# Public Budget Composition, Fiscal (De)Centralization and Welfare*

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**Abstract**

This paper studies the optimal degree of fiscal decentralization in a dynamic general equilibrium model of a federal economy where governments decide optimally on budget size (tax rate) and its allocation between public education and infrastructure spending. Infrastructure productivity can differ across regions. This assumption (well supported by empirical evidence) highlights regional heterogeneity in a previously unexplored dimension. We find that full centralization of tax and expenditure policies is the optimal fiscal arrangement when infrastructure spending productivity is similar across regions. When regional differences are not too large, the partial centralization regime (common tax rate but region specific budget allocations) is optimal. Only when the differences are sufficiently large does full decentralization become the optimal regime. National steady state output, on the other hand, tends to be highest under full decentralization. The paper provides a theoretical justification for the mixed results of empirical studies testing the Oates conjecture by showing that under reasonable parameter values, full centralization dominates partial decentralization, despite being inferior to complete decentralization.

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# I. Introduction

Starting with Tiebout (1956), the question on the optimal level of decentralization of government activities has received considerable attention.[1] A second and directly related question focuses on the linkage between (de)centralization and growth. The well known "Oates conjecture" (Oates (1993)) states that the degree of decentralization and economic growth should be positively correlated, since decentralization ought to allow better tailoring of public policies to suit local economic conditions. Empirical evidence on this relationship is mixed, however. While some authors find a negative relation (Davoodi and Zou 1998, Zhang and Zou 1998), others find a positive or no systematic one (Iimi 2005). At the same time, there is surprisingly little theoretical work on the relationship between fiscal decentralization and growth. A notable exception is Brueckner (2006) who argues that, when regions differ in the age structure of their inhabitants, decentralization fosters growth by increasing the incentives to save and invest in human capital.

We explore the implications of fiscal (de)centralization for capital accumulation and aggregate national welfare in a dynamic general equilibrium model of a federal small open economy with two heterogeneous regions that are completely specialized in the production of one good and trade with each other. Governments optimally decide on the size of the public budget by setting the level of taxes, and on the expenditure composition across two productive types of public spending: education and infrastructure. These two types of spending mirror, together with the level of taxation, the main policies that actually shape the accumulation of capital in an economy and therefore are essential for understanding the effect of (de)centralized policies on output and welfare.

We study three different fiscal regimes: 1) Full decentralization in which each region chooses both its tax rate and its budget shares allocated to education and infrastructure in order to maximize regional welfare; 2) Complete centralization where the federal government sets the same policy parameters in both regions equally such as to maximize national welfare; 3) A mixed regime where the federal government sets a common tax rate, but allows the regional governments to decide on the public budget composition. This mixed regime is perhaps the most realistic scenario. It is consistent with tax policies that are constant across geographic regions. It is also consistent with central governments in federations typically choosing expenditure policies that differ across regions. This aspect of the fiscal policy is especially relevant in the European context where regional policies are widespread. In Germany, for example, the governments of the single *Länder* have no discretion over tax rates, but they can decide on the structure of their regional budgets. The cases of complete centralization and complete decentralization are less realistic but represent important theoretical benchmarks.

[1] For example, Oates (1972), Alesina and Spolaore (1997) and Bolton and Roland (1997) stress the role of scale economies in the provision of public services. According to Oates (1972) and Besley and Coate (2003), externalities that extend beyond jurisdiction boundaries may make centralization an optimal arrangement. Tax competition with a mobile tax base may constitute one drawback of a decentralized structure (see, for example, Brueckner (2004)). Seabright (1996) and Persson and Tabellini (2000) study how political accountability and rent seeking influence political (de)centralization. Diaz-Cayeros (2005) studies how differences in the cost of delivery of public services and income differences across regions influence the optimal degree of decentralization. Arzaghi and Henderson (2005) allow for fixed costs and spatial decay in the delivery of public services. They find that demographic shifts favor decentralization.

A crucial assumption of our paper is that regions differ in the productivity of public infrastructure spending. This type of regional heterogeneity, which is important for the decentralization-growth nexus, has not been studied - to the best of our knowledge - in the context of a dynamic general equilibrium model.

However, empirical studies provide robust evidence that (i) public investment has robust growth-enhancing effects, and (ii) the output elasticity with respect to infrastructure capital varies substantially across regions[2]. Charlot and Schmitt (1999) estimate that the regional output elasticity with respect to infrastructure capital in France differs by a factor of about 4 (2 if Corsica is ignored). According to Moreno, Lopez-Bazo and Artis (2002), in Spain this ratio is about 2. Cohen and Morrison (2001) estimate this ratio for the US to be about 4. Moreover, the elasticity of industry output with respect to core infrastructure capital (basically transportation networks) ought to vary according to industry characteristics, such as vehicle intensity. Indeed, Fernald (1999) finds large differences in both vehicle intensity and elasticity of output with respect to transportation infrastructure. This difference is especially pronounced for manufacturing vs. non-manufacturing industries. Nadiri and Mamuneas (1994) estimate cost functions at industry level using US data. The elasticity with respect to public infrastructure is statistically significant in all but one of the industries included in the sample. Across industries, the cost reductions due to infrastructure vary by a factor of about 2. Given these sizeable differences, it is plausible that unequal spatial distribution of these industries induces differences in the regional output elasticity with respect to infrastructure. In our model regions completely specialize, hence differences in the vehicle intensities across industries may be one reason for the regional heterogeneity of infrastructure spending productivity.

Besides empirical support, there are strong theoretical reasons to believe that the response of output to changes in infrastructure ought to vary by region. As argued by Haughwout (1998): "[I]n spatial equilibrium, the output response with respect to infrastructure capital depends in subtle and complicated ways on price-responses that are brought about by household and firm behavior." There is in general no reason to believe that household and firm responses to changes in public infrastructure capital ought to be similar in congested urban regions and in low density rural regions. Haughwout concludes from his analysis that it is "difficult a priori to predict even the sign, let alone the magnitude, of the relationship between a public good and equilibrium aggregate output." (p.222). The standard benchmark for modeling regional economies ought to be different infrastructure elasticities across regions.

The degree of regional heterogeneity determines which fiscal regime (centralized, de-centralized or mixed) maximizes aggregate national welfare in the steady state. We show that full fiscal centralization is welfare-maximizing when infrastructure spending productivity is similar across regions. When regional differences are not too large, partial centralization is the optimal arrangement. Only when infrastructure productivity differences are sufficiently large does full decentralization become optimal. There are two forces in the model that account for these results. On the one hand, regional

[2] See the critical survey conducted in Romp and de Haan (2005).

governments use the policy instruments *strategically* in order to shift the terms of trade in their favour. In the full centralization case, the federal government (which maximizes the national welfare) internalizes the fiscal externality, minimizing the manipulation of the terms of trade. On the other hand, the central government imposes an identical policy ("one size fits all") on both regions. If regions are similar, however, this cost is low and hence centralization is preferable over decentralization. Under partial centralization, taxes are set at national level, which mitigates the fiscal externality, but regions may still differentiate their spending allocations to account for their heterogeneity.

More generally, the two fundamental building blocks of our model – jurisdictional heterogeneity and a fiscal externality induced by regional trade – create a tension between centralized and decentralized fiscal arrangements. It is noteworthy that, regardless of the source of regional heterogeneity, any central policy based on some weighted average of the regions' characteristics will impart a welfare loss relative to a decentralized regime. In this paper we focus on a particular set of policy instruments and on a specific, empirically relevant type of regional heterogeneity to better illustrate this tension.

Another important result concerns the comparison of the three different fiscal regimes with respect to long-run aggregate national output. We provide a new confirmation for the "Oates conjecture" by establishing that steady state aggregate income is highest when the economy is most decentralized, provided that regional differences in overall productivity are not too large, but irrespective of regional heterogeneity in spending productivity. However, this confirmation of the Oates conjecture notwithstanding, the ranking of the three centralization regimes in terms of welfare may be different. That is, even if decentralization maximizes national output, it need not be the optimal regime. Moreover, expanding the output comparison to all three regimes yields an interesting non-monotonic pattern. We find that under reasonable parameter values, full centralization is dominated, in terms of output, by full decentralization, but at the same time dominates partial decentralization.

Our paper is related to a large literature on the effects of public education and infrastructure funding on capital accumulation and growth[3]. In these models the focus is usually on one type of government expenditure and its effects on capital accumulation are relatively well understood.[4] What is less well understood is how government policy influences economic outcomes when either the national or the sub-national government chooses optimally between two types of productive public expenditure. We also contribute to the literature on fiscal competition[5] which studies the ability and desire of

[3] Examples of work in this literature include Loury (1981), Barro (1990), Glomm and Ravikumar (1992), Glomm and Ravikumar (1994), Turnovsky and Fisher (1995), Benabou (1996), Fernandez and Rogerson (1996), Cassou and Lansing (1998), Blankenau and Simpson (2004), among many others.

[4] There is also a smaller literature that studies growth models where the government runs several programs, e.g. Devajaran et al (1996), Kaganovich and Zilcha (1999), Baier and Glomm (2001), Arcalean et al. (2006). Most of the above models take government policy as exogenous and all of these models study the effects of policy reform in a single region economy.

[5] Starting with Tiebout (1956), and continuing with Wilson (1986), Zodrow and Mieszkowski (1986), Wildasin (1998, 2003), Bucovetsky (2005), among many others.

independent local governments to attract mobile factors of production by altering their tax and public expenditure policies. In our model regions are small open economies hence cannot alter the interest rate. While in the benchmark model we consider the case of immobile labor, we do relax this assumption in section 6 and consider population distributions across regions that are consistent will full labor mobility at zero migration costs. Our result concerning the optimality of centralization when regions are similar survives this generalization. The comparison between partial and complete decentralization yields new results: When regions are different in infrastructure productivity, the welfare comparison between the decentralized regime and the partially centralized regime depends upon *average* infrastructure productivity in the two regions. This result arises because labor mobility induces a higher concentration of workers in the more productive region and the tax distortion arising under complete decentralization has higher aggregate welfare effects.

Among the related literature on fiscal federalism, Besley and Coate (2003) show in a political economy framework that centralized provision is preferable to decentralization if inter-regional externalities are sufficiently strong. There are two fundamental differences between the Besley and Coate set up and our model: In their framework the externality is a feature of the technology and hence exogenously given, while in our model the external effect is generated endogenously through the actions of the local governments; moreover, the size of these externalities depends explicitly on both the degree of regional heterogeneity and the precise nature of the fiscal arrangement. In a model of heterogeneous regions that compete in both taxes and productive public spending, Hindriks et al. (2008) find that equalization grants can be welfare improving for each region if the degree of asymmetry is small. While we do not explicitly model transfers, our centralized policy regime can be considered a limiting case of their experiment, with similar qualitative implications. Complementary to their study, our paper highlights an empirically relevant source of heterogeneity and sheds light on the differences between decentralizing the revenue or the expenditure side of the budget.

The paper is organized as follows. Section 2 presents the model. Section 3 contains the solution for the competitive equilibrium for given fiscal arrangements. Section 4 describes the optimal policies under different fiscal regimes while section 5 compares these regimes. Section 6 studies the case of regionally mobile labor. Section 7 concludes.

## II. The Model

We consider an economy that consists of two regions. Each region produces one distinct consumption good, and both of these goods are traded at no cost across the regions. Each region is populated by two-period lived overlapping generations. A new cohort of young agents is born in every period, so that total population in each region remains constant. We denote with $\rho_{i,t} > 0$ the size of a generation in region i=1,2 at time t. For the moment we treat $\rho_{i,t}$ as exogenous, i.e., we abstract from labor migration. All individuals in the economy are identical in preferences.

The utility function of an individual born at time t in region i=1,2 is given by

$$\ln n_{i,t} + \ln c_{i,t+1} + \ln d_{i,t+1} + \ln\left(E_{i,t+1}/\rho_{i,t}\right) \tag{1}$$

where $c_{i,t+1}$ and $d_{i,t+1}$ are the goods produced in region 1 and in region 2, respectively, consumed by a household in period (t+1) in region i. Here $n_{i,t}$ denotes leisure. The term $\left(E_{i,t+1}/\rho_{i,t}\right)$ can be interpreted as schooling expenditure per student and hence the quality of public schooling at time (t + 1), which we assume is given by the aggregate spending on public education ($E_{i,t+1}$) weighted by regional population size ($\rho_{i,t}$).[6] Each child in region i has access to the following technology to produce human capital:

$$h_{i,t+1} = \theta\left(1-n_{i,t}\right)^{\eta}\left(E_{i,t}/\rho_{i,t}\right)^{\gamma} h_{i,t}{}^{\delta} \qquad \theta,\eta,\gamma,\delta > 0, \quad \gamma+\delta \le 1 \tag{2}$$

where $(1-n_{i,t})$ is time allocated by the child to schooling, $h_{i,t}$ is parental human capital and $h_{i,t+1}$ is the human capital acquired by the child. The parameter $\theta$ represents a productivity shifter of human capital accumulation, $\eta$ and $\delta$ measure the elasticity of own time spend in education and parental human capital, respectively, and $\gamma$ represents the productivity of government spending in the education sector. Output $Y_{i,t}$ is produced according to the following technology:

$$Y_{i,t} = A_{i,t} H_{i,t} = A_{i,t}\rho_{i,t} h_{i,t} \ , \tag{3}$$

where $H_{i,t}$ is the aggregate, and $h_{i,t}$ is the per capita level of human capital in region i.[7] Productivity $A_{i,t}$ depends upon the per capita stock of infrastructure $G_{i,t}/\rho_{i,t}$ according to

$$A_{i,t} = \bar{A}_i \cdot \left(G_{i,t}/\rho_{i,t}\right)^{\Psi_i} \ , 0 < \psi_i < 1 \tag{4}$$

The parameter $\bar{A}_i > 1$ is a region-specific overall productivity level, and $\psi_i$ represents the productivity of public infrastructure spending in region i. This latter parameter is crucial, as regional heterogeneity in $\psi_i$ is central to our analysis. The other productivity parameters $\theta$, $\eta$, $\delta$ and $\gamma$ are assumed to be identical across regions. Furthermore we assume for simplicity that the stock of infrastructure fully depreciates between periods.

In this paper we compare three fiscal regimes. In the first case, each region has its own government and fiscal policy is completely decentralized. The regional government finances both education spending and infrastructure investment by raising income taxes,

[6] This specification of preferences with the warm glow altruism follows Glomm and Ravikumar (1992).

[7] Notice that this formulation is consistent with constant returns to scale production function using physical and human capital in the case of a small open economy. In other words, our framework nests the case of perfect capital mobility across regions, assuming, quite realistically, that regions are small enough compared to the world economy such that they cannot influence the level of the interest rate.

and decides on the regional tax rate and public budget composition. It is not allowed to borrow. In the second case, there is complete fiscal centralization. We abstract from regional fiscal transfers, i.e., we assume that total government spending in region i equals total tax revenue. The tax rate and the budget composition for both regions are decided at the national level by a central government authority. Finally, in the partially centralized regime, the central government sets the tax rate for both regions and allows the local governments to decide on the expenditure composition.

Let $\tau_{i,t}$ denote the tax rate at time t in region i. Furthermore, let $0 < \lambda_{i,t} < 1$ denote the share of the government budget that is allocated to infrastructure, so that the residual share $\left(1-\lambda_{i,t}\right)$ is allocated to education. The policy parameters $\tau_{i,t}$ and $\lambda_{i,t}$ are either set at the regional or at the national level, depending on the fiscal regime. For the total stocks of education and infrastructure spending in region i we obtain

$$G_{i,t} = \lambda_{i,t}\tau_{i,t}w_{i,t}H_{i,t} = \lambda_{i,t}\tau_{i,t}Y_{i,t} \tag{5}$$

$$E_{i,t} = (1-\lambda_{i,t})\tau_{i,t}w_{i,t}H_{i,t} = (1-\lambda_{i,t})\tau_{i,t}Y_{i,t}\,. \tag{6}$$

where $w_{i,t}$ is the wage per efficiency unit of labor.

## III. Solving the Model for the Competitive Equilibrium

An agent in region 1 solves the following problem:

$$\underset{\{n_{1,t},c_{1,t+1},d_{1,t+1}\}}{Max} \quad U_{t,t+1} = \ln n_{1,t} + \ln c_{1,t+1} + \ln d_{1,t+1} + \ln\left(E_{1,t+1}/\rho_{1,t}\right) \tag{7}$$

subject to

$$h_{1,t+1} = \theta\left(1-n_{1,t}\right)^{\eta}\left(E_{1,t}/\rho_{1,t}\right)^{\gamma} h_{1,t}{}^{\delta} \tag{8}$$

$$c_{1,t+1} + p_{t+1}\,d_{1,t+1} = \left(1-\tau_{1,t+1}\right)w_{1,t+1}\,h_{1,t+1} \tag{9}$$

$$given\;\; E_{1,t}, E_{1,t+1}, \tau_{1,t+1}, w_{1,t+1}, p_{t+1}, h_{1,t}$$

where $p_{t+1}$ is the relative price of the good produced in region 2. Households in region 2 solve an analogous problem. A competitive equilibrium for this economy can be defined as follows:

**Definition 1.** A competitive equilibrium in a two-region economy (i=1,2) is a set of sequences of allocations $\{c_{i,t}, d_{i,t}, h_{i,t}\}_{t=0}^{\infty}$, prices $\{p_t, w_{i,t}\}_{t=0}^{\infty}$, such that, in each region, for a given set of government policies $\{\tau_{i,t}, \lambda_{i,t}\}_{t=0}^{\infty}$:

1) Given the prices, the allocations $\{c_{i,t}, d_{i,t}, h_{i,t}\}_{t=0}^{\infty}$ solve the household problem;
2) Given the prices, the allocations $\{h_{i,t}\}_{t=0}^{\infty}$ solve the firm's problem;
3) Final good markets clear: $\rho_1 d_{1,t} + \rho_2 d_{2,t} = (1-\tau_{2,t})\,Y_{2,t}$ and $\rho_1 c_{1,t} + \rho_2 c_{2,t} = (1-\tau_{1,t})\,Y_{1,t}$
4) Government budget is balanced for each region.

Solving the maximization problem above yields the following individual demand functions for the two goods in each region:

$$c_{1,t+1} = \frac{1}{2}\left(1-\tau_{1,t+1}\right) w_{1,t+1}\, h_{1,t+1}, \qquad d_{1,t+1} = \frac{1}{2p_{t+1}}\left(1-\tau_{1,t+1}\right) w_{1,t+1}\, h_{1,t+1} \tag{10}$$

$$c_{2,t+1} = \frac{p_{t+1}}{2}\left(1-\tau_{2,t+1}\right) w_{2,t+1}\, h_{2,t+1}, \qquad d_{2,t+1} = \frac{1}{2}\left(1-\tau_{2,t+1}\right) w_{2,t+1}\, h_{2,t+1} \tag{11}$$

The optimal amount of time allocated to schooling is constant and given by

$$1-n_{1,t} = 1-n_{2,t} = 2\eta/\left(1+2\eta\right). \tag{12}$$

With perfect competition, the wage rate per unit of human capital is given by $w_{i,t} = A_{i,t}$, and from (3) - (6) it follows that

$$G_{i,t} = \left(\lambda_{i,t}\,\tau_{i,t}\,\bar{A}_i\,H_{i,t}\left(\rho_{i,t}\right)^{-\psi_i}\right)^{1/(1-\psi_i)} = \rho_{i,t}\cdot\left(\lambda_{i,t}\,\tau_{i,t}\,\bar{A}_i\,h_{i,t}\right)^{1/(1-\psi_i)} \tag{13}$$

$$w_{i,t} = \bar{A}_i\left(\lambda_{i,t}\,\tau_{i,t}\,H_{i,t}\,\bar{A}_i/\rho_{i,t}\right)^{\psi_i/(1-\psi_i)} \tag{14}$$

$$E_{i,t} = \left(1-\lambda_{i,t}\right)\tau_{i,t}\left(\bar{A}_i\,H_{i,t}\right)\left(\lambda_{i,t}\tau_{i,t}\bar{A}_i\,H_{i,t}/\rho_{i,t}\right)^{\psi_i/(1-\psi_i)} \tag{15}$$

Using (6), (12) and (14) in (8) we obtain the following law of motion for human capital in region i:

$$h_{i,t+1} = \left[B\left(\bar{A}_i\left(1-\lambda_{i,t}\right)\tau_{i,t}\left(\bar{A}_i\;\lambda_{i,t}\;\tau_{i,t}\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]\cdot\left(h_{i,t}\right)^{\delta+\gamma\left(1+\frac{\psi_i}{1-\psi_i}\right)} \tag{16}$$

where $B \equiv \theta\left(2\eta/(1+2\eta)\right)^{\eta}$. Assuming that $\gamma < \left(1-\delta\right)\left(1-\psi_i\right)$ imposes decreasing returns to scale in the augmentable factors and ensures that the economy will converge to a steady state in levels.[8] With time-constant policy parameters $\tau_i$, $\lambda_i$ we then obtain a unique steady state level for human capital:

$$h_i\left(\tau_i,\lambda_i\right) = \left[B\left(\bar{A}_i\left(1-\lambda_i\right)\tau_i\left(\bar{A}_i\;\lambda_i\;\tau_i\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]^{\frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)}} \tag{17}$$

Next, we use the market clearing for good 2, $\rho_1 d_{1,t}+\rho_2 d_{2,t}=(1-\tau_{2,t})\,Y_{2,t}$, to get the relative price. Plugging in the expression for individual demands $d_{1,t}$ and $d_{2,t}$, and solving for the relative price, we obtain:

[8] If we alternatively imposed constant returns to scale in the augmentable factors the model would permit a balanced growth equilibrium instead. In this case we would obtain analogous results.

$$p_t = \frac{\left(1-\tau_{1,t}\right) w_{1,t}\, \rho_{1,t} h_{1,t}}{\left(1-\tau_{2,t}\right) w_{2,t}\, \rho_{2,t} h_{2,t}} = \frac{\rho_{1,t}}{\rho_{2,t}} \cdot \frac{\left(1-\tau_{1,t}\right) \bar{A}_1\, h_{1,t} \left(\lambda_{1,t}\, \tau_{1,t}\, \bar{A}_1\, h_{1,t}\right)^{\psi_1/(1-\psi_1)}}{\left(1-\tau_{2,t}\right) \bar{A}_2\, h_{2,t} \left(\lambda_{2,t}\, \tau_{2,t}\, \bar{A}_2\, h_{2,t}\right)^{\psi_2/(1-\psi_2)}} \tag{18}$$

Notice that $p_t$ depends on the relative size of the two regions, $\rho_{1,t}/\rho_{2,t}$. The larger region 1, the higher is the supply of good c and, thus, the higher is the relative price of good d that is produced in region 2. The relative price $p_t$ also depends on the parameters $\tau_{i,t}$ and $\lambda_{i,t}$, because policy affects both goods demand and effective labor supply in the two regions via the education and the production technology.

## IV. Optimal policies under different fiscal regimes

In this section we solve for the optimal fiscal policies in each regime. For notational convenience we normalize the size of region 1 to one ($\rho_{1,t} = 1$), and let $\rho_{2,t} = \rho$ measure the (relative) size of region 2. Population sizes are still exogenous at this stage.

### IV.1. Complete decentralization

We start with the decentralized case where each region decides independently on the size and the composition of its respective public budget. This regime can perhaps be thought of as corresponding to the case of the United States, where the single states have considerable fiscal autonomy with respect to both revenue and expenditure decisions, at least compared to most of their European counterparts. The local governments choose their respective taxes and public budget allocation each period to maximize the indirect utility function of a representative individual of the currently adult generation.[9] Since $\rho_1 = 1$, the optimization problem of the government in region 1 is the following:

$$\underset{\{\tau_{1,t+1},\, \lambda_{1,t+1}\}}{Max}\; U_{t,t+1} = \ln n_{1,t} + \ln c_{1,t+1} + \ln d_{1,t+1} + \ln\left(E_{1,t+1}\right)$$

Abstracting from constants and using (10), (11) and (12) the optimization problem in region 1 can be re-formulated as follows:

$$\underset{\{\tau_{1,t+1},\, \lambda_{1,t+1}\}}{Max}\; 2\ln\left(\left(1-\tau_{1,t+1}\right) w_{1,t+1} h_{1,t+1}\right) + \ln\left(E_{1,t+1}\right) - \ln p_{t+1} \tag{19}$$

subject to (14), (15), (18), the government budget constraint $E_{1,t} + G_{1,t} = \tau_{1,t} w_{1,t} H_{1,t}$, and given $H_{1,t+1}$. The corresponding problem in region 2 is:

[9] In this problem we assume that the government choosing the policy parameters lives only as long as agents that voted for it. In other words, the government is "myopic" in the sense it does not take into account the effects of the policies chosen on future generations in its optimization problem. In the supplementary appendix D we show how to solve the infinitely-lived social planner's problem of maximizing time-discounted utility stream of all future generations. All results regarding the optimal fiscal regime are qualitatively the same as the myopic government's problem but analytically much less tractable.

$$\underset{\{\tau_{2,t+1},\lambda_{2,t+1}\}}{Max} \quad 2\ln\left(\left(1-\tau_{2,t+1}\right)w_{2,t+1}\rho h_{2,t+1}\right)+\ln\left(E_{2,t+1}/\rho\right)+\ln p_{t+1} \tag{20}$$

subject to (14), (15), (18), and the constraint $E_{2,t}+G_{2,t}=\tau_{2,t}w_{2,t}H_{2,t}$, where $H_{2,t+1}=\rho\cdot h_{2,t+1}$ is given. The solutions to this problem (with subscript "D" for fiscal decentralization) are given by

$$\tau_{i,t}=\tau_{i,t+1}=\tau^{*}_{D,i}=\frac{1+\psi_i}{2} \quad \in(0,1) \tag{21}$$

$$\lambda_{i,t}=\lambda_{i,t+1}=\lambda^{*}_{D,i}=\frac{2\psi_i}{1+\psi_i} \quad \in(0,1)\,, \tag{22}$$

Equations (21) and (22) state that both the size of the public budget in region i, and the budget share devoted to infrastructure increase with the regional productivity of public infrastructure spending, $\psi_i$. This optimal policy under decentralization neither depends on regional sizes, nor on any education-related variable. The reasons are that agents take school quality at time t ($E_{1,t}$) as given and that utility takes the logarithmic form. Substituting (21) and (22) back into (17) yields the steady state level of human capital in region i under decentralization with all policy parameters chosen optimally:

$$h^{*}_{i,D}\left(\tau^{*}_{i,D},\lambda^{*}_{i,D}\right)=\left[\left(2^{-\gamma}B\right)\cdot\left(\bar{A}_i\left(1-\psi_i\right)\left(\bar{A}_i\,\psi_i\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]^{\frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)}} \tag{23}$$

Upon substitution one obtains the respective values for wages, output, schooling quality, infrastructure, and utility of the representative consumer in region i,$U^{*}_{i,D}$. Postulating a utilitarian social welfare function, we finally obtain a measure of total national welfare under a decentralized fiscal regime as a function of exogenous parameters only, namely

$$\Omega^{*}_{D}\left(\tau^{*}_{i,D},\lambda^{*}_{i,D}\right)=U^{*}_{1,D}+\rho\cdot U^{*}_{2,D}$$

Details about the derivation can be found in appendix A.1.

IV.2. The fully centralized case

In the centralized case, distinguished by the subscript "C", a federal government optimally sets $\tau_i$ and $\lambda_i$ so as to maximize the weighted utility of agents living in both regions. France may be considered an example of such an economy, where most fiscal decisions on both the revenue and the expenditure side are made by the central government. It is useful at this stage to acknowledge that even in the case of very centralized governance structures it is possible and quite common for governments to choose public expenditure policies which vary substantially across regions. Furthermore, in centralized fiscal regimes implicit and explicit regional transfers often exist. In this paper we abstract from both aspects and assume that i) total tax revenue equals total government spending for each region, and ii) the central government imposes the same policies across the two regions. Therefore, neither the tax rate nor the expenditure share devoted to infrastructure is allowed to differ. This case is an important theoretical benchmark that allows us to focus on the trade-off between the fiscal externality that arises under a decentralized fiscal regime and the "one-size-fits all" policy by a central government.[10] The objective of the government is:

$$\underset{\{\tau_{t+1},\lambda_{t+1}\}}{Max}\ \Omega_C = \ln n_{1,t} + \ln c_{1,t+1} + \ln d_{1,t+1} + \ln\left(E_{1,t+1}\right) + \rho\left[\ln n_{2,t} + \ln c_{2,t+1} + \ln d_{2,t+1} + \ln\left(\frac{E_{2,t+1}}{\rho}\right)\right]$$

Again abstracting from constants, the objective function can be re-written as follows:

$$\ln\left(E_{1,t+1}\right) + \rho\cdot\ln\left(\frac{E_{2,t+1}}{\rho}\right) + 2\left[\ln\left(\left(1-\tau_{t+1}\right)w_{1,t+1}\,h_{1,t+1}\right) + \rho\cdot\ln\left(\left(1-\tau_{t+1}\right)w_{2,t+1}\,h_{2,t+1}\right)\right] - \left(1-\rho\right)\ln\left(p_{t+1}\right)$$

subject to

$$h_{1,t+1} = \theta\left(\frac{2\eta}{1+2\eta}\right)^{\eta} E_{1,t}{}^{\gamma} h_{1,t}{}^{\delta} \qquad h_{2,t+1} = \theta\left(\frac{2\eta}{1+2\eta}\right)^{\eta}\left(E_{2,t}/\rho\right)^{\gamma} h_{2,t}{}^{\delta}$$

$$w_{1,t+1} = \bar{A}_1\left(\lambda_{t+1}\tau_{t+1}H_{1,t+1}\bar{A}_1\right)^{\psi_1/(1-\psi_1)} \qquad w_{2,t+1} = \bar{A}_2\left(\lambda_{t+1}\tau_{t+1}H_{2,t+1}\bar{A}_2/\rho\right)^{\psi_2/(1-\psi_2)}$$

$$E_{i,t} + G_{i,t} = \tau_{i,t}w_{i,t}H_{i,t} \qquad E_{i,t+1} = (1-\lambda_{t+1})\tau_{t+1}w_{i,t+1}H_{i,t+1}$$

$$p_{t+1} = \frac{1}{\rho}\cdot\frac{\left(\bar{A}_1 h_{1,t+1}\right)^{1+\psi_1/(1-\psi_1)}}{\left(\bar{A}_2 h_{2,t+1}\right)^{1+\psi_2/(1-\psi_2)}}\left(\lambda_{t+1}\tau_{t+1}\right)^{\frac{\psi_1}{1-\psi_1}-\frac{\psi_2}{1-\psi_2}} \qquad H_{1,t+1} \text{ and } H_{2,t+1} \text{ given}$$

It can be shown that revenue and expenditure decisions are separable in this model: the first order condition with respect to the tax rate does not depend on $\lambda_{t+1}$, just like the first order condition with respect to the budget share does not depend on $\tau_{t+1}$. Solving out these conditions we obtain the following utility maximizing tax rate and budget share for the fully centralized case, which depend on the regional infrastructure spending productivities $\psi_1$ and $\psi_2$ weighted by the relative regional population size $\rho$:

$$\tau_C^* = \frac{1+\psi_1\left(1-2\psi_2\right)+\rho\left(1+\psi_2\left(1-2\psi_1\right)\right)}{3-\psi_1-2\psi_2+\rho\left(3-2\psi_1-\psi_2\right)} \in (0,1) \tag{24}$$

$$\lambda_C^* = \frac{\psi_1\left(2+\rho\right)+\psi_2\left(1+2\rho\right)-3\left(1+\rho\right)\psi_1\psi_2}{1+\rho+\psi_1+\rho\psi_2-2\left(1+\rho\right)\psi_1\psi_2} \in (0,1) \tag{25}$$

[10] As Besley and Coate (2003) point out, regions in a country do share a common tax code, hence our main aim is to compare two second-best worlds where the central government is obliged to set the same policies across regions. If the central government could differentiate policies across regions it would internalize the fiscal externality and achieve an allocation that dominates the fiscal decentralization regime from a welfare point of view. We briefly return below to this case of "flexible centralization" (see section V.3).

When policies are set according to (24) and (25) in both regions the optimal level of human capital in steady state in region i=1,2 follows directly from (17), and all other endogenous variables can be computed accordingly. We can then derive total national welfare under centralization, $\Omega_C^*\left(\tau_C^*, \lambda_C^*\right) = U_{1,C}^* + \rho \cdot U_{2,C}^*$. The derivation of this expression is deferred to appendix A.2. Comparing the optimal tax rate and the optimal infrastructure budget share under centralization and decentralization, we can establish two important intermediate results:

**Proposition 1**

*Assume without loss of generality that $\psi_2 < \psi_1$, i.e. infrastructure spending is more productive in region 1 than in region 2.*

*1.1. There exists a threshold $\bar{\psi} = \left(1+\rho+\psi_2(\rho+2)\right)/\left(3+2\rho\right) \in (0,1)$ such that $\tau_C^* < \tau_{D,2}^* < \tau_{D,1}^*$ if $\psi_1 < \overline{\psi}$ and $\tau_{D,2}^* < \tau_C^* < \tau_{D,1}^*$ otherwise.*

*1.2. There exists a threshold $\tilde{\psi} = \left(\psi_2(1+2\rho)\right)/\left(\rho+\psi_2(1+\rho)\right) \in (0,1)$ such that $\lambda_{D,2}^* < \lambda_{D,1}^* < \lambda_C^*$ if $\psi_1 < \tilde{\psi}$ and $\lambda_{D,2}^* < \lambda_C^* < \lambda_{D,1}^*$ otherwise.*

**Proof:** see Appendix B

In words, the move from de-centralization towards centralization may lead to a tax rate that is “in between” the two regional tax rates under decentralization. A sufficient condition for this case is that $\psi_1$ is larger than some threshold $\bar{\psi}$, which is more likely to be true when the difference in regional spending productivities is large. Yet, it is also possible that the centralization leads to a lower tax rate in both regions, irrespective of regional sizes. A sufficient condition for this case is that $\psi_1 < \bar{\psi}$, which is more likely to be true when the difference in regional infrastructure spending productivities is relatively small. Centralization can never lead to a higher tax rate in both regions. Similarly, the move towards centralization will always increase the budget share devoted to infrastructure in the “low-$\psi$” region that used to spend relatively little on infrastructure under decentralization. In the “high-$\psi$” region the infrastructure share may increase or decrease. The former case occurs if $\psi_1$ is below the threshold $\tilde{\psi}$ given above, i.e., when the difference in regional infrastructure spending productivities is not too large. In case of a large difference between $\psi_1$ and $\psi_2$ it is possible that the budget share under centralization ranges “in between” the two regional ones under decentralization.

More generally, our model offers one theoretical explanation for the empirical observation by Arze del Granado et al. (2005) that decentralization affects the functional composition of public budgets. These theoretical predictions regarding the optimal public budget composition complement earlier work by Keen and Marchand (1997) and Matsumoto (2004) who study if fiscal competition generates an optimal mix of public inputs. Their results however focus on publicly provided goods whose benefits vary according to the mobility of factors of production, while we still concentrate on the case with immobile labor whose productivity is enhanced by the publicly provided goods.

The main mechanism behind the results in proposition 1 is that the relative price of the two region goods (the "terms of trade", $p_t$) can be manipulated by the regional policy parameters. To illustrate this, consider the special case where regions are equally large and where infrastructure spending productivity is the same in both regions, i.e., $\rho$=1 and $\psi_1 = \psi_2 = \psi$. Comparing (21) and (22) with (24) and (25) it can be shown that:

$$\tau_C^* = \frac{1+2\psi}{3} < \tau_{D,1}^* = \tau_{D,2}^* = \frac{1+\psi}{2}, \qquad \lambda_C^* = \frac{3\psi}{1+2\psi} > \lambda_{D,1}^* = \lambda_{D,2}^* = \frac{2\psi}{1+\psi}$$

If the two regions are exactly identical, centralization leads to a lower optimal tax rate, and to a higher budget share devoted to infrastructure. The reason is that, under fiscal decentralization, both regions have an incentive to increase tax rates and decrease the infrastructure budget share, in order to shift the terms of trade in the desired direction. This is shown formally in appendix B. In the policy decision of the central government the terms of trade effect does not play a role when regions are equally large, as the term containing $p_t$ cancels from the expression for $\Omega_C$ when $\rho$=1. Thus, the central government would choose a lower tax rate and spend relatively more on infrastructure as it internalizes the fiscal externality that is at work in the decentralized regime.

<u>IV.3. The partially centralized case</u>

Finally, suppose the tax rate is set at the federal level, but the expenditure decisions are made by the single regions. We view this regime as our most realistic case since in many countries, especially in the European context, tax rates are uniform within a country while expenditure policies are often allowed to vary across regions.[11] As revenue and expenditure choices are completely separated in the present model, it is straightforward to see that the optimal choices of tax rate and infrastructure budget share are simply given by $\tau_{1,P}^* = \tau_{2,P}^* = \tau_C^*$ and $\lambda_{i,P}^* = \lambda_{i,D}^*$ for $i = 1,2$. The subscript "P" refers to the partly centralized case. Given our previous results we can infer that, compared to the decentralized case, partial centralization will lead to a lower optimal tax rate for at least the "high-$\psi$" region, if not for both regions. In an analogous way we can compute all endogenous variables for this fiscal regime, in particular total national welfare (see also appendix A.3): $\Omega_P^*\left(\tau_C^*, \lambda_{i,D}^*\right) = U_{1,P}^* + \rho \cdot U_{2,P}^*$.

## V. Comparison of fiscal regimes

We now compare the different fiscal regimes by analyzing total national welfare in the two-region economy for complete decentralization, full and partial centralization (see appendices A.1-A.3). For this comparison we consider total welfare *differences*

[11] It should be mentioned that there is also another partially centralized case where the tax rates are decided upon at the regional level, but the expenditure share is set at the federal level. We neglect this case, however, because we cannot think of a real world example where public finance is organized in this way.

$$\Delta\Omega_C \equiv \Omega_C^*\left(\tau_C^*, \lambda_C^*\right) - \Omega_D^*\left(\tau_{i,D}^*, \lambda_{i,D}^*\right) \quad \text{and} \quad \Delta\Omega_P \equiv \Omega_P^*\left(\tau_C^*, \lambda_{i,D}^*\right) - \Omega_D^*\left(\tau_{i,D}^*, \lambda_{i,D}^*\right), \quad (26)$$

which describe the welfare *gains* of full (partial) centralization compared to complete decentralization. Some important results can be proven analytically:

**Proposition 2**
*The optimal fiscal regime does not depend on the total factor productivity (TFP) levels* $\overline{A}_1, \overline{A}_2$*, the productivity of human capital accumulation,* $\theta$*, and the input elasticity of own time spent in education,* $\eta$*.*

**Proof:** *Plugging all endogenous variables into* (26) *it is possible to show that* for $z = C, P$ and $i = 1,2$ we have $\partial(\Delta\Omega_z)/\partial\overline{A}_i = \partial(\Delta\Omega_z)/\partial\theta = \partial(\Delta\Omega_z)/\partial\eta = 0$ □

The parameters $\overline{A}_1, \overline{A}_2, \theta$ and $\eta$ affect the welfare *levels* in the two regions. For example, the larger is $\overline{A}_i$, the higher is welfare in region *i* under any fiscal regime, everything else equal. However, the respective parameters (i) have no effect on the optimal policy choices under any fiscal regime, and (ii) enter welfare functions as constant terms due to log utility.[12] Hence, when comparing different fiscal regimes from a welfare perspective in our model it is – in particular – safe to neglect regional differences in overall productivity $A_i$, as this does not affect which regime is optimal for the country.

V.1. Gains from full centralization

We first study the gains from full centralization of fiscal policy. The crucial parameters for the normative analysis of $\Delta\Omega_C$ are $\psi_1$, $\psi_2$, and $\rho$ because they directly influence optimal policy choices $\tau_i^*$ and $\lambda_i^*$. Still the expression for $\Delta\Omega_C$ does not render straightforward analytical results for general values of $\delta$ and $\gamma$. Hence we assign specific numerical values to these parameters, namely $\delta = 0.1$ and $\gamma = 0.05$. These values are in line with estimates used in the literature studying human capital accumulation.[13]

[12] Taking logs of the human capital level in eq.(17), which fixes all other endogenous variables, we obtain

$$\ln(h_i) = \frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)} \cdot \ln\left(B \cdot \left(\overline{A}_i\right)^{\gamma+\gamma\psi_i/(1-\psi_i)}\right) + \frac{\gamma(1-\psi_i)}{1-\gamma-\delta-\psi_i(1-\delta)} \cdot \ln\left[(1-\lambda_i)\tau_i\left(\lambda_i\,\tau_i\right)^{\psi_i/(1-\psi_i)}\right]$$

The first term consists of exogenous parameters only and does not depend on $\tau_i$ or $\lambda_i$, hence it will cancel out when differencing welfare expressions for different fiscal regimes as in (26). Since the parameters θ, η and $\overline{A}_i$ only show up in this first term, they do not affect the welfare differences $\Delta\Omega_C$ and $\Delta\Omega_P$. The same is not true for the parameters $\delta$ and $\gamma$. Although they do not directly affect the policy choices $\tau_i$ or $\lambda_i$, they enter also the second term in and will therefore have an impact on $\Delta\Omega_C$ and $\Delta\Omega_P$. Notice however, that in equation (18) both $\psi_i$ and $A_i$ have the same qualitative impact on the price level - the actual channel through which the fiscal externality occurs

[13] Common values for the elasticity of public education that are used in the context of the US lie in the range 0.05-0.15, and for the elasticity of parental human capital in the education production function values

We illustrate the gains from centralization in figure 1. We fix $\psi_2$ at some level and plot the function $\Delta\Omega_C$ against $\psi_1$ for different scenarios of country size $\rho$.[14]

**FIGURE 1 HERE**

If $\psi_1$ coincides with the predetermined level $\psi_2 = 0.25$ both regions are identical in terms of their infrastructure spending productivity, otherwise spending is more (less) productive in region 1 than in region 2 if $\psi_1$ is to the right (left) of $0.25$. The thick solid curve represents the case where both regions are equally large ($\rho = 1$), the thin solid line illustrates the case where region 1 has double the size of region 2 ($\rho = 0.5$) and the thin broken line is the case with $\rho = 2$ where region 1 has half the size.

If spending productivity in region 1 is similar to that in region 2 full centralization yields higher aggregate national welfare than decentralization ($\Delta\Omega_C > 0$). In fact the gains from centralization are highest if the two regions have identical spending productivities. As regions get more dissimilar, i.e., if $\psi_1$ is sufficiently different from $\psi_2$, decentralization yields higher national welfare ($\Delta\Omega_C < 0$). Country size $\rho$ matters only insofar as it affects the quantitative size of gains/loss from centralization, but the parameter range of $\psi_1$ where centralization is preferable over decentralization does not depend on $\rho$. Graphically this can be seen by the fact that the inverse U-shaped curves cross the horizontal axis in the same two points. Lastly it can be shown that the curve $\Delta\Omega_C$ is symmetric around $\psi_2$. That is, for given $\rho$ results depend only on the degree of dissimilarity but are analogous independent of whether $\psi_1$ is larger or smaller than $\psi_2$.

The intuition of this result is that centralization has one advantage and one disadvantage compared to decentralization in this model. While decentralized governments fully try to manipulate the relative price, the centralized government internalizes this fiscal externality by maximizing a population-weighted average of regional welfares. However, the disadvantage of centralization is that the federal government imposes an identical policy ("one size fits all") on both regions, although regions may be heterogeneous in terms of their infrastructure spending productivity. If both regions have the same spending productivity ($\psi_1 = \psi_2$), the costs of centralization are immaterial in the sense that both regions would choose identical policies also under decentralization, yet not the "right" policy because the fiscal externality is not internalized under decentralization.

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between 0.1-0.2 are typically used (see e.g. Rangazas 2000, among others). To address the sensitivity of our results we ran several robustness checks where we let $\delta$ and $\gamma$ vary. It turns out that parameter changes have little effects on our qualitative findings (see the supplementary appendix E to this paper).

[14] Given the parameter restriction $\gamma < (1-\delta)(1-\psi_i)$ stated above, our choice of γ and δ imposes an upper bound of 0.944 for the infrastructure spending productivity $\psi_i$. Furthermore, in figure 1 we pick a predetermined level $\psi_2 = 0.25$ for expositional purposes. Notice that this parameter range for $\psi_i$ which follows from our choice of γ and δ is broadly consistent with estimates of output elasticities with respect to various measures of public capital found by studies focusing on regional data, ranging from 0.08 to 0.65 (see Cadot et al., 2006 and Stephan, 2003).

Hence centralization must lead to higher aggregate welfare in this case. The more dissimilar the regions are in terms of their $\psi_i$'s, the more costly becomes the "one size fits all" policy associated with centralization. Beyond a certain degree of dissimilarity decentralization is preferable over a centralized fiscal regime.

V.2. Gains from partial centralization

The analysis of the gains from partial centralization is analogous. In figure 2 we plot $\Delta\Omega_P$ against $\psi_1$ for different scenarios of country size $\rho$, given the same parameter constellation as in figure 1. We again find that centralization, in this case only of the tax revenue decision, yields higher aggregate welfare than decentralization ($\Delta\Omega_P > 0$) if regions are similar in terms of their $\psi_i$s, and lower welfare ($\Delta\Omega_P < 0$) if they are sufficiently different.

**FIGURE 2 HERE**

However, in contrast to $\Delta\Omega_C$ from figure 1, the curve $\Delta\Omega_P$ is not symmetric around $\psi_2$. To understand intuitively why this is so, consider first the case of equally sized regions ($\rho = 1$). For the parameter constellation $\psi_2 = 0.25$ one can compute:

$$\tau_C^* = \frac{3}{7-4\psi_1},\ \tau_{D,1}^* = \frac{(1+\psi_1)}{2},\ \tau_{D,2}^* = 0.625 \qquad \lambda_C^* = \frac{1+2\psi_1}{3},\ \lambda_{D,1}^* = \frac{2\psi_1}{1+\psi_1},\ \lambda_{D,2}^* = 0.4$$

It is easy to check that a move from decentralization towards the partially centralized regime would lead to lower tax rates in both regions. The downward adjustment in the size of the public budget is stronger in the "high-$\psi$" than in the "low-$\psi$" region. This can also be seen in figure 3 (panel A) where we graphically illustrate the optimal tax rates under the partially centralized and the de-centralized regime. If $\psi_1 < 0.25$, the difference between $\tau_C^*$ and $\tau_{D,2}^*$ is larger than between $\tau_C^*$ and $\tau_{D,1}^*$, hence the *size* of the public budget would change by less in region 1 (vice versa if $\psi_1 > 0.25$).

**FIGURE 3 HERE**

Under partial centralization every region can still make its own decision on the composition of its budget, i.e. the regions maintain one policy tool that they can use strategically in order to shift the terms of trade in their respective favour. With $\psi_1 < 0.25$ region 1 is the "low-$\psi$" region, and finds it optimal to spend a lower budget share on infrastructure than the "high-$\psi$" region 2. The optimal budget share $\lambda_{D,1}^*$ is further away than $\lambda_{D,2}^*$ from the budget share $\lambda_C^*$ that would result if also the expenditure decision were centralized (see panel B). This explains why there is a conflict of interest between regions when comparing decentralization and partial centralization. This is illustrated in panel C, where we depict the welfare difference between regimes for both regions, $U_{i,P}^* - U_{i,D}^*$ for i=1,2. If $\psi_1$ is sufficiently small region 2 prefers full decentralization, because partial centralization implies a loss of fiscal autonomy in the dimension where region 2 is relatively stronger affected (the adjustment of tax rates). In contrast, region 1 prefers a centralization of the tax rate setting. It is relatively less affected by the implied change in the budget *size*, but the region maintains fiscal autonomy with respect to the budget composition.[15] As it turns out, this preference of region 1 for the partially centralized regime is stronger than the preference of region 2 for the decentralized regime, because the difference in the optimal budget shares for different regimes is relatively stronger than the difference between optimal tax rates for small values of $\psi_1$ (see panels A, B). As regions have equal weights in the aggregate welfare when $\rho = 1$, it follows that $\Delta\Omega_P > 0$ for $0 < \psi_1 < 0.25$.

For increasing levels of $\psi_1$ the interest of the "low-$\psi$" region to maintain autonomy over its expenditure decision becomes less important compared to the effect of falling budget sizes. This can be seen by noting that $\left|\tau^*_{D,1} - \tau^*_C\right|$ is increasing in $\psi_1$ while $\left|\lambda^*_C - \lambda^*_{D,1}\right|$ is decreasing in $\psi_1$ (panels A, B). The preference of the "high-$\psi$" region for the decentralized regime will dominate beyond a certain level of $\psi_1$ because the gains from lower taxation increase while there is little loss from changing the share spent on infrastructure. Hence, the asymmetry of the curve $\Delta\Omega_P$ in figure 2 follows. When $\rho$=2, i.e. the population in region 2 is twice as large as in region 1, the decentralized regime is preferred over the partially centralized one when $\psi_1$ approaches zero, and vice versa when $\psi_1$ approaches its maximum value (see figure 2). This is because the weight of region 2 in the aggregate welfare is now higher. A similar argument applies when $\rho$=0.5.

A comparison of figures 1 and 2 reveals parameter constellations for which the move to full centralization generates a welfare gain, but a move to partial centralization generates a welfare loss. This is the case when ρ=0.5 and when $\psi_1$ is just below 0.4. This result is reminiscent of analogous results from the tax competition literature (see, for example, Keen, 2001 and Janeba and Smart, 2003) where restricting a policy variable chosen by the regional governments is detrimental as it induces them to compete more vigorously along those dimensions which remain fully under their control.

<u>V.3. Optimal fiscal regime</u>

Finally we can address the question which of the three fiscal regimes is optimal for the economy. In figure 4 we jointly plot the gains from full and partial centralization, and we limit ourselves to the case of equal regional size ($\rho = 1$). The figure suggests that full centralization is optimal if regions have very similar infrastructure spending productivities, partial centralization is optimal if the regions are mildly dissimilar, and

[15] Note that a comparable regional conflict of interest does not arise when comparing decentralization and full centralization, where local governments lose the autonomy over both fiscal decisions. As can be seen in panel D of figure 3, welfare in the single regions is almost identically affected by a move from decentralization to full centralization. Either both regions are better off with decentralization, or they are both better off with full centralization. This illustrates why the curve $\Delta\Omega_C$ is symmetric in figure 1.

decentralization is optimal if they are sufficiently strongly different in their $\psi_i$'s. Based on the previous discussion, it is worthwhile to notice the asymmetry in the optimal regime as the regions become more dissimilar. When $\psi_1$ approaches zero, implying different regional and *low average infrastructure spending productivity,* the partial centralization prevails as the optimal regime. When $\psi_1$ increases beyond the given $\psi_2$ this also implies more different regions but *high average infrastructure spending productivity* in the nation as a whole. Starting from $\psi_1 = \psi_2$ where full centralization is optimal, an increase in $\psi_1$ first renders partial centralization the optimal regime. After a certain level of dissimilarity when $\psi_1$ increases further, full decentralization becomes the optimal arrangement. This prevails until $\psi_1$ reaches its maximum value $1-\gamma/(1-\delta)$.

**FIGURE 4 HERE**

This result captures the underlying tension in this model. Centralization is best when externalities can be internalized and when "one size fits all." This is only true when the two infrastructure productivities and population sizes are similar. An increase in the difference between the two regions increases the cost of internalization of externalities; for sufficiently large differences the cost of trying to make one size fit all becomes too large. Notice that the welfare rankings of the three regimes are sensitive to relative population sizes. As is clear from Figure 2, for large values of $\rho$ decentralization is dominated by partial centralization over a wide range of values of $\psi_1$ larger than $\psi_2$.

Lastly, simulations suggest that the scenario of "flexible centralization", where the central government can differentiate policies across regions, tends to dominate all other regimes. This is plausible since this scenario allows the central government to internalize the fiscal externality without imposing a "one size fits all" approach. However, in the case of extreme dissimilarity across regions, we find that full decentralization even provides higher welfare than "flexible centralization", because the steady state gains from switching to decentralization in the more productive region dominate the relative losses incurred in the other region

V.4. Implications for steady state output level

Apart from the normative question which fiscal regime maximizes aggregate national welfare one can also analyze the implications of fiscal (de)centralization for aggregate (gross) national income in the steady state. For time constant policy parameters, national output can be derived from (14) and (17) as $\Upsilon = w_1 \cdot h_1(\tau_1, \lambda_1) + \rho \cdot w_2 \cdot h_2(\tau_2, \lambda_2)$.

$$\Upsilon(\tau_1, \tau_2, \lambda_1, \lambda_2) = \frac{\left(\bar{A}_1 \lambda_1 \tau_1 \cdot h_1(\tau_1, \lambda_1)\right)^{1/(1-\psi_1)}}{\lambda_1 \tau_1} + \rho \cdot \frac{\left(\bar{A}_2 \lambda_2 \tau_2 \cdot h_2(\tau_2, \lambda_2)\right)^{1/(1-\psi_2)}}{\lambda_2 \tau_2} \qquad (27)$$

Plugging the values $\tau_i$ and $\lambda_i$ from (21), (22), (24) and (25) into (27) yields expressions for national steady state output in the three different fiscal regimes, given that the respective policies are chosen *optimally*.[16] Similarly as before we can now derive $\Delta\Upsilon_C = \Upsilon_C^*\left(\tau_C^*, \lambda_C^*\right) - \Upsilon_D^*\left(\tau_{D,i}^*, \lambda_{D,i}^*\right)$ and $\Delta\Upsilon_P = \Upsilon_P^*\left(\tau_C^*, \lambda_{D,i}^*\right) - \Upsilon_D^*\left(\tau_{D,i}^*, \lambda_{D,i}^*\right)$, which represent the output gains from full and partial fiscal centralization, respectively. For the derivation of these expressions, also refer to appendices A.1-A.3.

**FIGURE 5 HERE**

In figure 5a we plot $\Delta\Upsilon_C$ and $\Delta\Upsilon_P$ for the same parameter constellation as in figure 4. We find that any type of fiscal centralization is associated with lower steady state output, which is consistent with the "Oates conjecture" that fiscal decentralization leads to faster capital accumulation. It is also qualitatively in line with Brueckner (2006) although our model relies on entirely different mechanisms. Notice further that full centralization is dominated, in terms of output, by full decentralization, but at the same time dominates partial decentralization. This may be seen as one theoretical explanation for the mixed empirical evidence on the relationship between output and decentralization.

In appendix C we formally prove that fiscal decentralization maximizes total national output for the case of identical regions, i.e., if $\psi_1 = \psi_2$ and $\rho = 1$. Recall, however, that in the same constellation fiscal centralization is the *optimal* fiscal regime that maximizes aggregate national welfare. Hence, the ordering of fiscal regimes in terms of output need not be the same as in terms of welfare. The reason for this discrepancy is intuitive: If $\psi_1$ and $\psi_2$ are the same, fiscal centralization will lead to a lower tax rate and to a higher budget share devoted to infrastructure in both regions, see proposition 1. This implies a lower level of human capital accumulation and lower school quality under centralization than under decentralization, because a smaller share of a smaller budget goes to education funding. Wages will also decline, despite the larger infrastructure investments, hence fiscal centralization causes a loss of gross national income. The lower school quality has an additional negative impact on welfare due to the warm glow altruism entailed by the utility function. However, the lower tax rate under fiscal centralization implies a higher *net* income that is available for consumption. This effect actually compensates the various negative impacts, and fiscal centralization increases aggregate national welfare although it decreases the gross domestic product.

It should be noted that these results hinge on the assumption that regions do not differ in overall productivity. Although differences in $A_i$ would not affect our conclusions on the optimal fiscal regime (see proposition 2), they do affect our conclusions on the Oates conjecture. In fact, it is possible to construct cases where fiscal centralization maximizes national output if regional differences in $A_i$ are large (see figure 5.b). If the differences in $A_i$ are not too large, however, our model generally verifies the Oates conjecture, even though it does not suggest that fiscal decentralization is always the optimal regime.

[16] We do not consider new policy rules that maximize (local or national) output, but we evaluate the consequences of welfare maximizing policies for output in the different regimes.

## VI. Labor mobility

In this section we allow for labor mobility. At the beginning of their working life, agents decide in which region to reside, by comparing the utilities they enjoy in each region. Since in our model individuals have identical preferences, migration occurs only in the presence of regional heterogeneity, such as different initial populations, TFP or infrastructure spending productivities and continues until the utility levels are equalized. The human capital of an agent depends on the human capital of her parent, hence it is region specific. Thus, when labor mobility occurs, regions are inhabited by dynasties with different levels of human capital. However, under the assumption $\gamma < (1-\delta)(1-\psi_i)$, human capital of any dynasty converges to a steady state (see equation (16)) which is independent of initial conditions, such as the migration date. Thus, the distribution of human capital in the receiving region becomes degenerate in the long-run, as all dynasties finally reach the same level of human capital.[17]

In the following, we focus on the steady state population distribution that is consistent with labor mobility. We solve for the equilibrium value of the relative population size $\rho$ such that the steady state utility levels across the two regions are equalized. Notice that our model does not display any agglomeration force. Hence, in the long-run equilibrium, both regions are inhabited and regional size differences are solely due to *exogenous* regional productivity differences.[18] Figure 6 illustrates the determination of the long-run equilibrium population distribution under different fiscal regimes ($\rho_D*$, $\rho_C*$ and $\rho_P*$) with identical (6.a) and heterogeneous (6.b) regions in infrastructure productivity.

**FIGURES 6 AND 7 HERE**

As can be seen, utility in region 1 is increasing in the relative population size of region 2 $\rho$, whereas utility in region 2 is decreasing. The larger $\rho$ is, the higher is the supply of the good $d$ that is produced in region 2, hence the lower is the relative price of that good and the lower is utility in region 2. This stabilizing "terms of trade effect" leads to an interior equilibrium for the population distribution. In panel 6.a the two regions have equal infrastructure productivities ($\psi_1 = \psi_2$). The unique and stable long-run equilibrium is an equal division of population across the two regions, $\rho^* = 1$. When the productivity of infrastructure differs across regions ($\psi_1 > \psi_2$) as in panel 6.b, the more productive region will end up being larger in the long-run. This equilibrium value $\rho^*$ depends on the regional productivity levels and on the choice of the fiscal regime in this economy.[19]

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[17] This happens because both public education and parental human capital display decreasing returns to scale and there are no other frictions in acquiring human capital.

[18] In particular, the two local public goods enter individual utility functions in per capita terms, so there is no Stiglitz-type cost sharing motive for regional concentration.

[19] In a case where regions differ in overall productivity $\overline{A}_i$ but not in infrastructure spending productivity $\psi_i$ the more productive region will also end up larger in the long-run equilibrium. Hence, $\rho^* < 1$ if $\overline{A}_1 > \overline{A}_2$ and $\rho^* > 1$ otherwise. The equilibrium value $\rho^*$ would not depend on the fiscal regime, however, since differences in $\overline{A}_i$ are irrelevant for the welfare implications of fiscal decentralization.

Interestingly, the long-run population distribution is the most equal under the partial centralization regime. This result is robust to changes in parameter values. However, the ranking in terms of population dispersion between full centralization and full decentralization depends on the degree of regional heterogeneity. Thus, for similar regions, $\rho_P* > \rho_C* > \rho_D*$ and for dissimilar regions we obtain $\rho_P* > \rho_D* > \rho_C*$ . The reason is the following: Full centralization sets out to equalize (marginal) utilities hence the possibilities one has to arbitrage by relocating are substantially reduced. When regions are similar, "one size fits all" policies are less distortionary. Partial decentralization has the double advantage of lower taxes and more flexible spending compared to full centralization, hence population dispersion is relatively lower. Conversely, when differences between regions are significant, so are the distortions introduced under centralization compared to full decentralization and migration alleviates them. Partial centralization yields the lowest population dispersion since the (common) tax level is lower compared to full decentralization. This in fact reduces the importance of the difference in public spending elasticity, and consequently the need to relocate.

Finally, we compare welfare under the three regimes in the labor mobility case. Figure 7 presents the gains from full and partial centralization relative to the full decentralization benchmark. Formally, the welfare-maximizing fiscal regime $z \in \{D, C, P\}$ with endogenous population distribution follows from the maximization problem

$$z = \arg\max\left[\Omega_D^*\left(\rho_D^*(\bar{A}_i,\psi_i)\right),\Omega_C^*\left(\rho_C^*(\bar{A}_i,\psi_i)\right),\Omega_P^*\left(\rho_P^*(\bar{A}_i,\psi_i)\right)\right] \tag{28}$$

The main result of the paper is preserved under labor mobility in the sense that full centralization is better suited for relatively similar regions. However, the optimal choices in the case of very different infrastructure elasticities change. Very heterogeneous regions with a low *average* infrastructure elasticity (left half of the figure) benefit the most from complete decentralization as the tax distortion is low (recall that ${\tau^D}_i$ varies directly with $\psi_i$ ). In the case of large differences and high *average* infrastructure elasticity (right half of the figure), partial decentralization dominates since it removes the now significant tax distortion. In the benchmark case with no labor mobility, the welfare in the latter situation was maximized under full decentralization. In contrast, labor mobility induces a higher concentration of people in the more productive region hence the tax distortion under decentralization has larger *aggregate* welfare effects. The ability to alleviate it under partial decentralization makes it the optimal choice.

## VII. Conclusion

In this paper, we present a tractable dynamic general equilibrium model of a federal economy with trade and regional heterogeneity in productivity. Our paper adds to the small but growing literature that focuses on the dynamic aspects of fiscal federalism by modelling a realistic array of public policy instruments that are decisive for the accumulation of capital, namely public education and infrastructure spending.

Furthermore, in our analysis, we distinguish between policy (de)centralization on the revenue and the expenditure side of the public budget. In particular, we study the implications of the government policies on education and infrastructure under three different regimes (centralized, de-centralized or mixed).

The assumption of regional differences in productivity of government infrastructure is essential for our results. We find that full fiscal decentralization is welfare maximizing if the regional differences in the productivity of public capital are sufficiently large. On the contrary, fiscal centralization is optimal in countries where infrastructure productivity is similar across regions. The optimal governmental allocation between infrastructure and public education is shown to depend upon the degree of centralization. While welfare gains from full centralization are symmetric in infrastructure productivity differences, partial centralization generates asymmetric welfare gains. Introducing labor mobility produces qualitatively similar results.

We also find that fiscal decentralization tends to cause faster capital accumulation and higher steady state output, consistent with the "Oates-conjecture", but it may still be inferior to centralization in terms of aggregate welfare. Besides offering a novel theoretical justification for the Oates conjecture, our model also provides an explanation for the mixed empirical evidence on the relationship between output and decentralization. We show that full centralization is dominated, in terms of output, by full decentralization, but at the same time dominates partial decentralization. Hence, starting under full centralization, decentralizing public policy (e.g. by devolving spending allocations) can generate lower output, while an even higher degree of decentralization (by allowing both spending and taxation to be region specific) generates higher output in the long run.

The framework used in this paper relies on a few simplifying assumptions. For example, we assumed that regions are completely specialized and that utility functions treat both consumption goods symmetrically. If one of the regions specializes in agricultural products and the other region specializes in manufacturing or services, Engel curves are not straight lines and income elasticities for agricultural products are close to zero. This can be modeled with semi-linear utility functions. Combining semi-linear utility functions with differences in TFP may prove fruitful. Studying this or a different extension of the present model is left for future work.

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# Appendix A: Welfare under different fiscal regimes

## A.1 Decentralization

Substituting (21)-(23) into (14), (15) and (18) we can express the following endogenous variables in terms of the model parameters only

$$w_{i,D}^{*} = \bar{A}_i \left( \bar{A}_i \, \psi_i \, h_{i,D}^{*} \right)^{\frac{\psi_i}{1-\psi_i}}, \qquad Y_{i,D}^{*} = \rho_i \cdot w_{i,D}^{*} \cdot h_{i,D}^{*} = \frac{\rho_i}{\psi_i} \cdot \left( \bar{A}_i \, \psi_i \, h_{i,D}^{*} \right)^{\frac{1}{1-\psi_i}},$$

$$E_{i,D}^{*} = \left(1 - \lambda_{i,D}^{*}\right) \cdot \tau_{i,D}^{*} \cdot Y_{i,D}^{*} = \frac{1-\psi_i}{2\psi_i} \cdot \rho_i \cdot \left( \bar{A}_i \, \psi_i \, h_{i,D}^{*} \right)^{\frac{1}{1-\psi_i}}$$

$$p_D^{*} = \left[ \frac{\bar{A}_1 \left(1-\psi_1\right) h_{1,D}^{*} \left( \bar{A}_1 \, \psi_1 \, h_{1,D}^{*} \right)^{\psi_1/(1-\psi_1)}}{\rho \, \bar{A}_2 \left(1-\psi_2\right) h_{2,D}^{*} \left( \bar{A}_2 \, \psi_2 \, h_{2,D}^{*} \right)^{\psi_2/(1-\psi_2)}} \right] \qquad \text{with } \rho_1 = 1 \text{ and } \rho_2 = \rho$$

Substituting this into (19) and (20) we obtain regional welfare levels:

$$U_{1,D}^{*} = \ln\left[\frac{1}{32+64\eta}\right] + 2\ln\left[ \frac{\left(1-\psi_1\right)}{\psi_1} \cdot \left( B \, \bar{A}_1 \, \psi_1 \cdot \left(h_{1,D}^{*}\right)^{\delta} \cdot \left( \frac{\left(1-\psi_1\right)}{2} \bar{A}_1 \, h_{1,D}^{*} \left( \bar{A}_1 \, \psi_1 \, h_{1,D}^{*} \right)^{\frac{\psi_1}{(1-\psi_1)}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_1}} \right]$$
$$+ \ln\left[ \frac{\rho\left(1-\psi_2\right)}{\psi_2} \cdot \left( B \, \bar{A}_2 \, \psi_2 \cdot \left(h_{2,D}^{*}\right)^{\delta} \cdot \left( \frac{\left(1-\psi_2\right)}{2} \bar{A}_2 \, h_{2,D}^{*} \left( \bar{A}_2 \, \psi_2 \, h_{2,D}^{*} \right)^{\frac{\psi_2}{1-\psi_2}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_2}} \right]$$

and

$$U_{2,D}^{*} = \ln\left[\frac{1}{32+64\eta}\right] + \ln\left[ \frac{\left(1-\psi_1\right)}{\rho \cdot \psi_1} \cdot \left( B \, \bar{A}_1 \, \psi_1 \cdot \left(h_{1,D}^{*}\right)^{\delta} \cdot \left( \frac{\left(1-\psi_1\right)}{2} \bar{A}_1 \, h_{1,D}^{*} \left( \bar{A}_1 \, \psi_1 \, h_{1,D}^{*} \right)^{\frac{\psi_1}{(1-\psi_1)}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_1}} \right]$$
$$+ 2\ln\left[ \frac{\left(1-\psi_2\right)}{\psi_2} \cdot \left( B \, \bar{A}_2 \, \psi_2 \cdot \left(h_{2,D}^{*}\right)^{\delta} \cdot \left( \frac{\left(1-\psi_2\right)}{2} \bar{A}_2 \, h_{2,D}^{*} \left( \bar{A}_2 \, \psi_2 \, h_{2,D}^{*} \right)^{\frac{\psi_2}{1-\psi_2}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_2}} \right]$$

Aggregate national welfare is then given by $\Omega_D^{*} = U_{1,D}^{*} + \rho \cdot U_{2,D}^{*}$. The closed form solution for national output under decentralization follows as $\Upsilon_D^{*} = Y_{1,D}^{*} + \rho \cdot Y_{2,D}^{*}$.

### A.2 Full centralization

With policy parameters as in (24) and (25) steady state human capital (17) becomes:

$$h_{i,C}^{*}(\cdot)=\left[B^{1/\gamma}\left(\bar{A}_i\,\sigma'\cdot\left(\frac{\bar{A}_i\,\psi_1(2+\rho)+\bar{A}_i\,\psi_2(1+2\rho-3\psi_1(1+\rho))}{3-\psi_1-2\psi_2+\rho(3-2\psi_1-\psi_2)}\right)^{\frac{\psi_i}{1-\psi_i}}\right)\right]^{\frac{\gamma(1-\psi_i)}{1-\gamma-\delta-\psi_i(1-\delta)}}$$

Using this expression in (14), (15) and (18) we derive the endogenous variables

$$w_{i,C}^{*}=\bar{A}_i\left(\bar{A}_i\cdot\sigma\cdot h_{i,C}^{*}\right)^{\frac{\psi_i}{1-\psi_i}},\qquad Y_{i,C}^{*}=\rho_i\cdot\bar{A}_i\cdot\left(\bar{A}_i\cdot\sigma\right)^{\frac{\psi_i}{1-\psi_i}}\cdot\left(h_{i,C}^{*}\right)^{\frac{1}{1-\psi_i}}$$

$$E_{i,C}^{*}=\left(\rho_i\cdot\bar{A}_i\cdot\sigma'\right)\left(\bar{A}_i\cdot\sigma\right)^{\frac{\psi_i}{1-\psi_i}}\left(h_{i,C}^{*}\right)^{\frac{1}{1-\psi_i}}$$

$$p_C^{*}=\left[\left(\bar{A}_1\,h_{1,C}^{*}\left(\bar{A}_1\,\sigma\,h_{1,C}^{*}\right)^{\frac{\psi_1}{1-\psi_1}}\right)\Big/\left(\rho\,\bar{A}_2\,h_{2,C}^{*}\left(\bar{A}_2\,\sigma\,h_{2,C}^{*}\right)^{\frac{\psi_2}{1-\psi_2}}\right)\right]$$

where $\sigma\equiv\dfrac{\psi_1(2-3\psi_2+\rho(1-3\psi_2))+\psi_2(1+2\rho)}{3-\psi_1-2\psi_2+\rho(3-2\psi_1-\psi_2)},\quad \sigma'\equiv\dfrac{(1+\rho)(1-\psi_1)(1-\psi_2)}{3-\psi_1-2\psi_2+\rho(3-2\psi_1-\psi_2)}$

Using this, we can determine regional welfare levels under full fiscal centralization:

$$U_{1,C}^{*}=Ln\left[\frac{1}{1+2\eta}\right]+2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_1\,\sigma\cdot\left(h_{1,C}^{*}\right)^{\delta}\left(E_{1,C}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right]+Ln\left[\frac{\rho\sigma'}{\sigma}\left(B\,\bar{A}_2\,\sigma\left(h_{2,C}^{*}\right)^{\delta}\left(E_{2,C}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right]$$

$$U_{2,C}^{*}=Ln\left[\frac{1}{1+2\eta}\right]+2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_2\,\sigma\left(h_{2,C}^{*}\right)^{\delta}\left(E_{2,C}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right]+Ln\left[\frac{\sigma'}{\rho\sigma}\left(B\,\bar{A}_1\,\sigma\left(h_{1,C}^{*}\right)^{\delta}\left(E_{1,C}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right]$$

And aggregate steady state welfare and output are then, respectively, given by

$$\Omega_C^{*}=U_{1,C}^{*}+\rho\cdot U_{2,C}^{*}\qquad\text{and}\qquad \Upsilon_C^{*}=Y_{1,C}^{*}+\rho\cdot Y_{2,C}^{*}$$

**A.3 Partial centralization**

Finally, with policy parameters (22) and (24) endogenous variables are:

$$h_{i,P}^{*}(\cdot)=\left[B\left(\frac{(1-\psi_i)}{\psi_i}\cdot\left((2)^{\psi_i}\,\bar{A}_i\,\sigma_i''\right)^{\frac{1}{1-\psi_i}}\right)^{\gamma}\right]^{\frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)}}$$

$$w_{i,P}^{*}=\bar{A}_i\left(\frac{2\bar{A}_i\,\psi_i}{(1+\psi_i)}\cdot\sigma''\cdot h_{i,P}^{*}\right)^{\frac{\psi_i}{1-\psi_i}},\qquad Y_{i,P}^{*}=\rho_i\cdot\bar{A}_i\cdot\left(\bar{A}_i\cdot\sigma_i''\right)^{\frac{\psi_i}{1-\psi_i}}\cdot\left(h_{i,P}^{*}\right)^{\frac{1}{1-\psi_i}}$$

$$E_{i,P}^{*}=\rho_i\left(\frac{1-\psi_i}{\psi_i}\right)\cdot\left((2)^{\psi_i}\,\bar{A}_i\,\sigma_i''\,h_{i,P}^{*}\right)^{\frac{1}{1-\psi_i}},\qquad p_P^{*}=2^{\frac{\psi_1-\psi_2}{(1-\psi_1)(1-\psi_2)}}\left[\frac{\bar{A}_1\,h_{1,P}^{*}\left(\bar{A}_1\,\sigma_1''h_{1,P}^{*}\right)^{\frac{\psi_1}{1-\psi_1}}}{\bar{A}_2\,h_{2,P}^{*}\left(\bar{A}_2\,\sigma_2''h_{2,P}^{*}\right)^{\frac{\psi_2}{1-\psi_2}}}\right]$$

where $\sigma_i''\equiv\frac{\psi_i}{(1+\psi_i)}\cdot\frac{1+\psi_1(1-2\psi_2)+\rho(1+\psi_2(1-2\psi_1))}{3-\psi_1-2\psi_2+\rho(3-2\psi_1-\psi_2)}$ (for i = 1,2).

This gives rise to the following regional welfare levels:

$$U_{1,P}^{*}=Ln\left[\frac{1}{1+2\eta}\right]+2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_1\,\sigma_1''\cdot\left(h_{1,P}^{*}\right)^{\delta}\left(E_{1,P}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right]+Ln\left[\frac{\rho\sigma'}{\sigma}\left(B\,\bar{A}_2\,\sigma_2''\left(h_{2,P}^{*}\right)^{\delta}\left(E_{2,P}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right]$$

$$U_{2,P}^{*}=Ln\left[\frac{1}{1+2\eta}\right]+2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_2\,\sigma_2''\left(h_{2,P}^{*}\right)^{\delta}\left(E_{2,P}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right]+Ln\left[\frac{\sigma'}{\rho\sigma}\left(B\,\bar{A}_1\,\sigma_1''\left(h_{1,P}^{*}\right)^{\delta}\left(E_{1,P}^{*}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right]$$

which can be used in an analogous way to compute aggregate welfare $\Omega_P^{*}=U_{1,P}^{*}+\rho\cdot U_{2,P}^{*}$ and national output $\Upsilon_P^{*}=Y_{1,P}^{*}+\rho\cdot Y_{2,P}^{*}$.

**Appendix B: Proof of Proposition 1 and the fiscal externality**

Proof of Proposition 1.1.: First, from (21) we get $\tau^*_{D,2} < \tau^*_{D,1}$ when $\psi_2 < \psi_1$. Moreover, this assumption guarantees that $\tau^*_C < \tau^*_{D,1}$. To see this, solve $\tau^*_C < \tau^*_{D,1}$ for $\psi_1$. This yields $\psi_1 > \chi = \left(-1-\rho+\psi_2(2+3\rho)\right)/\left(1+2\rho\right)$ and $\chi > \psi_2$. Thus $\psi_1 > \psi_2$ is a sufficient condition for $\tau^*_C < \tau^*_{D,1}$. On the other side, when $\psi_1 > \bar{\psi} = \left(1+\rho+\psi_2(\rho+2)\right)/\left(3+2\rho\right)$ it follows that $\tau^*_{D,2} < \tau^*_C$ Thus, $\psi_1 > \bar{\psi}$ is a sufficient condition for $\tau^*_{D,2} < \tau^*_C < \tau^*_{D,1}$. Alternatively, $\tau^*_C < \tau^*_{D,2} < \tau^*_{D,1}$ if $\psi_1 < \bar{\psi}$. □

Proof of Proposition 1.2.: From (22) we get $\lambda^*_{D,2} < \lambda^*_{D,1}$ when $\psi_2 < \psi_1$. The inequality $\lambda^*_{D,2} < \lambda^*_C$ is equivalent to $\psi_1 > \kappa = \psi_2/\left(\psi_2(1+\rho)-2-\rho\right)$. It can be shown that $\kappa > \psi_2$, so the assumption $\psi_1 > \psi_2$ is sufficient to guarantee $\lambda^*_{D,2} < \lambda^*_C$. On the other side, $\lambda^*_{D,1} < \lambda^*_C$ whenever $\psi_1 < \tilde{\psi} = \left(\psi_2(1+2\rho)\right)/\left(\rho+\psi_2(1+\rho)\right)$. Thus, a sufficient condition for $\lambda^*_{D,2} < \lambda^*_{D,1} < \lambda^*_C$ is $\psi_1 < \tilde{\psi}$. Alternatively, $\lambda^*_{D,2} < \lambda^*_C < \lambda^*_{D,1}$ if $\psi_1 > \tilde{\psi}$. □

Illustration of the fiscal externality: Focus on the case with $\rho = 1$ and $\psi_1 = \psi_2 = \psi$. Furthermore, suppose $\tau_{D,1} = \tau_{D,2} = \tau^*_C$. The expression for the relative price (18) becomes:

$$p_t = \frac{\left(1-\tau_{1,t}\right) w_{1,t}\, h_{1,t}}{\left(1-\tau_{2,t}\right) w_{2,t}\, h_{2,t}} = \frac{\left(1-\tau_{1,t}\right)\bar{A}_1\, h_{1,t}\left(\lambda_{1,t}\,\tau_{1,t}\,\bar{A}_1\, h_{1,t}\right)^{\psi/(1-\psi)}}{\left(1-\tau_{2,t}\right)\bar{A}_2\, h_{2,t}\left(\lambda_{2,t}\,\tau_{2,t}\,\bar{A}_2\, h_{2,t}\right)^{\psi/(1-\psi)}} \tag{29}$$

Recall that the per capita stocks of human capital $h_{1,t}$ and $h_{2,t}$ have been accumulated in the previous period, so they are not affected by current policies. Using (29) we find

$$\frac{\partial p_t}{\partial \tau_{1,t}} = \Phi\, \tau_{1,t}^{\frac{1}{1-\psi}}\left(\frac{\psi-\tau_{1,t}}{1-\psi}\right), \qquad \text{where } \Phi = \frac{\bar{A}_1\, h_{1,t}\left(\lambda_{1,t}\,\bar{A}_1\, h_{1,t}\right)^{\psi/(1-\psi)}}{\left(1-\tau_{2,t}\right)\bar{A}_2\, h_{2,t}\left(\lambda_{2,t}\,\tau_{2,t}\,\bar{A}_2\, h_{2,t}\right)^{\psi/(1-\psi)}}$$

But $\tau^*_C > \psi$, so $\tau_{1,t} > \psi$. Thus, an increase in $\tau_{D,1}$ reduces the relative price $p_t$ (which benefits region 1). It can be shown also that an increase in $\tau_{D,2}$ increases $p_t$ (which benefits region 2). Thus, under full decentralization, $\tau_C < \tau_{D,1} = \tau_{D,2}$ since both regions have an incentive to raise tax rates in order to shift the terms of trade. Similarly, starting from $\lambda_{D,1} = \lambda_{D,2} = \lambda^*_C$, a reduction in $\lambda_{D,1}$ results in a decrease in $p_t$, which benefits region 1. Similarly, a reduction in $\lambda_{D,2}$ increases $p_t$, which benefits region 2. Thus, $\lambda^*_{D,1} = \lambda^*_{D,2} < \lambda^*_C$.

## Appendix C: Output versus welfare

Focus on the case with $\bar{A}_1 = \bar{A}_2 = \bar{A}$ and $\rho = 1$. Furthermore, let $\psi_1 = \psi_2 = \psi$ so that regions are identical. The difference in human capital formation between decentralization and full centralization then reads as

$$\Delta h_C \equiv h^*_{i,C} - h^*_{i,D} = \left(3^{-\gamma} - 2^{-\gamma}\right) \cdot \left( B\left( A\left(1-\psi\right)\left(A\psi\right)^{\psi/(1-\psi)}\right)^{\gamma}\right)^{\frac{\gamma(1-\psi)}{1-\gamma-\delta-\psi(1-\delta)}} = \left(3^{-\gamma} - 2^{-\gamma}\right) \cdot \tilde{h}^* < 0$$

for i=1,2. Centralization leads to less human capital formation in both regions. The respective differences in wages, school quality, gross and net national output are given by

$$\Delta w_C \equiv w^*_{i,C} - w^*_{i,D} = \left(3^{-\gamma} - 2^{-\gamma}\right) \bar{A} \left(\bar{A}\psi \cdot \tilde{h}^*\right)^{\psi/(1-\psi)} < 0$$

$$\Delta q_C \equiv q^*_{i,C} - q^*_{i,D} = \left( \frac{3^{-\gamma}(1-\psi)}{3\psi} - \frac{2^{-\gamma}(1-\psi)}{2\psi} \right) \left(\bar{A}\psi \cdot \tilde{h}^*\right)^{1/(1-\psi)} < 0$$

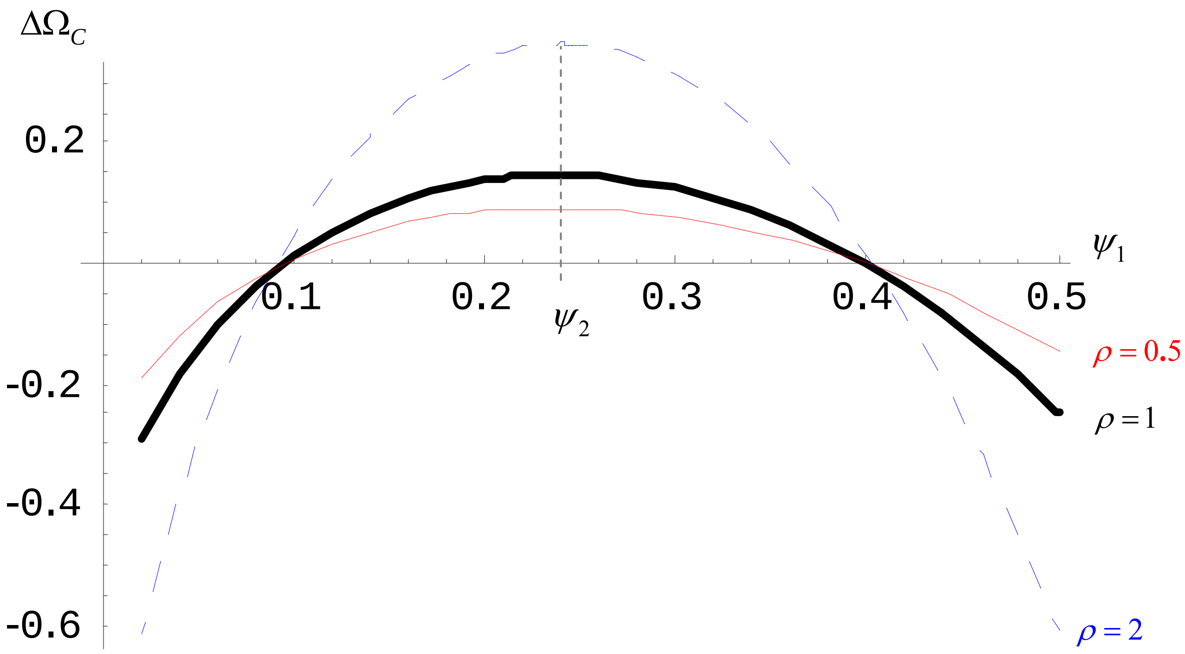
$$\Delta \Upsilon_C = \Upsilon^*_C - \Upsilon^*_D = \left(2/\psi\right)\left(3^{-\gamma} - 2^{-\gamma}\right)\left(\bar{A}\psi \cdot \tilde{h}^*\right)^{1/(1-\psi)} < 0$$

That is, fiscal centralization leads to lower wages, school quality and gross output. Since $\Upsilon^*_C$ is hump-shaped in $\psi_1$ for given $\psi_2$, these conclusions are robust to allowing for differences in $\psi_i$. Hence, the Oates conjecture holds in our model for the case of $\bar{A}_1 = \bar{A}_2 = \bar{A}$ and $\rho = 1$ also if regions differ in their infrastructure spending productivity. However, net income and thus consumption is higher under centralization:

$$\Delta N\Upsilon_C = (1-\tau^*_C)\Upsilon^*_C - (1-\tau^*_D)\Upsilon^*_D = \left(2/\psi\right)\left(\tfrac{4}{3} \cdot (3)^{-\gamma} - 2^{-\gamma}\right)\left((1-\psi)/\psi\right)\left(\bar{A}\psi \cdot \tilde{h}^*\right)^{1/(1-\psi)} > 0 .$$

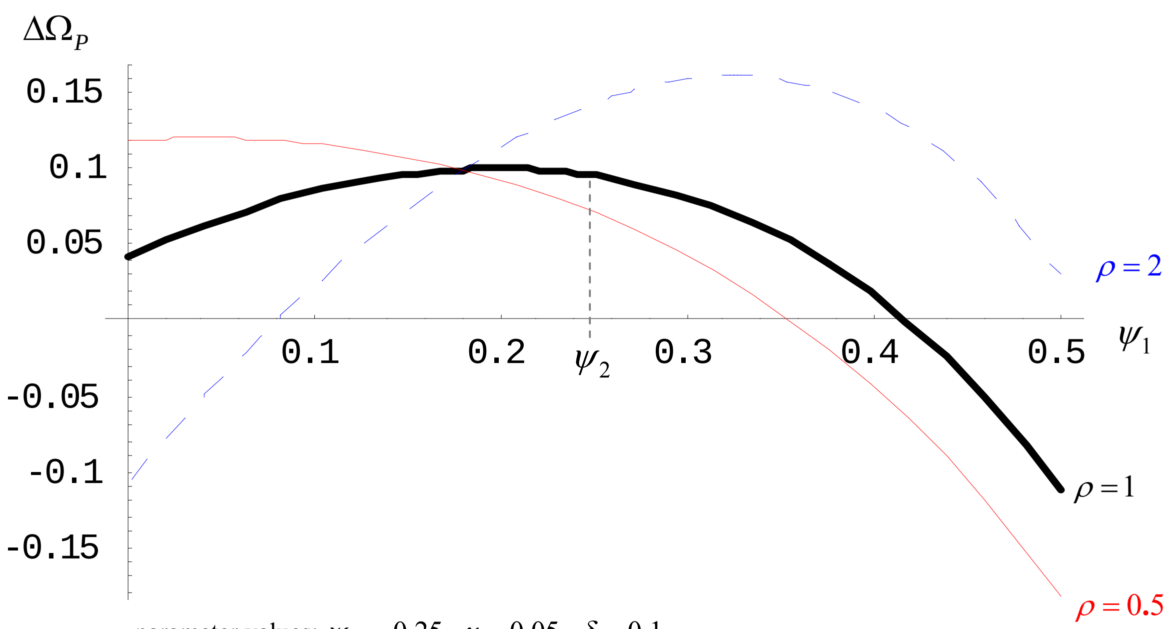
This effect dominates so welfare is higher under centralization with two identical regions.

**Figure 1: Welfare gains from full fiscal centralization**



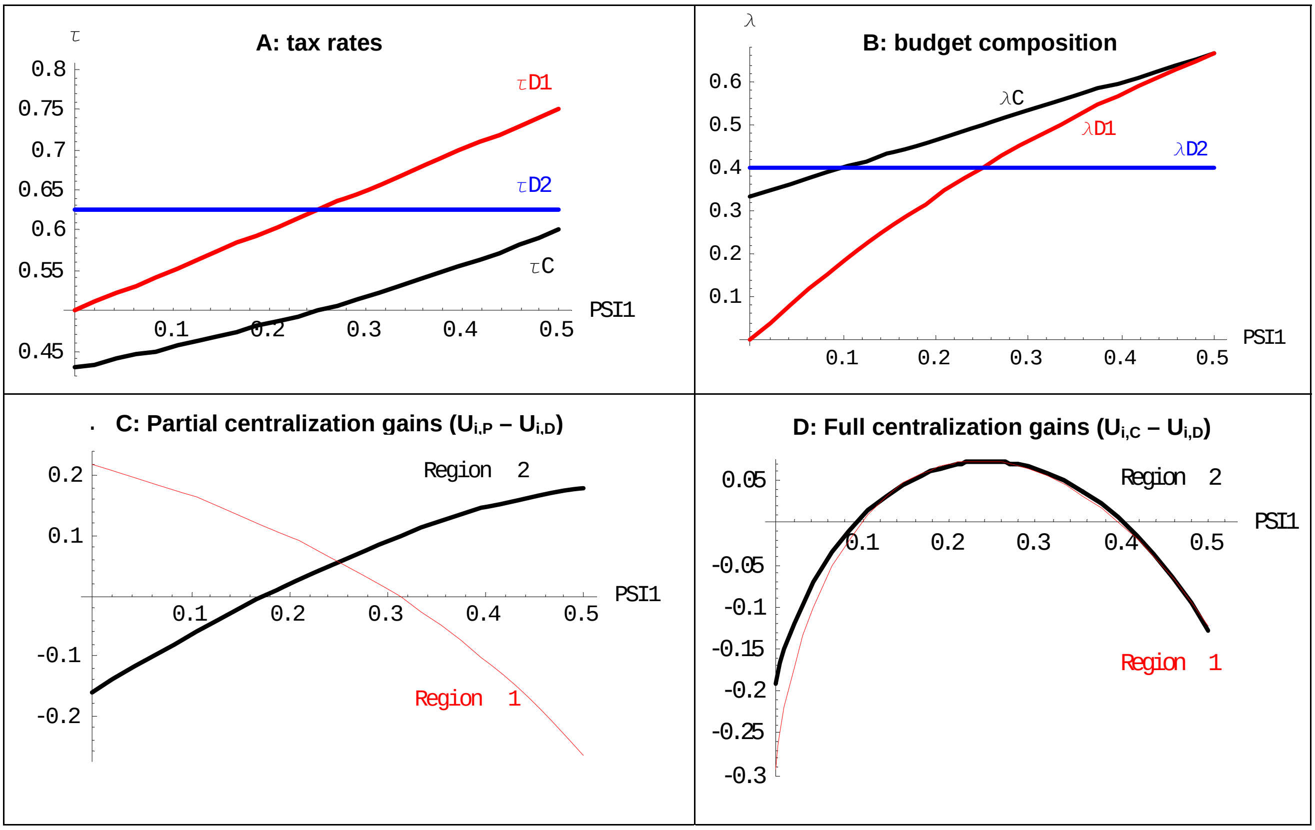

parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$

**Figure 2: Welfare gains from partial fiscal centralization**



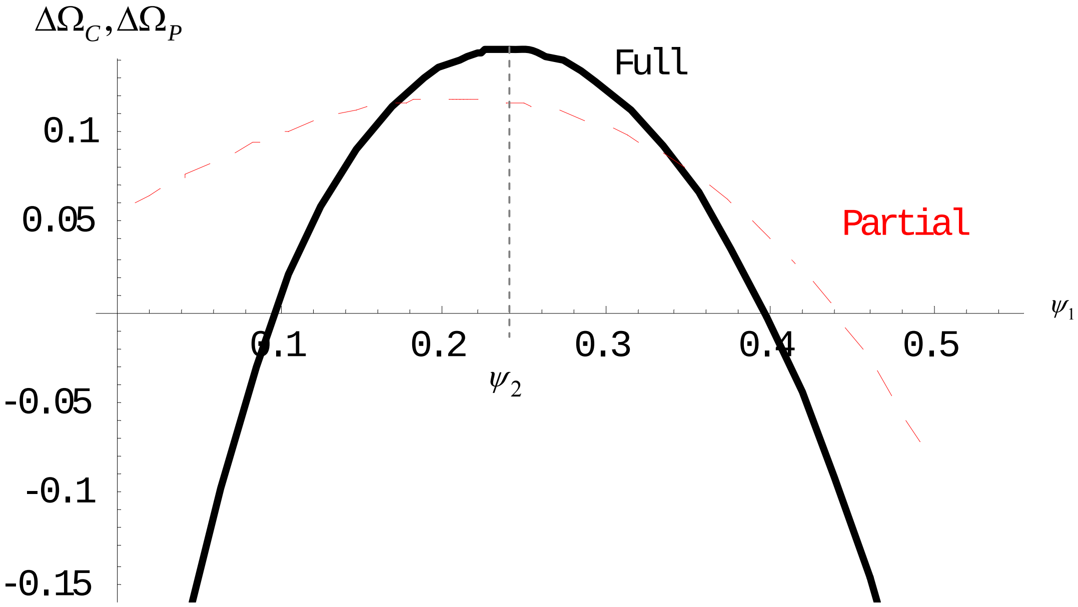

parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$

**Figure 3: Tax rate, budget composition and welfare under different fiscal regimes**



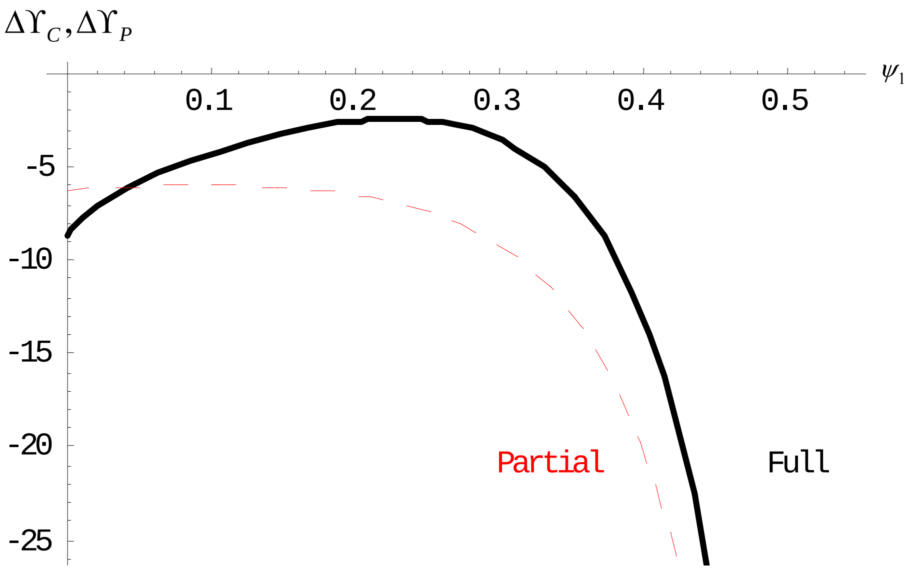

parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$, $\rho = 1$

**Figure 4: Optimal fiscal regime**



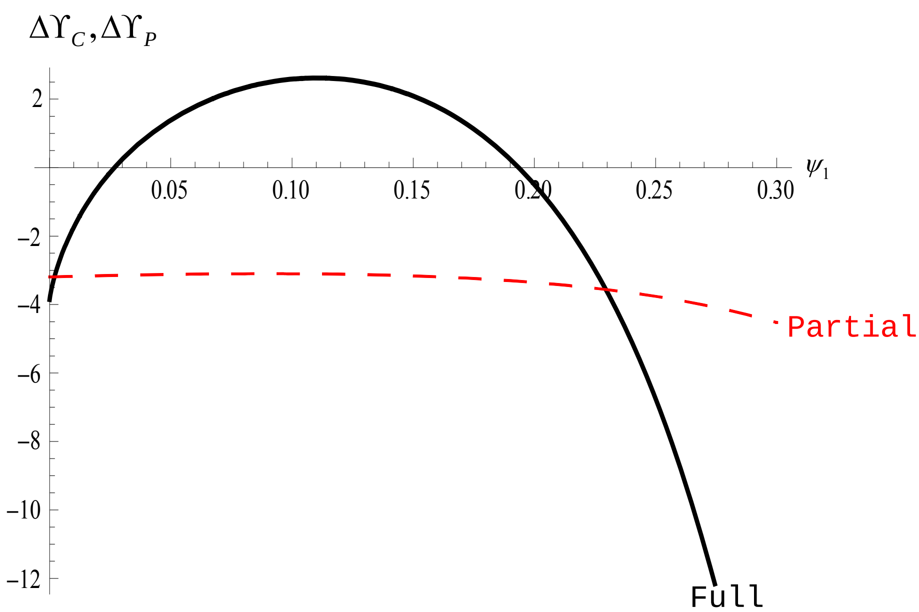

parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$, $\rho = 1$

**Figure 5: Fiscal centralization and output**




parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$, $\rho = 1$, $\overline{A}_1 = \overline{A}_2 = 5$

**Figure 5b: The Oates conjecture with regional differences in overall productivity**




parameter values: $\psi_2 = 0.25$, $\gamma = 0.05$, $\delta = 0.1$, $\rho = 1$, $\overline{A}_1 = 200$, $\overline{A}_2 = 5$

**Figure 6: Equilibrium population distribution**

**6a – identical regions**

$\bar{A}_1 = \bar{A}_2 = 4, \quad \psi_1 = \psi_2 = 0.25$

$\rightarrow \rho_D{*} = \rho_C{*} = 1 \ (= \rho_P{*})$

**6b – higher spending productivity in region 1**

$\bar{A}_1 = \bar{A}_2 = 4, \quad \psi_1 = 0.6, \psi_2 = 0.25$

$\rightarrow \rho_D{*} = 0.2959, \ \rho_C{*} = 0.2795, \ \rho_P{*} = 0.4039$

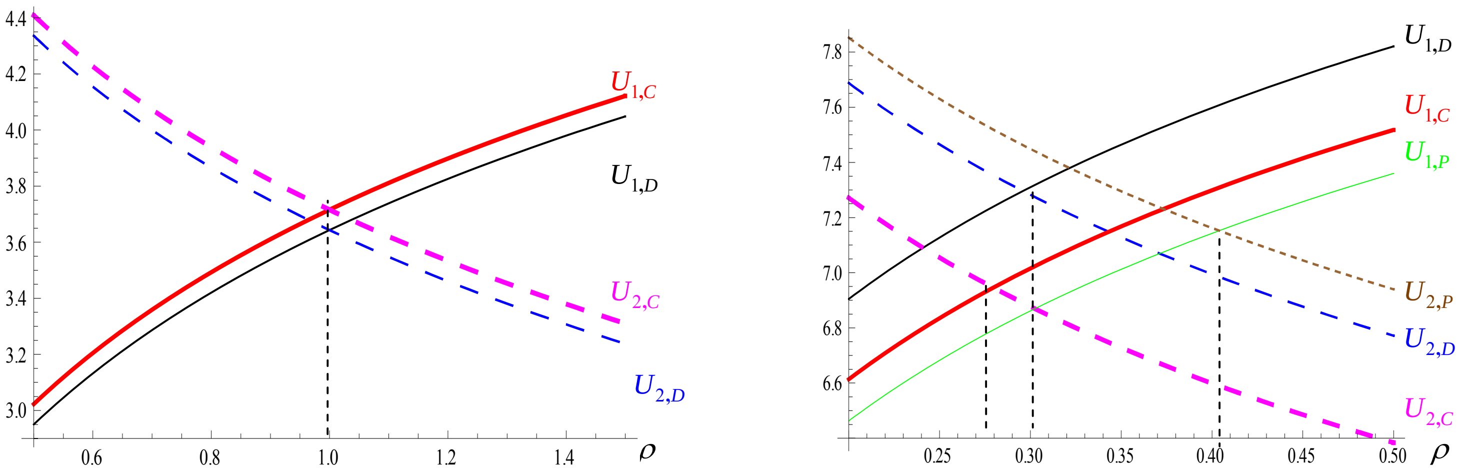
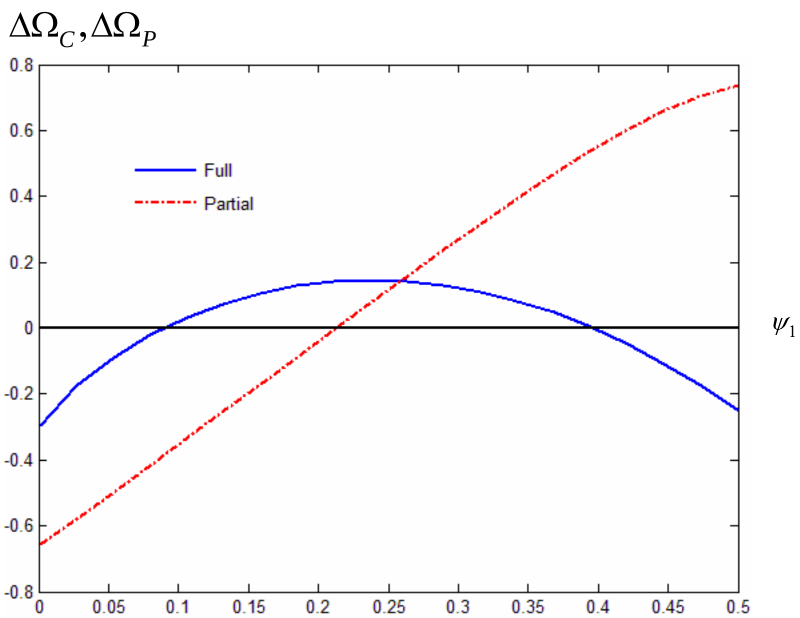



**Figure 7: Optimal fiscal regime with population mobility**

$\bar{A}_1 = \bar{A}_2 = 4, \quad \psi_1 = 0.6, \psi_2 = 0.25$




other parameter values: $\gamma = 0.05$, $\delta = 0.1$, $\beta = 0.9$, $\theta = 4$

# Supplementary material

(eventually not to be published or
only as a web appendix)

## Appendix D: The infinitely-lived Social Planner's problem

### D.1. Fiscal decentralization

<u>SP problem in region 1:</u> We assume the SP knows the demand for good 1 in region 2. Her problem can be formulated as follows:

$$\max_{\{\tau_{t+1},\lambda_{1t+1}\}} \sum_{t=0}^{\infty} \beta^t \left[ Log\left(n_{1,t}\right) + Log\left(c_{1,t+1}\right) + Log\left(d_{1,t+1}\right) + Log\left(E_{1,t+1}\right) - Log\left(p_{t+1}\right) \right]$$

$$= \max_{\{\tau_{t+1},\lambda_{1t+1}\}} \sum_{t=0}^{\infty} \beta^t \left[ Log\left(\frac{1}{1+2\eta}\right) + 2Log\left[(1-\tau_{1,t+1})w_{1,t+1}H_{1,t+1}\right] + Log\left(E_{1,t+1}\right) - Log\left(p_{t+1}\right) \right]$$

subject to $E_{1,t+1} = (1-\lambda_{1,t+1})\tau_{1,t+1}w_{1,t+1}H_{1,t+1}$ $\qquad w_{1,t+1} = A_1\left(\lambda_{1,t+1}\tau_{1,t+1}H_{1,t+1}A_1\right)^{k_1}$

$$H_{1,t+1} = \theta\left(\frac{1}{1+2\eta}\right)^{\eta} E_{1,t}{}^{\gamma} H_{1,t}{}^{\delta} \qquad p_t = \frac{\left(1-\tau_{1,t}\right)\left(\lambda_{1,t}\tau_{1,t}\right)^{k_1}\left(H_{1,t}A_1\right)^{1+k_1}}{\left(1-\tau_{2,t}\right)\left(\lambda_{2,t}\tau_{2,t}\right)^{k_2}\left(H_{2,t}A_2\right)^{1+k_2}}$$

This becomes:

$$\max_{\{\tau_{t+1},\lambda_{1t+1}\}} \sum_{t=0}^{\infty} \beta^t \begin{Bmatrix} 2Log\left[(1-\tau_{1,t+1})w_{1,t+1}H_{1,t+1}\right] + Log\left[(1-\lambda_{1,t+1})\tau_{1,t+1}w_{1,t+1}H_{1,t+1}\right] - \\ Log(1-\tau_{1,t+1}) - k_1 Log\lambda_{1,t+1} - k_1 Log\tau_{1,t+1} - (1+k_1)LogH_{1,t+1} \end{Bmatrix}$$

$$\Rightarrow \max_{\{\tau_{t+1},\lambda_{1t+1}\}} \sum_{t=0}^{\infty} \beta^t \begin{Bmatrix} Log(1-\tau_{1,t+1}) + (1-k_1)Log(\tau_{1,t+1}) + Log(1-\lambda_{1,t+1}) - k_1 Log(\lambda_{1,t+1}) + \\ 3Log(w_{1,t+1}) + (2-k_1)LogH_{1,t+1} \end{Bmatrix}$$

$\Rightarrow$

$$\max_{\{\tau_{t+1},\lambda_{1t+1}\}} \sum_{t=0}^{\infty} \beta^t \left\{ Log(1-\tau_{1,t+1}) + (1+2k_1)Log(\tau_{1,t+1}) + Log(1-\lambda_{1,t+1}) + 2k_1 Log(\lambda_{1,t+1}) + 2(1+k_1)LogH_{1,t+1} \right\}$$

subject to $H_{1,t+1} = \theta\left(\frac{1}{1+2\eta}\right)^{\eta}\left[(1-\lambda_{1,t})\tau_{1,t}\right]^{\gamma}\left(\lambda_{1,t}\tau_{1,t}\right)^{k_1\gamma} A_1^{\gamma(k_1+1)} H_{1,t}{}^{\gamma+\delta+k_1\gamma}$

First order conditions are

FOC ($\tau_{1,t+1}$): $-\frac{1}{1-\tau_{1,t+1}} + \frac{1}{\tau_{1,t+1}} + \frac{2k_1}{\tau_{1,t+1}} + 2(1+k_1)^2\beta\gamma\left(\frac{1}{\tau_{1,t+1}}\right) = 0$

FOC ($\lambda_{1,t+1}$): $-\frac{1}{1-\lambda_{1,t+1}} + \frac{2k_1}{\lambda_{1,t+1}} + 2(1+k_1)\beta\gamma\left(-\frac{1}{1-\lambda_{1,t+1}} + \frac{k_1}{\lambda_{1,t+1}}\right) = 0$

Hence, $\tau_1 = \frac{1+2\beta\gamma-\psi_1^2}{2(1+\beta\gamma-\psi_1)}$ and $\lambda_1 = \frac{2\psi_1(1+\beta\gamma-\psi_1)}{1+2\beta\gamma-\psi_1^2}$

Solving the problem for the second region yields similar allocations.

**D.2. Fiscal centralization**

$$\max_{\{\tau_{t+1},\lambda_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \begin{bmatrix} Log\left(n_{1,t}\right) + Log\left(c_{1,t+1}\right) + Log\left(d_{1,t+1}\right) + Log\left(E_{1,t+1}\right) + \\ \rho\left[Log\left(n_{2,t}\right) + Log\left(c_{2,t+1}\right) + Log\left(d_{2,t+1}\right) + Log\left(E_{2,t+1}\right)\right] \end{bmatrix}$$

subject to

$$E_{1,t+1} = (1-\lambda_{t+1})\tau_{t+1} w_{1,t+1} H_{1,t+1} \qquad E_{2,t+1} = (1-\lambda_{t+1})\tau_{t+1} w_{2,t+1} H_{2,t+1}$$

$$w_{1,t+1} = A_1\left(\lambda_{t+1}\tau_{t+1} H_{1,t+1} A_1\right)^{k_1} \qquad w_{2,t+1} = A_2\left(\lambda_{t+1}\tau_{t+1} H_{2,t+1} A_2\right)^{k_2}$$

$$h_{1,t+1} = \theta\left(\frac{1}{1+2\eta}\right)^{\eta} E_{1,t}{}^{\gamma} h_{1,t}{}^{\delta} \qquad h_{2,t+1} = \theta\left(\frac{1}{1+2\eta}\right)^{\eta} E_{2,t}{}^{\gamma} h_{2,t}{}^{\delta}$$

and $H_{1,t} = h_{1,t}$, $H_{2,t} = \rho h_{2,t}$

Taking the FOC yields

$$\tau = \frac{(1-\psi_1)(1-\psi_2)(1+\psi_1 - 2\psi_1\psi_2 + \rho(1+\psi_2 - 2\psi_1\psi_2)) + \beta\gamma Z}{(1-\psi_1)(1-\psi_2)(3-\psi_1 - 2\psi_2 + \rho(3-\psi_2 - 2\psi_1)) + \beta\gamma Z_1}$$

$$where\ \ Z_1 = (3-(2-\psi_1)\psi_1 - 2(2-\psi_2)\psi_2 + \rho(3-2(2-\psi_1)\psi_1 - (2-\psi_2)))$$

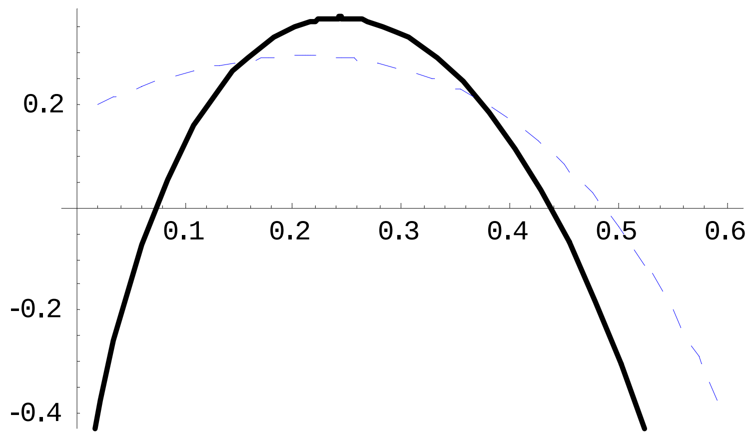
and

$$\lambda = \frac{(1+2\rho)(1+\beta\gamma - \psi_2)\psi_2 + \psi_1 Z_2 - \psi_1^2 Z_3}{(1-\psi_1)(1-\psi_2)(1+\psi_1 - 2\psi_1\psi_2 + \rho(1+\psi_2 - 2\psi_1\psi_2)) + \beta\gamma Z_1}$$

where

$$Z_1 = (3-(2-\psi_1)\psi_1 - 2(2-\psi_2)\psi_2 + \rho(3-2(2-\psi_1)\psi_1 - (2-\psi_2)))$$
$$Z_2 = (1+\beta\gamma)(2+\rho) - 6(1+\beta\gamma)(1+\rho)\psi_2 + (4+5\rho+\beta\gamma(2+\rho))\psi_2^2$$
$$Z_3 = 2-\psi_2(5+\beta\gamma - 3\psi_2) + \rho(1-(4+2\beta\gamma - 3\psi_2)\psi_2)$$

Plugging the optimal allocations in their respective welfare functions and comparing them for the benchmark calibration used in the main paper, we obtain the same broad qualitative implication: for very similar infrastructure productivities centralization maximizes welfare; for moderate differences, decentralizing spending is optimal, while for large differences in infrastructure productivities the highest welfare is attained by devolving both taxation and spending.

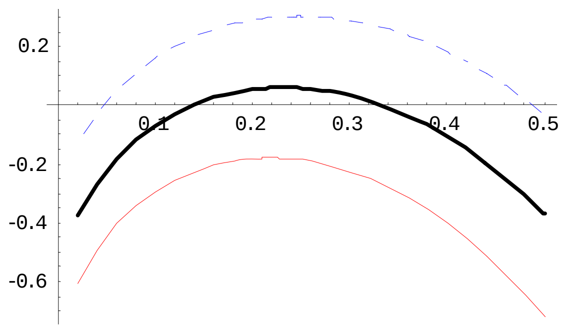


**Appendix E: Sensitivity analysis of parameter changes in γ and δ**

In this appendix we study the robustness of our results with respect to parameter changes in $\gamma$ and $\delta$. For brevity we will only consider the gains from centralization ($\Delta\Omega_C$) as in Figure 1. Furthermore, since country size plays no critical role we only look at the case with $\rho = 1$.

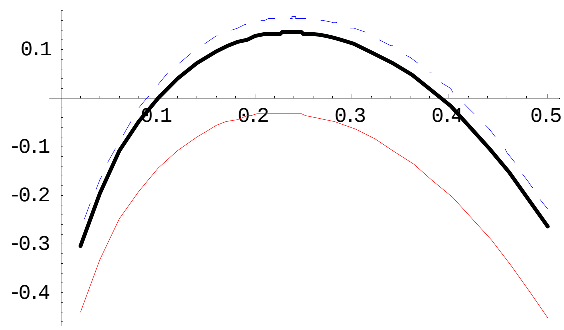
In figure 8.a we plot $\Delta\Omega_C$ for three different scenarios of the productivity of public education spending $\gamma$, for given values of $\delta$ and $\psi_2$. In all scenarios we obtain the same reverse U-shaped curve as in Figure 1, i.e. the gains from centralization mainly accrue when regions are similar in terms of their infrastructure spending productivities $\psi_i$. However, if $\gamma$ exceeds a certain level the centralization gains are never positive, hence decentralization always yields a higher aggregate welfare level than centralization. In Figure 8.b we perform a similar exercise for the parameter $\delta$ that measures the impact of parental human capital in the offspring's learning technology. The reverse U-shape remains for the curve $\Delta\Omega_C$, but beyond a certain level of $\delta$ centralization can never outperform decentralization. It can be checked that all contemplated scenarios satisfy the parameter restriction $\gamma < (1-\delta)(1-\psi_1)$ in the relevant range of $\psi_1$.

**Figure 8a: Changing γ**




(γ =0.01, γ =0.15, γ =0.3), given δ =0.1

**Figure 8b: Changing δ**




(δ=0.01, δ=0.15, δ=0.5), given γ=0.05

In sum, these simulations suggest that there are cases where centralization is never better than decentralization, even if the regions have identical $\psi_i$'s. This is more likely to happen if the learning technology is rather productive, meaning that the parameters $\delta$ and $\gamma$ are large. Intuitively this is due to the fact that under a centralized fiscal regime the government tends to devote a larger budget share to infrastructure and a smaller share to education funding (see proposition 1). This has particularly large effects if the elasticity of the single components of the learning technology is large.