Public Budget Composition, Fiscal (De)Centralization and Welfare

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Abstract
We present a dynamic two-region model with overlapping generations. There are two types of productive public expenditure, education and infrastructure funding, and governments decide optimally on budget size (tax rate) and its allocation across the two outlays. Productivity of government infrastructure spending can differ across regions. This assumption follows well established empirical evidence, and highlights regional heterogeneity in a previously unexplored dimension. We study the implications of three different fiscal regimes for capital accumulation and aggregate national welfare. Full centralization of revenue and expenditure decisions is the optimal fiscal arrangement for the country when infrastructure spending productivity is similar across regions. When regional differences exist but are not too large, the partial centralization regime is optimal where the federal government sets a common tax rate, but allows the regional governments to decide on the budget composition. Only when the differences are sufficiently large does full decentralization become the optimal regime. National steady state output is instead highest when the economy is decentralized. This result is consistent with the "Oates conjecture" that fiscal decentralization increases capital accumulation. However, in terms of welfare this result can be reversed.

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I. Introduction

The question of the optimal level of decentralization of government activities has received considerable attention in the last decades. Starting with Tiebout (1956) a large body of literature has analyzed a variety of reasons that determine whether a particular government activity ought to be carried out by the national government or by sub units of the national government.[1] What has, in contrast, received relatively little attention is the "Oates conjecture". Oates (1993) conjectured 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 (e.g., Davoodi and Zou 1998, Zhang and Zou 1998), others find a positive or no systematic one (e.g., Iimi 2005). There is also surprisingly little theoretical work on the relationship between fiscal decentralization and growth. The recent paper by Brueckner (2006) who argues that decentralization fosters growth by increasing the incentives to save and to invest in human capital, is a notable exception. This study is complementary to his since it emphasizes a different channel that is important for the decentralization-growth nexus. A starting point of our analysis is the assumption that the stock of infrastructure is an essential input in the production of final goods and that the productivity of infrastructure varies considerably across different regions. This assumption is well supported by data[2], and it highlights an interesting dimension of regional heterogeneity that has previously not received sufficient attention in the theoretical literature.

We study the implications of fiscal (de)centralization for capital accumulation and aggregate national welfare in a simple dynamic model of a small federal economy with two heterogeneous regions. The (local or federal) government decides optimally on the size of the public budget by setting a tax rate, and on the composition of public spending across two types of productive expenditure, education and infrastructure funding. Revenue and expenditure decisions are not necessarily carried out by the same layer of government. More specifically, we study three different fiscal regimes: 1) Full decentralization in which each region chooses all its policy parameters – the tax rate and budget shares allocated to education and respectively infrastructure – independently in

[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.

[2] Charlot and Schmitt (1999) estimate the regional output elasticities of public capital for the regions of France and find that they differ by more than a factor of 4. Cohen and Morrison (2001) estimate how average manufacturing costs respond to public investment and find elasticities that vary by more than a factor of 4 across the US regions. For Spain, Moreno, Lopez-Bazo and Artis (2002) find the analogous elasticity to vary by more than a factor of 2. Romp and de Haan (2005) provide a comprehensive review on estimates for public capital elasticity, including studies at the regional level.

order to maximize regional welfare; This case is best viewed as applying to countries that are engaged in trading relationships but that have no common government structure at all. 2) Complete centralization where the federal government sets the same policy parameters in both regions 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 of the three regimes we consider . 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 we consider is especially relevant in the European context where regional policies are widespread. We view the cases of complete centralization and complete decentralization as important theoretical bench marks. This mixed regime of "partial centralization" captures the situation in many federal states fairly well. 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.

In the model we assume that the each region is completely specialized in the production of one particular good. All consumers are identical and value the two different goods from the two regions symmetrically. They live in an overlapping generations fashion for two periods and then die. The specification of individual preferences is similar to Glomm and Ravikumar (1992): All individuals derive utility from leisure when young, consumption goods when old, and from the quality of the child's education. In order to finance the expenditures on the two types of public goods, a tax on labor income is raised. In the first period agents choose to allocate time to learning or to leisure. Learning time together with parental human capital and publicly provided education generates the child's human capital. In the second period of life human capital is supplied inelastically to the labor market. Infrastructure, which is available as a local public good, augments the productivity of labor. The interaction between the two outlays of the public budget is incorporated naturally in our model, by recognizing the inherently dynamic nature of human capital formation in contrast to the contemporaneous effect of infrastructure.

Regions are assumed to differ in the productivity of infrastructure. Consequently, the degree of heterogeneity of the regional infrastructure spending productivities is key in determining which fiscal regime (centralized, de-centralized or mixed) maximizes aggregate national welfare in the steady state. We show that full fiscal centralization is the optimal regime when infrastructure spending productivity is similar across regions. When regional differences are not too large, our most realistic case of partial centralization is the optimal arrangement. Only when infrastructure productivity differences are sufficiently large does full decentralization become optimal.

The intuition for these results is that centralization has one advantage and one disadvantage compared to decentralization in this model. When making the optimal revenue and expenditure decision, regional governments fully try to manipulate the relative price of the two consumption goods, i.e., they try to use the policy instruments *strategically* in order to shift the terms of trade in their respective favour. If all decisions were made at the central level, the federal government, which maximizes a weighted sum of utilities of residents in both regions, takes into account the relative population sizes of the two regions when it calculates the effects of its policies on the relative price. It internalizes the fiscal externality that is at work under decentralization and minimizes the manipulation of the terms of trade.. It is useful to note that only when the two regions are of equal size, is there no relative price effect in the centralized solution. The disadvantage of centralization on the other hand 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 regions are similar, however, this cost is low and hence centralization is preferable over decentralization. In the regime of partial centralization one policy tool is taken away from regional governments (the tax rate), but they maintain one instrument that they can use strategically (the budget composition). This fiscal regime compromises on the pros and cons of (de)centralization. The fiscal externality is "partly" internalized, but regions may still differentiate policies to account for their heterogeneity. Yet, we also find some important asymmetries in the welfare gains (losses) that arise from partial centralization. In particular, there are cases where national welfare rises if both policy tools are centralized, but not if there is only a centralization of the decision about the tax rate. Underlying all these results is the fact that the optimal size, and the optimal budget composition depends on the degree of (de)centralization. In particular, we find that when two regions have similar infrastructure productivities, centralization implies a lower budget size but a higher optimal fraction that goes to infrastructure investment.

The second central result of this paper concerns the comparison of the three different fiscal regimes with respect to aggregate national output. We provide in fact a confirmation of the "Oates conjecture" by establishing that steady state aggregate income is highest when the economy is most decentralized and second highest under partial centralization. Recall, however, that the ordering of the three centralization regimes in terms of welfare may be reversed. That is, decentralization maximizes capital accumulation and hence long-run levels of output, but it need not be the optimal fiscal arrangement.

Our paper is related to a large literature on the effects of public infrastructure funding on capital accumulation and growth. Examples of work in this literature include Barro (1990), Glomm and Ravikumar (1994), Turnovsky and Fisher (1995) and Cassou and Lansing (1998). There is a similarly large literature on the effects of public education funding on capital accumulation and growth including papers by Loury (1981), Glomm and Ravikumar (1992), Benabou (1996), Fernandez and Rogerson (1996), Blankenau and Simpson (2004). In these models the focus is typically on *one* type of government expenditure and its effects on capital accumulation are relatively well understood. There is also a smaller but growing 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 ask: What are the effect on capital accumulation and growth of exogenous changes in policy? All of these models study the effects of policy reform in a single region economy. What is less well understood is how government policy influences economic outcomes when the economy has a federal structure where either the national or sub-national government chooses optimally between two types of productive public expenditure.

The paper is organized as follows. Section 2 presents the model, which is solved in section 3. Section 4 analyzes the optimal policies under different fiscal regimes while section 5 presents a welfare comparison of these regimes. Section 6 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. Each period a new cohort of young agents is born, so that total population in each region remains constant. We abstract completely from labor migration for three reasons. Firstly, a large previous literature (starting with Tiebout, 1956) has already analyzed (de)centralization when individuals are mobile and have heterogeneous preferences over the provision of public goods. Here we focus on trade as a different channel of interaction between regions. Second, together with the assumption of equal total factor productivity, regional wage differences are small, so that abstracting from migration may not be too restrictive an assumption. Third, at least in the context of many European countries, internal migration is small.

Regional population sizes may differ. We denote with $\rho_i > 0$ the size of a generation in region i=1,2. 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

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

where $c_{i,t+1}$ and $d_{i,t+1}$ are the goods produced in region 1 and in regions 2, respectively, consumed by a household in period (t+1) in region i. Here $n_{i,t}$ denotes leisure. The term $\left(E_{i,t+1}/\rho_i\right)$ 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 (ρ_i). This specification of preferences with the warm glow altruism is an extension of those used by Glomm and Ravikumar (1992). Each child in each of the two regions has access to a technology to produce human capital. This technology is given by

$$h_{i,t+1} = \theta\left(1-n_{i,t}\right)^{\eta}\left(E_{i,t}/\rho_i\right)^{\gamma} h_{i,t}{}^{\delta} \tag{2}$$

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 θ represents a productivity shifter of human capital accumulation, η and δ measure the elasticity of own time spend in education and parental human capital, respectively, and γ represents the productivity of government spending in the education sector. We assume that $\theta, \eta, \gamma, \delta > 0$ and $\gamma + \delta \leq 1$. Notice that with logarithmic preferences and with the Cobb-Douglas specification of the learning technology, our specification of preferences is equivalent to a specification in which human capital of the off-spring enters the utility function.
In each region output $Y_{i,t}$ is produced with a technology that employs human capital. The corresponding production function is given by:

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

where $H_{i,t}$ is the aggregate, and $h_{i,t}$ is the per capita level of human capital in region i. Productivity $A_{i,t}$ is a function of the per capita stock of infrastructure capital $G_{i,t}$ available at the time. We assume the following functional form where public infrastructure is essential for production but exhibits decreasing returns[3]

$$A_{i,t} = \overline{A}_i \cdot \left(G_{i,t} / \rho_i \right)^{\Psi_i} \tag{4}$$

The parameter $\overline{A}_i > 1$ is an exogenous and region-specific overall productivity level, and $0 < \psi_i < 1$ represents the productivity of public infrastructure spending in region i. Note that $\overline{A}_i$ and ψ_i are allowed to differ, whereas the other productivity parameters θ, η, δ and γ are assumed to be identical across regions. We also assume that the stock of infrastructure fully depreciates between periods.

The government finances both types of public expenditure, education spending and infrastructure investment by raising income taxes. We consider three cases. In the first case, each region has its own government, that is fiscal policy is completely decentralized. Let $\tau_{i,t}$ denote the tax rate at time t. Then the government budget constraint in region i is

$$E_{i,t} + G_{i,t} = \tau_{i,t} w_{i,t} H_{i,t} = \tau_{i,t} w_{i,t} \rho_i h_{i,t},$$

where $w_{i,t}$ is the wage per efficiency unit of labor. The government is not allowed to borrow. We will be studying the implication of allocating government revenue between

[3] Adjusting the productivity of the public capital by population size allows us to focus on regional interaction in the absence of scale effects in production

infrastructure investment and public education. Letting $0<\lambda_{i,t}<1$ denote the share of the government budget allocated to infrastructure we get

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

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

Section IV studies the cases of partial and complete centralization. In the partially centralized regime, the central government sets a common tax rate in both regions and allows the local governments to decide on the expenditure composition. In the fully centralized regime, both dimensions of the fiscal policy are decided at the central level.

III. Solving the Model for the Competitive Equilibrium

An agent in region 1 solves the following problem:

$$\underset{\{n_{1,t},c_{1,t+1},d_{1,t+1}\}}{Max}\quad U_{t,t+1}=\ln n_{1,t}+\ln c_{1,t+1}+\ln d_{1,t+1}+\ln\left(E_{1,t+1}/\rho_1\right) \tag{7}$$

subject to

$$h_{1,t+1}=\theta\left(1-n_{1,t}\right)^{\eta}\left(E_{1,t}/\rho_1\right)^{\gamma}h_{1,t}{}^{\delta} \tag{8}$$

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

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

where p_{t+1} is the relative price of the tradable good produced in region 2. Households in region 2 solve a similar 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: $\rho_1 d_{1,t}+\rho_2 d_{2,t}=(1-\tau_{2,t})\,Y_{2,t}$[4];
4) Government budget is balanced.

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

[4] This is the market clearing condition for good produced in region 2. The total output in region 2 equals demand of residents in region 1 $(\rho_1 d_{1,t})$, demand of residents in region 2 $(\rho_2 d_{2,t})$ and the government consumption in region 2, which equals the total tax receipts $(\tau_{2,t}Y_{2,t})$.

$$1-n_{1,t}=1-n_{2,t}=\left(2\eta/\left(1+2\eta\right)\right). \tag{10}$$

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

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

$$d_{1,t+1}=\frac{1}{2\,p_{t+1}}\left(1-\tau_{1,t+1}\right)w_{1,t+1}\,h_{1,t+1} \tag{12}$$

$$c_{2,t+1}=\frac{p_{t+1}}{2}\left(1-\tau_{2,t+1}\right)w_{2,t+1}\,h_{2,t+1} \tag{13}$$

$$d_{2,t+1}=\frac{1}{2}\left(1-\tau_{2,t+1}\right)w_{2,t+1}\,h_{2,t+1} \tag{14}$$

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

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

$$w_{i,t}=\bar{A}_i\left(\lambda_{i,t}\,\tau_{i,t}\,H_{i,t}\,\bar{A}_i/\rho_i\right)^{\psi_i/(1-\psi_i)} \tag{16}$$

$$E_{i,t}=\left(1-\lambda_{i,t}\right)\tau_{i,t}\left(\bar{A}_i\,H_{i,t}\right)\left(\lambda_{i,t}\tau_{i,t}\bar{A}_i\,H_{i,t}/\rho_i\right)^{\psi_i/(1-\psi_i)} \tag{17}$$

Using (6), (10) and (16) in (8) we obtain the following law of motion for human capital in region i:

$$h_{i,t+1}=\left[B\left(\bar{A}_i\left(1-\lambda_{i,t}\right)\tau_{i,t}\left(\bar{A}_i\;\lambda_{i,t}\;\tau_{i,t}\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]\cdot\left(h_{i,t}\right)^{\delta+\gamma\left(1+\frac{\psi_i}{1-\psi_i}\right)} \tag{18}$$

where $B\equiv\theta\left(2\eta/(1+2\eta)\right)^{\eta}$. Let us assume that $\gamma<\left(1-\delta\right)\left(1-\psi_i\right)$. This assumption imposes decreasing returns to scale in the augmentable factors and ensures that the economy will converge to a steady state in levels. If we had 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. With time-constant policy parameters τ_i, λ_i we obtain a unique steady state for human capital:

$$h_i\left(\tau_i,\lambda_i\right)=\left[B\left(\bar{A}_i\left(1-\lambda_i\right)\tau_i\left(\bar{A}_i\,\lambda_i\,\tau_i\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]^{\frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)}} \tag{19}$$

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

$$\rho_1\frac{1}{2p_t}\cdot\left(1-\tau_{1,t}\right)w_{1,t}\,h_{1,t}+\rho_2\frac{1}{2}\cdot\left(1-\tau_{2,t}\right)w_{2,t}h_{2,t}=(1-\tau_{2,t})\mathrm{Y}_{2,t} \tag{20}$$

Solving for the relative price yields:

$$p_t=\frac{\left(1-\tau_{1,t}\right)w_{1,t}\,\rho_1 h_{1,t}}{\left(1-\tau_{2,t}\right)w_{2,t}\,\rho_2 h_{2,t}}=\frac{\rho_1}{\rho_2}\cdot\frac{\left(1-\tau_{1,t}\right)\bar{A}_1\,h_{1,t}\left(\lambda_{1,t}\,\tau_{1,t}\,\bar{A}_1\,h_{1,t}\right)^{\psi_1/(1-\psi_1)}}{\left(1-\tau_{2,t}\right)\bar{A}_2\,h_{2,t}\left(\lambda_{2,t}\,\tau_{2,t}\,\bar{A}_2\,h_{2,t}\right)^{\psi_2/(1-\psi_2)}} \tag{21}$$

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 ($\rho_1=1$) from now on, and let $\rho_2=\rho$ measure the (relative) size of region 2.

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. Alternatively, this regime can be thought of as applying to two separate countries thata are engaged in a trading relationship, but that share no common government structure of any kind. In this case, the assumption of no migration is particularly appropriate 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.[5]

[5] 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. We also solved the infinitely-lived social planner's problem of maximizing time-discounted utility stream of all future generations. All results regarding the welfare maximizing fiscal regime are qualitatively the same as the

Since $\rho_1 = 1$, the optimization problem of the government 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 formulated as follows:

$$\underset{\{\tau_{1,t+1},\lambda_{1,t+1}\}}{Max} \; 2\ln\left(\left(1-\tau_{1,t+1}\right) w_{1,t+1} h_{1,t+1}\right) + \ln\left(E_{1,t+1}\right) - \ln p_{t+1} \tag{22}$$

subject to (16), (17), (21), and given $H_{1,t+1}$.

The corresponding problem in region 2 is:

$$\underset{\{\tau_{2,t+1},\lambda_{2,t+1}\}}{Max} \; 2\ln\left(\left(1-\tau_{2,t+1}\right) w_{2,t+1} \rho h_{2,t+1}\right) + \ln\left(E_{2,t+1}/\rho\right) + \ln p_{t+1} \tag{23}$$

subject to (16), (17) and (21), where $H_{2,t+1} = \rho h_{2,t+1}$ is given. Taking first order conditions, we obtain:

$$-\frac{1}{1-\tau_{i,t+1}} + \frac{1+\psi_i}{\tau_{i,t+1}(1-\psi_i)} = 0 \tag{24}$$

$$-\frac{1}{1-\lambda_{i,t+1}} + \frac{2\psi_i}{\lambda_{i,t+1}(1-\psi_i)} = 0 \tag{25}$$

Solving the equations above yields:

$$\tau_{i,t} = \tau_{i,t+1} = \tau^*_{D,i} = \frac{1+\psi_i}{2} \quad \in (0,1) \tag{26}$$

$$\lambda_{i,t} = \lambda_{i,t+1} = \lambda^*_{D,i} = \frac{2\psi_i}{1+\psi_i} \quad \in (0,1) \tag{27}$$

Equations (26) and (27) 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 ψ_i. This optimal policy choice 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

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myopic government's problem but are analytically less tractable. Derivations are available from the authors upon request.

form. Note further that the government in either region has an incentive to use policy instruments *strategically* in order to shift the terms of trade, p_{t+1}, in their favour while taking the policy parameters of the other region as given (see (21)). This jurisdictional competition generates a fiscal externality under decentralization that we will describe in further detail below. The optimal policy choice in region 1 still does not directly depend on infrastructure spending productivity in region 2 (or vice versa). This is also due to the logarithmic preferences.

Substituting (26) and (27) back into (19) yields the steady state level of human capital in region i under decentralization with all policy parameters chosen optimally:

$$h_{i,D}^{*}\left(\tau_{i,D}^{*},\lambda_{i,D}^{*}\right)=\left[\left(2^{-\gamma}B\right)\cdot\left(\bar{A}_i\left(1-\psi_i\right)\left(\bar{A}_i\,\psi_i\right)^{\frac{\psi_i}{1-\psi_i}}\right)^{\gamma}\right]^{\frac{1-\psi_i}{1-\gamma-\delta-\psi_i(1-\delta)}} \tag{28}$$

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.

IV.2. The fully centralized case

In the centralized case, distinguished by the subscript "C", a federal government optimally sets τ and λ 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. The case of equalization of all policies in the tax and expenditure dimension across regions is still an important theoretical benchmark. Therefore, neither the tax rate nor the expenditure share devoted to infrastructure is allowed to differ across regions. The objective of the government is:

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

This can be rewritten (again abstracting from constants) as follows:

$$\underset{\{\tau_{t+1},\lambda_{t+1}\}}{Max}\ \Omega_C = \left(ln\left(E_{1,t+1}\right) + \rho \cdot ln\left(E_{2,t+1}/\rho\right)\right) \tag{29}$$

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

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

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

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

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

and given $H_{1,t+1}$ and $H_{2,t+1}$. Taking the first order conditions, we obtain:

$$\frac{\partial\Omega_C}{\partial\tau_{t+1}} = -\frac{2(1+\rho)}{1-\tau_{t+1}} + \frac{1+\psi_1-2\psi_1\psi_2+\rho\left(1+\psi_2-2\psi_1\psi_2\right)}{\left(1-\psi_1\right)\left(1-\psi_2\right)\tau_{t+1}} \tag{30}$$

$$\frac{\partial\Omega_C}{\partial\lambda_{t+1}} = -\frac{1+\rho}{1-\lambda_{t+1}} + \frac{\psi_2\left(1+2\rho\right)+\psi_1\left(2+\rho-3\psi_2\left(1+\rho\right)\right)}{\left(1-\psi_1\right)\left(1-\psi_2\right)\lambda_{t+1}} \tag{31}$$

The first order condition with respect to the tax rate, equation (30), does not depend on λ_{t+1}, just like the first order condition with respect to the budget share, equation (31) does not depend on τ_{t+1}. This illustrates the separability of revenue and expenditure decisions by a government in this model. 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 weighted by the regional size ρ

$$\tau_C^* = \frac{1+\psi_1\left(1-2\psi_2\right)+\rho\left(1+\psi_2\left(1-2\psi_1\right)\right)}{3-\psi_1-2\psi_2+\rho\left(3-2\psi_1-\psi_2\right)} \in (0,1) \tag{32}$$

$$\lambda_C^* = \frac{\psi_1\left(2+\rho\right)+\psi_2\left(1+2\rho\right)-3\left(1+\rho\right)\psi_1\psi_2}{1+\rho+\psi_1+\rho\psi_2-2\left(1+\rho\right)\psi_1\psi_2} \in (0,1) \tag{33}$$

When policies are set according to (32) and (33) in both regions the optimal level of human capital in steady state in region i=1,2 follows directly from (19), 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 also deferred to appendix A. 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. Then there exists a threshold* $\overline{\psi} = \left(1+\rho+\psi_2(\rho+2)\right)/\left(3+2\rho\right)$ $\in (0,1)$ *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.*

Proof

First, from (26) 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 ψ_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 $\psi_1 > \overline{\psi} = \left(1+\rho+\psi_2(\rho+2)\right)/\left(3+2\rho\right)$ it follows that $\tau_{D,2}^* < \tau_C^*$ Thus, $\psi_1 > \overline{\psi}$ is a sufficient condition for $\tau_{D,2}^* < \tau_C^* < \tau_{D,1}^*$. Alternatively, $\tau_C^* < \tau_{D,2}^* < \tau_{D,1}^*$ if $\psi_1 < \overline{\psi}$. □

That is, the move 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 ψ_1 is larger than the threshold $\overline{\psi}$ that is given above, 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 $\psi_1 < \overline{\psi}$, 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. A crucial assumption behind this result is the absence of migration across jurisdictions. If labor or another factor of production were mobile, the tax competition in the decentralized regime would induce downward pressure on tax rates in the decentralized relative to the centralized regime. Since income differentials are small by assumption in our model, incentives for migration will be small as well so that we can highlight the effects of terms of trade manipulation on tax rates in the two different regimes.

Similarly, we can state the following result:

Proposition 2

Assume without loss of generality that $\psi_2 < \psi_1$. *Then 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

First, from (27) 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 easily shown then 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 $\psi_1 > \tilde{\psi}$. □

In other words, the move from de-centralization to centralization will always increase the budget share devoted to infrastructure in the "low-ψ" region that used to spend relatively little on infrastructure under decentralization. In a sense this ordering of budget shares between the centralized and the decentralized regime derives from the same economic mechanism as the ordering of tax rates in Proposition 1.The relative price depends on the wage income in the two regions and wage income is a function of the stock of human capital, which in turn depends on public education expenditures. This the share of the government budget allocated to public education can be used to manipulate the terms of trade in a manner that is similar to the use of tax rates for terms of trade manipulation. In the "high-ψ" region the infrastructure share may increase or decrease. A sufficient condition that the budget share under centralization is higher than under decentralization in both regions is that ψ_1 is below the threshold $\tilde{\psi}$ given above, i.e. that the difference in regional infrastructure spending productivities is not too large. In case of a large difference between ψ_1 and ψ_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 whether 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 in our model both publicly provided goods enhance the productivity of immobile labor.

An instructive special case is the one with equally large regions where infrastructure spending productivity is the same in both regions, i.e. ρ=1 and $\psi_1 = \psi_2 = \psi$. Comparing (26) and (27) with (32) and (33) it can be shown that:

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

If the two regions are exactly identical, centralization clearly leads to a lower optimal tax rate, and to a higher budget share devoted to infrastructure. This illustrates the fiscal externality that is at work in this model. Under decentralization individual governments take into account the effect of public policies on the relative price p when choosing optimal policies, whereas the federal government takes the population size into account when it determines how policies influence the relative price. This effect disappears completely when the two countries are of equal size (this can be seen from expression (29) for total welfare where the term containing the relative price level falls out when $\rho=1$). To clearly see this, suppose $\tau_{D,1} = \tau_{D,2} = \tau_C^*$. When $\rho=1$ and $\psi_1 = \psi_2 = \psi$ the expression for the relative price (21) becomes:

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

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.

$$\frac{\partial p_t}{\partial \tau_{1,t}} = \Phi\, \tau_{1,t}^{\frac{1}{1-\psi}} \left(\frac{\psi - \tau_{1,t}}{1-\psi}\right), \text{ where}$$

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

But $\tau_C^* > \psi$, so $\tau_{1,t} > \psi$. Thus, an increase in $\tau_{D,1}$ reduces the relative price p (which benefits region 1). It can be shown also that an increase in $\tau_{D,2}$ increases p (which benefits region 2). Thus, under full decentralization, $\tau_C < \tau_{D,1} = \tau_{D,2}$. Similarly, starting from $\lambda_{D,1} = \lambda_{D,2} = \lambda_C^*$, a reduction in $\lambda_{D,1}$ decreases the productivity of workers in region 1 and their disposable income. This results in a decrease in p (which benefits region 1). Similarly, a reduction in $\lambda_{D,2}$ increases p (which benefits region 2). Thus, $\lambda_{D,1}^* = \lambda_{D,2}^* < \lambda_C^*$.

IV.3. The partially centralized case

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 across regions within a country while expenditure policies aare allowed to vary across geographically defined regions. This geographic variation seems especially pronounced when there are large income or wealth differences across regions while they are likely to be modest when geographic income differentials are small.This setup loosely corresponds to the situation in Germany, where the single states (*Länder*) have discretion over the composition of their local budgets but have few own sources of tax revenue. 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

$$\tau_{1,P}^{*} = \tau_{2,P}^{*} = \tau_{C}^{*} \qquad \text{and} \qquad \lambda_{i,P}^{*} = \lambda_{i,D}^{*} \qquad \text{for } i = 1,2$$

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-ψ" 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): $\Omega_{P}^{*}\left(\tau_{C}^{*}, \lambda_{i,D}^{*}\right) = U_{1,P}^{*} + \rho \cdot U_{2,P}^{*}$.

Finally, there is also the other 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.

V. Comparison of fiscal regimes

We now compare the different fiscal regimes from a normative point of view by analyzing total national welfare in the two-region economy for decentralization, full centralization and partial centralization (see also appendix A). For the matter of comparing these fiscal regimes, we consider total welfare *differences*

$$\Delta\Omega_{C} \equiv \Omega_{C}^{*}\left(\tau_{C}^{*}, \lambda_{C}^{*}\right) - \Omega_{D}^{*}\left(\tau_{i,D}^{*}, \lambda_{i,D}^{*}\right) \quad \text{and} \quad \Delta\Omega_{P} \equiv \Omega_{P}^{*}\left(\tau_{C}^{*}, \lambda_{i,D}^{*}\right) - \Omega_{D}^{*}\left(\tau_{i,D}^{*}, \lambda_{i,D}^{*}\right) \tag{34}$$

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

Proposition 3

The optimal fiscal regime does not depend on the total factor productivity levels $\bar{A}_1, \bar{A}_2$, *the productivity of human capital accumulation,* θ, *and the input elasticity of own time spent in education,* η.

Proof:
Plugging all endogenous variables into (34) *it is possible to show that*

$$\frac{\partial(\Delta\Omega_z)}{\partial\bar{A}_i} = \frac{\partial(\Delta\Omega_z)}{\partial\theta} = \frac{\partial(\Delta\Omega_z)}{\partial\eta} = 0 \qquad \text{for } z = C, P,\ i = 1,2$$

for all admissible values of $\psi_1, \psi_2, \rho, \delta$ *and* γ. □

The parameters $\bar{A}_1, \bar{A}_2, \theta$ and η affect the welfare *levels* in the two regions. For example, the larger is the total factor productivity $\bar{A}_i$, the higher is welfare in region i under any fiscal regime, everything else equal. However, these parameters do not influence which fiscal regime is the optimal one. The intuition behind proposition 3 is that the respective parameters (i) have no effect on the optimal policy choices under any fiscal regime, and (ii) that they enter welfare functions as constant terms due to log utility. This can be seen easily by taking logs of equation (19), the steady state level of human capital, which fixes all other endogenous variables:

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

The first term consists of exogenous parameters only and does not depend on τ_i or λ_i, hence it will cancel out when differencing welfare expressions for different fiscal regimes. The same is not true for the parameters δ and γ. Although they do not directly affect the policy choices of τ_i or λ_i, they enter also the second term in and will therefore have an impact on the welfare differences $\Delta\Omega_C$ and $\Delta\Omega_P$.

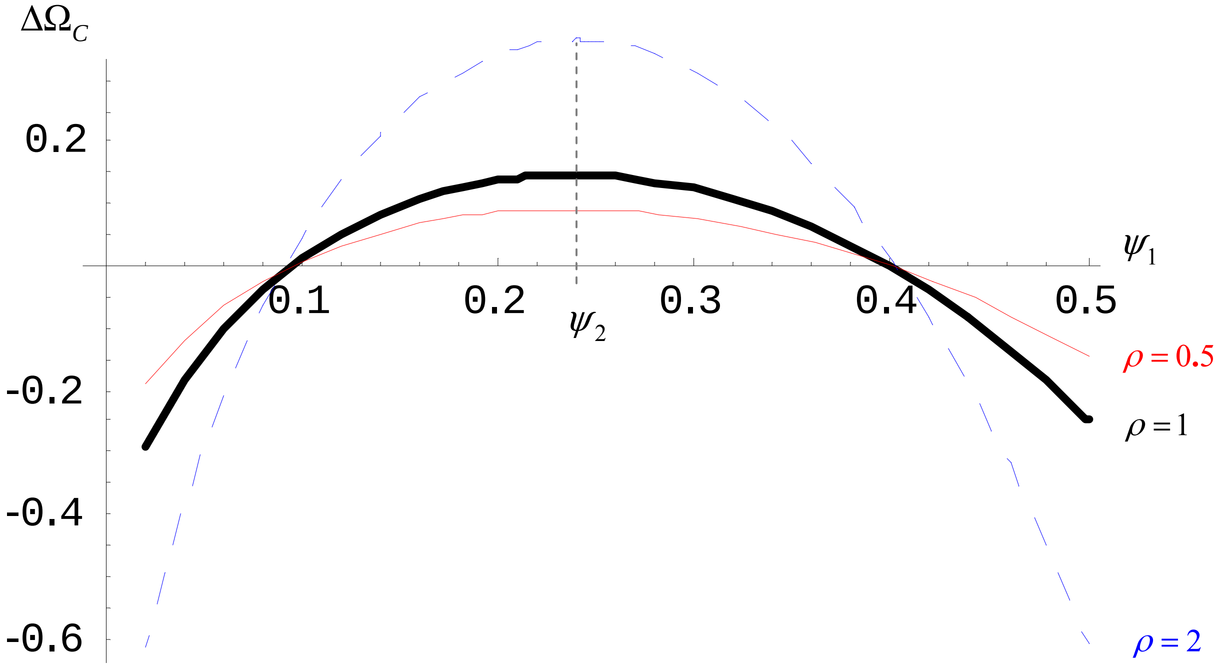
V.1. Gains from full centralization

We first study the gains from full centralization of fiscal policy. The crucial parameters for the normative analysis of $\Delta\Omega_C$ are ψ_1, ψ_2, and ρ because they directly influence optimal policy choices τ_i^* and λ_i^*. Still the expression for $\Delta\Omega_C$ does not render straightforward analytical results for general values of δ and γ. 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.[6] Given the parameter restriction $\gamma < (1-\delta)(1-\psi_i)$ stated above this imposes an upper bound of 0.944 for the infrastructure spending productivity ψ_i which

[6] For example, Rangazas (2000) uses values like 0.1-0.15 for the elasticity of public education and 0.2-0.25 for the elasticity of parental human capital in the education production function in the context of the US.

also seems to be perfectly in line with empirical estimates.[7] We present some robustness checks in appendix B where we let δ and γ vary. It turns out that parameter changes have little effects on our qualitative results.

Figure 1: Welfare gains from full fiscal centralization



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

We illustrate the gains from centralization in figure 1. We fix ψ_2 at some level and plot the function $\Delta\Omega_C$ against ψ_1 for different scenarios of country size ρ.[8] Purely for expositional purposes we pick $\psi_2 = 0.25$, and plot only the range of ψ_1 between zero and 0.5 instead of the full admissible range between zero and 0.944. If ψ_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 ψ_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

[7] Estimates of the elasticity of output with respect to public capital vary in the empirical literature depending on the type of data and the econometric methodology used. While time series studies obtain estimates as high as 0.4, panel data studies with fixed effects such as Holz-Eakin (1994) find much lower values. For an overview, see Romp and de Haan (2005).

[8] From proposition 3 we know that the choice of θ, η and $\overline{A}_i$ is completely irrelevant for our results, so we pick $\theta = 2$, $\eta = 0.5$ and $\overline{A}_1 = \overline{A}_2 = 5$.

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.

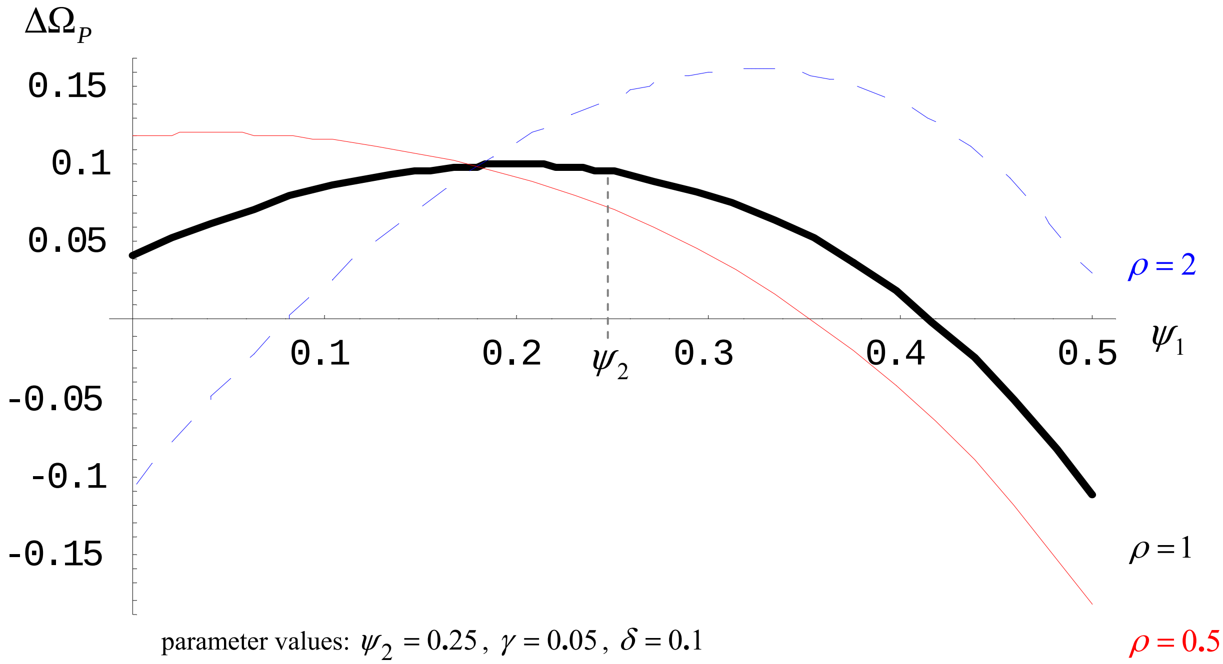
If spending productivity in region 1 is similar to that in region 2 full centralization yields higher aggregate national welfare than decentralization ($\Delta\Omega_C > 0$). In fact the gains from centralization are highest if the two regions have identical spending productivities. As regions get more dissimilar, i.e. if ψ_1 is sufficiently different from ψ_2, decentralization yields higher national welfare ($\Delta\Omega_C < 0$). Country size ρ matters only insofar as it affects the quantitative size of gains/loss from centralization. However, the parameter range of ψ_1 where centralization is preferable over decentralization does not depend on ρ. 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 ψ_2. That is, decentralization is preferable if regions are dissimilar in terms of their infrastructure spending productivity, but for given ρ results are analogous independent of whether ψ_1 is larger or smaller than ψ_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 also takes into account the effects of its policies on the relative price. In the case of centralization this relative price effect depends upon relative population sizes and vanishes completely when the two regions are of equal size. 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 happen to have the same spending productivity, i.e. if $\psi_1 = \psi_2$, 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. Hence centralization must lead to higher aggregate welfare in this case. The more dissimilar the regions are in terms of their ψ_i's, the more costly becomes the "one size fits all" policy associated with centralization. Hence, beyond a certain degree of dissimilarity decentralization is preferable over a centralized fiscal regime. For a given ψ_2 the gains from centralization increase quantitatively with the size of region 2.

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 ψ_1 for different scenarios of country size ρ, 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 tend to be similar in terms of their ψ_i s, and lower welfare ($\Delta\Omega_P < 0$) if they are sufficiently different.

Figure 2: Welfare gains from partial fiscal centralization



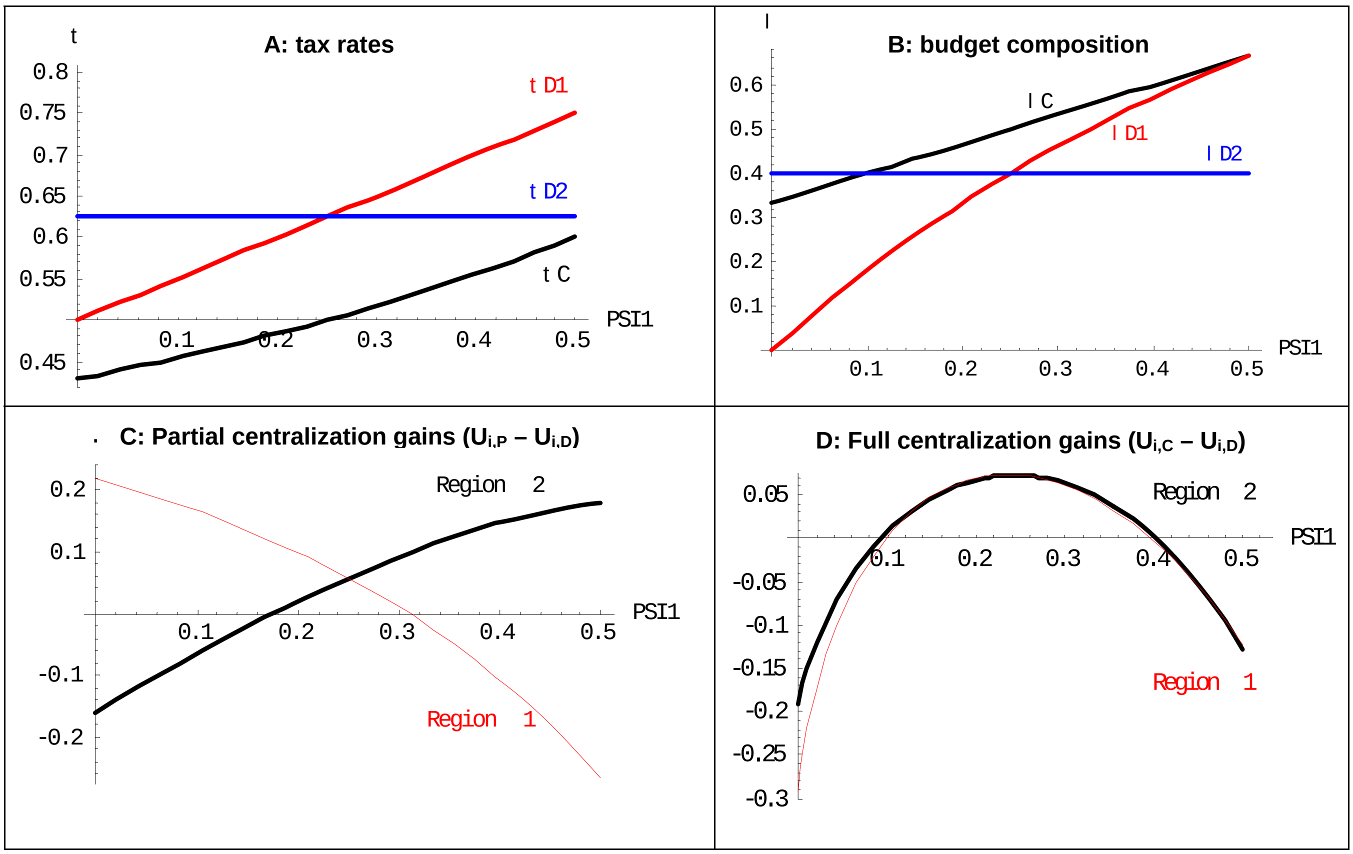
However, in contrast to $\Delta\Omega_C$ from figure 1, the curve $\Delta\Omega_P$ is not symmetric around ψ_2. To understand intuitively why this is so, consider first the case of equally sized regions ($\rho = 1$). For the parameter constellation $\psi_2 = 0.25$ and $\psi_1 \in [0,\ 0.5]$ one can compute:

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

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

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-ψ" region, and finds it optimal to spend a lower budget share on infrastructure than the "high-ψ" region 2. The optimal budget share $\lambda_{D,1}^*$ is further away than $\lambda_{D,2}^*$ from the budget share λ_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 ψ_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 which allows it to make a quite "idiosyncratic" strategic decision, namely to spend only a small share on infrastructure.

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



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

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 ψ_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 ψ_1 the interest of the "low-ψ" 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 ψ_1 while $\left|\lambda_C^{*} - \lambda_{D,1}^{*}\right|$ is decreasing in ψ_1 (panels A, B). The preference of the "high-ψ" region for the decentralized regime will dominate beyond a certain level of ψ_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.

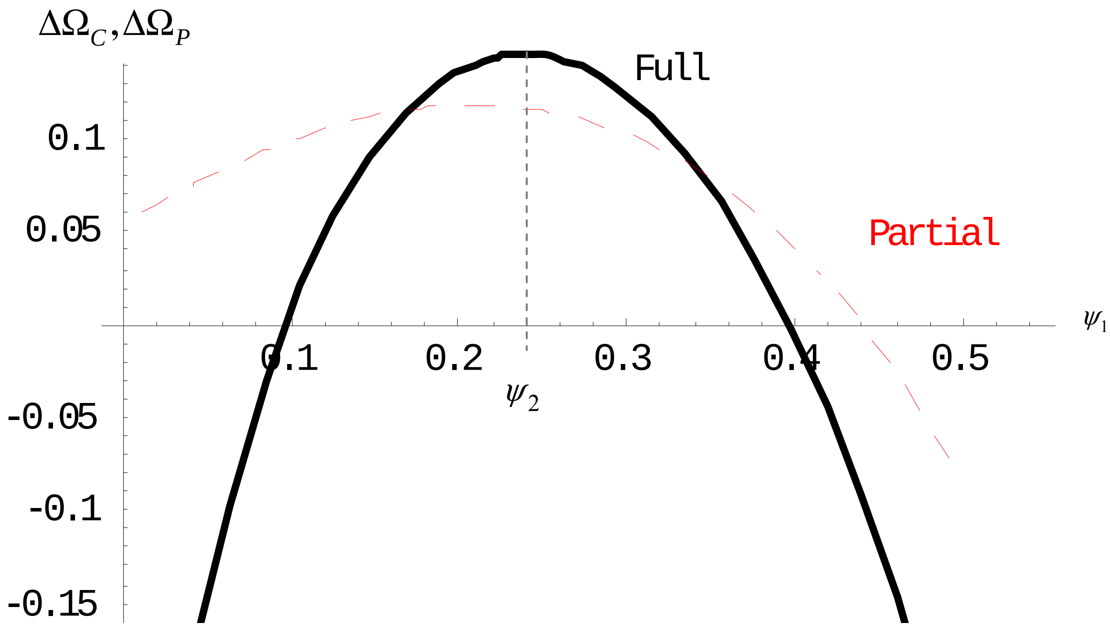
When ρ=2, i.e. the population in region 2 is twice as large as in region 1, the decentralized regime is preferred over the partially centralized one when ψ_1 approaches zero, and vice versa when ψ_1 approaches its maximum value (see figure 2). This is because the weight of region 2 in the aggregate welfare is now higher. A similar argument applies when ρ=0.5. Finally, 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 around $\psi_2 = 0.25$ in figure 1.

A comparison of figures 1 and 2 reveals the following interesting outcome: There are parameter constellations where the move to full centralization generates a welfare gain, but a move to partial centralization generates a welfare loss. This is the case when $\rho = 1$ and when ψ_1 is just below 4. This result is reminiscent of analogous results from the tax competition literature where restrictions on policy variables chosen by the regional governments might actually turn out to be detrimental since they could induce local governments to compete more vigorously along those dimensions which remain fully under their control (see, for example, Keen 2001 and Janeba and Smart, 2003).

V.3. Optimal fiscal regime

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 decentralization is optimal if they are sufficiently strongly different in their ψ_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 ψ_1 approaches zero, implying different regional and *low average infrastructure productivity,* the partial centralization prevails as the optimal regime. When ψ_1 increases beyond the given ψ_2 this also implies more different regions but *high average infrastructure productivity* in the nation as a whole. Starting from $\psi_1 = \psi_2$ where full centralization is optimal, an increase in ψ_1 first renders partial centralization the optimal regime. After a certain level of dissimilarity when ψ_1 increases further, full decentralization becomes the optimal arrangement. This prevails until ψ_1 reaches its maximum value $1-\gamma/(1-\delta)$.

Figure 4: Optimal fiscal regime



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

The above 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. For example, as is clear from Figure 2, for large values of ρ decentralization is dominated by partial centralization over a wide range of values of ψ_1 larger than ψ_2.

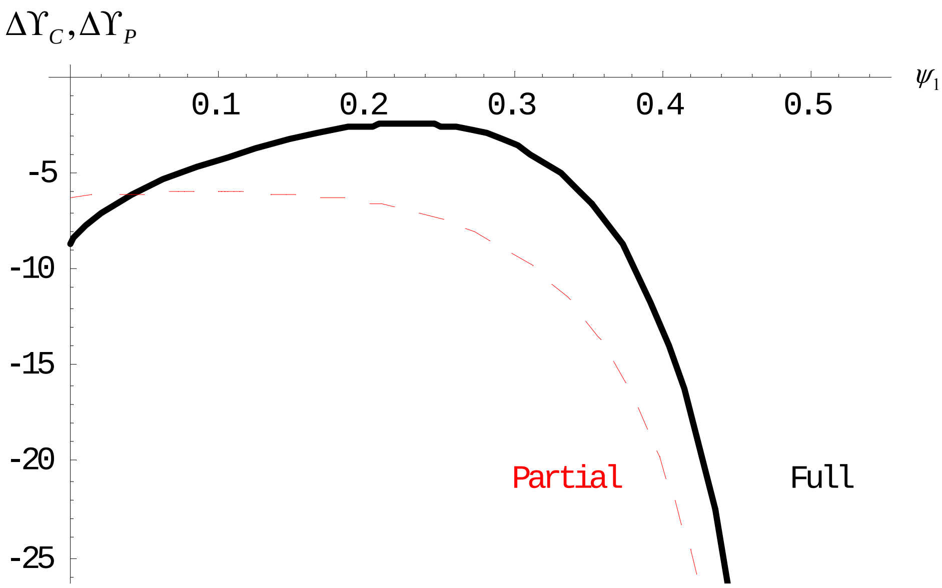
V.4. Implications for steady state output level

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 (19) as $\Upsilon = w_1 \cdot h_1(\tau_1, \lambda_1) + \rho \cdot w_2 \cdot h_2(\tau_2, \lambda_2)$. It is given by

$$\Upsilon(\tau_1,\tau_2,\lambda_1,\lambda_2)=\frac{\left(\bar{A}_1\lambda_1\tau_1\cdot h_1(\tau_1,\lambda_1)\right)^{1/(1-\psi_1)}}{\lambda_1\tau_1}+\rho\cdot\frac{\left(\bar{A}_2\lambda_2\tau_2\cdot h_2(\tau_2,\lambda_2)\right)^{1/(1-\psi_2)}}{\lambda_2\tau_2} \tag{35}$$

Plugging the values τ_i and λ_i from (26), (27), (32) and (33) into (35) yields expressions for national steady state output in the three different fiscal regimes, given that the respective policies are chosen *optimally*. That is, we do not consider new policy rules for revenue and expenditure decisions that maximize (local or national) output, but we evaluate the consequences of welfare maximizing policies for output in the different regimes. 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 appendix A.

Figure 5: Fiscal centralization and output



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

In figure 5 we plot $\Delta\Upsilon_C$ and $\Delta\Upsilon_P$ for the same parameter constellation as in figure 4. It turns out that in this constellation any type of fiscal centralization is always associated with a lower steady state output level. This finding is consistent with the "Oates conjecture" that fiscal decentralization leads to faster capital accumulation, and it is also qualitatively in line with the recent findings by Brueckner (2006) although our model relies on entirely different mechanisms. Note, however, that even though centralization is associated with lower gross domestic product in the present constellation, it is nevertheless the optimal, welfare maximizing fiscal regime if the regional infrastructure spending productivities are sufficiently similar.

The reason for this discrepancy can be described intuitively for the case of identical regions (for formal derivations of the argument, refer to appendix C). If ψ_1 and ψ_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 our propositions 1 and 2. This policy change implies a lower level of human capital accumulation h_i^* and lower school quality E_i^* 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 in 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 increase aggregate national welfare when $\psi_1 = \psi_2$ and $\rho = 1$ although it decreases the gross domestic product.[9] The output under partial decentralization is lower compared to the full centralization case since the size (τ) and the structure (λ) of the regions' budgets are jointly chosen optimally in the centralized regime while in the semi-centralized case the composition of the budget is suboptimal, *given* the budget size has already been chosen at the central level.

VI. Conclusion

We study the implications of the government policies on education and infrastructure in a two-region economy under three different regimes (centralized, de-centralized or mixed). Our main concern is to characterize the optimal tax rate and budget shares in each scenario and analyze which fiscal regime maximizes aggregate national welfare.

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. We also find that fiscal

[9] The result that fiscal centralization is associated with an output loss is not an entirely general conclusion. Numerical simulations suggest that $\Delta\Upsilon_C > 0$ may occur, in particular, if $\bar{A}_1 > \bar{A}_2$ and $\psi_1 < \psi_2$ (or $\bar{A}_1 < \bar{A}_2$ and $\psi_1 > \psi_2$).

decentralization may 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.

The framework used in this paper relies on a few simplifying assumptions. We assumed that both regions are characterized by the same level of total factor productivity (TFP). In most interesting cases there are large differences in incomes and TFP across regions. The 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. We have also abstracted completely from migration. Allowing for differences in TFP which can generate realistic income differences will give rise to substantial regional migration flows. Studying these extensions is left for future work.

References

Alesina, A. and Spolaore E. (1997), “On the Number and Size of Nations”, *Quarterly Journal of Economics*, 112, 1027-1056.

Arcalean C., G. Glomm and I. Schiopu (2006), “Growth Effects of Geographic Redistribution Policies”, *CAEPR Working Paper*, Indiana University.

Arzaghi, M. and J.V. Henderson (2005), “Why Countries are Fiscally Decentralizing?”, *Journal of Public Economics*, 89, 1157-1189.

Arze del Granado, H., J. Martinez-Vazquez and R.M. McNab (2005), “Fiscal Decentralization and the Functional Composition of Public Expenditure”, Georgia State University, Andrew Young School of Policy Studies, Working Paper 05-01

Baier, S. L. and Glomm, G. (2001), "Long-run growth and welfare effects of public policies with distortionary taxation", *Journal of Economic Dynamics and Control*, 25, 2007-2042

Barro, R.J. (1990), "Government Spending in a Simple Model of Endogenous Growth", *Journal of Political Economy*, 98, 103-26

Bénabou, R. (1996), "Inequality and Growth", *CEPR Discussion Papers* 1450, London

Besley, T. and S. Coate (2003), “Centralized Versus Decentralized Provision of Local Public Goods: A Political Economy Approach”, *Journal of Public Economics*, 87, 2611-2637.

Blankenau, W.F. and N.B. Simpson (2004), "Public education expenditures and growth", *Journal of Development Economics*, 73, 583-605

Bolton, P. and G. Roland. (1997), “The Breakup of Nations: A Political Economy Analysis”, *Quarterly Journal of Economics*, 112, 1057-1080.

Brueckner, J.K. (2006), “Fiscal Federalism and Economic Growth”, *Journal of Public Economics*, 90, 2107-2120

Brueckner, J.K (2004), “Fiscal Decentralization with Distortionary Taxation: Tiebout vs. Tax Competition”, *International Tax and Public Finance*, 11, 133-153.

Cassou, S. P. and K.J. Lansing (1998), "Optimal fiscal policy, public capital, and the productivity slowdown", *Journal of Economic Dynamics and Control*, 22, 911-935

Charlot, S. and B. Schmitt (1999), "Public Infrastructure and Economic Growth in France's Regions", ERSA conference papers, European Regional Science Association

Cohen, J. and P.C.Morrison (2001), "Public Infrastructure Investment, Costs, and Inter-State Spatial Spillovers in U.S. Manufacturing: 1982-96", Department of Agricultural & Resource Economics, UC Davis.

Cremer, J. and T.R. Palfray (1996), "In or Out? Centralization by Majority Vote", *European Economic Review*, 40, 43-60

Davoodi, H. and H. Zou (1998), "Fiscal decentralization and economic growth: A cross-country study", *Journal of Urban Economics*, 43, 244-257

Devajaran, S., V. Swaroop and H. Zou (1996). "The composition of public expenditure and economic growth", *Journal of Monetary Economics*, 37, 313-344

Diaz-Cayeros, A. (2005), "Fiscal Centralization, Political Institutions and the Territoriality of Local Public Goods Provision in Europe in the 20th Century." PIEP Conference Paper, Princeton University

Fernandez and Rogerson (1996), "Income Distribution, Communities, and the Quality of Public Education", *Quarterly Journal of Public Economics*, 111, 135-164

Glomm, G. and B. Ravikumar (1992), "Public versus Private Investment in Human Capital Endogenous Growth and Income Inequality", *Journal of Political Economy*, 100, 813-34

Glomm, G. and B. Ravikumar (1994), "Public investment in infrastructure in a simple growth model", *Journal of Economic Dynamics and Control*, 18, 1173-1187

Iimi, A. (2005), "Decentralization and economic growth revisited: An empirical note", *Journal of Urban Economics*, 57, 449-461

Janeba, E. and M. Smart (2003), "Is targeted tax competition less harmful than its remedies?", *International Tax and Public Finance* 10, 259-280.

Kaganovich, M. and I. Zilcha (1999), "Education, social security, and growth", *Journal of Public Economics*, 71, 289-309

Keen, M. and M. Marchand (1997), "Fiscal Competition and the pattern of public spending', *Journal of Public Economics*, 66, 33-53.

Keen, M. (2001), "Preferential regimes can make tax competition less harmful", *National Tax Journal*, 54, 757-762.

Loury, G.C (1981), "Intergenerational Transfers and the Distribution of Earnings", *Econometrica*, 49, 843-67

Martinez-Vazquez, J. and R.M. McNab (2003), “Fiscal Decentralization and Economic Growth”, *World Development*, 31, 1597-1616

Matsumoto, M. (2004), “The mix of public inputs under tax competition”, *Journal of Urban Economics,* 56, 389-396.

Moreno, R., E. Lopez-Bazo and M. Artis (2002), "Public infrastructure and the performance of manufacturing industries: short- and long-run effects," *Regional Science and Urban Economics*, 32, 97-121

Oates, W.E. (1972), *Fiscal Federalism*. New York, NY: Harcourt Brace, Jovanovich.

Oates, W. E. (1993), “Fiscal Decentralization and Economic Development”, *National Tax Journal,* 46, 237-243

Panizza, U. (1999), “On the Determinants of Fiscal Centralization: Theory and Evidence”, *Journal of Public Economics*, 74, 97-139

Persson, T. and G. Tabellini (2000), *Political economics: explaining economic policy*, MIT Press

Rangazas, P. (2000), “Schooling and Economic Growth: A King-Rebelo Experiment with Human Capital”, *Journal of Monetary Economics*, 46, 397-416

Seabright, P. (1996), “Accountability and Decentralization in Government: An Incomplete Contracts Model”, *European Economic Review*, 40, 61-89

Turnovsky, S. and W. Fisher (1995) "The Composition of Government Expenditure and its Consequences for Macroeconomic Performance”, *Journal of Economic Dynamics and Control*, 19, 747-786

Zhang, T. and H. Zou (1998), “Fiscal Decentralization, Public Spending, and Economic Growth in China”, *Journal of Public Economics*, 67, 221-240

Appendix A: Welfare under different fiscal regimes

A.1 Decentralization

Substituting (26)-(28) into (16), (17) and (21) 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 (22) and (23) we obtain regional welfare levels:

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

$$+ Ln\left[\frac{\rho\,(1-\psi_2)}{\psi_2} \cdot \left(B \, \bar{A}_2 \, \psi_2 \cdot \left(h_{2,D}^{*}\right)^{\delta} \cdot \left(\frac{(1-\psi_2)}{2} \bar{A}_2 \, h_{2,D}^{*} \left(\bar{A}_2 \, \psi_2 \, h_{2,D}^{*} \right)^{\frac{\psi_2}{1-\psi_2}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_2}} \right]$$

and

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

$$+ 2Ln\left[\frac{(1-\psi_2)}{\psi_2} \cdot \left(B \, \bar{A}_2 \, \psi_2 \cdot \left(h_{2,D}^{*}\right)^{\delta} \cdot \left(\frac{(1-\psi_2)}{2} \bar{A}_2 \, h_{2,D}^{*} \left(\bar{A}_2 \, \psi_2 \, h_{2,D}^{*} \right)^{\frac{\psi_2}{1-\psi_2}} \right)^{\gamma} \right)^{\frac{1}{1-\psi_2}} \right]$$

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 (32) and (33) steady state human capital (19) 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 (16), (17) and (21) 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 (27) and (33) 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:

$$U^*_{1,P} = Ln\left[\frac{1}{1+2\eta}\right] + 2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_1\, \sigma''_1 \cdot \left(h^*_{1,P}\right)^{\delta} \left(E^*_{1,P}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right] + Ln\left[\frac{\rho\sigma'}{\sigma}\left(B\,\bar{A}_2\, \sigma''_2 \left(h^*_{2,P}\right)^{\delta} \left(E^*_{2,P}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right]$$

$$U^*_{2,P} = Ln\left[\frac{1}{1+2\eta}\right] + 2Ln\left[\frac{\sigma'}{\sigma}\left(B\,\bar{A}_2\, \sigma''_2 \left(h^*_{2,P}\right)^{\delta} \left(E^*_{2,P}\right)^{\gamma}\right)^{\frac{1}{1-\psi_2}}\right] + Ln\left[\frac{\sigma'}{\rho\sigma}\left(B\,\bar{A}_1\, \sigma''_1 \left(h^*_{1,P}\right)^{\delta} \left(E^*_{1,P}\right)^{\gamma}\right)^{\frac{1}{1-\psi_1}}\right]$$

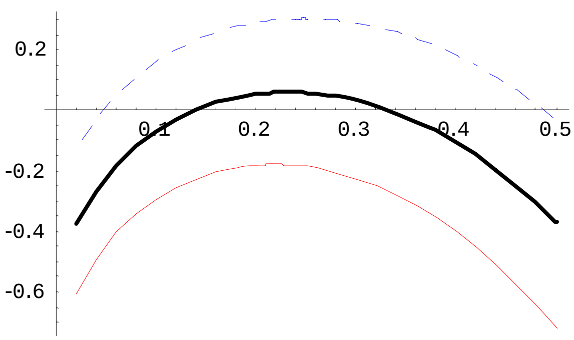
which can then be used in an analogous way to compute aggregate welfare $\Omega^*_P = U^*_{1,P} + \rho \cdot U^*_{2,P}$ and national output $\Upsilon^*_P = Y^*_{1,P} + \rho \cdot Y^*_{2,P}$.

Appendix B: 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 γ and δ. For brevity we will only consider the gains from centralization ($\Delta\Omega_C$). Furthermore, since country size plays no critical role we only look at the case with $\rho = 1$

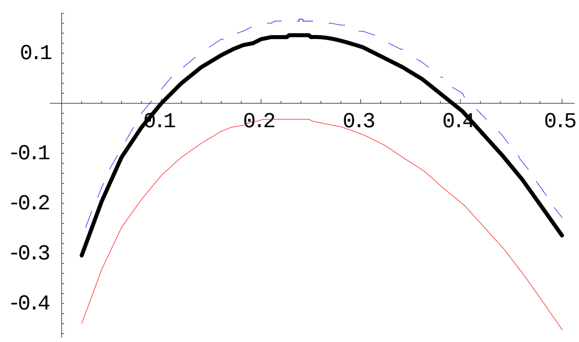
In figure 6a we plot $\Delta\Omega_C$ for three different scenarios of the productivity of public education spending γ, for given values of δ and ψ_2. In all scenarios we obtain the same reverse U-shaped curve as in fig.1, i.e. the gains from centralization mainly accrue when regions are similar in terms of their infrastructure spending productivities ψ_i. However, if γ exceeds a certain level the centralization gains are never positive, hence decentralization always yields a higher aggregate welfare level than centralization. In Figure 6b we perform a similar exercise for the parameter δ 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 δ 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 ψ_1.

Figure 6a: Changing γ



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

Figure 6b: 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 ψ_i's. This is more likely to happen if the learning technology is rather productive, meaning that the parameters δ and γ 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 2). This "neglect" of schooling has particularly large effects if the elasticity of the single components of the learning technology is large.

Appendix C: Output versus welfare

In the case with two identical regions ($\psi_1 = \psi_2 = \psi$, $\bar{A}_1 = \bar{A}_2 = \bar{A}$, $\rho = 1$), the difference in human capital formation between decentralization and full centralization 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, i.e. centralization leads to less human capital formation in both regions. The respective difference in wages, school quality, gross and net national output is given by

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

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

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

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

That is, fiscal centralization leads to lower wages, school quality and gross output. However, net income and thus consumption is higher under centralization. This effect dominates so welfare is higher under centralization with two identical regions.