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Oates' decentralization theorem with imperfect household mobility

Francis Bloch · Ünal Zenginobuz

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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. This results from two effects. First, mobility increases competition between jurisdictions in the decentralized régime, resulting in lower levels of public good provision. Second, while tyranny of the majority creates a gap between social welfare in different jurisdictions in the centralized régime, mobility allows agents to move to the majority jurisdiction, raising average social welfare. Our main result is obtained in a baseline model where jurisdictions first choose taxes, and households move in response to tax levels. We show that the result is robust to changes in the objective function and the strategic variable of local governments.

Keywords Oates' decentralization theorem · Fiscal federalism · Household mobility · Spillovers · Tax competition

JEL Classification H77 · H70 · H41

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F. Bloch
Université Paris 1 and Paris School of Economics, Paris, France

Ü. Zenginobuz (✉)
Bogazici University, Istanbul, Turkey
e-mail: zenginob@boun.edu.tr

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 (1956) notion of the alignment of local public goods to local tastes, Oates' framework did not allow for mobility of households across jurisdictions. In this paper, we 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 80s, there has been a worldwide trend toward 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 recentralized over the period.

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

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

[2] Dustmann et al. (2010) report that the share of immigrants from accession countries as a proportion of the UK working-age population increased from 0.01 to 1.3 % by the beginning of 2009.

agents. Agents may move to the other jurisdiction in response to differences in the public good/taxation packages of the two jurisdictions. In each jurisdiction, residents are imperfectly mobile and incur a psychic cost of mobility, measured by their home attachment. The intensity of home attachment 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.

In the baseline model, we consider jurisdictions that 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 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 of our model, 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. We illustrate this result by an example with quadratic cost of public good provision, highlighting the existence of a decreasing curve linking spillover and mobility parameters, such

[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.

[4] See Besley and Coate (2003), Koethenbuerger (2008) and Lockwood (2008) for other examples where welfare is non-monotonic in the level of spillovers and the choice between centralization and decentralization is sometimes counterintuitive.

that decentralization dominates centralization below this curve, and centralization dominates decentralization above.

We test the robustness of our intuitions by briefly considering two variants of the baseline model. In the first variant, we suppose that jurisdictions choose public good levels rather than taxes. As in Wildasin (1988)'s and Koethenbuerger (2012)'s models, competition in public good provision results in *stronger competition and lower public good levels than in the taxation game*. The basic intuition regarding the effect of mobility on the choice between centralization and decentralization is maintained. In the second variant, we assume that jurisdictions' objective is to maximize total utility rather than resident utility. This makes jurisdictions compete more aggressively, resulting in lower levels of public good provision in the decentralized régime. In the centralized régime, the majority jurisdiction will increase the tax rate in order to attract more immigrants. It may overshoot and select an inefficiently high level of public good provision, so that the comparison between centralization and decentralization is less stark than in the baseline model. However, we show that when mobility is not too high, an increase in mobility increases average welfare so that our basic intuition on the effect of mobility on the choice between centralization and decentralization remains valid.

We now contrast our analysis with the previous literature discussing the interaction between fiscal federalism and household mobility. Caplan et al. (2000) and Brueckner (2004) study the trade-off between centralization and decentralization with factor mobility. Caplan et al. (2000) focus on the pure public good case and focus attention on the role of interregional transfers to reach an efficient public good provision. Brueckner (2004) considers capital rather than labor mobility and examines the trade-off between fiscal externalities due to tax competition and the efficiency loss due to policy uniformity in the centralized régime. Most of the literature on Oates' Decentralization Theorem allowing for imperfect spillovers assumes that households are immobile [e.g., Besley and Coate (2003), Koethenbuerger (2008) and Janeba and Wilson (2011)].[5] Closest to our analysis are a series of papers by Wellisch (1993, 1994, 1995), Hoel and Shapiro (200, 2004) and Hoel (2004). Wellisch (1993, 1994, 1995) does not explicitly introduce spillovers in his analysis, so his model does not enable him to study how changes in mobility affect the trade-off between centralization and decentralization. Hoel and Shapiro (200, 2004) and Hoel (2004) 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 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. Naoto

5 See Epple and Nechyba (2004) and Boadway and Tremblay (2011) for surveys 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.

and Silva (2008) incorporate both spillovers and mobility of agents in the context of transboundary pollutants, but they do not address directly the relative merits of decentralization versus centralization. In sum, while there is sizable literature discussing household mobility, spillovers and optimal decentralization, our paper is the first attempt to establish a direct connection between the level of household mobility and public good spillovers and the choice between centralization and decentralization.

The rest of the paper is organized as follows. Section 2 presents the model, including a description of decentralization, centralization and objective functions 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 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.[6] 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 that an agent derives from consumption of the private good and the public good 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 Bergstrom et al. (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 and $U_{\text{ge}} \geq 0$.

Agents are (imperfectly) mobile and move in response to differences in the public good/taxation packages of the two jurisdictions. We model imperfect mobility, as Mansoorian and Myers (1993, 1997), Wellisch (1994) and Caplan et al. (2000), through

[6] This is the same spillover model as the one studied by Bloch and Zenginobuz (2006, 2007).

home attachment. Agents are uniformly distributed along the segment [0, 2] and agent $x \in [0, 2]$ values living in jurisdiction 1 at $\lambda(2 - x)$ and living in jurisdiction 2 at λx, where $\lambda \geq 0$ is the attachment intensity. Thus, the *overall* utility of an agent living in jurisdiction 1 is given by

$$\widetilde{U}_1 = U(g_1 + \alpha g_2, 1 - \tau_1) + \lambda(2 - x),$$

and the *overall* utility of an agent living in jurisdiction 2 is given by

$$\widetilde{U}_2 = U(g_2 + \alpha g_1, 1 - \tau_2) + \lambda x.$$

This measure of home attachment is a psychic measure, which cannot be directly observed by the local and central governments and does not enter the objective function of the governments. The parameter λ can be taken as the degree of mobility of agents in the society. Higher values of λ mean that agents are less mobile, and perfect mobility is obtained for $\lambda = 0$. After migration, the new jurisdiction sizes are given by (n_1, n_2).

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

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

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.[7]

[7] In our earlier work (Bloch and Zenginobuz 2006, 2007), we analyzed the Tiebout equilibria of the same model of public good provision with spillovers, but did not restrict attention to symmetric equilibria.

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 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 that is robust to deviations by groups of arbitrarily small sizes ϵ.[8] 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.[9] As opposed to Lockwood (2002) and Besley and Coate (2003), we do not model centralized provision as the outcome of

Footnote 7 continued
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)). In that case, 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.

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

[9] When the two jurisdictions are of equal size, we break ties by assuming that jurisdiction 1 holds the majority.

a bargaining process among members of the federal legislature. However, our modeling retains the inequality in provision of public goods among jurisdictions—the central feature that generates inefficiency in the central provision régime. In the federal régime, all agents are subject to the same tax rate τ, which is chosen to atisfy the budget constraint:

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

and the utility of an agent residing 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.

2.4 Objective functions of governments

In order to compute the optimal decisions of jurisdictions in the decentralized and federal régimes, we need to specify the objective of the local governments. 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 objective 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*, $W_i = U_i$. We consider in Sect. 5 an alternative specification, where the objective function of the local government is the *total utility* $W_i = U_i n_i$ of agents in the jurisdiction.

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 *overall* utility of all agents in society. Notice that, as opposed to the objective function of the governments, in comparing centralization with decentralization, we take into account the mobility costs borne by the agents when they migrate across jurisdictions. We thus consider (if $n_1 > n_2$)

$$W = n_1 U_1 + n_2 U_2 - 2 \int_1^{n_1} \lambda(1-x)\mathrm{d}x. \tag{7}$$

3 Equilibrium under 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 ($\alpha = 0$).

3.1 Pure public goods and pure local public goods

3.1.1 Pure public goods

We solve the game by backward induction and consider first the mobility choice of agents. In equilibrium, given (τ_1, τ_2), the equilibrium sizes of the jurisdictions are given by the indifference condition of the marginal agent located at the border between the two jurisdictions:

$$\begin{aligned} & U(n_1\tau_1 + (2-n_1)\tau_2, 1-\tau_1) + \lambda(2-n_1) \\ & \quad = U(n_1\tau_1 + (2-n_1)\tau_2, 1-\tau_2) + \lambda n_1. \end{aligned} \tag{8}$$

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:

$$\max_{\tau_1} U(n_1(\tau_1, \tau_2)\tau_1 + (2 - n_1(\tau_1, \tau_2), 1 - \tau_1). \tag{9}$$

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

$$U_g(2\tau^*, 1-\tau^*) = U_e(2\tau^*, 1-\tau^*). \tag{10}$$

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 that equilibrium, no agent moves. 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. The intuition underlying this result is as follows: at a symmetric equilibrium, any move of an agent across jurisdictions does not affect the total amount of pure public good provided. Hence, the equilibrium tax rate does not take into account the effect of the change in tax rates on mobility. Notice also that, as expected, the level of taxation chosen by the two local governments is suboptimal (the optimal level being the solution to the equation: $2U_g(2\tau, 1-\tau) = U_e(2\tau, 1-\tau)$). Tax competition results in under provision of the pure public goods.

3.1.2 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

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

The equilibrium taxation level in each jurisdiction is given by τ^{**}, the solution to the equation

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

Agents' incentives to move across jurisdictions depends on the deviation between τ^{**} and the effective tax level τ_i in the two jurisdictions. In equilibrium, for any (τ_1, τ_2), the sizes of jurisdictions are given by the condition:

$$U(\tau_1 n_1, 1-\tau_1) + \lambda(2-n_1) = U(\tau_2(2-n_1), 1-\tau_2) + \lambda n_1. \tag{12}$$

However, notice that, in the local public goods case, as agents' utilities are increasing in the size of the jurisdiction, they have an incentive to agglomerate in a single jurisdiction, so that the interior equilibrium condition (12) may no longer be valid. We assume that home attachment is sufficiently high for this not to happen. More precisely, we want to guarantee that any movement across jurisdictions results from a reaction to different tax/public good packages rather than agglomeration effects. A sufficient condition for this is that, when the two jurisdictions choose the same tax level τ, the unique equilibrium level of jurisdictions is $n_1 = n_2 = 1$. Formally, let

$$V(n) = U(\tau n, 1-\tau) - U(\tau(2-n), 1-\tau) + 2\lambda(1-n). \tag{13}$$

The function $V(n)$ is monotonically decreasing in n if the following sufficient condition holds:

Assumption 1 Suppose that for all $\tau \in [0, 1]$, $\tau U_g(\tau, 1-\tau) < \lambda$.

Assumption 1 places a strong lower bound on the home attachment parameter λ. When this condition is satisfied, for any (τ_1, τ_2), there is a unique equilibrium level of jurisdictions $n_1(\tau_1, \tau_2)$. We can then write the problem faced by the local government of jurisdiction 1 as follows:

$$\max_{\tau_1} U(n_1(\tau_1, \tau_2)\tau_1, 1-\tau_1). \tag{14}$$

Proposition 2 *In the local public goods model, the taxation game played by the two jurisdictions admits a unique equilibrium where* $\tau_1 = \tau_2 = \tau^{**}$.

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. The rationale for this result stems from the absence of spillovers across the jurisdictions. As τ^{**} is the efficient level of taxation in the case of local public goods when jurisdictions have equal sizes, any move away from τ^{**} will induce agents to leave the jurisdiction and lower the utility of the remaining residents. Hence, the autarchic efficient level of taxation is the only equilibrium of the game played by the jurisdictions. As no migration occurs in equilibrium, the equilibrium utility of all agents is also unaffected by the mobility parameter λ.

3.2 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 non-trivial way, and the characterization of inter-jurisdictional migrations becomes extremely complex. In order to keep the analysis tractable, we specialize the model in the following way.

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 2 is a common assumption in the study of non-cooperative 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.

Even under Assumption 2, the analysis of migrations is more complex than in the cases of pure public goods and local public goods. To see this, consider the model of tax competition when the two populations are immobile, $n_1 = n_2 = 1$. The condition equating utility in the two jurisdictions is as follows:

$$\tau_1(1 - \alpha) + v(1 - \tau_1) = \tau_2(1 - \alpha) + v(1 - \tau_2). \tag{15}$$

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) that guarantees equal utility in the two jurisdictions is

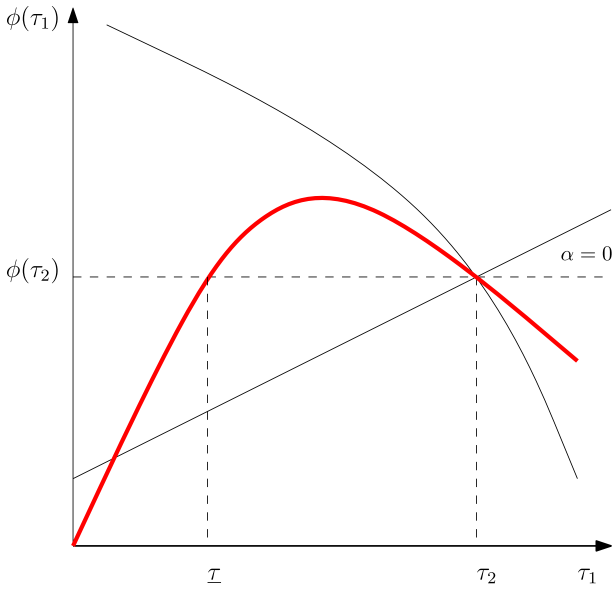

Fig. 1 Utility equalization in two jurisdictions with immobile agents

hard to characterize. Figure 1 maps the function $\phi(\tau_1) = \tau_1(1-\alpha) + v(1-\tau_1)$ when $\tau_2 \leq \tau^{**}$. 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 $(\underline{\tau}, \tau_2)$ for which $U_1 > U_2$ and a region of high tax levels $(\tau_2, 1]$ for which $U_2 > U_1$.

Consider next the equation characterizing the equilibrium sizes of the two jurisdictions:

$$n_1\tau_1(1-\alpha) + v(1-\tau_1) + \lambda(2-n_1) = (2-n_1)\tau_2(1-\alpha) + v(1-\tau_2) + \lambda n_1. \tag{16}$$

In order to guarantee that, when $\tau_1 = \tau_2$, the only equilibrium is $n_1 = n_2 = 1$, we specialize Assumption 1 to:

Assumption 3 Suppose that $1 - \alpha < \lambda$.

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:

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

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

$$1 - v'(1-\hat{\tau}) + (1-\alpha)\hat{\tau}\frac{(1-\alpha) - v'(1-\hat{\tau})}{2\lambda - 2\hat{\tau}(1-\alpha)} = 0. \tag{17}$$

Proposition 3 *In the quasi-linear model with arbitrary spillovers, the taxation game admits a unique symmetric equilibrium, where $\tau_1 = \tau_2 = \hat{\tau}$. Except for the pure public good ($\alpha = 1$) and the local public good cases ($\alpha = 0$), $\hat{\tau} < \tau^*$ and higher mobility (a reduction in λ) reduces the equilibrium tax rate $\hat{\tau}$. The equilibrium tax rate $\hat{\tau}$ is non-monotonic in the spillover parameter α.*

Proposition 3 characterizes the equilibrium tax level as a function of the spillover parameter α and the mobility parameter λ. In the two polar cases $\alpha = 0$ and $\alpha = 1$, the equilibrium tax level is the equilibrium tax level τ^* of the pure public good case, which is independent of λ.[10] But for any other value $\alpha \in (0, 1)$, the equilibrium tax level *depends on the mobility parameter λ and on the spillover parameter α*. Implicit differentiation of Eq. (17) immediately shows that the *equilibrium tax rate is increasing in λ*. Higher mobility (a reduction in λ) reduces the equilibrium tax rate. As no migration arises in equilibrium, a reduction in λ has no other effect on agents' utilities, and hence, *higher mobility reduces agents' equilibrium utility through an increase in tax competition.* By contrast, the effect of spillovers on the equilibrium tax rate is non-monotonic. The equilibrium tax rate is first decreasing, then increasing in α, attaining the same level τ^* for $\alpha = 0$ and $\alpha = 1$. Increases in the spillover parameter α also have a direct effect on agents' utilities, by increasing the benefits that an agent obtains from the public good provided in the other jurisdiction. For high values of α, the direct and indirect effects work in the same direction, so that an increase in α unambiguously raises the agent's utilities. But for low values of α, the direct effect is positive, whereas the indirect effect is negative, and the effect of an increase in the spillover parameter on equilibrium utilities is ambiguous.

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 $\hat{\tau}$.

4 Centralized public good provision and Oates' decentralization theorem

4.1 Centralized public good provision

In the centralized régime, because the jurisdictions are initially of equal size, our tie-breaking rule implies that jurisdiction 1 selects the public good levels in both jurisdictions. As public goods are produced using a constant returns to scale technology,

[10] Observe that the solutions to Eqs. 10 and 11 are identical in the quasi-linear model; hence, the equality of equilibrium tax levels for the pure public good and the local public good cases.

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.[11] The solution to this maximization problem is thus given by:

$$U_g(2\tau^o, 1-\tau^o) - \frac{1}{2}U_e(2\tau^o, 1-\tau^o) = 0. \tag{18}$$

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 agents 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 districts, migration will occur from the minority to the majority district, up to the point where:

$$U(2\tau^o, 1-\tau^o) + \lambda(2-n_1) = U(2\alpha\tau^o, 1-\tau^o) + \lambda n_1.$$

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 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. Taking into account the mobility costs of the agents who have migrated, the average utility is given by:

$$W^C = \frac{1}{2}\left[n_1 U(2\tau^0, 1-\tau^o) + (2-n_1)U(2\alpha\tau^o, 1-\tau^o) - 2\int_1^{n_1} \lambda(1-x)\mathrm{d}x\right].$$

[11] 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.

Differentiating with respect to λ, we obtain:

$$\frac{\partial W^C}{\partial \lambda} = \frac{\partial n_1}{\partial \lambda}[(U(2\tau^o, 1-\tau^o) + \lambda(2-n_1)) - (U(2\alpha\tau^o, 1-\tau^o) + \lambda n_1)$$

$$-2\int_1^{n_1}(1-x)\mathrm{d}x$$

$$< 0.$$

As members of the majority district receive a higher utility than members of the minority district, a decrease in the home attachment 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 decreasing in the home attachment 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 toward 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.

Note that the higher the mobility of households, the higher the proportion of households that move to the majority jurisdiction in the centralized régime. Except for the case of pure public goods, this amounts to a partial internalization of spillovers, diminishing the distortion caused by majority voting (that results in public good level choices for jurisdictions that disproportionately favors the majority jurisdiction). So the fact that households can migrate to the majority renders the drawback of centralization less severe.

We now illustrate Proposition 4 by considering a specific example.

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

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

$$\hat{\tau} = \frac{4\lambda + (1-\alpha)^2}{2(1-\alpha)} - \frac{\sqrt{(4\lambda + (1-\alpha)^2)^2 - 16\lambda(1-\alpha)}}{2(1-\alpha)},$$

yielding an average utility:

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

In the centralized model, the optimal level of taxation is

$$\tau^o = 1,$$

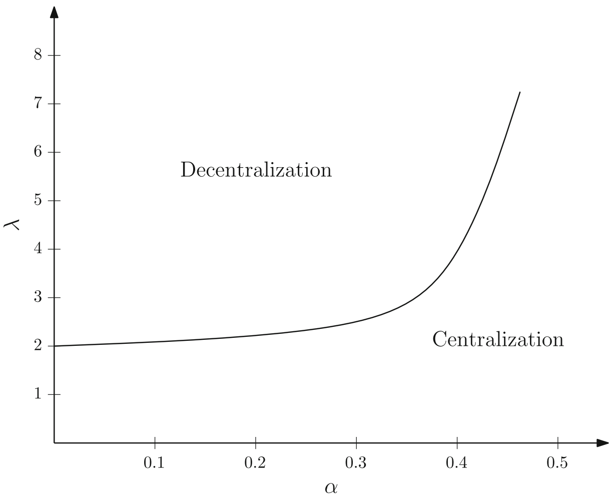

Fig. 2 Decentralization versus centralization

giving an average utility:

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

Figure 2 displays the values of (α, λ) for which $W^C = W^D$ in the quadratic example. The locus for which centralization and decentralization are equivalent is an upward 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, decentralization dominates when agents are less mobile (when the home attachment parameter λ is higher), whereas centralization dominates when agents are more mobile (when λ is lower). In the quadratic example, the map $\lambda(\alpha)$ is increasing and convex, 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.

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:

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

The condition defining the sizes of the two jurisdictions for any choice (g_1, g_2) becomes:

$$g_1 + \alpha g_2 + v\left(1 - \frac{g_1}{n_1}\right) + \lambda(2 - n_1) = g_2 + \alpha g_1 + v\left(1 - \frac{g_2}{2 - n_1}\right) + \lambda n_1.$$

Following the same steps as in Sect. 3.2, we characterize a symmetric pure Nash equilibrium by the conditions:

$$1 - v'(1 - \hat{g}) + v'(1 - \hat{g})\hat{g}\frac{(1-\alpha) - v'(1 - \hat{g})}{2\lambda - 2\hat{g}v'(1 - \hat{g})} = 0. \tag{19}$$

It is easy to see that, when $\tau \geq \tilde{\tau}$, $v'(1 - \tau) > 1 - \alpha$ and

$$v'(1 - \hat{g})\hat{g}\frac{(1-\alpha) - v'(1 - \hat{g})}{2\lambda - 2\hat{g}v'(1 - \hat{g})} < (1 - \alpha)\hat{\tau}\frac{(1-\alpha) - v'(1 - \hat{\tau})}{2\lambda - 2\hat{\tau}(1 - \alpha)},$$

showing that any solution $\hat{g}$ to Eq. (19) is smaller than the unique solution $\hat{\tau}$ to Eq. (17), i.e., the equilibrium tax rate under tax competition. Hence, as Wildasin (1988), we observe that when factors are mobile, the tax competition and public good competition games are not equivalent. When jurisdictions choose public good levels, competition is fiercer, resulting in lower tax rates.[12] This result is due to the differences in the effect of an increase in the size of the jurisdiction on the utility of the residents in the two games. When jurisdictions commit to taxes, an increase in the size of a jurisdiction results in a *linear* increase in the level of public good. When jurisdictions commit to public good levels, on the other hand, an increase in the size of a jurisdiction results in *a hyperbolic* reduction in the expenditure on the private good. Due to this difference, competition between jurisdictions is stronger in the public good game. Finally, notice that the analysis of the trade-off between centralization and decentralization remains identical to that of the baseline model, and an increase in mobility favors centralization as well.

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

[12] Wildasin (1991) and Koethenbuerger (2012) also compare the equilibria of games where local jurisdictions choose different strategic variables. In particular, they analyze the difference between taxation of mobile and immobile factors.

computations in the baseline model. The objective of jurisdiction i is given by

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

Following the same steps as in the proof of Proposition 3, we characterize the unique equilibrium in pure strategies by the solution to the equation:

$$1 - v'^T + \tau^T(1+\alpha) + v(1-\tau^T) + 1 - \alpha\tau^T \frac{1-\alpha-v'^T}{2\lambda - 2\tau(1-\alpha)}. \tag{20}$$

Again, as $\hat{\tau} > \tilde{\tau}$,

$$\tau^T(1+\alpha) + v(1-\tau^T) + 1 - \alpha\tau^T \frac{1-\alpha-v'^T}{2\lambda - 2\tau(1-\alpha)} < 1 - \alpha\tau^T \frac{1-\alpha-v'^T}{2\lambda - 2\tau(1-\alpha)},$$

so that the tax rate chosen by jurisdictions maximizing total utility, τ^T, is lower than the tax rate chosen by jurisdictions maximizing average utility, $\hat{\tau}$, reflecting the intuition that jurisdictions maximizing total utility compete more aggressively.

At the federal level, if the majority jurisdiction maximizes total utility, it will select a tax rate τ^M to maximize:

$$T = (2\tau + v(1-\tau))\left(1 + \frac{\tau(1-\alpha)}{\lambda}\right). \tag{21}$$

Contrary to the case of resident utility, the total utility is not necessarily concave in τ. However, notice that if the home attachment parameter λ is sufficiently large,

$$v''(1-\tau)\left(1 + \frac{\tau(1-\alpha)}{\lambda}\right) < -2\frac{1-\alpha}{\lambda}(2 - v'(1-\tau)),$$

guaranteeing concavity of the total utility function T. The optimal tax rate τ^M is then characterized by the first-order condition:

$$2 - v'(1-\tau^M)\left(1 + \frac{\tau^M}{1-\alpha}\right)\lambda + \frac{1-\alpha}{\lambda}(2\tau^M + v(1-\tau^M)). \tag{22}$$

A comparison of Eqs. (18) and (22) shows that the tax rate τ^M is always higher than the equilibrium tax rate τ^o under average utility. In addition, Eq. (22) shows that the tax rate τ^M is decreasing in the spillover parameter α and in the home attachment parameter λ. When agents are more mobile, the federal government chooses a higher tax rate in order to increase the population of the majority jurisdiction.

As in the baseline case, we can now compare welfare under centralization and decentralization and analyze the effect of an increase in mobility (a decrease in λ) on the difference $W^C - W^D$. A decrease in λ reduces τ^T and hence lowers the welfare in the decentralized régime. Simultaneously, a decrease in λ increases the tax rate τ^M in the majority jurisdiction and accelerates migration to the majority jurisdiction in the centralized régime. However, when jurisdictions maximize total utility, the majority jurisdiction may overshoot and select a tax rate τ^M, which largely exceeds the optimal tax rate, so that an increase in mobility reduces average utility. Hence, the comparison of Proposition 4 only remains valid if the speed of migration to the majority jurisdiction is not too high, i.e., if the home attachment parameter remains sufficiently large.

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 low levels of 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.

While our model clearly indicates in which direction Oates' Theorem should be modified in order to take into account household mobility, it needs to be enriched to better explain the current trend toward increased mobility and fiscal decentralization. In order to capture the political aspects of devolution of public services to local governments, we plan to analyze in more detail the political processes of centralized and decentralized decision making. In addition, our current model, where all agents have identical preferences, is too simplistic to analyze other aspects of jurisdiction formation and migration, such as stratification. We plan to introduce heterogeneous preferences in the model in order to emphasize the sorting effect of migrations and obtain a richer and more realistic model of fiscal decentralization.

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^*. Using Eq. (8), we compute the marginal effect of an increase in τ_1 on n_1:

$$\frac{\partial n_1}{\partial \tau_1} = \frac{n_1(U_g(G, 1-\tau_1) - (U_g(G, 1-\tau^*)) - U_e(G, 1-\tau_1)}{(U_g(G, 1-\tau_1) - U_g(G, 1-\tau^*))(\tau^* - \tau_1) + 2\lambda}.$$

Notice that the denominator is always positive as $(U_g(G, 1-\tau_1) - U_g(G, 1-\tau^*))(\tau^* - \tau_1) > 0$. Next, we compute the derivative of the resident's utility with respect to an increase in taxes:

$$\frac{\partial U_1}{\partial \tau_1} = n_1 U_g(G, 1-\tau_1) - U_e(G, 1-\tau_1) + (\tau_1 - \tau^*) U_g(G, 1-\tau_1) \frac{\partial n_1}{\partial \tau_1}.$$

Developing, we find that the sign of $\frac{\partial U_1}{\partial \tau_1}$ is the same as the sign of

$$2\lambda(n_1 U_g(G, 1-\tau_1) - U_e(G, 1-\tau_1)) + n_1 U_g(G, 1-\tau^*) U_g(G, 1-\tau_1)(\tau^* - \tau_1).$$

If $\tau_1 < \tau^*$, this expression is positive and $\frac{\partial U_1}{\partial \tau_1} > 0$. If $\tau_1 > \tau^*$, the expression is negative and $\frac{\partial U_1}{\partial \tau_1} < 0$, showing that $\tau_1 = \tau^*$ is a best response to $\tau_2 = \tau^*$.

To show that there cannot be any other symmetric equilibrium, we compute $\frac{\partial U_1}{\partial \tau_1}$ along the diagonal when $\tau_1 = \tau_2 = \tau$:

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

The only point at which $\frac{\partial U_1}{\partial \tau_1} = 0$ is the point $\tau_1 = \tau_2 = \tau^*$.

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

$$U(n_1\tau, 1-\tau) < U(\tau, 1-\tau) < U(\tau^{**}, 1-\tau^{**}).$$

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. To this end, compute first:

$$\frac{\partial U_1}{\partial \tau_1} = \frac{n_1 U_g(n_1\tau_1, -\tau_1) - U_e(n_1\tau_1, 1-\tau_1)}{-\tau_1 U_g(n_1\tau_1, 1-\tau_1) - \tau_2 U_g((2-n_1)\tau_2, 1-\tau_2) + 2\lambda},$$

showing that the only tax level at which $\frac{\partial U_1}{\partial \tau_1}$ is equal to zero along the diagonal is $\tau_1 = \tau_2 = \tau^{**}$.

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 $U_1 < U_2$ and $n_1 < 1$. 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

$$\begin{aligned} U_1 &= \tau_1 + \alpha\hat{\tau} + (1-n_1)(\alpha\hat{\tau} - \tau_1) + v(1-\tau_1) \\ &< \tau_1 + \alpha\hat{\tau} + v(1-\tau_1) \\ &< (1+\alpha)\hat{\tau} + v(1-\hat{\tau}) \end{aligned}$$

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, as $U_1 < U_2$, $\phi(\tau_1) < \phi(\hat{\tau})$ so that

$$\begin{aligned} U_1 &= \tau_1(1-\alpha) + v(1-\tau_1) + \alpha(\tau_1 + \hat{\tau}) + (1-n_1)(\alpha\hat{\tau} - \tau_1) \\ &< \hat{\tau}(1-\alpha) + v(1-\hat{\tau}) + \alpha(\tau_1 + \hat{\tau}) + (1-n_1)(\alpha\hat{\tau} - \tau_1) \\ &= (1+\alpha)\hat{\tau} + v(1-\hat{\tau}) - n_1(\alpha\hat{\tau} - \tau_1) - (1-\alpha)\tau_1. \\ &< (1+\alpha)\hat{\tau} + v(1-\hat{\tau}), \end{aligned}$$

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

Next consider values of $\tau_1 > \underline{\tau}$. Compute

$$\frac{\partial n_1}{\partial \tau_1} = \frac{-v'(1-\tau_1) + n_1(1-\alpha)}{2\lambda - (\hat{\tau} + \tau_1)(1-\alpha)}$$

and

$$\frac{\partial U_1}{\partial \tau_1} = n_1 - v'(1-\tau_1) + (\tau_1 - \alpha\hat{\tau})\frac{\partial n_1}{\partial \tau_1},$$

so that $\frac{\partial U_1}{\partial \tau_1}$ is of the same sign as:

$$\begin{aligned} A &= [n_1 - v'(1-\tau_1)][2\lambda - (\hat{\tau} + \tau_1)(1-\alpha)] + (\tau_1 - \alpha\hat{\tau})[n_1(1-\alpha) - v'(1-\tau_1)] \\ &= n_1[2\lambda - (1-\alpha)^2\hat{\tau}] - v'(1-\tau_1)[2\lambda - (1-\alpha)\hat{\tau} + \alpha(\tau_1 - \hat{\tau})]. \end{aligned}$$

If $\underline{\tau} < \tau_1 < \hat{\tau}$, $n_1 > 1$, $v'(1-\tau_1) < v'(1-\hat{\tau})$ and $[2\lambda - (1-\alpha)\hat{\tau} + \alpha(\tau_1 - \hat{\tau})] < [2 - \lambda - (1-\alpha)\hat{\tau}]$, so that $A > 0$ and $\frac{\partial U_1}{\partial \tau_1} > 0$. On the other hand, if $\tau_1 > \hat{\tau}$, $n_1 < 1$, $v'(1-\tau_1) > v'(1-\hat{\tau})$ and $[2\lambda - (1-\alpha)\hat{\tau} + \alpha(\tau_1 - \hat{\tau})] > [2 - \lambda - (1-\alpha)\hat{\tau}]$, so that $A < 0$ and $\frac{\partial U_1}{\partial \tau_1} < 0$. Hence, U_1 attains its maximum at $\tau_1 = \hat{\tau}$.

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

$$\frac{\partial U_1}{\partial \tau_1}|_{\tau_1=\tau_2=\tau} = 1 - v'(1-\tau) + (1-\alpha)\tau\frac{(1-\alpha) - v'(1-\tau)}{2\lambda - 2\tau(1-\alpha)}.$$

Hence, along the diagonal, $\frac{\partial U_1}{\partial \tau_1} = 0$ if and only if $\tau = \hat{\tau}$.

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