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Public expenditure, policy coordination, and regional inequality

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Public expenditure, policy coordination, and regional inequality

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Abstract

We analyze within a spatial endogenous growth setting the impact of public policy coordination on regional inequality. Governments in each of the two symmetric regions provide a local public input that becomes globally effective due to integration. Micro-foundation of governmental behavior is based on three different coordination schemes: autarky, full or partial coordination. The 'optimal' size of the local public inputs - as measured by the expenditure share ratios - differs depending upon the extent to which the governments take interregional interdependencies and feedback effects into account. The resulting spatial distribution of economic activity is driven by integration, which acts as dispersion force, and scale effects, which act as concentration force. The latter are drivers of regional inequality. Given full symmetry, local externalities cancel w.r.t to their impact on spatial concentration. We show that coordination of public decisions that base on productivity considerations unequivocally foster concentration and destabilize the spreading equilibrium. Regional inequality is thus an optimal result or put differently, the convergence goal can only be met by applying additional arguments.

Key words: policy coordination; income convergence; bifurcation;

JEL: H10, E60, O40, R50

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1 Introduction

The recent discussion on policy coordination is strongly driven by the challenges of the topical financial crisis. Already in 2010, the European Union introduced the so-called European Semester. In this light, the EU tries to influence national policies via several initiatives that focus on policy coordination (compare e.g. Andersen et al. (2018) for a recent assessment of that policy). In addition to these reasonings, we argue that an analogous logic applies for policies beyond monetary and fiscal policy. Within the framework of a spatial growth model with a productive public input, we discuss the impact of various policy coordination schemes on regional (in-)equality, or put differently, on convergence. Within the model's framework, policy coordination is linked to national decisions upon the type of the public input and its size. The resulting spatial distribution of economic activity is crucially driven by the extent of spillovers and their transmission across the nations via integration. Examples for the productive public input that we have in mind are infrastructure, education, defence, environmental protection or health and the associated public expenditure.

In analogy to the related theoretical literature, we interpret the term 'policy coordination' as a situation where – e.g. due to well-designed incentives, institutional rules, or political agreements – a group of countries moves away from individual Nash policies to a joint policy that internalizes (at least) some cross-border externalities. Usually the outcome is then Pareto superior. In doing so we provide a micro-foundation of governmental behavior and how this affects the distribution of economic activity in growing economies and thus regional (in-)equality.

There is striking economic relevance for the formulation of the theoretical paper developed at hand: Since the era of industrialization, an empirical regularity is sustained worldwide growth.¹ Another global trend is ongoing urbanization which results in production and wealth being increasingly concentrated in big cities, leading provinces, and industrialized nations. Finally, globalization comes along with increased economic integration together with issues of governance such as policy coordination and the associated institutional frameworks, e.g. the European semester.

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Analyses on the impact of productive governmental expenditure on aggregate income draw back on the seminal work of Barro (1990). Figure 4 provides support for a positive

¹Exceptions are e.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).

²full list: .

relationship between these two economic aggregates for the European countries. The public expenditure share there refers to the general government and covers any public activity.³

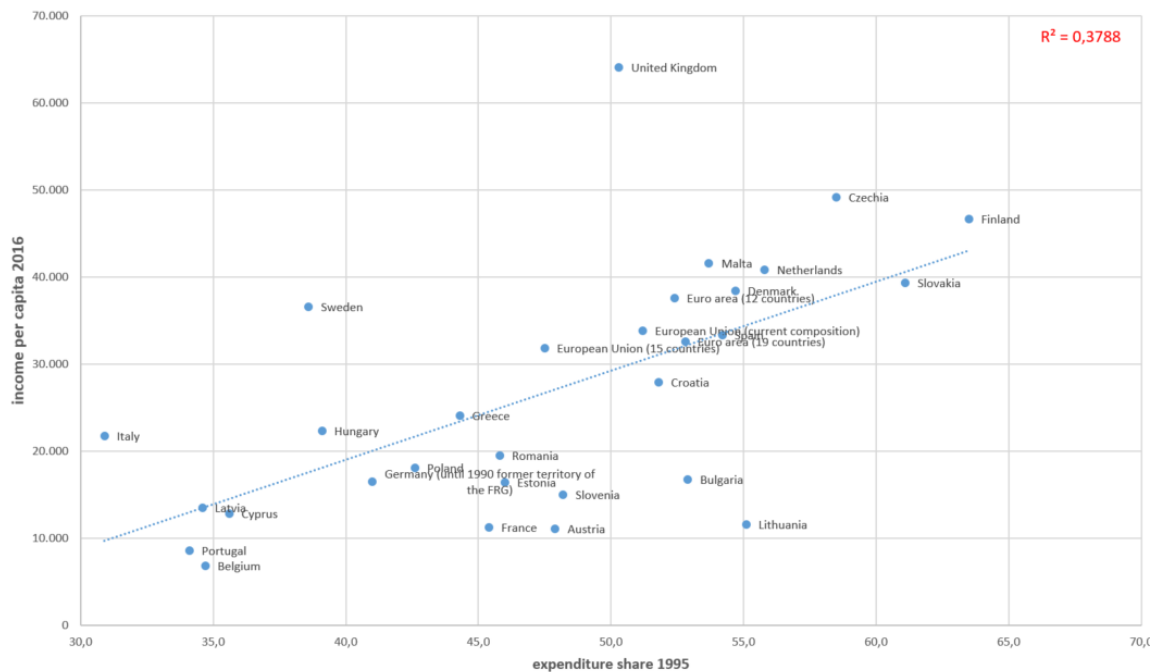


Figure 1: public expenditure share 1995 and income per capita 2016; source: cofog data from Eurostat, sector general government.

However, it has been well recognized that governments perform various functions which are endowed with different financial resources. To capture this variety, the UN has developed a classification system that allows to break down the structure of government expenditure by their main socio-economic function, e.g. health, education, public order and safety. This allows to exploit information on the composition of the governmental budget and the respective impact on value creation for empirical analyses. As such it is natural to expect a variety of effects of public activity on aggregate production. Besides, given the variety of functions, governments also have to decide upon their expenditure structures. Detailed information on evolution across time and

³The COFOG data (classification of functions of government) allows to break down the sector of the general government into central government, state government, local government and social security funds. The full list contains data on health, general public services, economic affairs, public order and safety, education, environmental protection, defence, recreation, culture, religion, social protection, housing and community amenities. Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Government_expenditure_by_function_%93_COFOG.

differentiated by countries can be found at OECD or Eurostat.⁴ Figure 2 provides a recent overview on the public expenditure shares across European countries for selected functions.

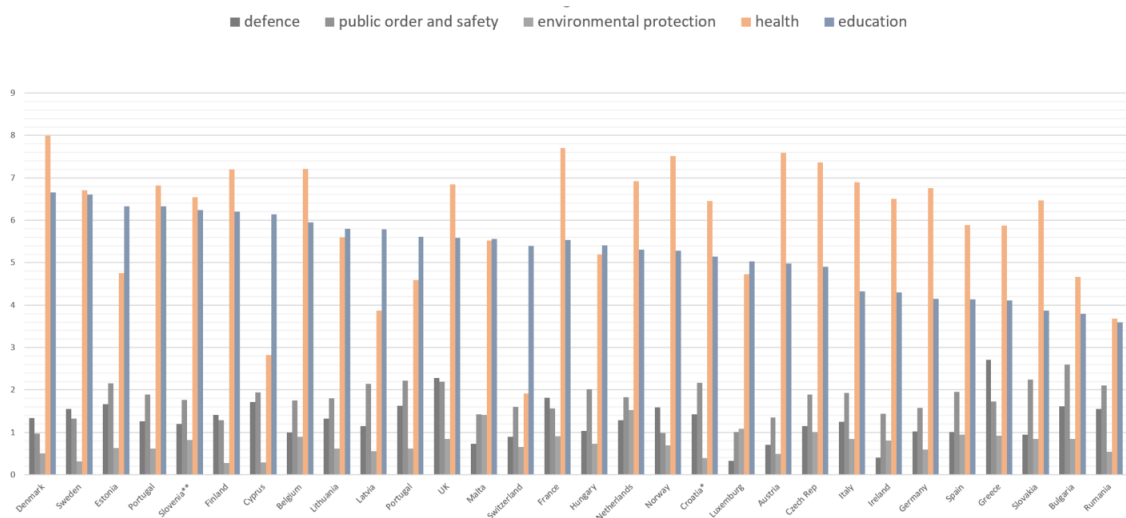


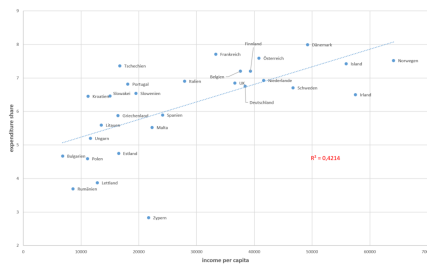
Figure 2: public expenditure shares across selected government function; average 1995–2016, in % of income; * data for Croatia 2001–2016; ** data for Slovenia 1999–2016; order of countries descending by expenditure share on education; functions according to COFOG; source: cofog data from Eurostat, sector general government.

It becomes clear that all countries spend the largest amount on health and education. However, neither function dominates the other for all countries. Looking at the expenditure shares spent for health, public order and safety as well as on environmental protection leads to the same conclusion. In that sense, countries are similar wrt their spending priorities but at the same time there are also differences visible. One might stress the fact that both environmental protection and defence have more the character of being global public goods whereas public order and safety are less characterized by having inherent potential for spillovers across the nations. Besides, figures 3 illustrate that the positive relationship between public expenditure and income as illustrated in figure 4 does not hold for any governmental function. This is especially true for figure 3(b).

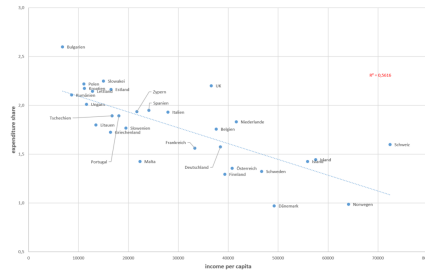
Key drivers that shape the economic landscape are imperfect competition, increasing returns, and transportation costs. Spatial inequality is then the natural outcome of efficiency consideration of optimizing private individuals.⁵

⁴e.g. https://ec.europa.eu/eurostat/statistics-explained/index.php/Government_expenditure_by_function_-%E2%80%93_COFOG.

⁵To better understand the emergence of core-periphery structures is the key concern of the 'New



(a) expenditure on health



(b) expenditure on public order and safety

Figure 3: average expenditure on selected governmental functions 1995-2016 and income per capita in 2016; own calculations based on data from the Eurostat cofog database

Only few papers focus on public activity in the context of regional inequality and if so, they implement transport cost reducing infrastructure (among them Martin and Rogers (1995) or Brakman et al. (2002, 2008)). The public input then unequivocally reinforces regional inequality. Contrastingly, Puga (2002) highlights that the provision of a productive input might even act as dispersion force given certain characteristics of the public input and integrated regions.

To cover a variety of the public input we refer to the sophisticated representation of a congestion function (compare e.g. Eicher and Turnovsky (2000)). Empirically, this is represented by a breakdown of government expenditure by functions they perform.⁶ The different functions reflect "the main priorities and challenges of governments. [...] also common goals set by regional agreements (such as OECD-EU countries) on energy, infrastructure and research and development programmes are all reflected in the structure of government's expenditure." (OECD (2015, 72)). This highlights that a more differentiated view of public duties and the associated expenditure is worthwhile to consider.

However, decisions upon the optimal size of the governmental input or coordination schemes between different regions are not addressed. It becomes obvious that political economy responses to choice of public expenditure are far from trivial, and uniform policy responses are not adequate. Although within the economic discipline it is common sense that integration in general creates aggregate gains, it typically comes along with inequality which arises mostly from the exploitation of scale economies. As a con-

Economic Geography' (NEG; recent overviews based on the work of Krugman (1995, 1991), are provided by Fujita et al. (2001), Brakman et al. (2009) and several contributions in the Handbook of Regional Science (Fischer and Nijkamp 2014)).

⁶See e.g. annex C in OECD (2015) which provides a differentiated overview of first- and second-level classification of functions of governments (COFOG).

sequence there will be winners and losers both within and between countries. How this translates into policy responses then depends on the specific design of the political environment.

Starting from the aforementioned issues, 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 spatial distribution of economic activity. It is based on micro-founding of policy coordination. The key questions addressed might be summarized as follows: How do the governments' decisions on the size and type of local public input affect private investment? How does this feed back to the spatial distribution of economic activity in case of integrated countries? How do different coordination schemes affect this result? What determines the stability of a spatial equilibrium given symmetric production and factor endowment?

Put differently: The major gap of the literature addressed here is the micro-foundation of public policy coordination and its impact on the stability of the spatial equilibrium thereby linking the aforementioned fields of the literature on public economics, growth theory and economic geography.

Governmental policies in such a framework cover various dimensions. The degree of integration affects to which extent local public inputs become part of a global public input thus having implications for productivity also in neighboring countries. The type of the public input affects to which extent scale effects apply and if the public input is (partially) congested. Finally, the way how coordination between the two regions is organized and subsequently the relative size of the local public inputs also is crucial.⁷

The remainder of the paper is as follows. After presenting the theoretical framework in Section 2 we discuss the spatial distribution of the local public inputs for three different coordination schemes in Section 3. We derive the consequences for agglomeration in Section 4. Section 5 addresses the feedback effects between private and public decisions and their consequences for the spatial equilibrium. Section 7 briefly concludes while formal derivations are relegated to the appendix.

2 Theoretical framework

We assume a two region setting and a productive public input (compare the seminal work of Barro (1990)). Firms in the symmetric regions produce the homogenous final

⁷Though not explicitly addressed until now, the existence of externalities is associated with welfare losses and any appropriate policy should also correct for market failures.

good, Y_i , according to the production function

$$Y_i = L_i^\lambda K_i^\alpha D_i^\gamma, \quad 0 < \lambda, \alpha, \gamma < 1, \quad i = 1, 2 \quad (1)$$

with L_i as immobile labor and K_i as physical capital in region i . The global public input, D_i , covers access to both regional public inputs, G_{si} , and is modeled as

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

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

The degree of integration between the two regions is parameterized by $\beta \in [0, 1)$. It may be interpreted as the extent to which the two public inputs become globally effective: If $\beta = 0$, firms in each region only utilize the public input provided by their local governments. In contrast to this, $\beta > 0$ implies that firms in one region also have (partial) access to the other region's public input. For a broad specification of the public input, integration may e.g. be interpreted as increasing the flows of ideas between two regions (e.g. Rivera-Batiz and Romer (1991) argue similarly), as connecting national physical infrastructure networks, recognition of foreign degrees of joint defense.

We specify the regional public input according to the well recognized congestion function utilized by Eicher and Turnovsky (2000). The 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 analogously G_i denotes the aggregate flow of government expenditure.⁸ The congestion 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 scale effects, ε_A , to be negative but also allow for positive values. The associated productivity effects result from the fact that the public input benefits a variety of people or firms. Natural examples are governmental spending for education or comprehensive large research institutions (e.g. CERN in France). Concerning relative congestion, ε_R , the usual interpretation applies. It measures the degree of rivalry arising in the utilization of the public input: $\varepsilon_R = 0$ specifies a public input that is available as pure public

⁸Allowing for balanced growth requires that the condition $-\alpha \leq \varepsilon_A$ has to be satisfied. It results from the knife-edge assumption $\alpha + \gamma(1 + \varepsilon_A) = 1$ that has to be met to allow for equilibrium endogenous growth. We discuss the implications below. The formal setup of the underlying growth model is presented in Appendix 8.1.

good (e.g. an empty road) whereas the other polar case, $\varepsilon_R = 1$, implies that each firm only benefits from $1/N$ parts of the public input with N denoting the number of firms.⁹

As usual within growth models, we assume that governments set the aggregate expenditure levels, G_i , as a constant fraction, Θ_i , of aggregate capital, \bar{K}_i , i.e.

$$G_i = \Theta_i \bar{K}_i, \quad 0 < \Theta_i < 1 \quad (4)$$

An expansion in government expenditure is then parameterized by an increase in the capital share, Θ_i . Since in equilibrium $\bar{K}_i = N_i K_i$ applies

$$g_s = \theta k^{1+\varepsilon_A} n^{1+\varepsilon_A-\varepsilon_R} \quad (5)$$

defines the equilibrium ratio of governmental activity, with $\theta \equiv \frac{\Theta_1}{\Theta_2}$, $k \equiv \frac{K_1}{K_2}$, $g_s \equiv \frac{G_{s1}}{G_{s2}}$. Utilizing equations (2)–(5), production from equation (1) may be rewritten in relative form as¹⁰

$$y = k^\alpha l^\lambda \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^\gamma \quad (6)$$

Our spatial equilibrium concept is based on firm's decision (details below). Private firms determine their investment according to productivity considerations and realize further capital accumulation in the region delivering the higher marginal capital return.¹¹

Due to the complementarity of the private and the public sector, capital productivity is also affected by the public input share, θ . As will be shown below, the associated impact on the spatial equilibrium is quite complex, especially since the two region setting includes a variety of government's interaction. This sets ground for different feedback effects and also affects the stability of the spatial equilibrium. A potential outcome of these feedback effects can be seen, e.g. in figure 4

3 Public coordination: $\theta^*(k)$

Why coordination and characteristics of different degrees of coordination Efficiency considerations require to equalize marginal productivity and unit marginal costs

⁹Notice that throughout the discussion of this paper we focus on the implications of scale, ε_A , and integration, β , thereby just assuming a certain degree of relative congestion $\varepsilon_R > 0$ in order to confine the input from a pure public good that is characterized by the absence of rivalry.

¹⁰The relative perspective immediately allows to identify spatial concentration processes (in region 1) if the value of the considered factor exceeds unity.

¹¹This is the same assumption as taken within Ott and Soretz (2010) or within the knowledge diffusion model of Bröcker (2003).

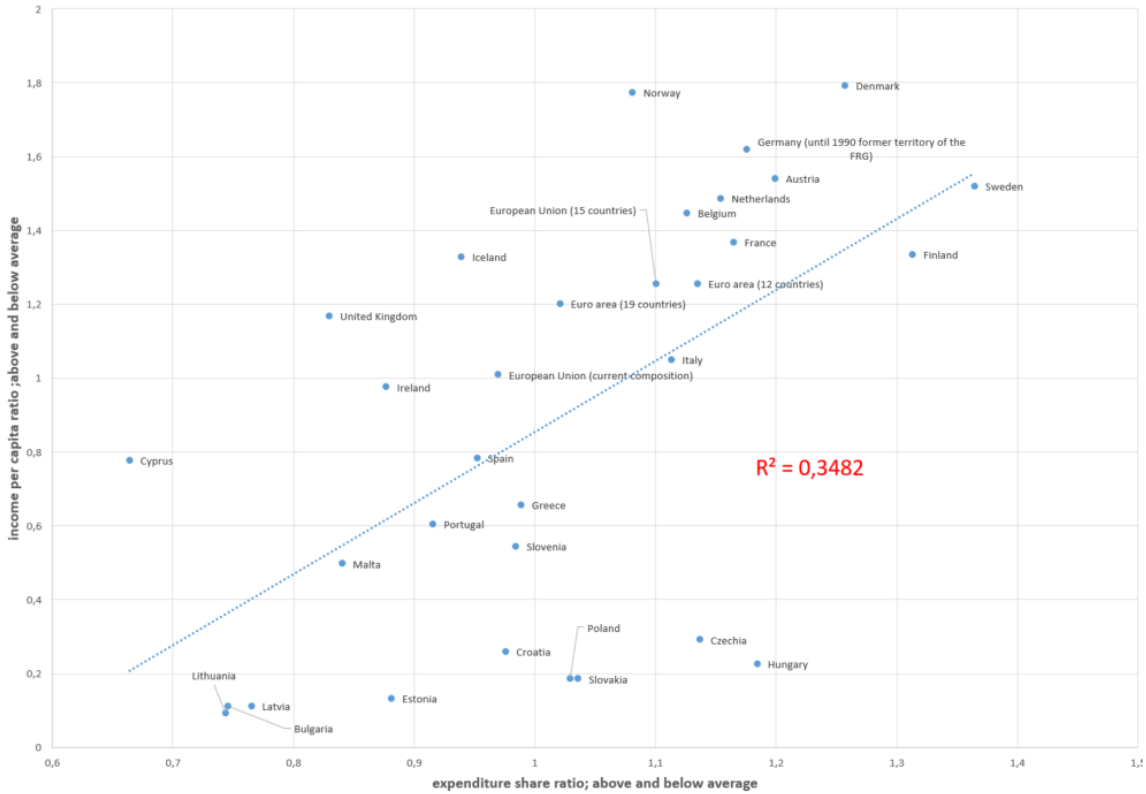


Figure 4: public expenditure share ratio and income per capita ratio; source: cofog data from Eurostat, sector general government.

of providing the public input. We thus adopt the public efficiency condition which already has been imposed by Barro (1990) and which extends the well-recognized assumption within growth models that one unit of consumption can be transformed costlessly into one unit of capital also to the public input.¹²

The coordination schemes discussed below base on different interpretations of the public efficiency condition (PEC) and these are key to the resulting effects. We argue that, depending upon the respective coordination scheme, different formulations for the PEC apply. First, aggregate production amounts to $Y = Y_1 + Y_2$, but the governments do not necessarily focus on aggregate but on local output. Second, there are two governments that decide upon the provision of the respective public input. Basically, since $G = G_1 + G_2$, the two local public inputs might substitute for each other. From a firm's perspective, however, the global public input is perceived as $D_1 = G_{s1} + \beta G_{s2}$, which implies that integration, scale, and congestion come into play. Third, there are inter-regional transmission effects due to integration. The decision of a region on the local public input affects capital productivity – and thus private investment incentives – also

¹²Note that the public input is modeled as a flow. We thereby follow ? who imposes the public efficiency condition $dY/dG = 1$.

in the respective other region. The decision about where to install the 'local' public input might thus be a non-trivial task for the governments.

The key question is whether and to which extent these various relationships and feedback effects are taken into account by the local governments.¹³ We argue that both the PEC and the considered restrictions depend upon the coordination schemes of the local public decisions. We address the following coordination schemes of the two governments:

1. full coordination (planner): this setting assumes joint decision of both governments thereby taking regional interdependencies and feedback effects into account. The focus is on joint output ($Y = Y_1 + Y_2$) and it is recognized that the two local public inputs may perfectly substitute for each other ($G = G_1 + G_2$) such that $dG_1 = -dG_2$. Since the public input may be installed in any region public investments will be allocated as to equalize productivities of the local public inputs.
2. no coordination (autarky; Cournot-Nash duopoly): the other region's policy is treated as being exogenous. Consequently the two public inputs are not considered as possible substitutes and the focus of a government is on local output, Y_1 and Y_2 , only.
3. partial coordination (Stackelberg leader-follower setting): this setting assumes a leading and a following region. The leading region is quite aware of the productivity impact of the other region's public input and also considers the decisions of the (myopic) follower region that just optimizes as in case of no coordination. Again, only local output Y_1 and Y_2 is addressed for each region independently.

All coordination schemes consider the resulting size of the local public input. We assume for all coordination schemes non-distortionary financing of the provision of the public input as determined by the PEC. Besides, the public budget balances in each period and there are no interregional transfers.

Depending upon the underlying coordination scheme,

The resulting public input shares derived by the governments, $\theta(k, \dots, \epsilon_A, \beta, \dots)$, are affected by private investment, scale and integration. It will be shown that governmental decisions affect equilibrium agglomeration not only w.r.t. to concentration but also stability.

¹³Within Section 5 we address feedback effects between the private and the public sector.

3.1 Full coordination: derivation of θ^*

The PEC in case of fully coordinated public policies assumes that the regional governments take both aggregate output, $Y = Y_1 + Y_2$, and the aggregate public input, $G = G_1 + G_2$, into account. Formally, this transforms to

$$\frac{dY}{d\theta} = \frac{\partial Y}{\partial G_1} \frac{\partial G_1}{\partial \theta} + \frac{\partial Y}{\partial G_2} \frac{\partial G_2}{\partial \theta} \stackrel{!}{=} 0 \quad (7)$$

Both governments recognize the substitutional relationship of the two public inputs, $dG_1 = -dG_2$, together with $\frac{\partial Y}{\partial G_1} = \frac{\partial Y}{\partial G_2} = 1$. Marginal productivities of the two public inputs are given by

$$\frac{\partial Y}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} + \gamma \frac{Y_2}{D_2} \beta N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} \quad (8a)$$

$$\frac{\partial Y}{\partial G_2} = \gamma \frac{Y_1}{D_1} \beta N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} + \gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \quad (8b)$$

Replacing them into efficiency condition (7) and utilizing proportionality according to (4) provides $G_1 = \theta nkG_2$. This implies $\frac{dG_1}{d\theta} = nkG_2$ and $-\frac{dG_2}{d\theta} = nkG_2$ and one obtains the key condition describing fully coordinated policies:

$$\left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\Upsilon - 1} = \frac{1 - \beta k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R}}{k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R} - \beta} l^{-\lambda} k^{-\alpha} \quad (9)$$

This relationship provides the basis for the analysis of rich interdependencies between private sector (as embedded within private capital, k) and the public sector (especially public capital, θ , scale, ε_A and integration, β).

Utilizing equations (3), (5) and solving (9) for θ provides the explicit representation of $\theta^*(k, \dots, \varepsilon_A, \beta, \dots)$ of full coordination

$$\theta^*(k, \dots) \equiv \frac{\Psi - \beta}{(1 - \Psi\beta)\Upsilon}, \quad \text{where} \quad \Psi \equiv \left(\frac{k^\alpha l^\lambda (k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R} - \beta)}{1 - \beta k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R}} \right)^{\frac{1}{1-\Upsilon}}, \quad (10)$$

and

$$\Upsilon \equiv k^{1+\varepsilon_A} n^{1+\varepsilon_A-\varepsilon_R} \quad (11)$$

Figure 5 plots $\theta^*(k)$ for various parameter constellations of scale (ε_A) and integration (β). If the regions are symmetric ($l = n = 1$) and spreading applies (i.e. given that $k = 1$), the right hand side in (9) equals unity. Using (5), the optimality condition (9) reduces to

$$\frac{g_s + \beta}{1 + \beta g_s} = 1 \quad \Rightarrow \quad g_s = 1 \quad \Rightarrow \quad \theta^*(k) = 1 \quad (12)$$

In the spreading equilibrium, efficient government expenditures will be equally distributed across the two regions.

If instead $k > 1$, the ratio θ^* will be adjusted correspondingly. In order to calculate the adjustment in θ^* , one has to notice that both g_s at the left hand side as well as the term on the right hand side of (9) are influenced by the capital distribution k . Utilizing the implicit function theorem, this adjustment can be described by

$$\frac{d\theta^*}{dk} = \left(\frac{1 - \beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A}}{n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta} \alpha k^{-1} + \frac{n^{\varepsilon_A - \varepsilon_R} \varepsilon_A k^{\varepsilon_A - 1} (1 - \beta^2)}{(n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} - \beta)^2} \right) \frac{l^{-\lambda} k^{-\alpha} (g_s + \beta)^{2 - \gamma \theta^*}}{(1 + \beta g_s)^{-\gamma} (1 - \gamma) (1 - \beta^2) g_s} - (1 + \varepsilon_A) \frac{\theta^*}{k} \geq 0 \quad (13)$$

The sign of (13) and thus the reaction of public activity across space on concentrated private investment is indeterminate. The total effect originates from three different sources that describe the relationships between k and θ :

First, a *positive complementarity effect* arises. If the private capital distribution becomes more concentrated (i.e. in case of $k > 1$), the productivity of the public input increases relatively more in the larger region due to the better endowment with physical capital and the complementarity of the two production inputs private and public capital. Other things being equal, 'global' expenditure for the public input will be shifted towards the larger region in order to equalize the marginal productivities of the two local public inputs. As a consequence, the distribution of the public input becomes more concentrated as well, θ^* increases. This effect is unequivocally positive.

Second, there is a *negative substitution effect*. For any expenditure share, θ , the actually available amount of the public input, g_s , increases with $k > 1$ (compare (5)). Consequently, in order to obtain a certain level of governmental services, g_s , stronger concentration of the public input might substitute for less concentration of the private input and vice versa. As can be seen in the second line equation (13), this effect is affected by the size of the scale effects and reinforced (dampened) in case of a positive (negative) sign of ε_A .

Third, there are *ambiguous effects due to integration* which allows for interregional substitution of local government expenditure, G_i . From an efficiency perspective, crucial in this context is the sign of ε_A : If scale effects are positive, $\varepsilon_A > 0$, any increase in k augments the available amount of the public input in the larger region.¹⁴ Integration provides (partial) access also to the remote public input. In order to benefit from the scale effects, government expenditure is shifted from the smaller to the larger region

¹⁴Formally, this can be derived by introducing the equilibrium condition $\bar{K}_i \equiv N_i K_i$ into (3) which then reduces to $G_{si} = G_i N_i^{\varepsilon_A - \varepsilon_R} K_i^{\varepsilon_A}$.

– and taken back to the 'home' region via integration. Other things being equal, θ^* increases. Contrariwise, if scale effects are negative, i.e. if $\epsilon_A < 0$, an increase in k reduces the effective amount of the public input in the larger region. A shift of government expenditures from the larger to the smaller region lowers the scale disadvantage and results in a decrease in θ^* .¹⁵

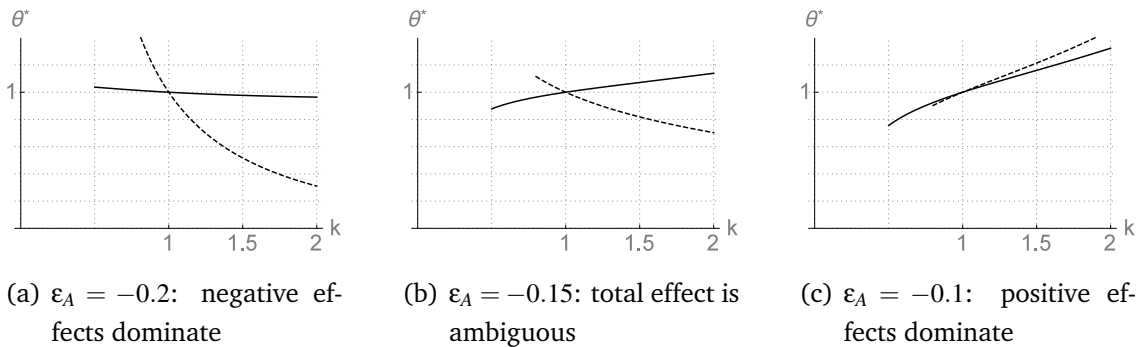


Figure 5: full coordination: $\theta^*(k, \dots, \epsilon_A, \beta, \dots)$
symmetric factor endowment: $n = 1, l = 1$ (no impact of ϵ_R if $n = 1$) and $\alpha = 0.5$;
dashed functions: $\beta = 0.5$, solid functions: $\beta = 0.25$

Altogether, the sign of $d\theta^*/dk$ depends upon the interaction of the discussed effects. Figure 5 illustrates this ambiguity and highlights the impact of scale, ϵ_A , and integration, β , on the optimal level of $\theta^*(k)$.

In case of spreading, $k = 1$, the optimal coordinated choice results in identical expenditure shares for the two local public inputs: $\theta^* = 1$. This holds for all levels of integration and scale (compare the intersections of the dashed and the solid functions in Figures 5).

If instead private economic activity is concentrated, $k > 1$, optimal public activity will also be concentrated but not necessarily in the bigger region 1. For sufficiently low ϵ_A (compare Figure 5(a)), the negative effects derived in equation (13) dominate such that private activity in the larger region substitutes for public activity. Put differently, in order to dampen the negative scale effects, public expenditure is shifted from the larger to the smaller region. As a consequence θ^* declines as k increases. This negative effect is reinforced by integration. For sufficiently high (though not necessarily positive) levels of scale, the positive effects in (13) dominate and θ^* increases in k . Again, integration reinforces this relationship (compare Figure 5(c)). For intermediate levels of scale (compare Figure 5(b)), however, integration has an ambiguous impact: other

¹⁵Notice that the sign of ϵ_A only determines the direction of the integration effect but not necessarily the sign of the total effect.

things being equal, reducing the degree of integration then turns the dominance of the negative effects to a dominance of the positive effects.

3.2 No coordination: derivation of θ^a

If each region decides autarkic on the level of government expenditure, the local governments consider the public input of the respective other region as exogenous factor such that the option to substitute between the two local public inputs (i.e. $-dG_1 = dG_2$) is neglected. The same applies concerning the contribution of local output to aggregate output. Finally, autarkic local optimization assumes an efficiency concept that amounts to equalizing the marginal productivities independently and the PEC

$$\frac{\partial Y_1}{\partial G_1} = 1 \quad \text{and} \quad \frac{\partial Y_2}{\partial G_2} = 1 \quad (14)$$

with the marginal products given by

$$\frac{\partial Y_1}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} \quad (15a)$$

$$\frac{\partial Y_2}{\partial G_2} = \gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \quad (15b)$$

Due to the neglect of the interregional interdependencies, the productivity impact of integration becomes a positive externality. Completely uncoordinated policies then may be described by¹⁶

$$\left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1} = \frac{1}{k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R}} l^{-\lambda} k^{-\alpha - \varepsilon_A} \quad (16)$$

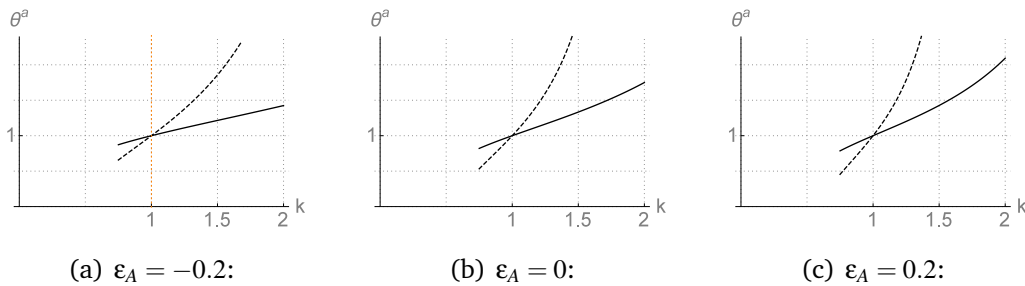


Figure 6: The Cournot solution $\theta^a(k, \dots, \varepsilon_A, \beta, \dots)$; symmetric factor endowment $n = l = 1$; solid line: $\beta = 0.25$, dashed line: $\beta = 0.5$

¹⁶The explicit representation of θ^a , which also serves as basis for the plots in Figure 6, is derived in (17) in Appendix ?? by utilizing (5) and solving (16) for θ .

Utilizing equations (3), (5) and solving (16) for θ provides the explicit representation of θ^a

$$\theta^a \equiv \frac{\Omega - \beta}{(1 - \Omega\beta)\Upsilon}, \quad \text{where} \quad \Omega \equiv \left(k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R} k^\alpha l^\lambda \right)^{\frac{1}{1-\gamma}} \quad (17)$$

and Υ from (11)

The interdependency between private and public sector is as follows. If both regions are symmetric, $l = n = 1$, and spreading of private activity applies (i.e. $k = 1$), the right hand side of equation (16) is unity and the uncoordinated solution implies equally distributed government expenditure, like in the coordinated policy case. This result relies on the assumption of symmetric factor endowment such that both regions disregard the productivity impact of their public input on the respective other region. Both governments, although they choose suboptimal levels of expenditure, deviate with their decision to the same extent from the optimum. Consequently, since the externality is symmetric, it cancels from a relative perspective. In case of spreading, $\theta^a(k) = 1$ results (which coincides with $\theta^*(k) = 1$ derived in equation (12)).

If in contrast private activity is concentrated, i.e. if $k > 1$ is realized, public expenditure will also be concentrated. Formally this might be shown by the unequivocally positive sign of the derivative.

$$\frac{\partial \theta^a}{\partial k} = \frac{(g_s + \beta)^{-\gamma} (1 - \beta^2) n^{\varepsilon_A - \varepsilon_R} l^{-\lambda} \theta^a k^{-\varepsilon_A - \alpha - 1}}{(1 + \varepsilon_A)(1 + \beta g_s)^{2-\gamma} g_s} - (1 + \varepsilon_A) \frac{\theta^a}{k} > 0 \quad (18)$$

Compared with the optimal adjustment of government expenditures in case of coordinated policies (see (13)), the interregional substitution effect is not employed but only the positive complementarity effect applies. Concentration of public and private capital come along with each other.

As can be seen in Figure 6, for reasonable parameter settings, the positive effect of capital concentration on government expenditure concentration dominates and the ambiguity discussed in the context of coordinated policies disappears. 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, θ^a increases. This effect is reinforced by integration (dashed lines) and scale (the slopes of both the dashed and the solid lines increase with ε_A).

3.3 Partial coordination: derivation of θ^S

Aside from the polar scenarios of full and no coordination it is also quite natural to think about economies in which the large region's government behaves as a 'Stackelberg-leader' and expects the follower region's government to react on its decisions. 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. We assume such a leader-follower setting in which the leading region 1 considers the behavior of the following region 2. 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 before for the uncoordinated setting. The larger region 1 anticipates this behavior and chooses the amount of the public input subject to the constraint that region 2 will adjust its public input accordingly.

Formally, the decision rule of the follower region 2 is part of the uncoordinated policy derived in Section 3.2 and consists in equalizing marginal cost and marginal benefit, $\partial Y_2 / \partial G_2 = 1$ from (15b), hence

$$\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} = 1 \quad (19)$$

Marginal productivity of G_2 is affected by the amount of the public input in region 1, G_1 , since this enters the follower region's global public input, D_2 . Again, the two local inputs G_1 and G_2 may substitute for each other. Hence, public expenditure in the follower region 2 is adapted to the observed amount of G_1 such that condition (19) is fulfilled. Put differently, the smaller region 2 adjusts its expenditure accordingly and follows with its decision. This behavior results in

$$\frac{dG_2}{dG_1} = - \frac{\partial \left(\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \right) / \partial G_1}{\partial \left(\gamma \frac{Y_2}{D_2} N_2^{\varepsilon_A - \varepsilon_R} K_2^{\varepsilon_A} \right) / \partial G_2} = -\beta n^{\varepsilon_A - \varepsilon_R} k^{\varepsilon_A} \quad (20)$$

If integration is positive, $\beta > 0$, an increase in the public input in region 1 induces an increase in the global public input, D_2 , which is available within to region 2. The associated decrease of marginal productivity leads to a reduction in the chosen amount of public input in region 2, G_2 . For $k > 1$, the strength of this effect is reinforced by integration and scale.¹⁷

The leader region 1 anticipates this reaction of follower region 2 within its own optimization. When calculating the marginal benefit of public input, region 1 takes into

¹⁷Compare Table 8.2 which calibrates the sensitivity of (20).

account that the public input of region 2 will be the lower, the higher the amount of the public input of region 1. Put differently, the government in region 1 calculates both the positive direct and the induced indirect replacement effect and equalizes the associated marginal product to the marginal costs. The associated PEC is

$$\frac{dY_1}{dG_1} = \frac{\partial Y_1}{\partial G_1} + \frac{\partial Y_1}{\partial G_2} \frac{\partial G_2}{\partial G_1} = \gamma \frac{Y_1}{D_1} N_1^{\varepsilon_A - \varepsilon_R} K_1^{\varepsilon_A} (1 - \beta^2) \stackrel{!}{=} 1 \quad (21)$$

Combining the two optimality conditions (19) and (21) results in

$$\left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1} = \frac{1}{(1 - \beta^2) k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R}} l^{-\lambda} k^{-\alpha} \quad (22)$$

The right hand side of this equation exceeds the right hand side of equation (16) describing the uncoordinated solution. Hence, the left hand side has to be higher too, which implies a lower value of θ^s . The larger region 1 anticipates the reaction in the public input of region 2, hence it decreases its own public input. As a consequence, the ratio of public inputs, θ^s , decreases for all levels $k > 1$. This holds for all parameter constellations, expect for $\beta = 0$ where $\theta^* = \theta^s = \theta^a$. Otherwise, i.e. for $\beta > 0$, it follows immediately that $\theta^s < \theta^a$.¹⁸ The leading region benefits from the negative substitution effect resulting from the smaller region's behavior.

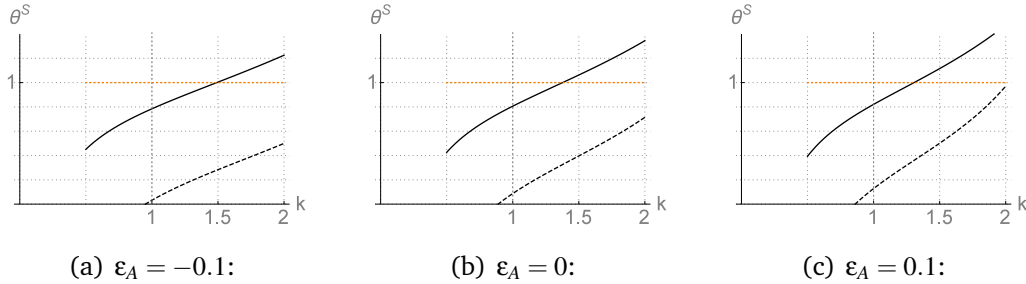


Figure 7: Stackelberg solution $\theta^s(k, \dots, \varepsilon_A, \beta, \dots)$; symmetric factor endowment $n = l = 1$; solid lines: $\beta = 0.25$, dashed lines: $\beta = 0.5$

Even in case of full symmetry, i.e. if $n = l = k = 1$, θ^s unequivocally falls below unity. The leading region anticipates the effort of the smaller region and pursues a beggar-thy-neighbor policy. The arising level of θ^s increases with a decrease in integration, β , and an increase in scale, ε_A (compare Figures 7). Put differently, equalized public activity only results if private capital is concentrated in the bigger region 1. This effect is reinforced by integration which allows for accessing the other region's public input.

However, it rightly has to be doubted that such a strategy is sustainable in case of repeated interaction. We discuss this in Section 5.

¹⁸compare equations (17) and (23) in Appendix ??.

Utilizing equations (3), (5) and solving (22) for θ provides the explicit representation of $\theta^S(k)$

$$\theta_s \equiv \frac{\Lambda - \beta}{(1 - \Lambda\beta)\Upsilon}, \quad \text{where} \quad \Lambda \equiv ((1 - \beta^2)k^{\varepsilon_A}n^{\varepsilon_A - \varepsilon_R}k^\alpha l^\lambda)^{\frac{1}{1-\gamma}} \quad (23)$$

and Υ from (11).¹⁹

4 Equilibrium income distribution from a private sector perspective: $k^*(\bar{\theta})$

So far we argued that the spatial distribution of public activity strongly depends upon the underlying coordination mechanism, scale and integration. We now shift the perspective from the two local governments to the private firms.

For the individual firm, θ is seen as an exogenous variable (compare (4) together with the definition of $\theta \equiv \Theta_1/\Theta_2$). Due to the complementarity of private and public capital, the level of $\bar{\theta}$ also affects in which region investment is more efficient and hence where the accumulation of the private capital is realized. Notice that the assumption of the exogenous level of $\bar{\theta}$ neglects feedback effects between private and public capital. We turn to this point in Section 5.

Following Bröcker (2003), we assume that investment in physical capital is spatially mobile across the regions such that capital accumulation is realized in the region delivering the higher marginal returns. Within a two-region setting, the ratio of marginal productivities of physical capital is given by

$$R \equiv \frac{\partial Y_1/\partial K_1}{\partial Y_2/\partial K_2} \quad (24)$$

Definition of a spatial equilibrium A spatial equilibrium or put differently a balanced steady state is characterized by a stationary capital distribution, $R = 1$, with non-negative investment in both regions. Then firms are indifferent as to invest either in region 1 or 2; agglomeration and spreading forces cancel.²⁰ Utilizing equations (1)–(5) yields

$$R = l^\lambda k^{\alpha-1} \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1} \cdot \left(\frac{\alpha(g_s + \beta) + \gamma \varepsilon_R g_s}{\alpha(1 + \beta g_s) + \gamma \varepsilon_R} \right) \quad (25)$$

¹⁹Note that reasonable values of $\theta^S(k)$ may only be derived for restricted domains of ε_A and β . Figure 15 in the Appendix gives a graphical representation of valid parameter constellations (the red area).

²⁰Since the basic framework assumes a growth model, the full description of the spatial equilibrium also requires that in equilibrium regional capital stocks are growing at constant rate. The corresponding growth model is presented in Appendix 8.1.

The distribution of governmental activity enters this ratio R via g_s . Taking logarithms of (25) leads to the relationship

$$R \geq 1 \iff i(k, \bar{\theta}, \dots) \geq -\lambda \ln l \quad (26)$$

with $i(k, \bar{\theta}, \dots)$ given by

$$i(k, \bar{\theta}, \dots) \equiv (\alpha - 1) \ln k + (\gamma - 1) \ln \left(\frac{g_s + \beta}{1 + \beta g_s} \right) + \ln \left(\frac{\alpha(g_s + \beta) + \gamma \epsilon_R g_s}{\alpha(1 + \beta g_s) + \gamma \epsilon_R} \right) \quad (27)$$

where $g_s = g_s(\bar{\theta}, \dots)$. The term $-\lambda \ln l$ in (26) represents the spatial distribution of immobile labor.²¹

Formally, a spatial equilibrium results when the non-linear function $i(k, \bar{\theta}, \dots)$ from (27) intersects the horizontal line. The latter represents the threshold value $-\lambda \ln l$ of immobile labor. It is independent of k and θ and coincides with the horizontal axis if immobile labor is equally distributed across space.²²

4.1 Stability considerations

Two different scenarios for a spatial equilibrium are basically feasible. They are illustrated in Figure 8(a) for the case of completely symmetric regions. (i) If $i(k, \bar{\theta}, \dots)$ is monotone and negatively sloped in the capital ratio $k = 1$ (the solid line), the spreading equilibrium is unique and stable. (ii) If instead, $i(k, \bar{\theta}, \dots)$ is non-monotone, multiple equilibria with different stability characteristics arise. Then $k^* = 1$ is unstable whereas $k^{**} > 1$ represents a stable core-periphery equilibrium (intersection of the dashed line with the horizontal axis).²³ Summarizing, the spreading equilibrium is unstable whenever function $i(k, \bar{\theta}, \dots)$ is positively sloped in the steady state capital distribution, k^* . Deviations from the steady state involve agglomeration forces, $R > 1$. The resulting productivity advantage in region 1 attracts investment and induces further increases of k . The capital distribution departs continuously from the initial spreading equilibrium. As capital accumulation in region 1 is realized, the marginal productivity of capital decreases until finally again $R = 1$ with a stable core-periphery equilibrium with $k^{**} = 1$. If on the contrary the function $i(k, \bar{\theta}, \dots)$ is negatively sloped in the spreading equilibrium, an increase in k reduces the ratio of capital productivities ($R < 1$), thus giving

²¹It provides a threshold that secures the existence of also the smaller region and might thus be interpreted in analogy to the no-black-hole condition discussed within models of the New Economic Geography.

²²An increase (a decrease) in share of immobile labor, l , implies a deviation of from the full symmetry assumption made before. It shifts the horizontal line downwards (upwards) and thereby affects the spatial equilibrium.

²³The notion of a core-periphery relies on the seminal work of Krugman (1991).

rise to a productivity advantage in region 2. Then k declines and converges again to its original steady state value $k^* = 1$. Put differently, in case of multiple equilibria, the spreading equilibrium is unstable and the core-periphery structure is stable whereas given a unique spatial equilibrium, spreading is stable.²⁴

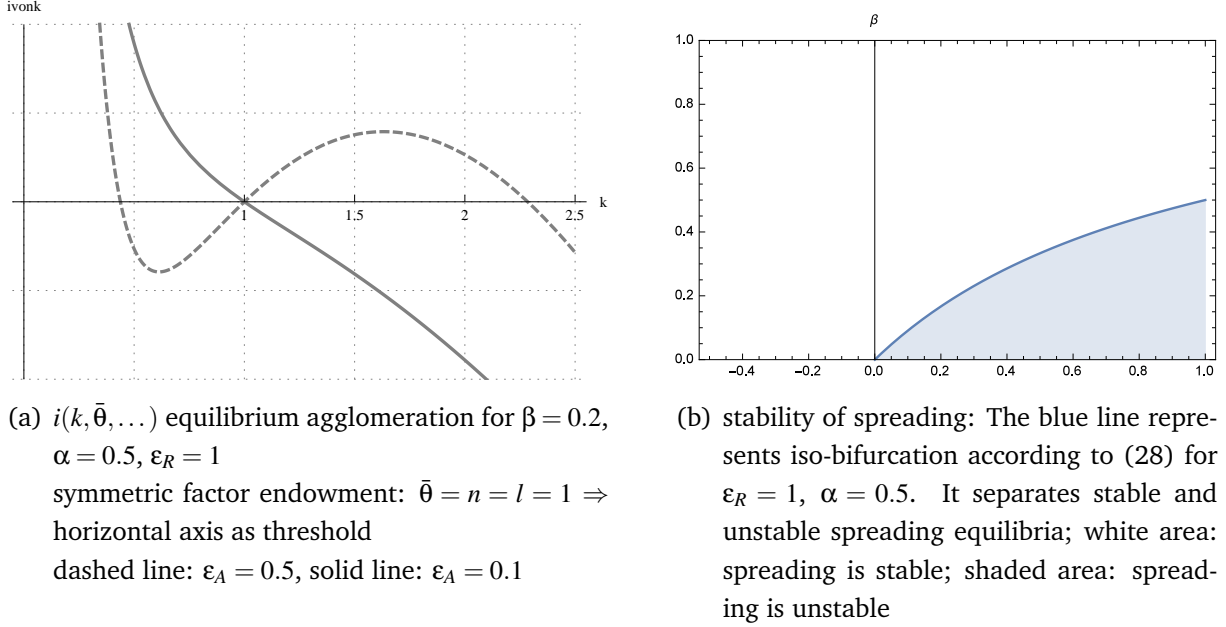


Figure 8: Equilibrium agglomeration and stability of spreading

In case of complete symmetry, including exogenous public activity $\bar{\theta} = 1$, it is possible to derive a closed form solution for the underlying bifurcation, i.e. to derive those parameter combinations of congestion, scale, and integration that separate stable from unstable equilibria.²⁵

$$\bar{\beta} \equiv \frac{\varepsilon_R(\alpha + \varepsilon_A) - \alpha(1 + \varepsilon_A)}{\alpha(1 + \varepsilon_A)} \quad (28)$$

Other things being equal, multiple equilibria arise, if agglomeration forces exceed a certain level. This threshold level arises whenever for given ε_A and ε_R , integration

²⁴Former work has shown that in such a framework integration acts as a dispersion force whereas high levels of scale and relative congestion are agglomeration forces (compare Ott and Soretz (2010)).

²⁵Formally, the crucial characteristic is the sign of the slope of $i(k, \bar{\theta}, \dots)$ from (27) evaluated at the equilibrium capital distribution, $k^* = 1$. This may be derived by zeroising the first derivative of $i(k, \bar{\theta}, \dots)$ w.r.t k , setting $k = 1$ and solving for β which provides the bifurcation function in (28). In Section 5 we show that for a huge variety of parameters, public coordination activities activates agglomeration forces thereby imposing a destabilizing impact on the spreading equilibrium.

exceeds $\beta > \bar{\beta}$. Otherwise, dispersion forces dominate and spreading results as a unique and stable equilibrium. Reducing congestion stabilizes the spreading equilibrium.²⁶

Figure 8(b) plots the iso-bifurcation line from (28) for alternative combinations of scale and integration that separates the unique equilibria (shaded area) where spreading is stable from multiple equilibria (plain area) where spreading is unstable.

4.2 Exogenous public inequality: k^* if $\bar{\theta} \neq 1$

Asymmetric public activity as discussed in Section 3 affects both the formation and the stability of the spatial equilibrium. Formally this phenomenon may be captured by introducing $\bar{\theta} \neq 1$ in (27) and applying the spatial equilibrium condition, $R = 1$. This leads to an upward shift of the dashed and solid lines in Figure 8(a) if $\bar{\theta} > 1$ and analogously to a downward shift of both functions if $\bar{\theta} < 1$. We now focus on the impact of a leader-follower setting ($\theta(k) < 1$; compare Section 3.3) on the spatial equilibrium.²⁷ Figure 9 compares two different levels of $\bar{\theta} < 1$ to the benchmark setting of $\theta = 1$. The corresponding spatial equilibria are given by the intersections of the plotted lines and the horizontal axis. If $\bar{\theta}$ is sufficiently reduced (dotted functions), region 2 which provides the larger public input share, becomes the stable core. This is due to the complementarity of the two inputs. An initially unique spreading equilibrium just shifts to the left (compare Figure 9(a)). Given that initially there have been multiple equilibria this multiplicity is broken and again leads to a core-periphery with region 2 becoming the core if $\theta^s(k)$ is sufficiently reduced (compare Figure 9(b)). From an agglomeration perspective, a bother thy neighbor policy, which is in accordance with the PEC in the Stackelberg setting is contra-productive from a private sector perspective. Slight reductions of $\theta^s(k)$, however, have an unclear impact. The resulting spatial equilibrium is indeterminate and depends upon the initial capital distribution (compare Figure 9(c)). Basically both regions 1 and regions 2 might become the stable core.

If the initial situation was characterized by multiple equilibria and this setting still holds for $\bar{\theta} < 1$ (e.g. dashed line in Figure 9(c)), the unstable spreading equilibrium becomes an unstable core-periphery with $k^* \geq 1$. The corresponding stable core-periphery structure, however, will end up in less concentration. In any case, the stable equilibrium ends up in less concentration in region 1. The intuition for this result is that basically

²⁶Though not explicitly shown in Figure 8(b), an increase in θ results in a downward rotation of the iso-bifurcation line in the point where the line intersects the horizontal axis thus also reducing unstable parameter settings.

²⁷If $\bar{\theta} > 1$ the stable core-periphery structure gets reinforced such that concentration increases. This is due to the complementarity of the private and the public input which makes capital accumulation in the larger region more attractive.

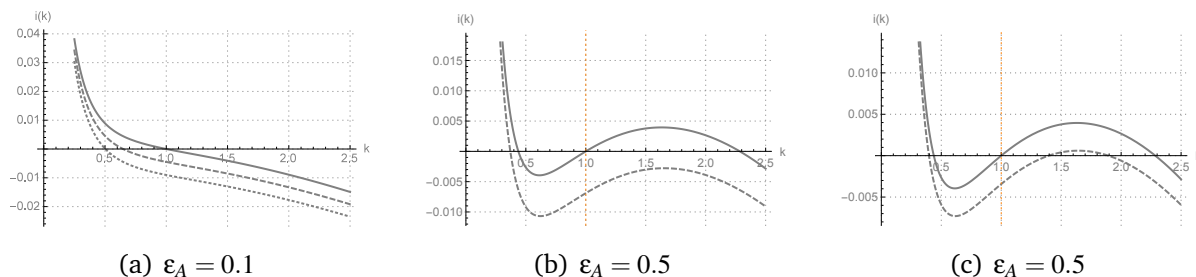


Figure 9: $\bar{\theta} < 1$; all functions assume $\beta = 0.2$ and $\alpha = 0.5$; benchmark case: solid lines: $\bar{\theta} = 1$; reference cases: dashed lines: $\bar{\theta} = 0.99$, dotted lines: $\bar{\theta} = 0.98$.

the complementarity effects also work for small reductions of $\bar{\theta} < 1$. This makes private capital accumulation in region 1 less attractive, but in case of only a small deviation of $\bar{\theta} < 1$ these effects are not strong enough to break the agglomeration forces which generate multiple equilibria.

To summarize: The complementarity of the private and the public input acts in two directions: it reinforces investment incentives in region 1 if $\theta > 1$ and analogously reduces them if $\theta < 1$. As a consequence, any policy with $\bar{\theta} < 1$ comes at the cost of private capital accumulation in region 1. Such a policy does not pay off in the sense of attracting private investment but on the contrary induces a shift of private investment from the larger to the former smaller region.

5 Feedback effects as drivers of regional inequality

Until now, the interdependencies between private and public sector have been discussed isolated. Section 3 analyzes how governments decide upon the provision of the public input for a given spatial distribution of private activity. In contrast, Section 4 focuses on equilibrium agglomeration thereby treating the governmental decisions as being exogenous. We now combine the two perspectives and show that the consideration of the mutual interdependencies destabilizes spreading for almost all types of public input (ϵ_A) and degree of integration (β). Considering public policy coordination sets ground for a process of cumulative causation in which the respective effects are reinforced (compare Figure 10). This holds for all discussed coordination schemes.



Figure 10: cumulative causation

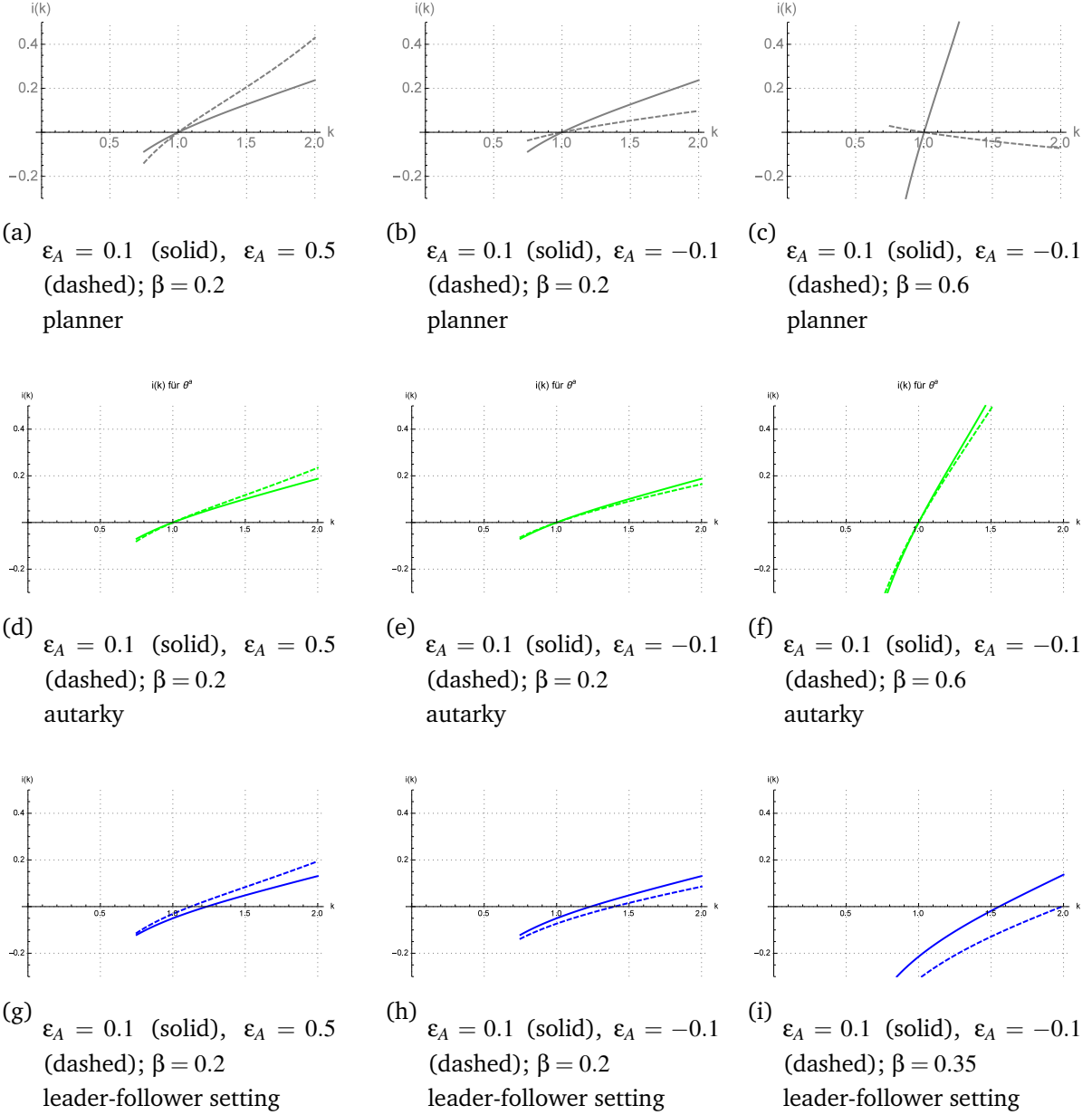


Figure 11: $i(k|\theta = \theta(k), \dots, \varepsilon_A, \beta, \dots)$, i.e. (a-c) planner solution; (d-f) Cournot coordination (i.e. autarky), (g-i) leader-follower setting; ... reference for all three scenarios is given by $\varepsilon_A = 0.1$ (solid line – which is included in all three subfigures); as comparison, various values of ε_A and β have been chosen

Formally: Again, we focus on the concept of the spatial equilibrium from equations (25) and (26). But we now replace the so far exogenous ratio $\bar{\theta}$ by those levels that have been determined by the different coordination schemes, i.e. by $\theta^*(k)$ from equation (10), $\theta^a(k)$ from (17) and θ^s from (23). Thus, function $i(k, \bar{\theta} \dots)$ from (27) may be reformulated to only depend upon k .

Figure 11 plots the modified functions $i(k, \dots)$ and thereby visualizes the result for the three coordination schemes. For identical distribution of immobile workers, i.e. if $l = 1$, the horizontal axis provides the threshold and again the intersection between

the $i(k, \dots)$ determines the spatial equilibrium. As argued before, the slope of the intersection determines the stability characteristics of the equilibrium. The following results become obvious (comparisons are taken keeping other things equal):

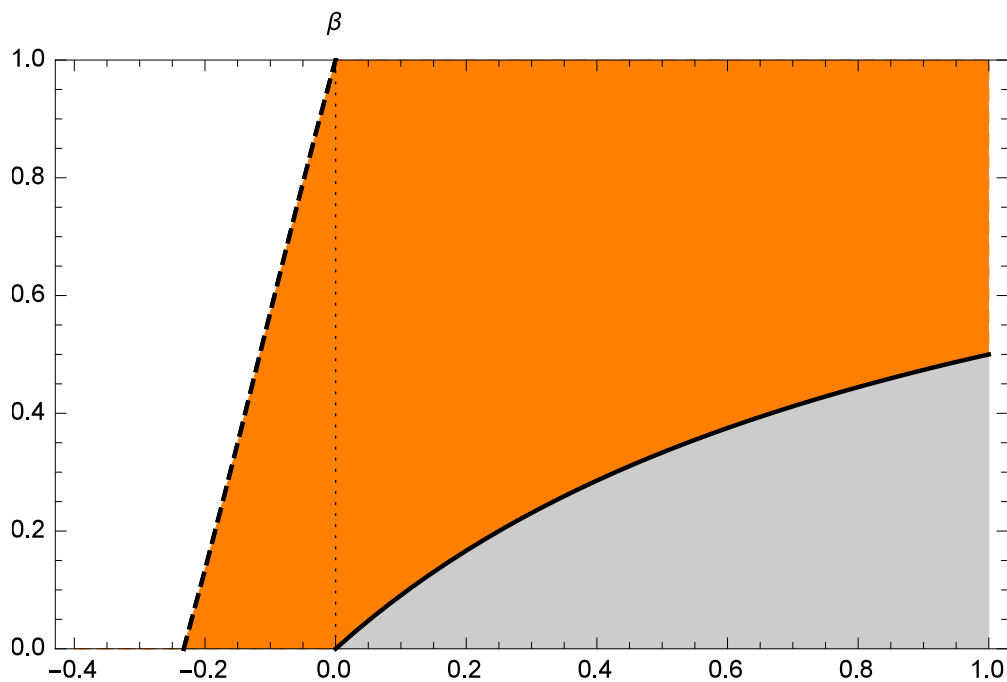


Figure 12: parameter constellations that distinguish between stability and instability of spreading

For full coordination, a spatial equilibrium characterized by $k^* = \theta^* = 1$ results (Figures 11(a)-11(c)). Due to the symmetry assumptions imposed, it coincides with spreading. But the spreading equilibrium is only stable, if integration is high and scale effects are low (compare the dashed line in Figure 11(c) which is the only negatively sloped function in the fully coordinated setting). Coordination activates agglomeration forces such that spreading becomes destabilized. Since fully coordinating governments internalize the interregional substitution effect this basically dampens concentration.

Figure 12 highlights how the range of integration and scale that end up in an unstable spreading equilibrium increases if feedback effects are taken into account. The solid line is identical to the blue line in Figure 8(b) where the shaded area represents parameter constellations leading to an unstable spreading equilibrium given $\bar{\theta} = 1$. The dashed line, instead, assumes endogenously determined public input shares under full coordination, θ^* .

It becomes obvious that the basic pattern of exogenously given θ persists: the parameter range that ends up in unstable spreading increases with ϵ_A and decreases with β . In case of full coordination, only few parameter constellations remain that are compatible

with stable spreading (namely the white area above the dashed line). This result confirms the findings derived in Figure 5 which highlights that the negative substitution effect between private and public sector only becomes effective for low scale effects and is dampened by integration. In contrast to the exogenously given public input share, unstable parameter constellations do not end up in just transforming unstable spreading into stable core-periphery structures but, due to cumulative causation processes between $\theta(k)$ and $k(\theta)$, concentration processes become persistent and are even reinforced since the involved actors are aware of the respective complementarity.

In case of no or only partial coordination, the spreading equilibrium unambiguously becomes unstable (compare Figures 11(d)-(11(i))). But now the positive relationship is reinforced by both scale and integration. It is worthwhile to stress that integration looses its stabilizing impact on spreading. In case of partial coordination, the illustrated asymmetry between the private and the public sector now transforms into asymmetric agglomeration with the leading region representing the unstable core. This effect is reinforced if scale effects are small and by integration.

One might summarize that, as a consequence of the endogenous determination of the public input, the spatial equilibrium for the large majority of integration and scale and for almost all coordination settings (with the sole exception of the dashed line in Figure 11(c)) destabilizes the spatial equilibrium. The consideration of feedback effects sets ground for a process of cumulative causation in which the complementarity of the two inputs leads to mutual reinforcements. As a result, the agglomeration forces almost always dominate.

6 Policy implications

One might summarize the results discussed in Section 3 as follows. The settings differ to which extent they consider the spatial interdependencies of the two local public inputs. Concerning the substitutability of the public inputs, the condition $G = G_1 + G_2$ is taken differently into account: Formally, $\frac{dG_2}{dG_1}$ equals -1 in case of full coordination, zero if autarky prevails and $-\beta k^{\varepsilon_A} n^{\varepsilon_A - \varepsilon_R}$ according to (20) in case of partial coordination. If integration is absent, i.e. for $\beta = 0$, and full symmetry including spreading applies, $\theta^* = \theta^S = \theta^C = 1$.

A closer look on the two benchmark cases of no and full coordination provides additional findings. One key result is the emergence of the positive externality that the provision of a public input by one region represents for the respective other region in case of no coordination. Related to this is the fact that the negative substitution effect

then unequivocally disappears. Besides, we argued that the direction of the integration effect depends upon the sign of scale, ϵ_A . It basically allows for a positive relationship between the private and the public sector (thus reinforcing complementarity) if ϵ_A is positive whereas the integration effect reinforces the negative substitution effect, if ϵ_A is negative.

It is possible to derive the described effects more broadly and thus to discuss if concentration of government expenditure in the uncoordinated setting ends up to be higher or lower than for coordinated policy. To do so one might start by comparing the right hand side of equations (9) and (16)

$$n^{\epsilon_A - \epsilon_R} k^{\epsilon_A} \geq 1 \quad \Leftrightarrow \quad \frac{1 - \beta n^{\epsilon_A - \epsilon_R} k^{\epsilon_A}}{n^{\epsilon_A - \epsilon_R} k^{\epsilon_A} - \beta} l^{-\lambda} k^{-\alpha} \leq \frac{1}{k^{\epsilon_A} n^{\epsilon_A - \epsilon_R} k^{\alpha} l^{\lambda}} \quad (29)$$

Assuming $n = 1$, the result mainly depends on the characteristics of the public input as captured by ϵ_A . If scale effects are positive ($\epsilon_A > 0$), agglomeration in region 1 implies $k^{\epsilon_A} > 1$. For n near to 1, $n^{\epsilon_A - \epsilon_R} k^{\epsilon_A} > 1$ follows immediately, hence the right hand side in equation (16) is larger than in (9). Contrariwise, if scale effects are negative ($\epsilon_A < 0$), agglomeration implies $n^{\epsilon_A - \epsilon_R} k^{\epsilon_A} < 1$ and therefore the right hand side in equation (16) is smaller than in (9). The left hand side decreases in θ^a because

$$\frac{d \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1}}{d\theta^a} = \frac{\partial \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-1}}{\partial g_s} \frac{\partial g_s}{\partial \theta^a} = (\gamma-1) \left(\frac{g_s + \beta}{1 + \beta g_s} \right)^{\gamma-2} \frac{1 - \beta^2}{(1 + \beta g_s)^2} \frac{g_s}{\theta^a} < 0 \quad (30)$$

This implies that the respective ratio of governmental activity is lower (higher) in the uncoordinated setting than with coordinated policy, if scale effects apply:

$$\epsilon_A \geq 0 \quad \Leftrightarrow \quad \theta^a \leq \theta^* \quad (31)$$

The reason is the positive externality of the public input on the other region's income which becomes prevalent in the ambiguous integration effect. 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 . If instead there are positive scale effects, the distortion is smaller in the larger region, hence the resulting concentration of government expenditure is suboptimally high. Increasing integration reinforces the effects if scale is negative and is dampening in case of positive scale effects. Figure 13 summarizes this.

Linking these arguments to agglomeration one might pick up the hint of Ostry and Ghosh (2013, 4) concerning the "policy maker's failure to recognize the fact that they

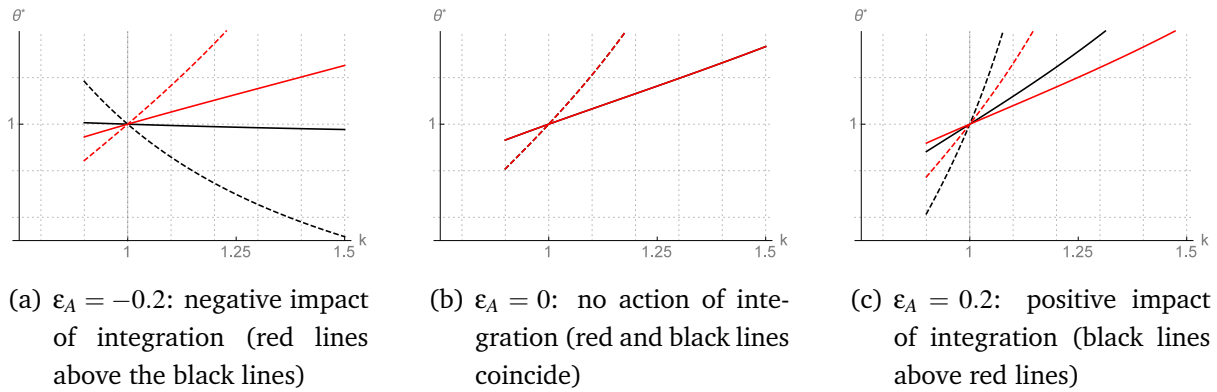


Figure 13: Comparing coordinated policies (black functions) and uncoordinated policies (red functions); symmetric factor endowment $n = l = 1$; solid line: $\beta = 0.25$, dashed line: $\beta = 0.5$. Vgl. Fig 18 im Anhang für eine Darstellung der Abweichungen von $k=1.01$ und aller zulässigen Werte von integration und scale

face important tradeoffs across various objectives." It is especially worthwhile to stress that the convergence goal is almost incompatible with the goal of public efficiency considerations (but needs additional redistributive activity). Symmetric regions are only realized under very specific assumptions - and if so - spreading is not a stable outcome. The deviation from spreading becomes even more pronounced in case of asymmetries of power as discussed in the leader-follower setting in Section 3.3.

7 Conclusions

This paper analyzes the impact of various public policies on the spatial distribution of private economic activity. In doing so we have differentiated the three settings of full coordination (comparable to a social planner's perspective), full autonomy (i.e. governments that decide completely independent from each other on the size of the respective local public input) and the case of partial coordination (in which we assume the governments of the two countries to behave as a leader and a follower in a Stackelberg duopoly). In doing so, we provide a micro-foundation for governmental behavior in a spatial growth model with a productive public input and discuss the implications for the spatial distribution of private economic activity. We also address the stability characteristics for the different coordination schemes and show that governmental coordination may destabilize the spatial equilibrium. Endogenous determination of the public input thus strengthens agglomeration forces and thereby sets ground for processes of cumulative causation which end up in ongoing spatial concentration.

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8 Appendix

8.1 Underlying growth model

Preferences of the identical and infinitely living household include maximizing lifetime utility out of consumption according to²⁸

$$U_i = \int_0^{\infty} \frac{\sigma}{\sigma-1} C_i(t)^{\frac{\sigma-1}{\sigma}} e^{-\rho t} dt \quad \rho > 0, \quad 0 < \sigma < 1 \quad (32)$$

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

$$\dot{V}_i(t) = w_i(t)L_i(t) + (r(t) - \delta)V_i(t) - C_i(t) - T_i(t) \quad (33)$$

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

$$\lim_{t \rightarrow \infty} K_{1i}(t)\xi_i(t) = 0 \quad \lim_{t \rightarrow \infty} K_{2i}(t)\xi_i(t) = 0 \quad (34)$$

have to be met, where ξ_i denotes the shadow value of capital in region i . Maximizing (32) subject to the accumulation constraint (33) leads to the Hamiltonian

$$\mathcal{H}_i = \frac{\sigma}{\sigma-1} C_i(t)^{\frac{\sigma-1}{\sigma}} e^{-\rho t} + \xi_i(w_i(t)L_i(t) + (r(t) - \delta)V_i(t) - C_i(t) - T_i(t)) \quad (35)$$

with optimal consumption described by the necessary conditions

$$\frac{\partial \mathcal{H}_i}{\partial C_i} = C_i^{-\frac{1}{\sigma}} e^{-\rho t} - \xi_i \stackrel{!}{=} 0 \quad (36a)$$

$$\frac{\partial \mathcal{H}_i}{\partial V_i} = \xi_i(r(t) - \delta) \stackrel{!}{=} -\dot{\xi}_i \quad (36b)$$

²⁸The setup of the model mainly borrows from Ott and Soretz (2010).

and leading to the well known growth rate of consumption as²⁹

$$\frac{\dot{C}_i}{C_i} = \sigma(r - \delta - \rho) \equiv \varphi \quad (37)$$

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.

8.2 Table that specifies $\frac{dG_2}{dG_1}$ from (20)

Out[69]/TableForm=

	$\beta=0.$	$\beta=0.2$	$\beta=0.4$	$\beta=0.6$	$\beta=0.8$
$\epsilon_A=-0.4$	-0.00998007	-0.209581	-0.409183	-0.608784	-0.808386
$\epsilon_A=-0.15$	-0.00999252	-0.209843	-0.409693	-0.609544	-0.809394
$\epsilon_A=0.1$	-0.010005	-0.210105	-0.410205	-0.610304	-0.810404
$\epsilon_A=0.35$	-0.0100175	-0.210367	-0.410716	-0.611066	-0.811415
$\epsilon_A=0.6$	-0.01003	-0.210629	-0.411229	-0.611828	-0.812428
$\epsilon_A=0.85$	-0.0100425	-0.210892			

Figure 14: $-dG_2/dG_1 = -\beta n^{\epsilon_A - \epsilon_R} k^{\epsilon_A}$ from (20) if $n = 1$ and $k = 1.005$

It becomes clear that $\frac{d \frac{dG_2}{dG_1}}{d\beta} < 0$, and $\frac{d \frac{dG_2}{dG_1}}{d\epsilon_A} < 0$

8.3 MatrixPlot of θ^s

²⁹In what follows time indices will be suppressed.

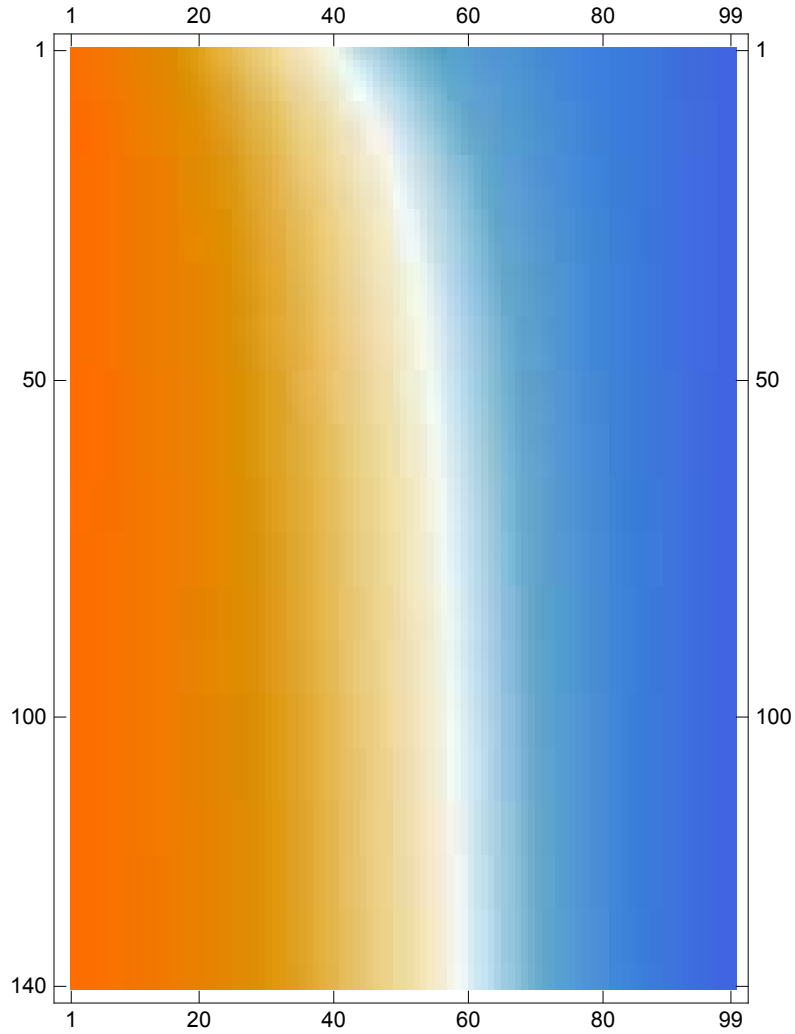


Figure 15: MatrixPlot of θ^s from (23); horizontal axis: $\beta \in [0, 1]$, vertical axis: $\epsilon_A \in [-0.4, 1]$

8.4 Table that specifies θ^S from (22) or (23)

partial coordination implies that for $k = n = l = 1 \Rightarrow \frac{gs+\beta}{1+\beta gs} = \frac{\theta+\beta}{1+\beta\theta}$

epsA=	$\beta=0$	$\beta=0.1$	$\beta=0.2$	$\beta=0.3$	$\beta=0.4$	$\beta=0.5$
- 1/4	1	0,964	0,832	0,586	0,253	-0,099
- 1/8	1	0,972	0,867	0,662	0,362	0,015
0	1	0,976	0,885	0,703	0,426	0,087
1/8	1	0,978	0,896	0,728	0,467	0,136
1/4	1	0,980	0,903	0,746	0,496	0,173
3/8	1	0,981	0,908	0,758	0,518	0,200
1/2	1	0,982	0,912	0,768	0,534	0,221
5/8	1	0,982	0,915	0,776	0,548	0,239
3/4	1	0,983	0,918	0,782	0,558	0,253
7/8	1	0,983	0,920	0,787	0,567	0,265
1	1	0,984	0,922	0,791	0,575	0,275

Figure 16: full symmetry: θ^s if $k = n = l = 1$

8.5 Table that specifies θ^s for endogenous agglomeration

	$\beta=0.1$	$\beta=0.2$	$\beta=0.3$	$\beta=0.4$	$\beta=0.5$	$\beta=0.6$	$\beta=0.7$	$\beta=0.8$	$\beta=0.9$
$\epsilon_A=-0.3$	1.39642	2.06216	3.22214	5.39843	9.99421	21.6375	61.2559	293.835	5565.37
$\epsilon_A=-0.2$	1.23361	1.59054	2.14854	3.06706	4.71186	8.0672	16.5118	47.649	335.145
$\epsilon_A=-0.1$	1.16162	1.39866	1.74998	2.2907	3.17964	4.80187	8.30787	18.5949	80.6454
$\epsilon_A=0.$	1.12177	1.29688	1.54877	1.92125	2.50269	3.4941	5.44765	10.4467	33.9606
$\epsilon_A=0.1$	1.09677	1.23459	1.42925	1.70974	2.13274	2.82188	4.09808	7.07878	18.9844
$\epsilon_A=0.2$	1.07977	1.19288	1.35077	1.57424	1.90313	2.42176	3.34038	5.35013	12.4997
$\epsilon_A=0.3$	1.06754	1.16316	1.29559	1.48063	1.74808	2.15966	2.86467	4.33316	9.12475
$\epsilon_A=0.4$	1.05836	1.14101	1.25485	1.41239	1.63695	1.97606	2.542	3.67658	7.13884
$\epsilon_A=0.5$	1.05124	1.12391	1.22362	1.36058	1.55369	1.84094	2.31045	3.22333	5.86407
$\epsilon_A=0.6$	1.04559	1.11035	1.19897	1.32	1.48914	1.73768	2.13704	2.89431	4.9914
$\epsilon_A=0.7$	1.04099	1.09935	1.17906	1.2874	1.43772	1.65637	2.00277	2.64601	4.36381
$\epsilon_A=0.8$	1.03719	1.09026	1.16265	1.26067	1.39585	1.5908	1.89597	2.45273	3.89463
$\epsilon_A=0.9$	1.034	1.08264	1.14892	1.23838	1.36113				

Figure 17: intersections of $i(k)$ with the horizontal axis in figure 11(i)

It becomes clear that $\frac{dG_2}{d\beta} < 0$, and $\frac{dG_2}{d\epsilon_A} < 0$

8.6 Comparison Planner -Cournot

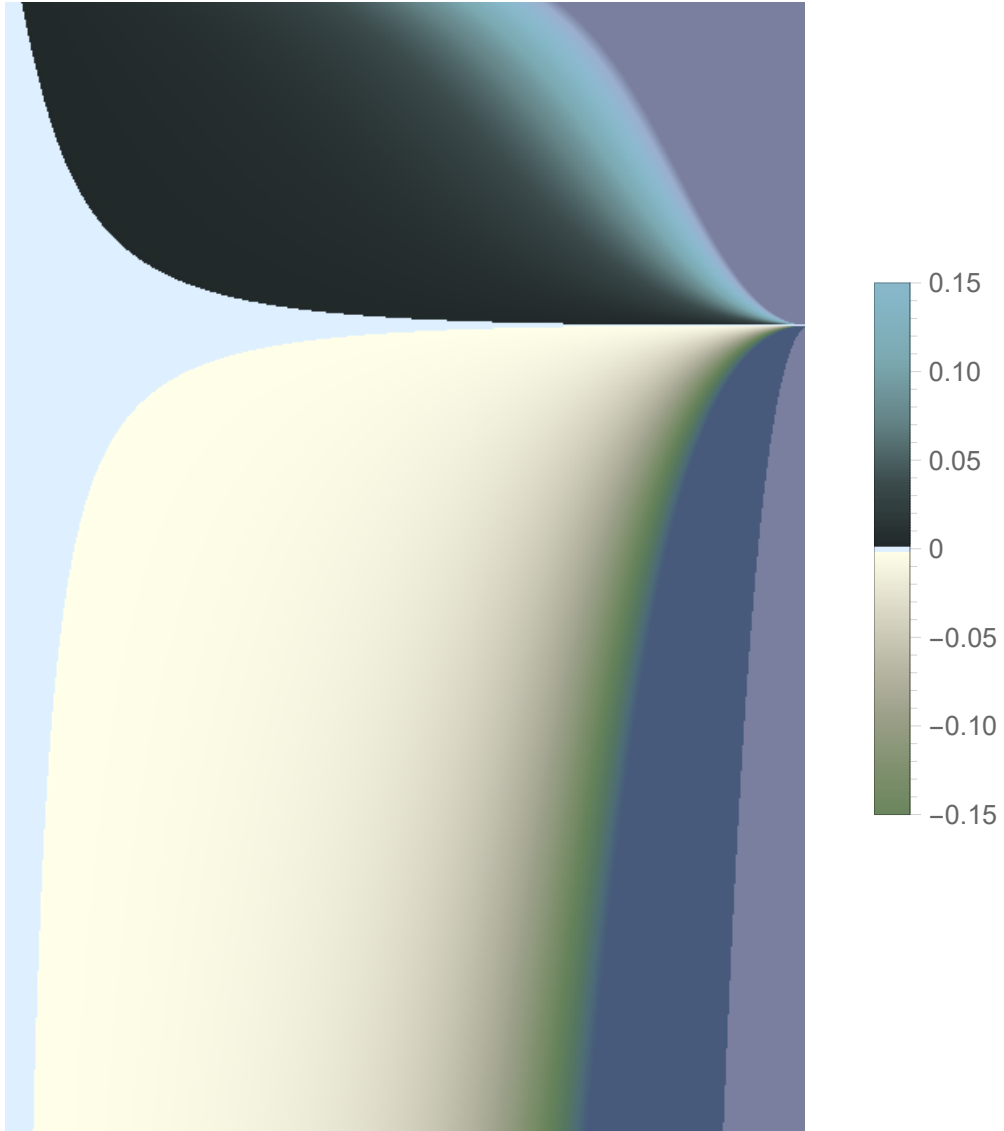


Figure 18: Alternative representation of the comparisons of coordinated and uncoordinated policies as shown in figure 13 for $k = 1.01$;
horizontal axis: $\beta \in (0, 1)$ vertical axis $\epsilon_A \in [-0.4, 1]$.