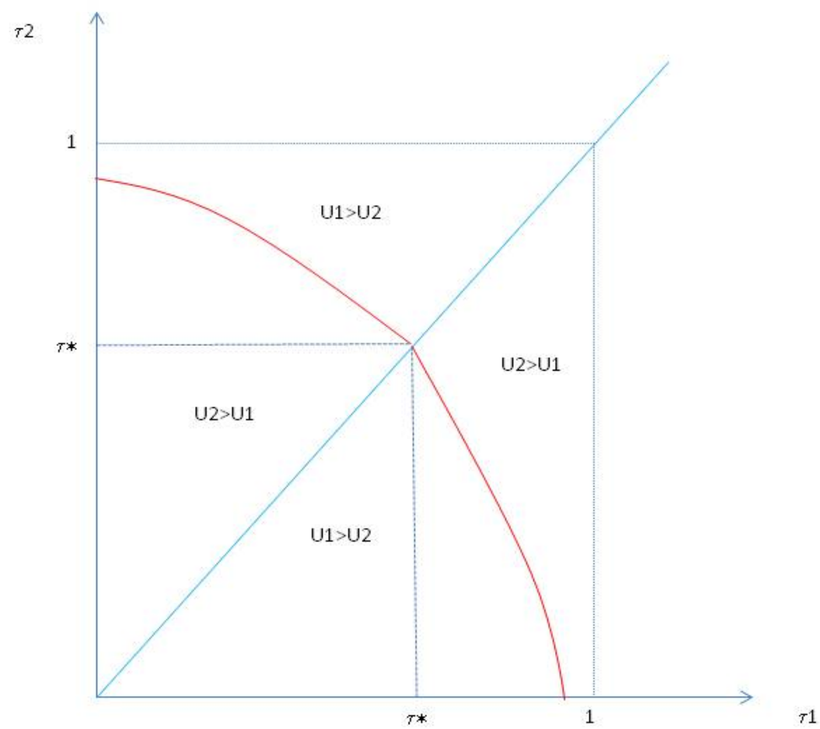

Figure 3: Local public goods

If $U_1 < U_2$, the migration flow from jurisdiction 1 to jurisdiction 2 is characterized by the index x of the last agent to move:

$$U(\tau_1(1 - \lambda F(x)), 1 - \tau_1) - x = U(\tau_2(1 + \lambda F(x)), 1 - \tau_2).$$

In a symmetric way, we define the migration flow from jurisdiction 2 to jurisdiction 1 when $U_1 > U_2$. Then, for any τ_2, jurisdiction 1 chooses τ_1 is chosen to solve the maximization problem:

$$\begin{aligned} \max_{\tau_1} \quad & \mathbf{1}_{\tau_1,\tau_2|U_2>U_1} U(\tau_1(1-\lambda F(x)), 1-\tau_1) \\ & + \mathbf{1}_{\tau_1,\tau_2|U_1>U_2} U(\tau_1(1+\lambda F(x)), 1-\tau_1) \end{aligned} \tag{13}$$

In the analysis of the local public good case, we need to introduce an additional assumption in order to guarantee that *migration only occurs in reaction to differences in taxes* and not simply in order to benefit from living in a larger jurisdiction. In other words, we suppose that when the two jurisdictions choose the same tax level, the only equilibrium migration flow is zero. Hence, for all τ, we want the equation:

$$U(\tau(1-\lambda F(x)), 1-\tau) - x = U(\tau(1+\lambda F(x)), 1-\tau).$$

to have a unique solution $x = 0$. A sufficient condition for this is that the mapping: $U(\tau(1-\lambda F(x)), 1-\tau) - x - U(\tau(1+\lambda F(x)), 1-\tau)$ be monotonic in x for all τ. This will be guaranteed by the assumption:

Assumption 1 *Suppose that for all x, $2\lambda f(x) U_g(0,1) < 1$.*

Assumption 1 places an upper bound on the size of the mobile population, the marginal utility of the public good at 0 and the rate of change of the distribution of migration costs. Under this assumption, we show that the unique equilibrium of the taxation game has both jurisdictions choosing the tax rate τ^*:

Proposition 2 *In the local public goods model, the taxation game played by the two jurisdictions admits a unique equilibrium, where both jurisdictions choose the tax rate τ^*.*

As in the case of pure public goods, the unique symmetric equilibrium of the taxation game with local public goods is independent of the mobility of agents. In equilibrium, both jurisdictions choose the taxation level τ^*, which would have been chosen even when agents are immobile. As no migration occurs in equilibrium, the equilibrium utility of all agents is also unaffected by the mobility parameter λ.

3.3 Arbitrary spillovers

In this Subsection, we consider public goods generating arbitrary spillovers parameterized by $\alpha \in (0,1)$. The analysis of the taxation game with arbitrary spillovers is much more complex than the analysis of the two polar cases of pure public goods and local public goods. When $\alpha = 1$, members of both jurisdictions consume the same level of public goods and migrations are only driven by the level of taxation which affects consumption of the private good. When $\alpha = 0$, the utility of the member of one jurisdiction does not depend on the tax levied in the other jurisdiction. With arbitrary values of the spillover parameter, the utility of a resident of one jurisdiction is affected by the tax level in the other jurisdiction in a nontrivial way, and the characterization of inter-jurisdictional migrations becomes extremely complex. In order to keep the analysis tractable, we specialize the model in two ways.

Assumption 2 *Assume that utility is quasi-linear in the public good:* $U(g_i + \alpha g_j, 1-\tau_i) = g_i + \alpha g_j + v(1-\tau_i)$ *where* $v(\cdot)$ *is strictly increasing and strictly concave.*

Assumption 3 *Assume that the distribution of migration costs is uniform,* $F(x) = \kappa x$, *with* $\kappa = \frac{1}{K}$.

Assumption 2 is a common assumption in the study of noncooperative games of public good provision across jurisdictions (see for example Ray and Vohra (2001), Carraro and Siniscalco (1993) or Bloch and Zenginobuz (2007)). It guarantees that the marginal utility of the public good in one jurisdiction is independent of the strategies chosen in other jurisdictions, and greatly simplifies the analysis of the game of public good provision. In our model, this assumption enables us to obtain clear comparative statics on the effect of changes in the taxation level on migrations. Assumption 3 is an implicit assumption in much of the public economic literature on inter-jurisdictional migration. (It is for example assumed in all models of regional attachment.) In our analysis, this assumption is needed because variations in the density of migration costs greatly complicate the analysis of the reaction of migration flows to tax levels in the model with arbitrary spillovers.

Even under the simplifying Assumptions 2 and 3, the analysis of migration flows as a function of the tax levels (τ_1, τ_2) is complex. Consider the formula equating utility in the two jurisdictions:

$$\tau_1(1-\alpha) + v(1-\tau_1) = \tau_2(1-\alpha) + v(1-\tau_2) \tag{14}$$

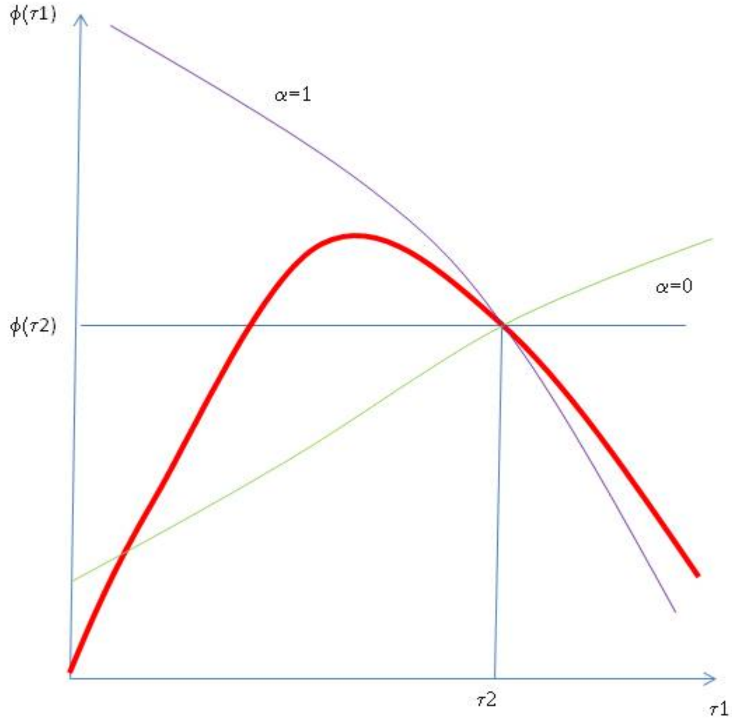

Figure 4: Utility equalization in two jurisdictions

The function $\tau_1(1-\alpha)+v(1-\tau_1)$ is *non-monotonic* in τ_1 which implies that the locus of tax rates (τ_1,τ_2) which guarantee equal utility in the two jurisdictions is hard to characterize. Figure 4 maps the function $\phi(\tau_1) = \tau_1(1-\alpha)+v(1-\tau_1)$ when $\tau_2 \leq \tau^*$. It shows why the arbitrary spillover case is more complex to analyze than any of the two polar cases $\alpha = 0$ or $\alpha = 1$. In the case of pure public goods and local public goods, the function $\phi(\cdot)$ is monotonic over $[0,\tau^*]$. When α is arbitrary, the function may not be monotonic, so that we may separate the parameter space into three regions: a region of low values of taxes, $[0,\underline{\tau})$ for which $U_2 > U_1$, a region of intermediate tax levels $(\underline{\tau},\overline{\tau})$ for which $U_2 > U_1$, and a region of high tax levels, $(\overline{\tau},1]$ for which $U_2 > U_1$. Let x denote the solution to the linear equation:

$$\tau_1(1-\lambda\kappa x)(1-\alpha)+v(1-\tau_1)+x=\tau_2(1+\lambda\kappa x)(1-\alpha)+v(1-\tau_2) \quad (15)$$

If $x < 0$, migration flows from region 2 to 1 and the migration flow is $-\lambda\kappa \max\{K, x\}$; if $x > 0$, migration flows from region 1 to 2 and the migration flow is $\lambda\kappa \max\{K, x\}$. In order to guarantee that $x = 0$ is the unique solution of equation 15 for all values $\tau_1 = \tau_2$, we make the following assumption, which generalizes Assumption 1 to arbitrary spillover parameters in the quasi-linear, uniform model:

Assumption 4 *Suppose that* $2(1-\alpha)\lambda\kappa < 1$

We now define two specific values of taxes: $\tilde{\tau}$ is the tax rate which maximizes $\phi(\tau)$, and τ^* is the equilibrium tax rate in the model with immobile agents:

$$\begin{aligned} (1-\alpha) &= v'(1-\tilde{\tau}), \\ 1 &= v'(1-\tau^*). \end{aligned}$$

Finally, we consider the tax rate $\hat{\tau}$, $\tilde{\tau} < \hat{\tau} < \tau^*$ which is the unique solution to the equation:

$$(1-v'(1-\hat{\tau}))-\lambda\kappa(v'(1-\tau)-(1-\alpha))\hat{\tau}(1-\alpha)=0. \quad (16)$$

Notice that in the two polar cases $\alpha = 0$ and $\alpha = 1$, $\hat{\tau} = \tau^*$, but for any other spillover value $\alpha \in (0, 1)$, $\hat{\tau} < \tau^*$.

Proposition 3 *In the quasi-linear, uniform model with arbitrary spillovers, the taxation game admits a unique symmetric equilibrium, where both jurisdictions choose the tax level* $\hat{\tau}$*.*

Proposition 3 shows that, for arbitrary spillover levels $\alpha \in (0, 1)$, the equilibrium tax level *depends on the mobility parameter* λ. An increase in mobility *reduces* the equilibrium tax level $\hat{\tau}$. This is an important result, as it also shows (because $\hat{\tau} < \tau^*$ and utility along the diagonal is increasing in $\tau < \tau^*$) that an increase in mobility *reduces* the resident utility of members of both jurisdictions in the decentralized régime. Figure 5 graphs the tax levels $\tilde{\tau}$, $\hat{\tau}$ and τ^* for arbitrary spillovers α. Notice that, by contrast, an increase in the spillover parameter α has an *ambiguous effect* on the level of public good provision: the highest levels of public good provision are obtained for the two polar cases $\alpha = 0$ and $\alpha = 1$. As a consequence, it is in general impossible to sign the effect of an increase in the spillover parameter on the equilibrium utility of jurisdiction residents.

The difficulty in the proof of Proposition 3 stems from the fact that in the game played by jurisdictions, the utility of residents is continuous in the tax rates but *not quasi-concave* in the tax rate chosen in their own jurisdiction. Hence, while the existence of an equilibrium in mixed strategies is guaranteed by a direct application of the Glicksberg Theorem, the existence of a symmetric equilibrium in *pure* strategies is not easy to prove. We use a constructive proof and show that, even though utility functions are not quasi-concave, it is always a best response to choose a tax level $\hat{\tau}$ when the other jurisdiction chooses the tax level $\hat{\tau}$.

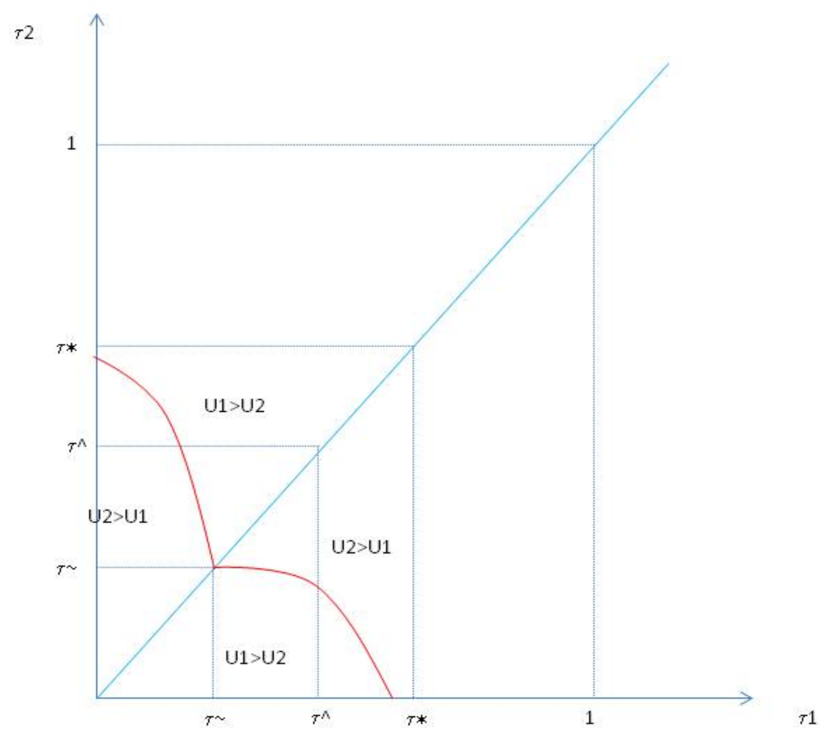

Figure 5: Arbitrary spillovers

4 Centralized public good provision and Oates' Decentralization theorem

4.1 Centralized public good provision

In the centralized régime, one of the two jurisdictions (say jurisdiction 1) is chosen at random to select the public good levels in both jurisdictions. As public goods are produced using a constant returns to scale technology, there is no diseconomy of scale in producing any of the public goods, so that it is optimal for the majority jurisdiction to locate all the public good in its jurisdiction.[10] The solution to this maximization problem is thus given by:

$$U_g(2\tau^o, 1 - \tau^o) - \frac{1}{2}(2\tau^o, 1 - \tau^o) = 0. \tag{17}$$

The level of public good provided in the federal system is thus *always greater than* τ^* and hence always higher than the public good provided in the decentralized model. The intuition for this result is very clear. The majority jurisdiction knows that all agent in the society will contribute to the public good, so that members of the jurisdiction will only support a fraction of the cost. This of course gives an incentive to the majority jurisdiction to increase the level of taxes and public good provision. Notice that the federal level of taxes and public good is *independent of the mobility of agents*. Neither the total taxes levied in the federation nor the provision of public good depend on the distribution of the population across jurisdictions, so that the utility of residents in the majority and minority distributions are not affected by mobility. Finally, note that, as there is a gap between the utility of members of the two district, migration will occur from the minority to the majority district, up to the point where:

$$x = U(2\tau^o, 1 - \tau^o) - U(2\alpha\tau^o, 1 - \tau^o).$$

so that the migration flow is computed as

$$F(U(2\tau^o, 1 - \tau^o) - U(2\alpha\tau^o, 1 - \tau^o)).$$

4.2 Oates' decentralization theorem with mobility

We now bring together the analysis of the decentralized and federal régimes to assess how the trade-off identified by Oates is affected by an increase

[10] By contrast, Besley and Coate (2003) implicitly assume that the technology of public good provision involves diseconomies of scale, so that the majority jurisdiction optimally chooses to provide positive amounts of public goods in both jurisdictions.

in agents' mobility. In the decentralized régime, in the unique symmetric equilibrium, no migration occurs and the tax level is given by $\hat{\tau}$ which is decreasing with λ. Hence the welfare in the decentralized régime is given by:

$$W^D = U((1+\alpha)\hat{\tau}, 1-\hat{\tau}),$$

with $\frac{\partial W^D}{\partial \lambda} < 0$. On the other hand, in the centralized régime, the tax level is independent of λ, and the average utility is given by:

$$\begin{aligned} W^C &= \frac{1}{2}U(2\tau^o, 1-\tau^o) + U(2\alpha\tau^o, 1-\tau^o) \\ &\quad +\lambda F(U(2\tau^o, 1-\tau^o) - U(2\alpha\tau^o, 1-\tau^o)) \\ &\quad (U(2\tau^o, 1-\tau^o) - U(2\alpha\tau^o, 1-\tau^o)). \end{aligned}$$

As members of the majority district receive a higher utility than members of the minority district, an increase in the mobility parameter λ increases migration to the district with higher utility, resulting in a higher average utility. We summarize this discussion in the main Proposition of the paper:

Proposition 4 *The difference in average utility between the centralized and decentralized régime, $W^C - W^D$, is increasing in the mobility parameter λ.*

Proposition 4 shows that in societies where agents are increasingly mobile, more decisions about public goods should be given to the federal level and less to the local level. This result seemingly contradicts a trend towards increased decentralization in modern societies. If the increase in geographic mobility results from a reduction in transportation costs which also affects externalities across jurisdictions, the case for centralization is strengthened, as both an increase in α and in λ tilt the balance in favor of centralization. We now illustrate Proposition 4 by considering two specific examples.

Example 1 (Quadratic costs) *Let $v(1-\tau) = -\tau^2$.*

In the decentralized game, the equilibrium level of taxation is given by

$$\hat{\tau} = \frac{\lambda + 2 - \alpha^2\lambda}{4\lambda(1-\alpha)} - \frac{\sqrt{(\lambda + 2 - \alpha^2\lambda)^2 - 8\lambda(1-\alpha)}}{4\lambda(1-\alpha)},$$

yielding an average utility:

$$W^D = (1+\alpha)\hat{\tau} - \hat{\tau}^2.$$

In the centralized model, the optimal level of taxation is

$$\tau^o = 1,$$

giving an average utility:

$$W^C = \alpha + 2\lambda(1-\alpha)^2.$$

Example 2 (Linear costs) *Let* $v(1-t) = (1+\beta)(1-\bar{t}) + (1-\beta)(t-\bar{t})$ *if* $t \leq \bar{t}$, $v(1-t) = (1+\beta)(1-t)$ *if* $t \geq \bar{t}$, *with* $0 < \beta < 1$.

In this Example, the marginal utility of the private good is constant and given by $1+\beta$ when $t \geq \bar{t}$ and $1-\beta$ when $t \leq \bar{t}$. In this simple, linear set-up, we compute the equilibrium tax in the decentralized game as:

$$\hat{\tau} = \min\{\frac{\beta}{\lambda\kappa(1-\alpha)(\alpha+\beta)}, \bar{t}\}.$$

with equilibrium utilities:

$$W^D = \hat{\tau}(\alpha+\beta) + 1 + \beta(1-2\bar{t}).$$

The optimal tax level in the federal system is given by: $\tau^o = 1$, with average equilibrium utilities:

$$W^C = 1 + \alpha + 2\lambda(1-\alpha)^2.$$

Figure 6 displays the values of (α, λ) for which $W^C = W^D$ in the quadratic case (panel a) and the linear cost case with $\beta = 0.25$ and $\bar{t} = 0.5$ (panel b). In both cases, the locus for which centralization and decentralization are equivalent is a downward sloping curve in the (α, λ) plane. Higher values of the spillover and mobility parameters correspond to a region where centralization dominates decentralization. For lower values of α and λ (for example, when $\alpha = \lambda = 0$), decentralization dominates centralization. In both cases, the map $\lambda(\alpha)$ is decreasing and concave, but neither property is necessarily obtained for the general case where the utility of the private good is an arbitrary increasing, concave function $v(\cdot)$.

5 Robustness and Extensions

In this Section, we analyze the robustness of our main Proposition, by considering two alternative specifications of the model. In the first variant, we suppose that jurisdictions select the level of *public good* rather than the level of taxation. In the second variant, we suppose that jurisdictions maximize *total utility* rather than resident utility. In both cases, we focus on the quasi-linear model with uniform distribution over mobility costs introduced in Section 3.3.

5.1 Public good game

When jurisdictions choose public good levels g_1 and g_2 rather than tax rates τ_1 and τ_2, the analysis of the decentralized model changes, whereas the analysis of the centralized régime remains unaffected. In the non-cooperative model, the utility of an agent in jurisdiction i is given by:

$$U_i = g_i + \alpha g_j + v(1 - \frac{g_i}{n_i}).$$

Equalization of utility in the two jurisdictions is equivalent to the condition:

$$g_i(1-\alpha) + v(1-g_1) = g_2(1-\alpha) + v(1-g_2).$$

This equations is identical to equation 14, (where tax rates are replaced by public good levels), so that the direction of migration flows is the same in the public good and taxation games. However, the value of the migration flows differ. In the public good game, the migration flow x from jurisdiction 1 to jurisdiction 2 is the solution to the non-linear equation:

$$g_1(1-\alpha) + v(1 - \frac{g_1}{1-\lambda\kappa x}) + x = g_2(1-\alpha) + v(1 - \frac{g_2}{1+\lambda\kappa x}). \quad (18)$$

In order to guarantee that this solution is unique for any (g_1, g_2), we make the following Assumption:

Assumption 5 *Suppose that* $1 > 2v'(0)\lambda_\kappa \frac{(1+\lambda\kappa)^2+(1-\lambda\kappa)^2}{(1+\lambda\kappa)^2(1-\lambda\kappa)^2}$.

Next, consider the solution $\hat{g}$ of the equation:

$$(1 - v'(1-\hat{g})) - \lambda\kappa\hat{g}v'(1-\hat{g})(1+\alpha - v'(1-\hat{g})) = 0. \quad (19)$$

Proposition 5 *In the quasi-linear, uniform model with arbitrary spillovers, if the local public good game admits a symmetric pure strategy equilibrium, then both jurisdictions choose the public good level $\hat{g}$. Furthermore, the level of public good provided in the public good game is lower than in the taxation game, $\hat{g} < \hat{\tau}$ for all $\alpha > 0$.*

Proposition 5 provides a necessary condition that a symmetric pure strategy equilibrium of the public good game must satisfy. It shows that *competition among jurisdictions is stronger when they choose public good levels rather than tax rates*, resulting in lower levels of public good provision. As in the taxation game, an increase in mobility reduces the level of public good provision. The basic insights of the previous analysis are preserved: an increase in mobility makes centralization more likely to be efficient. Furthermore, in contrast to the taxation game, an increase in the spillover parameter α has a clear effect on public good provision, leading to a lower level of public good provision. Hence, it is now clear that centralization dominates decentralization for higher spillover parameters.

Unfortunately, Proposition 5 does not provide a sufficient condition under which a pure strategy symmetric equilibrium exists in the public good game. As in the taxation game, the difficulty stems from the fact that, once jurisdictions take into account the effect of their decisions on household mobility, the payoff functions fail to be quasi-concave in own choices. In the taxation game, the resident utility is linear in the size of the jurisdiction, allowing for a simpler analysis than in the public good game where resident utility is non-linear in the size of the jurisdiction.

5.2 Total utility maximization

When jurisdictions maximize total utility, the computations of both the equilibrium tax in the decentralized game and the optimal tax in the federal régime differ from the computations in the baseline model. The objective of jurisdiction i is given by

$$T_i = n_i[n_i\tau_i + \alpha n_j\tau_j + v(1-\tau_i)].$$

In order to guarantee that no mobility occurs when the two jurisdictions choose the same tax rate, we need to assume:

Assumption 6 *Suppose that* $\lambda\kappa(2\alpha - v(1)) < 1$.

Let τ^T be the unique solution to the equation:

$$1 - v'(1-\tau^T) - \lambda\kappa(2\tau^T + v(1-\tau^T))(v'(1-\tau^T) - (1-\alpha)) = 0. \quad (20)$$

Proposition 6 *In the quasi-linear, uniform model with arbitrary spillovers when jurisdictions maximize total utility, the taxation game admits a unique pure strategy symmetric equilibrium, where both jurisdictions choose the tax level* τ^T*. Furthermore, the level of public good provided is lower than if jurisdictions maximize resident utility,* $\tau^T < \hat{\tau}$.

Proposition 6 characterizes the unique pure strategy equilibrium of the taxation game when jurisdictions care about total utility. As in the baseline model, we show that the game always admits a pure strategy equilibrium.

Compared to the situation where jurisdictions care about resident utility, the jurisdictions' incentive to attract new residents increases, resulting in *higher competition and a lower level of public good in equilibrium.* An increase in mobility reduces the equilibrium level of public good provision. As in the public good game, an increase in the spillover parameter has a nonambiguous effect and results in a decrease in public good provision, so that centralization becomes preferable when spillovers are high.

Consider next the optimal choice of the majority jurisdiction in the federal régime. If the majority jurisdiction chooses a tax rate τ^o, the migration flow of agents from the minority to the majority jurisdiction is given by:

$$x = \lambda\kappa(2\tau^o)(1-\alpha)$$

so that total utility of the majority jurisdiction is

$$T = (2\tau^o + v(1-\tau^o))(1 + \lambda\kappa 2\tau^o(1-\alpha)), \tag{21}$$

Contrary to the case of resident utility, the total utility is not necessarily concave in τ^o. In order to guarantee concavity, we put an upper bound on the size of the mobile population:

Assumption 7 *Assume that* $v''(1-\tau)+2\lambda\kappa(1-\alpha)(4-3v'(1-\tau)+2\tau v''(1-\tau)) < 0$ *for all* $\tau \in [0,1]$.

Under assumption 7, the optimal tax rate τ^o is uniquely defined as the solution to the equation:

$$2 - v'(1-\tau) + 2\lambda\kappa(1-\alpha)(4\tau - 2v'(1-\tau)\tau + v(1-\tau)) = 0. \tag{22}$$

Hence, contrary to the case of resident utility, the optimal tax rate τ^o is *strictly increasing in the mobility parameter* λ. As agents are more mobile, the majority jurisdiction has an incentive to increase the tax rate in order to increase the migration flow into the majority jurisdiction. Average resident utility is given by

$$W^C = (1+\alpha)\tau^o + v(1-\tau^o) + 2\lambda\kappa\tau^{o2}(1-\alpha)^2.$$

An increase in the mobility parameter λ thus affects the average welfare through two channels: it increases mobility to the majority jurisdiction (a positive effect) and raises the optimal tax level τ^o (an effect which can either be positive or negative). Notice however that

$$
\begin{aligned}
\frac{\partial W^C}{\partial \lambda} &= \frac{\partial \tau^o}{\partial \lambda}(1+\alpha - v'(1-\tau^o) + 2\lambda\kappa\tau^o(1-\alpha)^2) + 4\kappa\tau^{o2}(1-\alpha)^2, \\
&= (1-\alpha)(\frac{\partial \tau^o}{\partial \lambda}(1 - 2\lambda\kappa(2(1+\alpha)\tau^o - 2v'(1-\tau^o)\tau^o + v(1-\tau^o))) \\
&\quad +4\kappa\tau^{o2}(1-\alpha)).
\end{aligned}
$$

Hence, if $2\lambda\kappa(2(1+\alpha)+v(1)) < 1$, $\frac{\partial W^C}{\partial \lambda} > 0$. We conclude that, whenever the share of the mobile population is small enough, an increase in the mobility parameter λ results in an increase in the welfare in the centralized régime, so that the result of Proposition 4 continues to hold.

6 Conclusion

This paper studies how Oates' trade-off between centralized and decentralized public good provision is affected by changes in households' mobility. We show that an increase in household mobility favors centralization, as it increases competition between jurisdictions in the decentralized régime and accelerates migration to the majority jurisdiction in the centralized régime. Hence, decentralized provision only dominates centralized provision for low values of spillover and mobility. Our main result is obtained in a baseline model where jurisdictions first choose taxes, and households move in response to tax levels. We consider two other variants of the model. If jurisdictions choose public goods rather than tax rates, the equilibrium level of public good provision is lower, and mobility again favors centralization. If jurisdictions maximize total utility rather than resident utility, the equilibrium level of public good provision again decreases, and mobility favors centralization when the size of the mobile population is bounded.

The theoretical results we obtain are seemingly at odds with a recent trend of increased household mobility and increased fiscal decentralization. This suggests that our model is not rich enough to capture the political aspects of devolution of public services to local governments. We thus believe that an important next step in our research program is to enrich the model of the political process of public good provision and taxation, in order to bring our theory to the data. In addition, we believe that our current model, where all agents have identical preferences, may be too simplistic to capture the effects of jurisdiction formation and migration. We plan to introduce heterogenous preferences in the model, in order to emphasize the sorting effect of migrations, and obtain a richer and more realistic model of fiscal decentralization.

7 References

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8 Appendix

Proof of Proposition 1:

We first prove that (τ^*, τ^*) is a pure strategy Nash equilibrium of the taxation game. Suppose that jurisdiction 2 chooses τ^*. Consider first a choice $\tau_1 > \tau^*$. Let x be the marginal member of jurisdiction 1 who moves to jurisdiction 2. Let G be the total amount of public good provided. Simple computations show that

$$\frac{\partial x}{\partial \tau_1} = \frac{U_e(G, 1-\tau_1) + (U_g(G, 1-\tau^*) - U_g(G, 1-\tau_1))(1-\lambda F(x))}{1 + \lambda f(x)(\tau_1 - \tau^*)(U_g(G, 1-\tau^*) - U_g(G, 1-\tau_1))}.$$

As $U_{ge} > 0, U_g(G, 1-\tau^*) > U_g(G, 1-\tau_1)$ so that $\frac{\partial x}{\partial \tau_1} > 0$: an increase in the tax rate τ_1 unambiguously increases the migration of agents out of jurisdiction 1. Now, compute the effect of an increase in τ_1 on the resident utility of an agent in jurisdiction 1:

$$\begin{aligned}
\frac{\partial U_1}{\partial \tau_1} \quad = \quad & (1-\lambda F(x))U_g(\tau_1(1-\lambda F(x)) + \tau^*(1+\lambda F(x)), 1-\tau_1) \\
& - U_e(\tau_1(1-\lambda F(x)) + \tau^*(1+\lambda F(x)), 1-\tau_1) \\
& - \lambda f(x)(\tau_1 - \tau^*)U_g(\tau_1(1-\lambda F(x)) + \tau^*(1+\lambda F(x)), 1-\tau_1)\frac{\partial x}{\partial \tau_1}.
\end{aligned}$$

Now,

$$\begin{aligned}
U_g(\tau_1(1-\lambda F(x)) + \tau^*(1+\lambda F(x)), 1-\tau_1) \quad & < \quad U_g(\tau_1 + \tau^*, 1-\tau_1) \\
& < \quad U_g(2\tau^*, 1-\tau^*),
\end{aligned}$$

and

$$\begin{aligned}
U_e(\tau_1(1-\lambda F(x)) + \tau^*(1+\lambda F(x)), 1-\tau_1) \quad & > \quad U_e(2\tau^*, 1-\tau_1) \\
& > \quad U_e(2\tau^*, 1-\tau^*),
\end{aligned}$$

so that

$$\frac{\partial U_1}{\partial \tau_1} < -\lambda U_g F(x) + f(x)(\tau_1 - \tau^*)\frac{\partial x}{\partial \tau_1} < 0.$$

Next, consider a deviation to $\tau_1 < \tau^*$. Let y be the marginal agent of jurisdiction 2 who moves to jurisdiction 1 (with $y < K$). We easily compute:

$$\frac{\partial y}{\partial \tau_1} = -\frac{U_e(G, 1-\tau_1) + (U_g(G, 1-\tau^*) - U_g(G, 1-\tau_1))(1+\lambda F(y))}{1 + \lambda f(y)(\tau^* - \tau_1)(U_g(G, 1-\tau_1) - U_g(G, 1-\tau^*))}.$$

Notice that, as $U_g(G, 1-\tau^*) < U_g(G, 1-\tau_1)$, it is now impossible to sign the effect of an increase in the tax rate on migrations (unless the utility function is additive and $U_{ge} = 0$, in which case $\frac{\partial y}{\partial \tau_1} < 0$, as expected.) However, we compute:

$$\frac{\partial U_1}{\partial \tau_1} = (1 + \lambda F(y))U_g - U_e - \lambda f(y)(\tau^* - \tau_1)U_g \frac{\partial y}{\partial \tau_1}.$$

After rearranging, we observe that the sign of $\frac{\partial U_1}{\partial \tau_1}$ is the same as the sign of:

$$\begin{aligned} A &= \lambda f(y)(\tau^* - \tau_1)U_e(G, 1 - \tau_1)U_g(G, 1 - \tau^*) + U_g(G, 1 - \tau_1) \\ & \quad -U_e(G, 1 - \tau_1) + \lambda F(y)U_g(G, 1 - \tau_1). \end{aligned}$$

Next, note that, as $G < 2\tau^*$, $U_g(G, 1-\tau_1) > U_g(2\tau^*, 1-\tau_1) > U_g(2\tau^*, 1-\tau^*)$ and $U_e(G, 1 - \tau_1) < U_e(2\tau^*, 1 - \tau_1) < U_e(2\tau^*, 1 - \tau^*)$, establishing that

$$\frac{\partial U_1}{\partial \tau_1} > 0,$$

so that (τ^*, τ^*) is a symmetric equilibrium of the game.

We now show that there cannot be any other symmetric equilibrium. If $\tau_1 \geq \tau_2$, we compute the marginal utility of a change in τ_1 as:

$$\frac{\partial U_1}{\partial \tau_1} = (1 - \lambda F(x))U_g - U_e - (\tau_1 - \tau_2)\lambda f(x)U_g \frac{\partial x}{\partial \tau_1}.$$

Symmetrically, when $\tau_1 \leq \tau_2$, we compute:

$$\frac{\partial U_1}{\partial \tau_1} = (1 + \lambda F(x))U_g - U_e + (\tau_1 - \tau_2)\lambda f(x)U_g \frac{\partial x}{\partial \tau_1}.$$

Hence, letting τ_1 converge to τ_2, we have:

$$\frac{\partial U_1}{\partial \tau_1}|\tau_1 = \tau_2 = U_g(2\tau_2, 1 - \tau_2) - U_e(2\tau_2, 1 - \tau_2).$$

Hence, whenever $\tau_2 < \tau^*$, $\frac{\partial U_1}{\partial \tau_1}|\tau_1 = \tau_2 > 0$ and when $\tau_2 > \tau^*$, $\frac{\partial U_1}{\partial \tau_1}|\tau_1 = \tau_2 < 0$. This shows that whenever $\tau \neq \tau^*$, there cannot be a pure strategy equilibrium where τ is a best response to itself.

Proof of Proposition 2: We first verify that (τ^*, τ^*) is a pure strategy Nash equilibrium of the taxation game. As $U(\tau^*, 1 - \tau^*) > U(\tau, 1 - \tau)$ for any $\tau \neq \tau^*$, if the other jurisdiction charges τ^*, any deviation to another tax rate τ induces a migration out of the jurisdiction, resulting in a utility

$$U(\tau(1-\lambda F(x)), 1-\tau) < U(\tau, 1-\tau) < U(\tau^*, 1-\tau^*).$$

Hence, when the other jurisdiction chooses tax rate τ^*, any deviation to $\tau \neq \tau^*$ results in a loss of utility.

We now verify that (τ^*, τ^*) is the unique symmetric Nash equilibrium. Suppose that jurisdiction 2 chooses $\tau_2 \neq \tau^*$ and compute

$$\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2} = U_g(\tau_2, 1-\tau_2) - U_2(\tau_2, 1-\tau_2) + \lambda f(0)\tau_2 \frac{\partial y}{\partial \tau_1}|_{\tau_1=\tau_2}.$$

We compute:

$$\frac{\partial y}{\partial \tau_1}|_{\tau_1=\tau_2} = \frac{U_g(\tau_2, 1-\tau_2) - U_2(\tau_2, 1-\tau_2)}{1 - 2\lambda f(0)\tau_2 U_g(\tau_2, 1-\tau_2)}.$$

Under Assumption 1, whenever $\tau_2 < \tau^*$, $\frac{\partial y}{\partial \tau_1}|_{\tau_1=\tau_2} > 0$ so that $\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2} > 0$, and whenever $\tau_2 > \tau^*$, $\frac{\partial y}{\partial \tau_1}|_{\tau_1=\tau_2} < 0$ and $\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2} < 0$. This implies that there cannot be any other symmetric equilibrium of the taxation game.

Proof of Proposition 3: We first show that $(\hat{\tau}, \hat{\tau})$ is a pure strategy Nash equilibrium of the taxation game. Suppose that jurisdiction 2 chooses $\tau_2 = \hat{\tau}$.

Consider first a strategy $\tau_1 \leq \underline{\tau}$, namely a choice τ_1 so low that $U_1 < U_2$. We show that this choice is dominated by choosing $\tau_1 = \hat{\tau}$. Different cases have to be distinguished. First suppose that $\alpha\hat{\tau} < \tau_1$. Then

$$\begin{aligned} U_1 &= \tau_1 + \alpha\hat{\tau} + \lambda\kappa x(\alpha\hat{\tau} - \tau_1) + v(1-\tau_1) \\ &< \tau_1 + \alpha\hat{\tau} + v(1-\tau_1) \\ &< \hat{\tau}(1+\alpha) + v(1-\hat{\tau}) \end{aligned}$$

where the last inequality is obtained because $\tau_1 < \hat{\tau} < \tau^*$, so any increase in the tax rate increases $\tau + v(1-\tau)$.

Next, suppose that $\tau_1 \leq \alpha\hat{\tau}$. Notice that $\phi(\tau_1) < \phi(\hat{\tau})$ so that

$$\begin{aligned} U_1 &= \tau_1(1-\alpha) + v(1-\tau_1) + \alpha(\tau_1 + \hat{\tau}) + \lambda\kappa x(\alpha\hat{\tau} - \tau_1) \\ &< \hat{\tau}(1-\alpha) + v(1-\hat{\tau}) + \alpha(\tau_1 + \hat{\tau}) + \lambda\kappa x(\alpha\hat{\tau} - \tau_1) \\ &= \hat{\tau}(1+\alpha) + v(1-\hat{\tau}) + \alpha(\tau_1 - \hat{\tau}) + \lambda\kappa x(\alpha\hat{\tau} - \tau_1). \end{aligned}$$

If $\alpha < \lambda\kappa x$, as $\lambda\kappa x < 1$, $\tau_1(\alpha - \lambda\kappa x) - \alpha\hat{\tau}(1 - \lambda\kappa x) < 0$. If $\alpha \geq \lambda\kappa x$, as $\tau_1 \leq \alpha\hat{\tau}$,

$$\begin{aligned} \tau_1(\alpha - \lambda\kappa x) - \alpha\hat{\tau}(1 - \lambda\kappa x) &< \alpha(\alpha - 1)\hat{\tau} \\ &< 0 \end{aligned}$$

proving that choosing τ_1 is dominated by choosing $\hat{\tau}$.

Next consider values of $\tau_1 > \underline{\tau}$ such that (i) either $\underline{\tau} < \tau_1 < \hat{\tau}$ and $U_1 > U_2$ so that $x < 0$, or (ii) $\tau_1 > \hat{\tau}$ and $U_2 > U_1$, so that $x > 0$. We will show that $\frac{\partial U_1}{\partial \tau_1} > 0$ for all $\tau_1 < \hat{\tau}$ and $\frac{\partial U_1}{\partial \tau_1} < 0$ for all $\tau > \hat{\tau}$. Using equation (15), we compute:

$$\frac{\partial x}{\partial \tau_1} = \frac{v'(1 - \tau_1) - (1 - \alpha)(1 - \lambda\kappa x)}{1 - \lambda\kappa(1 - \alpha)(\tau_1 + \hat{\tau})}.$$

and

$$\frac{\partial U_1}{\partial \tau_1} = (1 - \lambda\kappa x) - v'(1 - \tau_1) - \lambda\kappa(\tau_1 - \alpha\hat{\tau})\frac{\partial x}{\partial \tau_1}.$$

Replacing, the sign of $\frac{\partial U_1}{\partial \tau_1}$ is the same as the sign of:

$$\begin{aligned} B &= (1 - \lambda\kappa x) - v'(1 - \tau_1) - \lambda\kappa(1 - \alpha)(1 - \lambda\kappa x)(1 - \alpha)\hat{\tau} \\ &+ \lambda\kappa v'(1 - \tau_1)(\hat{\tau} - \alpha\tau_1). \end{aligned}$$

We now separate the two cases (i) $\tau_1 < \hat{\tau}$ and (ii) $\tau_1 > \hat{\tau}$.

If $\tau_1 < \hat{\tau}$ and $x < 0$, as $\lambda\kappa(1 - \alpha)^2\hat{\tau} < 2\lambda\kappa(1 - \alpha) < 1$,

$$(1 - \lambda\kappa x)(1 - \lambda\kappa(1 - \alpha)^2\hat{\tau}) > (1 - \lambda\kappa(1 - \alpha)^2\hat{\tau}),$$

Furthermore, as $\hat{\tau} > \tau_1$ and $\lambda\kappa\hat{\tau}(1 - \alpha) < 1$,

$$\begin{aligned} -v'(1 - \tau_1)(1 - \lambda\kappa\hat{\tau} - \alpha\tau_1) &> -v'(1 - \tau_1)(1 - \lambda\kappa(1 - \alpha)\hat{\tau}) \\ &> -v'(1 - \hat{\tau})(1 - \lambda\kappa(1 - \alpha)\hat{\tau}) \end{aligned}$$

And using the definition of $\hat{\tau}$, we finally obtain:

$$B > 0,$$

so that choosing $\hat{\tau}$ dominates any choice $\tau_1 \in (\underline{\tau}, \hat{\tau})$.

If now $\tau_1 > \hat{\tau}$ and $x > 0$, we obtain in a symmetric fashion:

$$\begin{aligned}
(1-\lambda\kappa x)(1-\lambda\kappa(1-\alpha)^2\hat{\tau}) &< (1-\lambda\kappa(1-\alpha)^2\hat{\tau}), \\
-v'(1-\tau_1)(1-\lambda\kappa\hat{\tau}-\alpha\tau_1) &< -v'(1-\hat{\tau})(1-\lambda\kappa(1-\alpha)\hat{\tau})
\end{aligned}$$

so that

$$B < 0,$$

completing the proof that $\hat{\tau}$ is the unique best response when the other jurisdiction chooses $\hat{\tau}$.

In order to prove that there is no other symmetric equilibrium in the game, we compute

$$\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} = (1-v'(1-\tau))(1-\lambda\kappa\tau(1-\alpha)) - \alpha(1-\alpha)\lambda\kappa\, \tau.$$

Note that, when $\tau > \tau^*$, $\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} < 0$. It is easy to check that, when $\tau < \tau^*$, $\frac{\partial^2 U_1}{\partial \tau_1^2} < 0$, so that $\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} > 0$ for all $\tau < \hat{\tau}$ and $\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} < 0$ for all $\tau > \hat{\tau}$. Hence, there cannot be any equilibrium at $\tau \neq \hat{\tau}$.

Proof of Proposition 5: We first show that Equation (19) admits a unique solution $\hat{g}$. Differentiating the equation with respect to g, we find:

$$\begin{aligned}
\Phi'(g) &\equiv v''(1-g)(1-\lambda\kappa g v'(1-g)) - \lambda\kappa v'(1-g)(1-v'(1-g)) \\
&\quad + + \lambda\kappa g v''(1-g)(1-v'(1-g)) + \alpha v''(1-g)\lambda\kappa g - \alpha v'(1-g)\lambda\kappa \\
&< 0.
\end{aligned}$$

Now suppose that (g, g) is a pure strategy symmetric equilibrium of the public good game, then $\frac{\partial U_1}{\partial g_1}|_{g_1=g_2=g} = 0$. Now,

$$\frac{\partial U_1}{\partial g_1}|_{g_1=g_2=g} = 1 - v'(1-g)(1-g\lambda\kappa\frac{\partial x}{\partial g_1}).$$

and

$$\frac{\partial x}{\partial g_1}|_{g_1=g_2=g} = \frac{1-\alpha-v'(1-g)}{1-2\lambda\kappa g v'(1-g)}.$$

Hence, we obtain:

$$\frac{\partial U_1}{\partial g_1}|_{g_1=g_2=g} = (1-\lambda\kappa g v'(1-g))(1-v'(1-g)) - \alpha g\lambda\kappa v'(1-g).$$

Now notice that, for any $\alpha > 0$, as $v'(1-\hat{\tau}) > 1-\alpha$,

$$\begin{aligned}
\Psi(\tau) &\equiv (1-v'(1-\tau)(1-\lambda\kappa\tau(1-\alpha)) - \alpha(1-\alpha)\lambda\kappa\tau \\
&> (1-v'(1-\tau)(1-\lambda\kappa\tau(1-v'(1-\tau)) - \alpha(1-v'(1-\tau)\lambda\kappa\tau \\
&= \Phi(\tau)
\end{aligned}$$

Hence, as $\Phi(g)$ is decreasing in g, and $\Phi(\hat{g}) = 0 > \Phi(\hat{\tau})$, we conclude that $\hat{g} < \hat{\tau}$.

Proof of Proposition 6: We first observe that equation (20) has a unique solution as

$$\begin{aligned}
\chi'(\tau) &\equiv v''(1-\tau)(1-2\alpha\lambda\kappa\tau + \lambda\kappa v(1-\tau)) \\
&+ v'(1-\tau)(v'(1-\tau-1-\alpha) \\
&< 0.
\end{aligned}$$

where we make use of Assumption 6 to sign $(1-2\alpha\lambda\kappa\tau + \lambda\kappa v(1-\tau))$.

Next, we prove that, when the other jurisdiction chooses τ^T, the unique best response is to choose τ^T. Consider first the choice $\tau_1 < \underline{\tau}$. As in the proof of Proposition 3, the resident utility is lower than if the jurisdiction chose $\tau_1 = \tau^T$. (The only steps which are need to prove this statement are $\tilde{\tau} < \tau^T < \tau^*$, which is immediately obtained from the definition of τ^T.) In addition, as $n(\tau_1, \tau^T) < n(\tau^T, \tau^T) = 1$, total utility is higher at τ^T.

Next, consider a choice $\tau_1 > \tau^* > \tau^T$. Notice that $\frac{\partial x}{\partial \tau_1} > 0$ for all $\tau_1 > \tau^T$, so that

$$\begin{aligned}
U_1(\tau_1, \tau^T) &= \tau_1(1-\lambda\kappa x(\tau_1)) + \alpha(1+\lambda\kappa x(\tau_1))\tau^T + v(1-\tau_1) \\
&< \tau^*(1-\lambda\kappa x(\tau^*)) + \alpha(1+\lambda\kappa x(\tau^*))\tau^T + v(1-\tau^*)
\end{aligned}$$

where the last inequality derives from the fact that $\tau_1 + v(1-\tau_1) < \tau^* + v(1-\tau^*)$ and $x(\tau_1) > x(\tau^*)$.

Now, consider $\tau_1 \in (\underline{\tau}, \tau^*)$. Compute

$$\begin{aligned}\frac{\partial T_1}{\partial \tau_1} &= (1-\lambda\kappa x)((1-\lambda\kappa x) - v'(1-\tau_1) - \lambda\kappa(\tau_1 - \alpha\tau^T))\frac{\partial x}{\partial \tau_1} \\ &- \lambda\kappa\frac{\partial x}{\partial \tau_1}(\tau_1(1-\lambda\kappa x) + \alpha\tau^T(1+\lambda\kappa x) + v(1-\tau_1)).\end{aligned}$$

The sign of $\frac{\partial T_1}{\partial \tau_1}$ is thus identical to the sign of

$$\begin{aligned}C &= -\lambda\kappa(2\tau_1(1-\lambda\kappa x) + 2\alpha\tau^T\lambda\kappa x + v(1-\tau^1))(v'(1-\tau_1) - (1-\alpha)(1-\lambda\kappa x)) \\ &+ (1-\lambda\kappa x)(1-\lambda\kappa x - v'(1-\tau_1))(1-\lambda(1-\alpha)(\tau_1 - \tau^T).\end{aligned}$$

Suppose that $\tau_1 < \tau^T$ and $x < 0$. Then

$$(1-\lambda\kappa x)(1-\lambda\kappa x - v'(1-\tau_1))(1-\lambda(1-\alpha)(\tau_1 - \tau^T) > (1 - v'(1-\tau^T)).$$

In addition

$$v'(1-\tau_1) - (1-\alpha)(1-\lambda\kappa x) < v'(1-\tau^T) - (1-\alpha).$$

Finally, as $2\lambda\kappa x < 1$, and $\tau_1 + v(1-\tau_1) < \tau^T + v(1-\tau^T)$,

$$\tau_1 + \tau_1(1-2\lambda\kappa x) + 2\alpha\tau^T\lambda\kappa x + v(1-\tau^1) < 2\tau^T + v(1-\tau^T).$$

So that, finally,

$$C > 0.$$

Similarly, when $\tau^T < \tau_1 < \tau^*$, we have

$$\begin{aligned}(1-\lambda\kappa x)(1-\lambda\kappa x - v'(1-\tau_1))(1-\lambda(1-\alpha)(\tau_1 - \tau^T) &< (1 - v'(1-\tau^T)), \\ v'(1-\tau_1) - (1-\alpha)(1-\lambda\kappa x) &> v'(1-\tau^T) - (1-\alpha), \\ \tau_1 + \tau_1(1-2\lambda\kappa x) + 2\alpha\tau^T\lambda\kappa x + v(1-\tau^1) &> 2\tau^T + v(1-\tau^T)\end{aligned}$$

so that

$$C < 0,$$

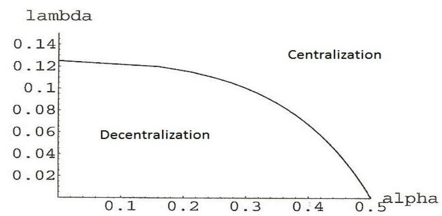
completing the proof of the fact that (τ^T, τ^T) is a pure strategy symmetric Nash equilibrium of the taxation game when jurisdictions maximize total utility.

To check that (τ^T, τ^T) is the unique pure strategy symmetric equilibrium, we compute:

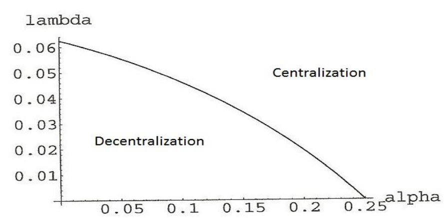
$$\begin{aligned}
\frac{\partial T_1}{\partial \tau_1}|\tau_1 = \tau_2 = \tau &= ((1 - v'(1-\tau)) - \lambda\kappa(2\tau + v(1-\tau))(v'(1-\tau) - (1-\alpha)) \\
&\equiv \chi(\tau)
\end{aligned}$$

so that the only point at which $\frac{\partial T_1}{\partial \tau_1}|\tau_1 = \tau_2 = \tau = 0$ is when $\tau = \tau^T$.

In order to prove that $\tau^T < \hat{\tau}$, we notice that, as $\frac{\partial T_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} < \frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau}$, $\chi(\hat{\tau}) < 0 = \chi(\tau^T)$. As $\chi(\cdot)$ is decreasing, this implies that $\tau^T < \hat{\tau}$.



(a) Quadratic costs



(b) Linear costs

Figure 6: Centralization vs decentralization