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Public policies, growth, and agglomeration

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Public policies, growth, and agglomeration

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Abstract

This paper analyzes within a two-region endogenous growth model how different types of public policies affect the equilibrium spatial distribution of economic activity. Integration is modeled as a continuum and enables firms to access the public input of the respective other region. Given a dominance of agglomeration forces, multiple equilibria arise at which spreading becomes unstable and the stable equilibrium is characterized by a core-periphery structure. If only partial coordination of the two governments' decisions is realized, the positive productivity impact of one region's public input on the other region's marginal capital return becomes a positive externality. Then, the concentration of public inputs may end up to be suboptimally high or low, depending on the degree of scale effects. We perform numerical simulations to derive the equilibrium capital distribution and to disentangle the impact of the various determinants on equilibrium agglomeration.

Key words: spatial endogenous growth; integration; policy coordination; multiple equilibria

JEL: O4, R5

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1 Introduction

The 2014 Annual Growth Report of the the European Union identifies five priority areas for the EU and its member states that altogether set the framework conditions for future growth in Europe. The spatial dimension of these policies is only implicitly addressed by the superordinate goal of convergence in the sense of EU wide equalization of living standards. One of the five priority areas, labeled 'Promoting growth and competitiveness for today and tomorrow', specifies the provision of infrastructure or the enhancement of cross border connections as policy instruments (compare European Commission 2013, Section 5).¹ Further lines within this priority area rely on the implementation of new forms of cooperation as regards e.g. the modernization of national innovation and research systems. In doing so, the underlying policy rationale is based on two different political dimensions: The EU simultaneously addresses projects conducted jointly at the EU level as well as country-specific (or even regional) challenges upon which the member states decide more or less autarkic. It is obvious that these two dimensions require different intensities of policy coordination thereby representing in extreme the regimes of either independent or coordinated policy-making across the nations.

Altogether, public policy may not be reduced to coordination but is much more complex and has to consider the respective institutional frameworks. Aside from the mere budget size, the members have to decide on its composition. Which share shall be devoted to consumptive or productive expenditure the latter covering e.g. investment in R&D or in (physical or digital) infrastructure? What is the impact of the chosen financing scheme, and to which extent may fiscal policy be used to simultaneously correct for market failures and secure sufficient revenues to guarantee a balanced budget? How do all these public decisions affect productivity of the complementary private factors, e.g. labor or capital thereby possibly inducing mobility to the most productive places?

The paper at hand intends, within a comprehensive spatial growth model with a productive public input and connected/ integrated economies, to disentangle how the various influencing channels of public policy affect the resulting spatial distribution of economic activity. In doing so, it contributes to getting a deeper understanding of the agglomeration-growth nexus of public policy thereby especially taking into account the impact of different institutional arrangements in the sense of the aforementioned various degrees of policy coordination and in light of the policy goals of ongoing growth

¹A map of the TNT-N infrastructure network can be found at http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/maps_upload/09_01_2014SchematicA0_EUcorridor_map_outlined.pdf, special attention on port and railway services.

and convergence. Aside from this, the paper relies on and combines several lines of economics, namely growth theory, new economic geography, and public economics.

The paper is organized as follows. After a discussion of the building blocks we set up the framework of the model in Section 3 and derive equilibrium agglomeration in Section 4. The subsequent section discusses government activities and different policy coordination mechanisms. The paper closes with a summary.

2 Building blocks and related literature

One striking empirical regularity since the era of industrialization is sustained and ongoing worldwide growth with only few exceptions.² Another global trend is ongoing urbanization with the result that today production and wealth is strongly concentrated in big cities, leading provinces, and industrialized nations.

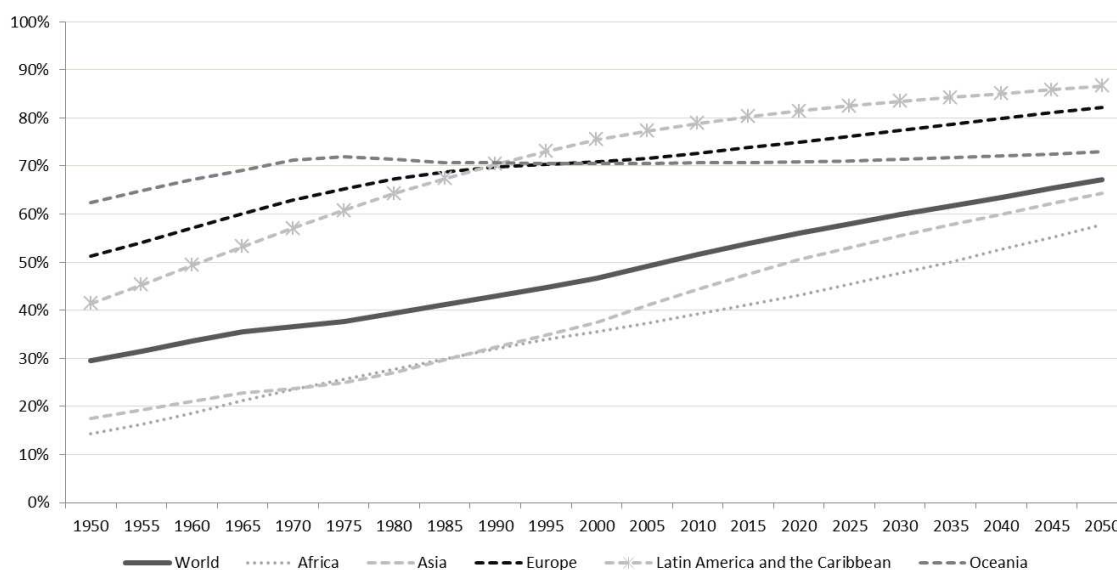


Figure 1: Urban population by selected global regions, history and forecast; source: own calculation based on data provided by the United Nations Department of Economic and Social Affairs, Population Division 2012.

²E.g. Sub-Saharan Africa. Detailed data since the year 1 AC can be found e.g. within the New Maddison Database (www.ggd.c.net/maddison) or the Penn World Tables (pwt.sas.upenn.edu) for time series starting in 1950. Accompanying the growth story are the famous stylized facts identified by Kaldor (1961) and recently updated by Jones and Romer (2010).

An in-depth analysis of the underlying mechanisms has been provided by the World Bank's 2009 report entitled 'Reshaping Economic Geography'. Forecasts of the United Nations impressively highlight that this trend is expected throughout the next several decades (compare also Figure 1). In addition, spatial zooming illustrates a fractal dimension of concentration, i.e. ongoing concentration might be observed at different levels of aggregation (global, continental, national, regional and even city-level)³ A less aggregated perspective, however, derives some critical thresholds that restrict the positive relationship such that the strengthening of the core-periphery structures might come to a halt (compare Brühlhart and Sbergami (2009)).



(a) geographical boundaries: Italy and the Mediterranean sea



(b) institutional boundaries: fisher boats at the yellow sea, the vertical line reflects the maritime political borders between the two Koreas

Figure 2: Both figures are taken from the NASA video found at <http://www.youtube.com/watch?v=Q3YYwIsMHzw>

Similarly, the NASA regularly presents beautiful pictures and videos that intuitively shape a natural understanding for spatial concentration of economic activity. Aside from intuitive evidence a more precise look unravels that it is not only natural but also man-made borders that underly the economic landscape (compare Figure 2).

Notice that the various empirical regularities are considerably not the outcome of the nation's natural factor endowment but of the institutional embedding of individual activity. Thus, the policy design and thus the role of the government is of major importance. The government's impact is even more pronounced if it additionally organizes the provision of a public input such as physical or research infrastructure. In what fol-

³Compare e.g. for the city-level the well-recognized Zipf's law (also known as rank-size distribution); demonstrations for a huge variety of countries can be found at <http://demonstrations.wolfram.com/ZipfsLawForCities/>.

lows we strongly relate the argumentation on the role of the government within growth and geographical economics thereby including productive governmental spending.

Within endogenous growth theory, those models strongly influenced by Barro (1990) analyze fiscal policies if the public input is productive and thus serves as a growth determinant. These models have been continuously refined to allow for different characteristics, e. g. congestion of the public input (see, e. g., Glomm and Ravikumar (1994a, 1994b), Eicher and Turnovsky (2000), Fisher and Turnovsky (1998) or Turnovsky (2000a) for a generalized presentation). However, all these models focus on the growth impact of a productive public input of a single economy and issues of convergence only rely on transitions paths to the long-run equilibrium. Naturally it is not possible to analyze comprehensive aspects such as integration and/or coordination within such a single-economy framework and hence to explain the spatial distribution of economic activity as a mere consequence of interacting economic spaces or to analyze how the provision of a 'local' public input contributes to the emergence of core-periphery structures.

This concern lies at the heart of the models known as 'New Economic Geography' (henceforth NEG) which bases on the seminal work of Krugman (1991) (for recent overviews on the NEG see Krugman (1995), Fujita et al. (2001) or Brakman et al. (2009); see also the recent Handbook of Regional Science (Fischer and Nijkamp 2014)). These models identify imperfect competition, increasing returns, and transportation costs as fundamental resources shaping the economic landscape as the outcome of interacting agglomeration and dispersion forces. Still few papers focus on public activity within a spatial context, among them are Martin and Rogers (1995) or Brakman et al. (2002, 2008) who implement transportation cost reducing infrastructure that facilitates trade within and between countries in the formal framework. This specification implies that the public input acts as unambiguous agglomeration force. A more precise view is presented by Puga (2002) who highlights that a more general consideration of infrastructure neglects that different characteristics of the public input also operate differently in the light of mitigating regional disparities. Consequently, a thorough analysis of the impact of regional policy also requires a sophisticated modeling of the public input and has to take into account other policy dimensions as, e. g., the extent of integration as well as the regimes determining the design of policy coordination across regions.

One might summarize: though some NEG models include public policies, they mostly consider productive governmental activity as the mere provision of infrastructure which reduces transportation costs thereby reinforcing prevailing regional disparities; in contrast, Barro-type growth models focus on the provision of a productive input that is complementary to private inputs but neglect spatial interaction of economies. More generally speaking, the exclusive focus of endogenous growth models on first-nature

geography as fundamental growth determinants neglects man-made 'second-nature geography' conditions, such as e.g. the institutional embedding. Today, however, the latter is more important for spatial concentration (e.g. Acs and Sanders (2014)). The literature covers several papers that address different parts of the discussed arguments in various combinations. A non-exhaustive list includes the following papers. Baldwin and Forslid (2000) combine agglomeration and growth in a formal model but neglect governmental activity. Devereux and Mansoorian (1992) analyze the growth impact of tax-financing schemes in an international context but the analyzed country's production conditions are spatially bounded. Baldwin and Martin (2004) only implicitly discuss the impacts of a public input in the context of growth and agglomeration and do distinguish neither between local and global public inputs nor the underlying coordination processes necessary for a joint provision. Baldwin et al. (2003) or Pflüger and Südekum (2008) combine economic geography with public policy but neglect growth and thus the dynamic perspective.

The goal of the paper at hand, however, is to analyze the impact of broadly defined governmental activity on agglomeration in growing economies that are linked to each other. Within such a setting, government activity includes various fiscal and non-fiscal instruments among them the decision to cooperate with respect to a certain public input and the financing of the corresponding expenditure. A comprehensive analysis includes both direct and indirect effects of any public policy.⁴ Hence governmental policy comprises several dimensions. *Cooperation* includes integration in the sense of the possibility to access the other region's input. What we have in mind is the following: Large research institutions, such as the CERN in Geneva are intensively used by international researchers from all around the world; national infrastructure networks are connected via bridges or ferries thereby providing access to individuals beyond the core region⁵; international approval of foreign schooling or university degrees, e.g. as a consequence of the Bologna reforms of the educational system in Europe. By way of integration, a locally provided public input may affect productivity of complementary private inputs in remote regions. In contrast to this, *coordination* refers to the governments' decision-making process (i.e. the aforementioned policy regimes) and addresses those policies related to decisions concerning amount, type, and financing details of the public input. For example, there is a common decision within the European Union on

⁴These activities, namely the provision of a public input and the underlying coordination processes usually also require an immense effort to coordinate various stakeholders aside from national or regional politicians. However, within this paper we strictly focus on the governments.

⁵Recall that one of the explicitly mentioned goals of the EU is the completion of the core TEN-T corridors as well as the enhancement of cross-border connections (European Commission 2013, Section 5).

the cohesion fund. But there are separate national decisions on infrastructure expenditures. Another important aspect in this context is, e.g., tax competition between regions in order to attract firms or feeding back to policy of the other region. Most recently, the European Commission stresses that: "Member States should design their national policies taking [...] EU level instruments fully into account. This will not only enhance the impact of national policies but will also produce synergies at the EU level." (European Commission 2013, 3).

Within the developed formal framework, if the economies jointly determine their policy decision they almost act as a single country or region ('full coordination'). In contrast to this are partial or intermediate coordination levels whereas we also address the situation of autarkic decisions as reference. The degree of integration between the two economies is presented by a scaling to which extent the two 'local' public inputs become effective for productivity of the other inputs in the respective other region. We detail this in equation (2).

3 The model

The aforementioned argumentation provides the basis for the theoretical model. We analyze the impact of integration and coordination on agglomeration with the goal to contribute to a differentiated analysis within the convergence debate. To do so we implement a Barro type growth model in a framework firstly presented by Bröcker (2003) and further developed by Ott and Soretz (2010) into a two-region setting. The public input is characterized by congestion parameters (absolute and relative) to allow for manifold interpretations, e. g. physical infrastructure (roads, airports, telecommunication networks) but also as basic research, universities or training networks of education. This requires a slightly extended specification of the congestion function provided by Eicher and Turnovsky (2000). Again, due to externalities, the decentralized decisions turn out to be suboptimal thus providing an additional justification for governmental activity.

Integration between the two regions is modeled as the extent to which one region may benefit from the other region's public input. This formulation relies on Alesina and Spolaore (2003) and captures a different approach than the usual one within NEG that considers integration as the source for reduced transportation costs.⁶ For the broad

⁶In these models, integration unambiguously strengthens agglomeration since it enables the individuals to benefit from local increasing returns in production and then shipping the goods to the other regions since transportation costs are a negligible component of total product price.

specification of the public input mentioned before, integration may e. g. be interpreted as increasing the flows of ideas between two regions (e. g. Rivera-Batiz and Romer (1991) argue similarly).

Firms in the symmetric regions, $i = 1, 2$, produce the homogenous final good, Y_i , according to the production function

$$Y_i = L_i^\lambda K_i^\alpha D_i^\gamma, \quad 0 < \lambda, \alpha, \gamma < 1; \quad \alpha + \gamma(1 + \varepsilon_A) = 1 \quad (1)$$

with L_i as immobile labor and K_i as physical capital in region i . The global public input, D_i , includes the regional public inputs, G_{si} , and access to the other region's input is given as

$$D_1 = G_{s1} + \beta G_{s2} \quad (2a)$$

$$D_2 = G_{s2} + \beta G_{s1} \quad (2b)$$

in which $\beta \in [0, 1]$ parameterizes integration between the two regions. It may be interpreted as a measure for the extent of integration between the two regions or, put differently, the extent to which the two public inputs become globally effective: If $\beta = 0$, firms in each region only benefit from the public input provided by their local governments; consequently, the scope of governmental policy is restricted to the home region. In contrast to this, $\beta > 0$ implies that firms in one region also have (at least partial) access to the other region's public input.

The symmetric public input provided by region i is given by

$$G_{si} = G_i \left(\frac{K_i}{\bar{K}_i} \right)^{\varepsilon_R} \bar{K}_i^{\varepsilon_A}, \quad 0 \leq \varepsilon_R \leq 1, \quad -\alpha \leq \varepsilon_A \leq 1 \quad (3)$$

where \bar{K}_i denotes the aggregate stock of private capital in region i , and G_i denotes the aggregate flow of government expenditure. Function (3) incorporates the potential for the regional public good to be associated with alternative degrees of scale effects, denoted by ε_A , or congestion, denoted by ε_R . We extend the specification of Eicher and Turnovsky (2000), such that we do not restrict the sign of ε_A to be negative but also allow for positive values. This enables us to interpret the formal analysis also in the light of education policies or comprehensive large research institutions (e. g. CERN)⁷ The goal is to analyze the concentration force of positive spillovers as well as the dispersion force of congestion and focus on the interdependent impact of them on the equilibrium distribution of economic activity.

⁷Nevertheless, in order to allow for ongoing growth, $-\alpha \leq \varepsilon_A$ has to be satisfied, as will be explained below.

Preferences of the identical and infinitely living household include maximizing lifetime utility out of consumption according to⁸

$$U_i = \int_0^{\infty} \frac{\sigma}{\sigma-1} C_i(t)^{\frac{\sigma-1}{\sigma}} e^{-\rho t} dt \quad \rho > 0, \quad 0 < \sigma < 1 \quad (4)$$

The subjective discount rate is denoted by ρ , σ is the elasticity of intertemporal substitution, and $C_i(t)$ describes consumption in region i .

Households save by accumulating a risk free asset. The asset value equals the value of the stock of capital at any point in time; hence, the asset value in region i at time t equals $V_i(t) \equiv q_1(t)K_{1i}(t) + q_2(t)K_{2i}(t)$, where q_i denotes the stock price of capital installed in region i . The immobile workers earn labor income as well as capital income from investment in both regions. Wages in region i are denoted by $w_i(t)$. The total income in region i evolves according to

$$\dot{V}_i(t) = w_i(t)L_i(t) + (r(t) - \delta)V_i(t) - C_i(t) - T_i(t) \quad (5)$$

with $r(t)$ denoting the interest rate determined in capital market equilibrium, δ as the constant depreciation rate of private capital and $T_i(t)$ a lump-sum tax that is used to finance the provision of the public input. To fully describe the optimization problem, the transversality conditions

$$\lim_{t \rightarrow \infty} K_{1i}(t)\xi_i(t) = 0 \quad \lim_{t \rightarrow \infty} K_{2i}(t)\xi_i(t) = 0 \quad (6)$$

have to be met, where ξ_i denotes the shadow value of capital in region i . Maximizing (4) subject to the accumulation constraint (5) leads to the Hamiltonian

$$\mathcal{H}_i = \frac{\sigma}{\sigma-1} C_i(t)^{\frac{\sigma-1}{\sigma}} e^{-\rho t} + \xi_i(w_i(t)L_i(t) + (r(t) - \delta)V_i(t) - C_i(t) - T_i(t)) \quad (7)$$

with optimal consumption described by the necessary conditions

$$\frac{\partial \mathcal{H}_i}{\partial C_i} = C_i^{-\frac{1}{\sigma}} e^{-\rho t} - \xi_i \stackrel{!}{=} 0 \quad (8a)$$

$$\frac{\partial \mathcal{H}_i}{\partial V_i} = \xi_i(r(t) - \delta) \stackrel{!}{=} -\dot{\xi}_i \quad (8b)$$

and leading to the well known growth rate of consumption as⁹

$$\frac{\dot{C}_i}{C_i} = \sigma(r - \delta - \rho) \equiv \varphi \quad (9)$$

⁸The setup of the model mainly borrows from Ott and Soretz (2010).

⁹In what follows time indices will be suppressed.

Households in both regions realize identical consumption growth, a direct consequence from homothetic preferences together with equal investment opportunities. Moreover, due to constant average returns of capital, the consumption-wealth ratio is constant and hence the growth rates of consumption, capital and income coincide. An increase in capital return, r , will increase the growth rate due to strengthened incentives for capital accumulation. In contrast, an income tax would reduce net capital return and therefore decrease the growth rate. It is well known from growth literature that a lump-sum tax $T_i(t)$ is growth neutral, since it does not influence capital return.

4 Equilibrium Agglomeration

4.1 Dynamic equilibrium

Denote the ratio of marginal capital productivities in both regions with

$$R \equiv \frac{\partial Y_1 / \partial K_1}{\partial Y_2 / \partial K_2} \quad (10)$$

A balanced steady state is then characterized by a stationary capital distribution, i. e., by $R = 1$, with positive investment in both regions and capital stocks growing according to (9).¹⁰

Since we focus on a growing economy, we assume that the public input grows with the equilibrium growth rate φ from (9). Governments in both regions set the aggregate expenditure levels, G_i , as a constant fraction, Θ_i , of aggregate capital, \bar{K}_i , namely

$$G_i = \Theta_i \bar{K}_i, \quad 0 < \Theta_i < 1 \quad (11)$$

An expansion in government expenditure is then parameterized by an increase in the capital share, Θ_i . Additionally we have to take into account that in equilibrium $\bar{K}_i = N_i K_i$ applies with N_i denoting the number of firms in region i . Then

$$\tilde{g}_s = \theta k^{1+\varepsilon_A} n^{1+\varepsilon_A-\varepsilon_R} \quad (12)$$

defines the equilibrium ratio of governmental activity, with $\theta \equiv \Theta_1 / \Theta_2$, $n \equiv N_1 / N_2$, and $\tilde{g}_s \equiv G_{s1} / G_{s2}$. In equilibrium, the ratio of marginal capital productivities turns out to equal

$$R = l^\lambda k^{\alpha-1} \left(\frac{\tilde{g}_s + \beta}{1 + \beta \tilde{g}_s} \right)^{\gamma-1} \cdot \left(\frac{\alpha(\tilde{g}_s + \beta) + \gamma \varepsilon_R \tilde{g}_s}{\alpha(1 + \beta \tilde{g}_s) + \gamma \varepsilon_R} \right) \quad (13)$$

¹⁰Note that, as long as the tax rates in both regions are equal, an income tax would not affect the balanced steady state.

Taking logarithms leads to the relationship

$$R \geq 1 \iff i(k) \geq -\lambda \ln l \quad (14)$$

with

$$i(k) \equiv (\alpha - 1) \ln k + (\gamma - 1) \ln \left(\frac{\tilde{g}_s + \beta}{1 + \beta \tilde{g}_s} \right) + \ln \left(\frac{\alpha(\tilde{g}_s + \beta) + \gamma \epsilon_R \tilde{g}_s}{\alpha(1 + \beta \tilde{g}_s) + \gamma \epsilon_R} \right) \quad (15)$$

representing the RHS of (13). The corresponding function is nonlinear and represents either one stable equilibrium if $i(k)$ is monotone (compare the dashed functions in figures 3(a)–3(c)). If instead, $i(k)$ is non-monotone, this reflects the existence of multiple equilibria, the latter showing different stability characteristics (compare the solid functions in figures 3(a) and 3(b)). An equilibrium results when this function $i(k)$ intersects the horizontal function which represents the threshold value $-\lambda \ln l$ which is independent of the capital distribution. Given identical endowments of the regions with immobile labor, i. e. given $l = 1 \Rightarrow -\lambda \ln 1 = 0$, the threshold value in (14) is represented by the horizontal axis. The resulting equilibrium is unstable whenever function $i(k)$ is positively sloped in the steady state distribution of capital, k^* . If then, starting from the steady state capital ratio, the relative capital productivity in region 1 increases ($R > 1$), the resulting productivity advantage in region 1 attracts investment and induces further increases of k . Hence the capital distribution departs continuously from the initial steady state and the system diverges from the unstable equilibrium. The argumentation holds analogously if, starting from an initially unstable equilibrium, k^{**} , the capital ratio is reduced and then declines continuously. If on the contrary the function $i(k)$ is negatively sloped for equilibrium capital ratios, an increase in k reduces the ratio of capital productivities ($R < 1$), thus giving rise to a productivity advantage in region 2. Then k declines and converges again to its original steady state value. Following Krugman (1991), for unequal steady state capital distributions, the region which holds the higher capital stock then represents the core of the entire economy, whereas the other region is the periphery.

4.2 Simulations

The simulations illustrate how equilibrium agglomeration is affected by integration (variation of β) and differentiates for two levels of the scale effect (red line: $\epsilon_A = 0.5$ and green line: $\epsilon_A = 0$). We assume symmetric factor endowments across the regions and proportional congestion. Formally, the analysis focuses on those determinants that affect the run of function $i(k)$ and in what follows, the underlying economic effects will be

discussed. Of special importance in this respect is the sign of the derivative $i'(k)$ which determines whether agglomeration forces ($i'(k) > 0$ evaluated at the spreading equilibrium, $k = 1$) or dispersion forces ($i'(k) < 0$ evaluated at the spreading equilibrium, $k = 1$) dominate. Formally, it is possible to derive the relationship between ε_A , ε_R and β that defines which parameter constellations finally end up in a stable spreading equilibrium and multiple equilibria. The bifurcation may be derived by solving $i'(k = 1) = 0$ for one of the three parameters, e.g. ε_A . Formally spoken, multiple equilibria arise, if the chosen value of ε_A exceeds the level of the bifurcation point $\bar{\varepsilon}_A(\beta, \varepsilon_R)$. Table 3 in Appendix A calculates the bifurcation point for various parameter constellations and thereby also provides the levels of $\bar{\varepsilon}_A$ mentioned in Figures 3(a)–3(c).

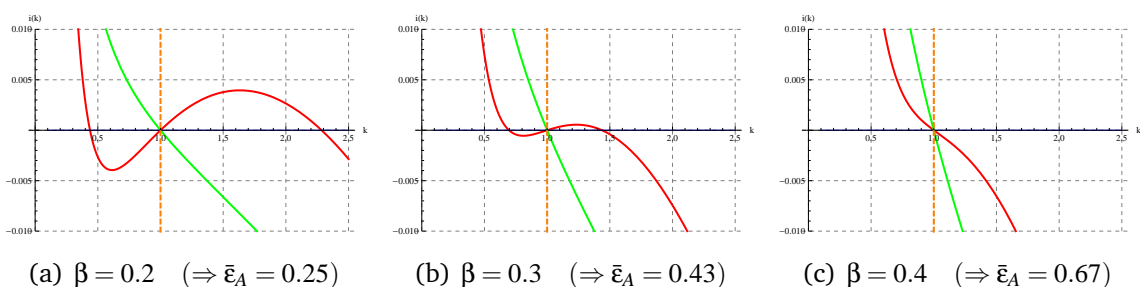


Figure 3: The impact of integration on equilibrium agglomeration parameters: $\alpha = 0.5$, $\lambda = 0.5$, $\varepsilon_R = 1$, symmetric factor endowment: $\theta = n = l = 1 \Rightarrow$ horizontal axis as threshold
red line: $\varepsilon_A = 0.5$, green line: $\varepsilon_A = 0$

Within the figures, the red lines represent high regional spillovers ($\varepsilon_A = 0.5$), while the green lines correspond to low levels ($\varepsilon_A = 0$). In case of $\varepsilon_A = 0 < \bar{\varepsilon}_A$, the prevailing agglomeration forces are too low, capital is equally distributed across the regions, and $k^* = 1$ (green line in figure 3(a)). If, instead, $\varepsilon_A = 0.5$, agglomeration is basically possible (see Figures 3(a) and 3(b)). There arise multiple equilibria with the two exterior ones being stable and representing a core-periphery structure. More integration reduces equilibrium concentration (lower k^*) as can be seen by comparing Figures 3(a) to 3(b). The intuition for this is as follows: Due to integration, the smaller region may also benefit from the spillovers of the bigger region. Consequently, capital accumulation does not move to the core. Figure 3(c) displays a situation in which dispersion forces dominate in either case and $k^* = 1$ represents the stable steady states. As argued before, increasing integration reduces the agglomeration forces.

5 Government activities

The following part sketches some fields for governmental activities, focusing on different degrees of coordination of regional policies. We distinguish (i) full coordination, where the regions decide simultaneously and commonly on their policy (ii) no coordination, hence decision on regional policy under the assumption that the other region's policy is exogenously given (Cournot solution), and (iii) partial coordination, where the bigger region takes care of the reaction function of the smaller region (leader-follower or Stackelberg solution).

Both regions' governments are assumed to be benevolent, that means they maximize the representative individual's welfare in the steady state, given in (4). Together with consumption growth according to (9), which is constant in the steady state, and implies a constant consumption-wealth-ratio $\mu = C/K$, individual welfare results in

$$\begin{aligned} U &= \frac{\sigma}{\sigma-1} \mu^{\frac{\sigma-1}{\sigma}} \int_0^{\infty} K(t)^{\frac{\sigma-1}{\sigma}} e^{-\rho t} dt = \frac{\sigma}{\sigma-1} (\mu K(0))^{\frac{\sigma-1}{\sigma}} \int_0^{\infty} e^{(-\rho + \varphi(\sigma-1)/\sigma)t} dt \\ &= \frac{\sigma (\mu K(0))^{\frac{\sigma-1}{\sigma}}}{(\sigma-1)(-\rho + \varphi(\sigma-1)/\sigma)} \end{aligned} \quad (16)$$

An increase in steady state growth ceteris paribus enhances welfare

$$\frac{\partial U}{\partial \varphi} = (\mu K(0))^{\frac{\sigma-1}{\sigma}} > 0 \quad (17)$$

The amounts of the regional public inputs, G_{s1} and G_{s2} , determine productivity in both regions and hence influence the income of the representative individual, $Y = Y_1 + Y_2$. Hence, a benevolent government sets the level of the public input in order to maximize the steady state growth rate

$$\frac{\dot{K}}{K} = \varphi = \frac{Y_1 + Y_2 - G}{K} - \delta - \mu \quad (18)$$

As both governments know the equilibrium relation $\bar{K}_i = N_i K_i$, the actually available amount of the public input is given by

$$G_{st} = G_t N_t^{\varepsilon_A - \varepsilon_R} K_t^{\varepsilon_A}, \quad (19)$$

The decision on government expenditures, G_i of both regions influences not only the own region's productivity, but due to integration also the amount of available public input in the other region. Hence, the decisions of both governments are interdependent and each government's expenditure will depend on its expectations about the other

government's expenditure. Therefore, we will distinguish between coordinated and uncoordinated governmental decisions. First, we analyze coordinated policy. Both regions decide conjointly on the respective amount of government expenditures. Afterwards, we focus on uncoordinated policies. Here we distinguish between the assumption of homogenous regions and the assumption of a leader-follower structure.

5.1 Full coordination

The public input basically is Barro-type. There is no production function for the public input, instead the homogenous consumption and investment good, Y , is converted 1:1 into government expenditures, G . Hence, marginal cost of government expenditure is 1. Marginal return of government expenditures is given by the marginal product, $\partial Y/\partial G$. The well known efficiency condition results in $\partial Y/\partial G = 1$.¹¹

If there is a coordinated decision of both governments about the respective government expenditures, they will choose G_1 and G_2 simultaneously and regard the impact of an increase in both public inputs on the aggregate income, $Y = Y_1 + Y_2$. Hence, coordinated policy is determined by

$$\frac{\partial Y}{\partial G_1} = \frac{\partial Y}{\partial G_2} = 1 \quad (20)$$

with the marginal products given by

$$\frac{\partial Y}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} + \gamma \frac{Y_2}{D_2} \beta N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} \quad (21a)$$

$$\frac{\partial Y}{\partial G_2} = \gamma \frac{Y_1}{D_1} \beta N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} + \gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \quad (21b)$$

Note that the productivity increase in region 2 caused by an increase in the public input of region 1 (and vice versa) is taken into account. This is due to the coordination of both regions' policies. Coordination implies that both governments regard aggregate income in both regions. Hence, the entire marginal return of the public inputs is taken into account, not only the productivity increase in the own region, but also the productivity increase in the other region.

Optimality then implies equalization of the marginal returns of government expenditures, (21a) and (21b), resulting in

$$\frac{Y_1}{Y_2} = \frac{D_1}{D_2} \frac{1 - \beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A}}{n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta} \quad (22)$$

¹¹See for example Barro and Sala-I-Martin (2004) p. 222 for this argumentation.

The use of the production functions (1) and the definition of the global public input (2) yields

$$\left(\frac{g_s + \beta}{1 + \beta g_s}\right)^{\gamma-1} = \frac{1 - \beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A}}{n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta} l^{-\lambda} k^{-\alpha} \quad (23)$$

If the regions are symmetric ($l = n = 1$) and the spreading equilibrium applies ($k = 1$), the right hand side equals unity. Using (12), the optimality condition reduces to

$$\frac{g_s + \beta}{1 + \beta g_s} = 1 \quad \Leftrightarrow \quad g_s = 1 \quad \Leftrightarrow \quad \theta^* = 1 \quad (24)$$

In the spreading equilibrium, government expenditures should be equally distributed. The reason is simply the diminishing returns of the public input.

If agglomeration arises, the steady state will be characterized by $k \neq 1$. Within the coordinated decision on the public inputs, the ratio θ^* will be adjusted correspondingly. In order to calculate the adjustment in θ^* , we have to notice that g_s at the left hand side as well as the term on the right hand side of (23) are influenced by the capital distribution k . This adjustment can be described by

$$\begin{aligned} \frac{d\theta^*}{dk} = & \left(\frac{1 - \beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A}}{n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta} \alpha k^{-1} + \frac{n^{\varepsilon_A - \varepsilon_R} \varepsilon_A k^{\varepsilon_A - 1} (1 - \beta^2)}{(n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta)^2} \right) \frac{l^{-\lambda} k^{-\alpha} (g_s + \beta)^{2-\gamma} \theta^* / k}{(1 + \beta g_s)^{-\gamma} (1 - \gamma) (1 - \beta^2) g_s} \\ & - (1 + \varepsilon_A) \frac{\theta^*}{k} \end{aligned} \quad (25)$$

The sign of (25) is indeterminate. The term in the first line may be positive or negative depending on the sign of ε_A . Additionally, there is a negative force, which is displayed in the second line of (25).

Three effects can be distinguished. First, if the steady state value of k increases, the capital distribution becomes more concentrated and hence the productivity of the public input increases in the larger region due to the better endowment with physical capital. *Ceteris paribus*, the expenditure for the public input will be shifted towards the larger region in order to equalize marginal productivity of the public input in both regions. The distribution of the public input becomes more unequal, θ^* increases. To give an example, in the metropolitan area, there is more need for infrastructure, hence the government share should be higher in the larger region. This effect is captured by the first term in parenthesis which is positive.

Second, the individually available amount of the public input increases in the larger region even if the government's expenditure share remains constant. The reason can be seen in equation (12). Without any change in the government share, the total amount of

government expenditures is higher in the larger region. For example, in the metropolitan area the range of professional education is much wider, and there are more fire brigades even if the ratio of government expenditure to aggregate capital is unchanged. This effect is captured in the second line of equation (25). It is negative, because it induces a substitution effect resulting in more equally distributed government's expenditure share, ceteris paribus θ^* decreases.

Third, there are interregional effects due to integration, because integration enables interregional substitution of government expenditures, G_i . Hence the optimal distribution of government expenditure shares, θ^* , is adjusted accordingly. This is described by the second term in parenthesis and can be positive or negative, depending on the sign of ϵ_A . If scale effects apply, $\epsilon_A > 0$, the increase in k augments the individually available amount of the public input in the larger region, according to (19). Hence, in order to increase the benefit from the scale effects, government expenditures are shifted from the smaller to the larger region. Ceteris paribus θ^* increases. Contrariwise, if absolute congestion applies, $\epsilon_A < 0$, an increase in k reduces the individually available amount of the public input in the larger region. A shift of government expenditures from the larger to the smaller region lowers the congestion disadvantage and results in a decrease in θ^* . Tables 1 and 2 and Figure 4 show the effects for different parameter settings.

Table 1: $\theta^*(k, \epsilon_A, \dots)$ from (23); symmetric factor endowment: $n = 1, l = 1$; other parameters: $\alpha = 0.5, \epsilon_R = 0.5, \beta = 0.5$

		ϵ_A										
		-1/4	-1/8	0	1/8	1/4	3/8	0.5	5/8	0.75	7/8	1
k	0.90	1.37	1	0.81	0.68	0.58	0.49	0.42	0.36	0.30	0.24	0.19
	0.95	1.17	1	0.90	0.83	0.77	0.72	0.68	0.63	0.59	0.56	0.52
	1	1	1	1	1	1	1	1	1	1	1	1
	1.05	0.86	1	1.10	1.19	1.28	1.36	1.45	1.54	1.64	1.74	1.84
	1.10	0.75	1	1.21	1.42	1.64	1.88	2.16	2.48	2.88	3.38	4.03

Comparing Tables 1 and 2 one can see the impact of the interregional substitution effect. With more integration (Table 1), the negative impact of an increase in k on θ^* in case of $\epsilon_A < 0$ as well as the positive impact in case of $\epsilon_A > 0$ both get more pronounced.

Figure 4 illustrates the optimal adjustment of the ratio of governments' expenditure shares, θ^* , depending on the degree of scale effects, ϵ_A . If ϵ_A is sufficiently low, absolute congestion applies and the individually available amount of the public input decreases with an increase in capital, according to (19). In order to evade the negative impact

Table 2: $\theta^*(k, \varepsilon_A, \dots)$ from (23); symmetric factor endowment: $n = 1, l = 1$; other parameters: $\alpha = 0.5, \varepsilon_R = 0.5, \beta = 0.25$

		ε_A										
		-1/4	-1/8	0	1/8	1/4	3/8	0.5	5/8	0.75	7/8	1
k	0.90	1.04	0.97	0.93	0.90	0.87	0.85	0.82	0.80	0.78	0.76	0.74
	0.95	1.02	0.99	0.97	0.95	0.94	0.92	0.91	0.90	0.89	0.88	0.86
	1	1	1	1	1	1	1	1	1	1	1	1
	1.05	0.98	1.01	1.03	1.05	1.07	1.08	1.09	1.11	1.12	1.13	1.15
	1.10	0.97	1.03	1.07	1.10	1.13	1.16	1.19	1.22	1.25	1.28	1.32

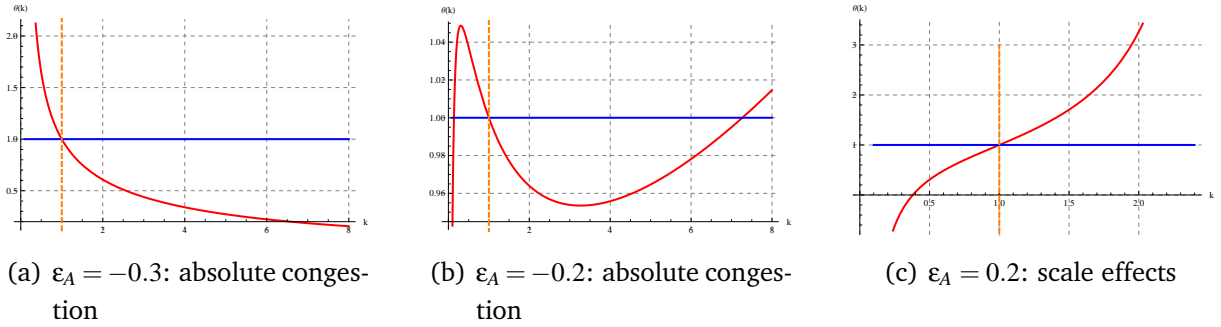


Figure 4: The impact of capital concentration on $\theta^*(k, \varepsilon_A, \dots)$
symmetric factor endowment: $n = 1, l = 1$
other parameters: $\beta = 0.25, \varepsilon_R = 0.5$

of absolute congestion, the public input is decreased in the larger region and increased in the smaller one. The negative effect of capital concentration on optimal government expenditure concentration in (25) dominates: optimal government expenditures are less concentrated if agglomeration arises. Moreover, the more concentrated the capital stocks in an agglomeration equilibrium the less concentrated the government expenditure should be. Nevertheless, if instead ε_A is sufficiently high, scale effects apply and the individually available amount of the public input increases with an increase in capital. Hence, an increase in capital concentration induces a rise in optimal government expenditure concentration in order to escalate the benefits from the scale effects. If agglomeration arises, the optimal government's expenditure share is higher in the larger region than in the smaller one. Integration enables the smaller region to occupy the public input provided by the larger region. This advice is in sharp contrast e.g. to the balancing EU regional policy.

In the following subsection, we focus on the absence of any coordination mechanism. If additionally the regions' governments behave symmetrically, the equilibrium turns out to be of Nash-Cournot type.

5.2 No coordination

Now we analyze the setting where each region decides autarkically on the level of government expenditure. Within their decision, the regions consider the public input of the respective other region as exogenous to the own decisions. This setting corresponds to the Cournot duopoly. Moreover, as no coordination mechanism exists, both regions only focus on the productivity enhancing impact of the public input on their own region's income. Hence, both regions compare marginal productivity of the public input in the own region with marginal cost

$$\frac{\partial Y_1}{\partial G_1} = 1 \quad \text{and} \quad \frac{\partial Y_2}{\partial G_2} = 1 \quad (26)$$

with the marginal products given by

$$\frac{\partial Y_1}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} \quad (27a)$$

$$\frac{\partial Y_2}{\partial G_2} = \gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \quad (27b)$$

Note that the marginal products which are taken into account in the Nash-Cournot setting neglect the productivity impact of the own public input on the other region's income. Therefore, this productivity impact becomes a positive externality.

The resulting ratio of governmental activity, θ^a , fulfills (26) and is consequently defined by

$$\frac{Y_1}{Y_2} = \frac{D_1}{D_2} n^{-\varepsilon_A + \varepsilon_R} k^{-\varepsilon_A} \quad (28)$$

and can be converted into

$$\left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma - 1} = n^{-\varepsilon_A + \varepsilon_R} k^{-\varepsilon_A - \alpha} l^{-\lambda} \quad (29)$$

If both regions are symmetric, $l = n = 1$ and the spreading equilibrium applies, the right hand side of equation (29) is unity and the Nash-Cournot solution implies equally distributed government expenditure, like in the coordinated policy case. Note that both regions disregard the productivity impact of their public input on the other region.

Hence, they choose a suboptimally low level of government expenditure. Nevertheless, since capital endowment is equal in both regions, the deviation between coordinated and autarkically chosen public input is same size resulting in $\theta^a = \theta^* = 1$.

Contrariwise, if there is agglomeration ($k \neq 1$), government expenditure will differ between the regions

$$\frac{\partial \theta^a}{\partial k} = \frac{(g_s + \beta)^{-\gamma} (1 - \beta^2) n^{\varepsilon_A - \varepsilon_R} l^{-\lambda} \theta^a k^{-\varepsilon_A - \alpha - 1}}{(1 + \varepsilon_A) (1 + \beta g_s)^{2-\gamma} g_s} - (1 + \varepsilon_A) \frac{\theta^a}{k} \quad (30)$$

Compared with the optimal adjustment of government expenditures to agglomeration, given in equation (25), the interregional substitution effect disappeared since the regional governments don't consider the interregional impact of their decisions. Figure 5 shows the effect of agglomeration on the concentration of government expenditures.

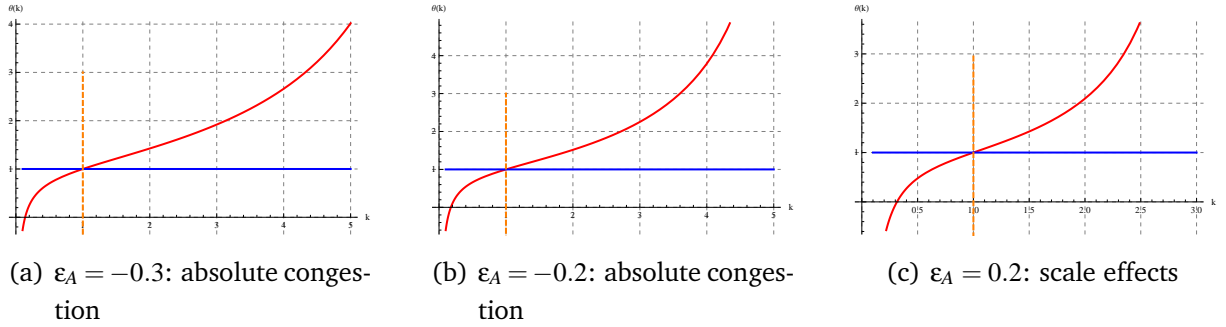


Figure 5: The impact of capital concentration on $\theta^a(k, \varepsilon_A, \dots)$; symmetric factor endowment $n = l = 1$; other parameters $\beta = 0.25$, $\varepsilon_R = 0.5$; blue line $\theta = 1$

For reasonable parameter settings, the positive effect of capital concentration on government expenditure concentration dominates. A rise in k increases the productivity of the public input prioritizing the larger region. Hence the government expenditure share in the larger region increases more rapidly than the government expenditure share in the smaller region. Consequently θ^a increases.

Even more interesting, will the concentration of government expenditure in the uncoordinated setting end up to be higher or lower than for coordinated policy? First, compare the right hand side of equations (23) and (29)

$$n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} \geq 1 \quad \Leftrightarrow \quad \frac{1 - \beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A}}{n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta} l^{-\lambda} k^{-\alpha} \leq n^{-\varepsilon_A + \varepsilon_R} k^{-\varepsilon_A - \alpha} l^{-\lambda} \quad (31)$$

Again, the result mainly depends on the characteristics of the public input described by ε_A . If there are scale effects ($\varepsilon_A > 0$), agglomeration with region 1 larger than region

2 implies $k_A^\varepsilon > 1$. For n near to 1, $n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} > 1$ follows immediately, hence the right hand side in equation (29) is larger than in (23). Contrariwise, if absolute congestion applies ($\varepsilon_A < 0$), agglomeration implies $n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} < 1$ and therefore the right hand side in equation (29) is smaller than in (23). The left hand side decreases in θ^a because

$$\frac{d \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1}}{d\theta^a} = \frac{\partial \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1}}{\partial g_s} \frac{\partial g_s}{\partial \theta^a} = (\gamma-1) \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-2} \frac{1 - \beta^2}{(1 + \beta g_s)^2} \frac{g_s}{\theta^a} < 0 \quad (32)$$

This implies that the respective ratio of governmental activity is lower (higher) in the Nash-Cournot setting than with coordinated policy, if scale effects (absolute congestion) apply

$$\varepsilon_A \geq 0 \quad \Leftrightarrow \quad \theta^a \leq \theta^* \quad (33)$$

The reason is the positive externality of public input on the other region's income. Both regions neglect this positive effect, hence they underestimate marginal productivity of the public input. As a consequence, they realize a suboptimally low level of the public input. If there are scale effects, the resulting distortion is the more pronounced, the bigger a region is. This leads to a suboptimally low realization of θ^a : the concentration of government expenditures is too low. If instead there is absolute congestion, the distortion is smaller in the larger region, hence the resulting concentration of government expenditure is suboptimally high.

5.3 Partial coordination

Of course, the assumption that each region considers the amount of the other region's public input as independent of the own decision, is quite unrealistic. Instead, the large region's government could behave as a leader and expect the small region's government to react on its decisions. This corresponds to the leader-follower situation in a Stackelberg duopoly. For instance, if a metropolitan area provides a university, the neighboring small city will discard to supply a university itself. Or, if one city decides to close some museums, the other city will consider to amplify its cultural environment. In the following, we assume that the larger region knows that the smaller region will react on its decisions. More precisely, the smaller region 2 takes the amount of the larger region's public input as given and reacts on it optimally according to what we derived above. The larger region 1 anticipates this reaction of the smaller region. It chooses the amount of the public input subject to the constraint that region 2 will adjust its public input accordingly.

The decision rule of the smaller region 2 was derived in the part above and consists in equalizing marginal cost and marginal benefit $\partial Y_2/\partial G_2 = 1$, hence

$$\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} = 1 \quad (34)$$

Marginal benefit is influenced by the amount of the public input in region 1, G_1 . Hence, government expenditures of region 2 are adapted to the observed amount of G_1 such that condition (34) is fulfilled again:

$$\frac{dG_2}{dG_1} = - \frac{\partial \left(\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \right) / \partial G_1}{\partial \left(\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \right) / \partial G_2} = -\beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} \quad (35)$$

If integration is positive, $\beta > 0$, an increase in the public input in region 1 induces an increase in the public input available to region 2, D_2 . Hence, the marginal product of the public input decreases and this leads to a reduction in the optimal amount of public input in region 2, G_2 . With stronger integration, this effect becomes more important.

Region 1 anticipates this reaction of region 2 within its optimization. When calculating the marginal benefit of public input, region 1 takes into account that the public input of region 2 will be the lower, the higher the amount of the public input of region 1:

$$\frac{dY_1}{dG_1} = \frac{\partial Y_1}{\partial G_1} + \frac{\partial Y_1}{\partial G_2} \frac{\partial G_2}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} (1 - \beta^2) \stackrel{!}{=} 1 \quad (36)$$

Combining both optimality conditions (34) and (36) immediately results in

$$\left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma - 1} = (1 - \beta^2) n^{-\varepsilon_A + \varepsilon_R} k^{-\varepsilon_A - \alpha} l^{-\lambda} \quad (37)$$

The right hand side of this equation is lower than the right hand side of equation (29) describing the Cournot solution. Hence, the left hand side has to be lower too, which implies a higher value of θ^s . The larger region 1 anticipates the reduction in the public input of region 2, hence it increases its own public input. As a consequence, the relation of public inputs, θ^s , increases and resulting concentration of economic activity gets nearer to optimal concentration.

5.4 Tax competition

Finally, we focus on the impact of tax policies. We assume that government income results out of linear taxes on income, τ_i , and a lump-sum tax, T_i , in the two regions. The

regional budgets are closed in each period if ¹²

$$G_t = \tau_t Y_t + T_t \quad (38)$$

Due to relative congestion, there is a negative externality of physical capital. With an increase in private capital, the individually available amount of the public input increases. For example, when a firm buys more trucks, it can use more of the streets. But if all firms buy more trucks, aggregate capital increases, the streets get more congested and the individually available amount of the public input decreases. Income taxation should be used in order to internalize the negative capital externality, whereas growth neutral lump-sum taxes close the budget.¹³ Nevertheless, since the income tax reduces the net capital return, the incentive for capital accumulation in the respective region is scaled down. Aggregate physical capital is reduced and scale effects of the public input will be lower. Hence, if the regional governments aim for regional growth maximizing, there is an incentive to reduce the income tax rates and to replace it by lump-sum tax financing.

With regional income taxation, the accumulation decision of households is determined by the ratio of net marginal capital productivities

$$R_{net} = \frac{(1 - \tau_1) \partial Y_1 / \partial K_1}{(1 - \tau_2) \partial Y_2 / \partial K_2} = \frac{1 - \tau_1}{1 - \tau_2} R \quad (39)$$

and taking logarithms leads to

$$R_{net} \geq 1 \iff i(k) \geq -\lambda \ln l - \ln \frac{1 - \tau_1}{1 - \tau_2} \quad (40)$$

where $i(k)$ remains unchanged as given in equation (15). When both income tax rates are chosen equally, $\tau_1 = \tau_2$, the ratio of net marginal capital productivities is unaffected. Of course, households will react on income taxation within their intertemporal utility maximization. Income taxation reduces the savings rate and consequently equilibrium capital growth, as is well known. However, the decision whether to invest in region 1 or region 2 is not modified when tax rates coincide. Hence, agglomeration remains unchanged.

If instead one region chooses to decrease the income tax rate, it enhances the attractiveness for investment in this region. For example, if region 1 decides to set the income tax rate below the tax rate of region 2, the threshold value of i in equation (40) is decreased. Hence, the interval where investment in region 1 remains favorable is extended and concentration increases. The argument is illustrated in Figure 6.

¹²We neglect government debt since in our simple growth model it would end up to be growth neutral.

¹³Optimal taxation in the presence of congestion is analyzed for example by Turnovsky (2000b, chapter 12).

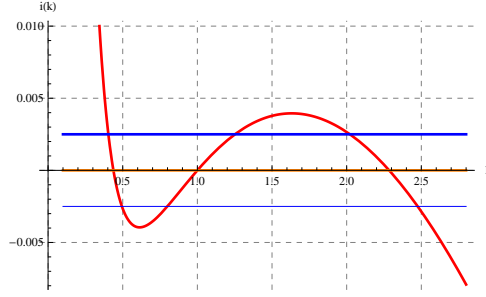


Figure 6: Tax competition; symmetric factor endowment: $n = 1$, $l = 1$; other parameters: $\beta = 0.25$, $\varepsilon_R = 0.5$

Figure 6 shows how different regional taxes affect agglomeration thereby comparing the situations of different income taxes levied in region 1. The income tax reduces capital productivity and hence agglomeration. Starting from a benchmark case of $k^* > 1$, concentration is reduced if the bigger region 1 chooses a higher tax rate, $\tau_1 > \tau_2$. The horizontal line moves upwards, decreasing the capital concentration resulting from the intersection with $i(k)$. Contrariwise, if the smaller region chooses a higher tax rate, $\tau_2 > \tau_1$, the horizontal line moves downwards and the intersection with $i(k)$ to the right. Equilibrium capital concentration increases. To conclude, each region has an incentive to reduce its own tax rate since this fosters agglomeration in the own region.

6 Conclusions

This paper analyzes within a two-region endogenous growth model how different types of public policies affect the equilibrium spatial distribution of economic activity. As production factors serve immobile labor, mobile (broad) capital and a tax-financed congested public input. Integration is modelled as a continuum and enables firms to access the public input of the respective other region (e.g. connecting infrastructure networks; bilateral recognition of university degrees). In case of symmetric factor endowments and identical production conditions, spreading (equal distribution) results as the unique stable equilibrium if dispersion forces dominate. Given a dominance of agglomeration forces, multiple equilibria arise at which spreading becomes unstable and the stable equilibrium is characterized by a core-periphery structure. Integration acts as dispersion force: local increasing returns to scale of the mobile factors are reduced and the smaller region may benefit from scale economies of the other region.

Policy coordination includes the joint endogenous determination of the public input as well as the decision on various tax financing schemes. If governmental activities are fully coordinated among the regions, both choose the amount of public input which

equalizes marginal benefits and marginal costs. In contrast, if only partial coordination is realized, the positive productivity impact of one region's public input on the other region's marginal capital return becomes a positive externality. Then, the amount of the public input is suboptimally low in both regions. Additionally, the distortion may increase or decrease with the capital stock, depending on scale effects and the level of integration. Thus the concentration of public inputs may end up to be suboptimally high or low. Income taxes only affect the spatial equilibrium if they change the ratio of capital productivities. We perform numerical simulations to derive the equilibrium capital distribution and to disentangle the impact of the various determinants on equilibrium agglomeration.

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Appendix A: The bifurcation point $\bar{\varepsilon}_A(\beta, \varepsilon_R)$

bifurcation point for uncoordinated agglomeration (compare (15)). Multiple equilibria arise, if $\varepsilon_A > \bar{\varepsilon}_A$;

Obacht: bei negativem Zähler oder Nenner Ungleichheitszeichen tauschen

$$\bar{\varepsilon}_A(\varepsilon_R, \beta) = \frac{\alpha(1 + \beta - \varepsilon_R)}{\varepsilon_R - \alpha(1 + \beta)} \quad (41)$$

in contrast to this, the bifurcation point of the coordinated decision is independent of ε_R and results as

$$\tilde{\varepsilon}_A = \alpha\beta \quad (42)$$

Table 3: Bifurcation points $\bar{\varepsilon}_A(\varepsilon_R, \beta)$ from (41) for $\alpha = 0.5$
 values in gray imply a violation of the knife-edge assumption $-\alpha < \varepsilon_A < 1$
 black values imply feasible levels of the bifurcation point
 boxed values refer to the bifurcation points mentioned in Figure 3

		ε_R								
		0	1/8	2/8	3/8	0.5	5/8	0.75	7/8	1
β	0	-1	-1.17	-1.50	-2.50	pole	1.50	0.50	0.17	0
	0.1	-1	-1.15	-1.42	-2.07	-6.00	3.17	0.88	0.35	0.11
	0.2	-1	-1.13	-1.36	-1.83	-3.50	11.50	1.50	0.59	0.25
	0.3	-1	-1.12	-1.31	-1.68	-2.67	-13.50	2.75	0.94	0.43
	0.4	-1	-1.11	-1.28	-1.58	-2.25	-5.17	6.50	1.50	0.67
	0.5	-1	-1.10	-1.25	-1.50	-2.00	-3.50	pole	2.50	1.00
	0.6	-1	-1.09	-1.23	-1.44	-1.83	-2.79	-8.50	4.83	1.50
	0.7	-1	-1.09	-1.21	-1.39	-1.71	-2.39	-4.75	16.50	2.33
	0.8	-1	-1.08	-1.19	-1.36	-1.63	-2.14	-3.50	-18.50	4.00
	0.9	-1	-1.08	-1.18	-1.33	-1.56	-1.96	-2.88	-6.83	9.00
	1	-1	-1.07	-1.17	-1.30	-1.50	-1.83	-2.50	-4.50	pole