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Public input competition and agglomeration

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ABSTRACT

This paper analyzes the impact of public input competition in a New Economic Geography framework. It is shown that regional competition yields an overprovision of public inputs if trade costs are sizable while it leads to underprovision if regions are highly integrated. Moreover, public input competition assures a dispersion of industry as long as trade costs are high but induces agglomeration even for ex ante identical regions if trade costs have fallen below a certain value. Finally, a trade-off between regional convergence and efficiency arises since the efficient distribution of regional infrastructure requires full agglomeration for sufficiently low trade costs.

1. Introduction

All over the world we observe the tendency for further economic integration that increases factor mobility and stimulates regional trade. Firms are moving from one region to another rapidly in search of the most favorable conditions. Besides taxes and subsidies the most important instrument for local governments in attracting industry is certainly the quality of its local public inputs. Hence, jurisdictions may compete by providing public transportation, IT- and communication infrastructure, R&D facilities or other public inputs that increase the factors' productivity. As Borck et al. (2007) have shown, there is clear evidence that regions investing in productivity enhancing infrastructure respond positively to an increased investment in the neighboring regions. Using data on capital expenditures by US majority-owned companies in 18 European countries, Bénassy-Quéré et al. (2007) find a significant positive effect of local public capital on inward FDI. However, their analysis suggests that public infrastructure raises FDI investment only if it is not financed by a tax on the mobile factor. In contrast, Gabe and Bell (2004) come to the conclusion that a strategy of high spendings on local public infrastructure along with high taxes is even more rewarding for attracting businesses than a strategy of low taxes and low local government spending. Bénassy-Quéré et al. (2007) analyze the effects of public infrastructure spending on European national level, whereas Gabe and Bell (2004) look at the location decision of businesses on the municipal level in Maine.

While public input competition gains relevance the more mobile the factors are, we observe that economic integration also leads to spatial agglomeration of industries. Midelfart-Knarvik and Overman (2002), Ezcurra et al. (2006), as well as Brühlhart (2001) have shown that the regional concentration of industrial activity in Europe has been increasing over the last decades. Moreover, the rise in geographic concentration coincided with the establishment of the single European market. For the United States Ellison and Glaeser (1999) estimate that only about 20% of observed geographic concentration can be explained by comparative advantages. The remaining part has to be explained by local spillover effects, vertical input linkages or by the provision of industry-specific infrastructure. The latter channel of industrial clustering is the one we focus on.

In this paper we bring together the spatial development of economic activity during a process of economic integration and the role of public input competition. We study the impact of fiscal competition via public inputs on the distribution of industry. From a positive point of view, we analyze under which conditions public input competition between two regions affects the process of agglomeration: will it hinder or enforce it? From a normative point of view, we determine whether competition leads to an efficient

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outcome in terms of the provision of public inputs as well as the resulting regional allocation of industry. The latter issue addresses the question of whether a federal policy reallocating public input resources across regions is necessary in order to achieve an optimal outcome.

We model public input competition in a New Economic Geography framework where regional agglomeration is driven by increasing returns on the firm level in combination with trade costs and monopolistic competition. This is a very useful framework to analyze the effects of public input competition on a regional level since it allows for factor mobility as well as for costly trade. As we will show, the inclusion of trade in addition to factor mobility provides important new insights. We employ an approach where trade is not determined by comparative advantages but by economies of scale and consumer preferences for differentiated varieties. Considering similar regions within federations such as the European Union or the USA this explanation of trade fits certainly better than comparative advantages. Due to the analytical tractability we use a footloose capital model (see e.g. Martin and Rogers, 1995; Baldwin et al., 2003; Dupont and Martin, 2006). Martin and Rogers (1995) model infrastructure as a means to reduce iceberg trade costs. They distinguish between infrastructure that facilitates trade within a certain region and infrastructure that reduces trade costs between regions. It is shown that improving domestic infrastructure induces firms to relocate to this region while improving international infrastructure in a region with poor domestic infrastructure induces firms to relocate outside this region. In contrast, we adopt the common view that public spending directly affects the production function (see i.e. Barro, 1990; Morrison and Schwartz, 1996). Moreover, we emphasize the strategic interaction between regions and the cross-regional externalities that arise from local infrastructure provision when accounting for trade. For most of our analysis we consider ex ante identical regions but in an extension we allow for differences in regional size. As opposed to the core-periphery model (see e.g. Krugman, 1991; Baldwin et al., 2003) the standard footloose capital model does not imply an agglomeration process for symmetric regions. However, once we add public input competition decreasing trade costs lead to agglomeration in the footloose capital model even for ex ante identical regions.

We derive the following main results: First of all we show that one region may decide not to provide any infrastructure and to free-ride on the other region's infrastructure if trade costs become sufficiently low. The reason is that the region benefits from importing goods at low trade costs instead of bearing the costs of infrastructure provision itself. This is the case where public input competition induces agglomeration even for ex ante identical regions. Only when trade costs are sufficiently high, will regional competition yield a symmetric provision of public inputs and agglomeration tendencies will be eliminated.

Second, regarding the normative question of aggregate public input provision two externalities are decisive. On the one hand, infrastructure provision in one region exerts a negative externality on the other region because it attracts industry from there. On the other hand, the possibility of trade in combination with the public good characteristics of infrastructure adds a positive externality of infrastructure provision. The region that provides all the infrastructure does not take into account the cost reduction of imported manufactured goods in the foreign region. If trade costs are sufficiently low this positive externality dominates and an underprovision of infrastructure is the outcome of fiscal competition. On the contrary, if the trade costs are sizable we show that the amount of aggregate infrastructure provided in the Nash equilibrium is too high compared to a centralized provision of regional infrastructure. The reason is that imports are expensive when trade costs are high and accordingly it is important to have industry located within one's own borders such that the negative externality dominates. Hence, for high trade costs our model confirms what has been derived within the standard fiscal competition framework, namely, an oversupply of public inputs (see, e.g., Keen and Marchand, 1997, who model competition between jurisdictions that provide both public inputs and public consumption goods), albeit induced by a quite different mechanism. However, we show that strong agglomeration forces turn this result upside down.

Third, concerning the distribution of infrastructure across regions, low trade costs allow the regions to import industrial goods at low consumer prices. In such an integrated market a central government chooses to concentrate public infrastructure in one region. This strategy assures that all industry is located in the core region and maximizes the aggregate productivity of the industrial sector. For high trade costs, in contrast, a central government would distribute infrastructure equally across regions because the benefit from saving trade costs is higher than the loss in overall productivity. For a range of higher trade costs we show that the Nash equilibrium is characterized by a symmetric provision whereas a central government would place all infrastructure in one region and implement an agglomeration pattern. The reason is that a single region benefits from increasing aggregate productivity only to the extent of the imported goods weighted at trade costs while the central government faces the full productivity gain. Moreover, the region that loses all industry faces a higher increase in trade costs than the average federation does, since the core region saves trade costs. Therefore, regions start to prefer the concentration of infrastructure and the agglomeration of industry in uncoordinated equilibrium only at a lower rate of trade costs than the central government does. Note that these results arise although we abstract from local spillover-effects between firms in our model.[1] A series of papers has addressed tax competition in the NEG, but to our knowledge, this paper is the first one which deals with public input competition in such a framework.[2] Bucovetsky (2005) analyzes public input competition in a model with perfect competition and external economies of scale. He shows that both under- or overinvestment may arise as a result of regional competition depending on the extent of economies of scale in public investment. However, he does not take costly trade between the regions into account, which is central to our argument. Egger and Falkinger (2006) examine the relationship between public infrastructure competition and outsourcing in a new trade model. They conclude that public infrastructure provision may prevent international outsourcing and that regional competition may therefore result in an overprovision. In contrast to our analysis, infrastructure provision does not affect consumer prices in their model which is the source of the positive externality in our model. They think of public infrastructure provision as an instrument that reduces the fixed costs of setting up a firm, whereas we model infrastructure such that it lowers the variable costs of production. Robert-Nicoud and Sbergami (2004) link the footloose capital model with endogenous regional policy to a political economy approach. A central government which is elected by the citizens of both regions decides on the amount of subsidies payed to each region. The subsidies in turn affect the spatial allocation of industry. However, regions do not explicitly compete in their setting and no normative conclusions are drawn. Moreover, these subsidies reduce only the fixed costs of setting up a firm, such that the consumer prices remain again exogenous. There is clearly anecdotical evidence that public inputs affect not only set up costs, but also variable costs. For instance, improvement in public transportation systems reduces transport time and thus costs per unit.

The next section introduces the basic model and derives the impact of regional infrastructure on the long-run allocation of industry. Section 3 describes the externality of infrastructure provision which

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[1] Such spillover effects can also lead to lower degree of agglomeration than desired from a welfare perspective as Martin and Ottaviano (1999) have shown.

[2] See Ludema and Wooton (2000), Kind et al. (2000), Andersson and Forslid (2003), Baldwin and Krugman (2004), Ottaviano and van Ypserle (2005), Borck and Pflüger (2006) or Baldwin et al. (2003) for tax competition in the New Economic Geography.

arises if fiscal competition between regions takes place and determines the Nash equilibria for critical values of trade freeness. Section 4 contrasts the Nash equilibria with the allocation of a central government taking account of the externalities. Section 5 extends the model to asymmetry in population size and to congestion costs and discusses the qualifications of the results. Section 6 summarizes the main findings and relates to policy issues.

2. The model

Following Martin and Rogers (1995) we use a model where the fixed cost in the manufacturing sector is attached to an internationally mobile factor. A federation consists of two regions H and F which are symmetric in terms of preferences, technology and trade costs. There are two sectors, a manufacturing sector (M) characterized by increasing returns, monopolistic competition and iceberg trade costs, and a perfectly competitive sector labeled agriculture (A) which produces under constant returns a homogenous good that is traded without costs. This good is produced in both regions and is taken as the numéraire, i.e. its price p_A is normalized to one. Individuals consume an agricultural good C_A and a composite manufactured good C_M as in Dixit and Stiglitz (1977). The utility of consuming the agricultural and the composite manufactured good is a logarithmic quasi-linear function where μ is the expenditure share of the composite manufactured good.[3]

The composite manufactured good again is given by a continuum of n differentiated varieties. In general individuals prefer to consume as many different varieties as possible. Their willingness to substitute between the quantities m_i of the varieties is given by the substitution elasticity $\sigma>1$. Hence, utility is[4]:

$$U = C_A + \mu \ln C_M + \mu - \mu \ln(\mu);\ \text{where } C_M = \left[\int_0^n m_i^{\frac{\sigma-1}{\sigma}} \mathrm{d}i\right]^{\frac{\sigma}{\sigma-1}}. \quad (1)$$

Denoting personal net income by y, the budget constraint is

$$y = C_A + PC_M, \quad (2)$$

where the economy's consumer price index of the composite good P can be expressed in terms of the prices $p(i)$ of varieties i:

$$P = \left[\int_0^n p_i^{1-\sigma} \mathrm{d}i\right]^{\frac{1}{1-\sigma}}. \quad (3)$$

Utility maximization leads to demand functions and indirect utility:

$$C_A = y - \mu,\ C_M = \mu / P,\ m_i(p_i) = \mu \frac{p_i^{-\sigma}}{P^{1-\sigma}},\ V = y - \mu \ln(P). \quad (4)$$

On the supply side, there are three productive factors: inter-regionally immobile labor, mobile capital and local infrastructure. The number of immobile workers in region $j=H,F$ is denoted by L_j, the number of capital owners by K_j, where each capital owner owns one unit of capital. The total stock of capital is given by $K^W=K_H+K_F$, while world labor endowment is given by $L^W=L_H+L_F$. Capital is invested internationally but its return is repatriated. The agricultural good is produced with labor under a linear technology. Perfect competition leads to marginal cost pricing. Furthermore, the wage is equal to the marginal product of labor, i.e. one. Manufacturing firms produce with a non-homothetic technology and each firm produces one variety. A firm located in region j requires one unit of capital and, per unit of output, c_j units of labor. Total costs of a firm which produces variety i are $R_j+c_jM_i$, where R_j is the reward to capital in region j and M_i is the output of this firm.

In the Dixit–Stiglitz model of monopolistic competition mill pricing is optimal.[5] Hence, indicating producer prices by a hat, in the region where the variety is produced $p_i=\hat{p}_i$ holds, and in the foreign region $p_i=\tau\hat{p}_i$ is fulfilled, where τ are iceberg trade costs with $\tau>1$. Profits of firm i in region j are

$$\Pi_i^j = \left(\hat{p}_i - c_j\right) M_i - R_j. \quad (5)$$

Market clearing for a variety i produced in region j implies $M_i=m_i(\hat{p}_i)(K_j+L_j)+\tau m_i(\tau\hat{p}_i)(K_k+L_k)$, $k\neq j$, $j,k\in\{H,F\}$. Hence, profit maximization leads to

$$\hat{p}_i = \frac{c_j\sigma}{\sigma-1}. \quad (6)$$

Since all firms in a single region set the same price for each variety, local consumers demand the same quantity of all local varieties and we may therefore refer to regions instead of varieties. The regional price index of manufactured goods in region j follows from Eq. (3), which is given by the sum of local produced (n_j) and imported varieties (n_k).

$$P_j = \left[\hat{p}_j^{1-\sigma} n_j + (\hat{p}_k\tau)^{1-\sigma} n_k\right]^{\frac{1}{1-\sigma}}, \quad k\neq j, \quad j,k\in\{H,F\} \quad (7)$$

Variable costs c_j depend on local infrastructure in the respective region. The better the local public good supply is, the lower variable costs are. We assume that investment in local infrastructure (X_j) reduces the variable factor's input coefficient (c_j) in the production of the manufacturing sector. We abstain from an effect of infrastructure on the immobile sector because we want to focus on that part of infrastructure that is used for regional competition by attracting mobile firms. Hence, the infrastructure is specific to the mobile sector. For example one could think of IT- and telecommunication infrastructure or R&D facilities which are of negligible value for the agricultural sector. Investing in sector specific infrastructure is a rational strategy for regions experiencing increasing competition for mobile capital. Since tax revenue and the scope for expenditures are limited they will try to focus on the mobile industries and the most lucrative industries which expect a promising future. This is why we do not observe regional competition for agricultural or heavy industries. From a local politician's point of view it makes no sense to waste tax revenue for the provision of public inputs that benefit sectors which are either not very mobile or not lucrative. The latter are not expected to significantly contribute to the local tax revenues. Pereira and Andraz (2007) analyze public infrastructure investment in Portugal between 1976 and 1998, which was financed to a large extent by the European Union. They can show that infrastructure investments did not only enhance labor productivity significantly but also that it shifted the countries industry mix towards more progressive sectors as for example the chemical and metal industry or the finance sector. In their analysis the seven sectors that benefited most captured

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[3] Since expenditure shares are exogenous in the footloose capital model, a reallocation of industry does not imply income effects. Using a quasi-linear utility function which captures only substitution effects exhibits all relevant features of the model and simplifies calculations. See Robert-Nicoud and Sbergami (2004) for an application of the footloose capital model with quasi-linear utility and Pflüger (2004) for a detailed analysis of the standard model with quasi-linear utility.

[4] $\mu-\mu\ln(\mu)$ is added to simplify the expression for indirect utility; see below.

[5] The Dixit–Stiglitz set up implies that mill prices depend only on costs in the region of origin. To the contrary, quadratic utility and linear demands (see, e.g., Ottaviano and Thisse, 2004) would imply that prices of exporters are affected by costs in the region of destination. Cost reductions in one region would translate to direct price changes of exporters in the other region.

about 78% of the benefits, but made up initially only about 21% of total employment.

In the model we let each region invest an amount X_j in sector specific local infrastructure which improves the productivity of labor:

$$X_j = c_j^{1-\sigma}. \tag{8}$$

The implicit assumption behind this definition is that the productivity of the variable input factor increases with local infrastructure. Moreover, it may increase at a diminishing, constant or increasing rate depending on σ (diminishing rate if $\sigma>2$), since the production function of the monopolistic competitive sector is given by:

$$Q_j = X_j^{\frac{1}{\sigma-1}} L_j, \tag{9}$$

where Q_j is total output of this sector in region *j*. Hence the output elasticity of infrastructure is set to $\frac{1}{\sigma-1}$, which simplifies our analysis.[6]

In order to finance infrastructure, wage and capital income of immobile residents will be taxed in each region. Note that this implies that taxation has no direct impact on the demand for manufactured goods, since we have assumed that there are no income effects in the markets for manufactured goods. Hence, the location of firms remains unaffected by the tax which follows the world income principle. Even though the residence principle seems unrealistic with respect to capital taxation we use it in order to focus on competition via the public input solely.

For now we model infrastructure as a pure public good, that is non-rivalry in its usage. Later on we also consider congestion costs in the provision of infrastructure and show how the results change if we have an impure public good.

Using the prices from Eq. (6), the definition of the price index (7), and the market clearing condition, the profits of each firm in region *j* from Eq. (5) are

$$\Pi_j = X_j \frac{\mu}{\sigma}\left(\frac{\left(K_j + L_j\right)}{X_j n^j + \tau^{1-\sigma} X_k n^k} + \tau^{1-\sigma}\frac{\left(K_k + L_k\right)}{X_k n^k + \tau^{1-\sigma} X_j n^j}\right) - R^j. \tag{10}$$

2.1. Short-run returns

In the monopolistic competition framework, free and instantaneous entry of firms drives pure profits to zero and the reward to capital is equal to the operating profit. Furthermore, each firm requires one unit of entrepreneurial capital (i.e. $n=K^W$), such that the number of local varieties is equal to the stock of employed capital. The share of industry or capital employed in region *H* can be defined as $s_n = n_H/n = n_H/K^W$, where $n = n_H + n_F$. Note that K_j represents the amount of capital, which is owned by region *j*, whereas n_j represent the amount of capital that is invested in region *j*. The share of population in region *H* (s_{pop}) is exogenously given by the regional factor endowments (L_H, K_H):

$$s_{\text{pop}} = \frac{K_H + L_H}{N}, \tag{11}$$

where $N \equiv K^W + L^W$ indicates worldwide population.

Using the fact that pure profits are zero, the short-run capital returns of both regions result from Eq. (10) as:

$$\begin{aligned} R_H &= \frac{\mu}{\sigma} X_H \left(\frac{s_{\text{pop}}}{\Delta_H} + \frac{\phi\left(1-s_{\text{pop}}\right)}{\Delta_F}\right)\frac{N}{n}, \\ R_F &= \frac{\mu}{\sigma} X_F \left(\frac{\phi s_{\text{pop}}}{\Delta_H} + \frac{\left(1-s_{\text{pop}}\right)}{\Delta_F}\right)\frac{N}{n}, \end{aligned} \tag{12}$$

$$\text{with } \Delta_H = X_H s_n + X_F \phi (1-s_n) \text{ and } \Delta_F = X_F(1-s_n) + X_H \phi s_n,$$

where $\phi = \tau^{1-\sigma}$ is the degree of trade freeness with $0<\phi\le 1$. These short-run capital returns illustrate the two opposing effects firms consider when choosing their location. On the one hand they prefer the larger market (greater s_{pop}) and on the other hand they prefer the less crowded one (less competitors for input factors, i.e. smaller s_n). Finally, note that average short-run returns are independent of population distribution and infrastructure endowment:

$$s_n R_H + (1-s_n) R_F = \frac{\mu N}{\sigma n} \equiv \overline{R}. \tag{13}$$

2.2. Long-run equilibrium

In the long-run equilibrium, capital owners cannot increase capital returns by relocation:

$$\begin{aligned} s_n &= 0 \quad \text{if } R_H - R_F|_{s_n=0} < 0 \Leftrightarrow \chi < \frac{\phi}{s_{\text{pop}} + \left(1-s_{\text{pop}}\right)\phi^2}, \\ s_n &= 1 \quad \text{if } R_H - R_F|_{s_n=1} > 0 \Leftrightarrow \chi > \frac{s_{\text{pop}}\phi^2 + 1 - s_{\text{pop}}}{\phi}, \\ s_n &= \frac{s_{\text{pop}}}{(1-\phi\chi)} - \frac{\phi\left(1-s_{\text{pop}}\right)}{(\chi-\phi)} \quad \text{otherwise}, \end{aligned} \tag{14}$$

where $\chi = X_H/X_F$. Either capital is completely located in the region with the larger returns or capital returns are equalized and both regions employ capital. If both regions have the same quality of infrastructure, the larger region (i.e. greater s_{pop}) will attract more and more industry during a process of falling trade costs. Sooner or later all industry will be concentrated in the larger region. This process is shown in Fig. 1, where the share of industry in region *H* is depicted against the freeness of trade. It is assumed that region *H* is larger in terms of population.

Having the larger share of industry implies also a lower consumer price index and accordingly a higher real income. This can be seen by rewriting the price indices (7) of regions *H* and *F* where prices (6) have been inserted:

$$\begin{aligned} P_H &= \left(\frac{\sigma}{\sigma-1}\right)\left[X_H s_n + \phi X_F (1-s_n)\right]^{\frac{1}{1-\sigma}} n^{\frac{1}{1-\sigma}}, \\ P_F &= \left(\frac{\sigma}{\sigma-1}\right)\left[X_F (1-s_n) + \phi X_H s_n\right]^{\frac{1}{1-\sigma}} n^{\frac{1}{1-\sigma}}. \end{aligned} \tag{15}$$

Considering only the interior solution it follows from Eq. (15) that a higher share of industry in one region decreases its price index and increases the price index in the other region. However, the local share of industry increases with local infrastructure, therefore smaller regions with a lower share of expenditure can compensate their home-market disadvantage by investing in infrastructure. For every combination of size asymmetry and trade freeness, there is one ratio of regional infrastructure that ensures an equal distribution of industry. Moreover,

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[6] Expressing the input coefficient in terms of the elasticity of substitution σ is a common way to simplify New Economic Geography models (Fujita et al., 1999 p. 54; Baldwin et al., 2003, p.23). It can easily be shown that the result holds true for a general output elasticity of infrastructure, too. See Appendix C for a formal discussion.

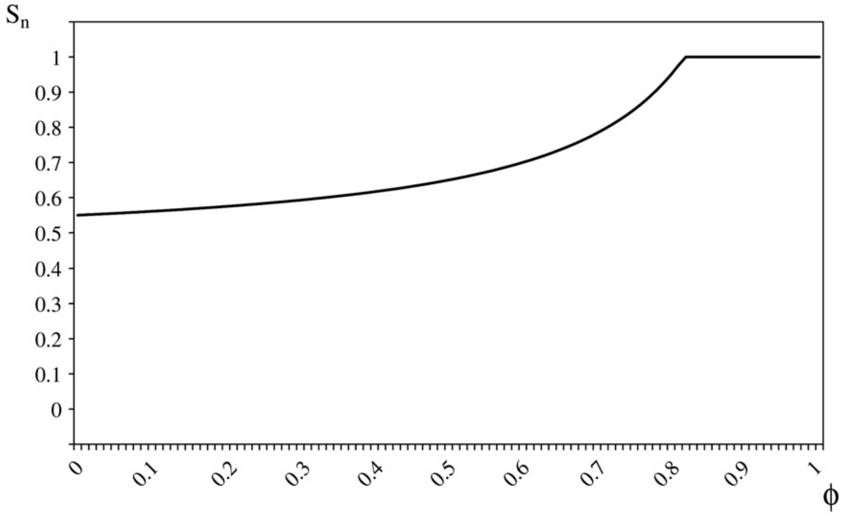

Fig. 1. Bifurcation diagram.

region H attracts all industry if it provides an infrastructure level X_H^{Agg}, just as well as region F does when providing X_F^{Agg}:

$$X_H^{\text{Agg}} = \frac{1 - s_{\text{pop}}\left(1 - \phi^2\right)}{\phi} X_F, \quad X_F^{\text{Agg}} = \frac{s_{\text{pop}} + \phi^2\left(1 - s_{\text{pop}}\right)}{\phi} X_H. \quad (16)$$

Taking the logarithm of price indices (15), we can express the impact of regional infrastructure in utility terms. Assuming interior solutions, that is $0 < s_n < 1$ we may further substitute for the long-run share of industry (14):

$$\ln(P_H) = \frac{1}{1-\sigma} \ln\left[\frac{X_H X_F s_{\text{pop}}\left(1 - \phi^2\right)}{X_F - \phi X_H}\right] + A \quad \text{and} \quad (17)$$

$$\ln(P_F) = \frac{1}{1-\sigma} \ln\left[\frac{X_H X_F\left(1 - s_{\text{pop}}\right)\left(1 - \phi^2\right)}{X_H - \phi X_F}\right] + A,$$

$$\text{with } A = \frac{1}{1-\sigma}\ln(n) + \ln\left(\frac{\sigma}{\sigma - 1}\right).$$

These prices are only defined for $\chi > \phi$ and $1/\chi > \phi$. This means, the higher the trade freeness the lower the potential infrastructure differences. Intuitively this restriction states that consumer prices of imported varieties (i.e. the producer price plus trade costs) have to be higher than the consumer price of locally produced varieties (i.e. the producer price).[7] Infrastructure differences that imply a lower consumer price for imports than for local varieties would lead to full concentration of industry in the region with the better infrastructure, no matter what expenditure shares apply.

If all industry is concentrated in region j, the price indices are from Eq. (15):

$$\ln\left(P_j\right) = \frac{1}{1-\sigma} \ln\left[X_j\right] + A \quad \text{and} \quad (18)$$

$$\ln(P_k) = \frac{1}{1-\sigma} \ln\left[\phi X_j\right] + A, \quad k \neq j.$$

In the following sections it will be analyzed how the distribution of industry in Fig. 1 changes if regions are allowed to compete with infrastructure.

3. Decentralization

First, we analyze a situation where the two regions act independently, which we call decentralization.

3.1. Infrastructure and price index

It is crucial to the argument that we illustrate the impact of infrastructure provision on the local price index, because this is the channel through which the indirect utility of a consumer is affected. Two distinct effects of infrastructure affect regions' welfare. First, a lower input coefficient obviously allows the production of more output for given input. Differentiating Eq. (15) with respect to infrastructure and keeping the share of industry constant yields:

Direct local price index effect

$$\frac{\partial \ln(P_H)}{\partial X_H}\Big|_{\bar{s}_n} = \left(\frac{1}{1-\sigma}\right) \frac{1}{X_H s_n + \phi X_F (1 - s_n)} s_n < 0. \quad (19)$$

Since the regional price index decreases, citizens utility increases. Second, from Eq. (12) we know that capital returns increase with the quality of local infrastructure provided. A region therefore attracts industry, when investing in infrastructure. The increasing share of local firms again lowers the local consumer price index, because less goods have to be imported in order to consume the optimal consumption bundle. This means citizens will save on trade costs. Differentiating Eq. (15) with respect to the share of industry and Eq. (14) with respect to infrastructure yields:

Indirect local price index effect

$$\partial \ln \frac{(P_H)}{\partial X_H} = \underbrace{\left(\frac{1}{1-\sigma}\right) \frac{X_H - \phi X_F}{X_H s_n + \phi X_F (1 - s_n)}}_{\frac{\partial \ln(P_H)}{\partial s_n}} \underbrace{X_F \phi \left(\frac{s_{\text{pop}}}{(X_F - \phi X_H)^2} + \frac{(1 - s_{\text{pop}})}{(X_H - \phi X_F)^2}\right)}_{\frac{\partial s_n}{\partial X_H}} < 0. \quad (20)$$

The first part of this effect $\left|\frac{\partial \ln(p_H)}{\partial s_n}\right|$ decreases with trade freeness ϕ, whereas the second part $\left|\frac{\partial s_n}{\partial X_H}\right|$ increases. This means for high trade freeness, it is not as important for consumers to have firms located in their home regions. However, firms get more footloose when trade costs fall, which implies that they are more easily attracted

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[7] $\chi > \phi$ implies $c_F \tau > c_H$, thus $\hat{p}_H \tau > \hat{p}_H$. $\frac{1}{\chi} > \phi$ implies $c_H \tau > c_F$, thus $\hat{p}_H \tau > \hat{p}_F$.

by infrastructure. This results from the fact that the home-market effect, which ties firms to the larger market, loses some of its strength. Overall the indirect effect increases with trade freeness.

For prohibitively high trade costs, that is $\phi = 0$, there is no indirect effect, because firms will choose their location only with respect to the exogenous home-market size. In this case infrastructure does not have any impact on the long-run location of firms. For infinitely low trade costs, that is $\phi = 1$, the restriction described above does not allow for interior solutions. A corner solution with one region not providing any infrastructure has to apply. The amount of industry one region attracts, the other will lose. This is because the number of firms in the economy as a whole is given by the stock of capital $n = K^W = K_H + K_F$. Therefore each region exerts a negative effect on the utility of foreigners, when investing in local infrastructure. Furthermore, in uncoordinated behavior each region does not consider this indirect negative effect it has on the other region, when lowering the regional consumer price index. A negative externality evolves, which gains relevance for welfare because of monopolistic competition and trade costs.

The public good characteristics of infrastructure generate an additional, counteracting externality which becomes relevant if the trade freeness is sufficiently high. For low trade costs it might be cheaper to import manufactured goods than bearing the costs of providing enough infrastructure to have a decent share of manufacturing firms located in the respective region. Therefore one of the two regions may decide not to provide any infrastructure at all and free-ride on the expenses of the other region. The same free-riding externality occurs if regions are very asymmetric in terms of population and infrastructural endowments. In this case it is very expensive for the smaller or less endowed region to attract industry and it may decide to better import and use the foreign infrastructure. Which of the two externalities dominate, the negative or the positive, depends crucially on the trade freeness and the initial distribution of industry as will be shown in the following.

3.2. Fiscal competition equilibria

Each region will maximize welfare of their citizens in the long run by local infrastructure investment financed through income taxes subject to the residence principle. Thereby, each region takes infrastructure endowment in the other region as given. Since wages are equal to one and capital returns in the long-run equilibrium are the same for all capital owners, the objective of region j can be written as

$$\max_{X_j} \quad W_j \equiv L_j + K_j\overline{R} - X_j - \left(K_j + L_j\right)\mu \ln\left(P_j\right) \quad \text{s.t. (14).} \tag{21}$$

In a Nash equilibrium, both regions solve simultaneously the respective optimization problem.

In order to obtain general analytic results, we assume a symmetric distribution of population in the remaining part of this section: $s_{\text{pop}} = 1/2$. Later on, we will numerically solve for equilibria when population is asymmetrically distributed.

From Eq. (21) we get for $0 < s_n < 1$ the following first-order conditions

$$\begin{aligned} 1 &= \frac{\mu N}{2(\sigma - 1)} \frac{X_F}{X_H(X_F - \phi X_H)}, \\ 1 &= \frac{\mu N}{(\sigma - 1)} \frac{X_H}{X_F(X_H - \phi X_F)}, \end{aligned} \tag{22}$$

with reaction functions in the interior

$$X_{H_{1,2}} = \frac{X_F(\sigma - 1) \pm \sqrt{X_F(\sigma - 1)[X_F(\sigma - 1) - 2\mu\phi N]}}{2\phi(\sigma - 1)},$$

$$X_{F_{1,2}} = \frac{X_H(\sigma - 1) \pm \sqrt{X_H(\sigma - 1)[X_H(\sigma - 1) - 2\mu\phi N]}}{2\phi(\sigma - 1)}.$$

However, zero public good supply or "threshold" supply that ensures full agglomeration of industry might also be optimal. As a consequence, depending on trade costs, fiscal competition may either lead to interior equilibria and dispersion of industry or to corner equilibria and agglomeration, as the following proposition states.

Proposition 1. ***(a)*** *A symmetric locally stable Nash equilibrium*

$$X_H = X_F = \frac{\mu N}{2(1 - \phi)(\sigma - 1)} > 0 \quad \text{with} \quad s_n = \frac{1}{2} \tag{23}$$

exists if and only if $\phi \leq 0.1748$.

(b) *No Nash equilibrium exists if and only if* $0.1748 < \phi < 0.2832$.

(c) *Corner Nash equilibria with*

$$\begin{aligned} X_H &= \frac{\mu N}{2(\sigma - 1)}, X_F = 0,\ s_n = 1 \quad \text{or} \\ X_F &= \frac{\mu N}{2(\sigma - 1)}, X_H = 0,\ s_n = 0 \end{aligned} \tag{24}$$

exist if and only if $\phi \geq 0.2832$.

Proof. See Appendix A. ☐

Note that these critical values of trade freeness are only true for ex-ante symmetric regions ($s_{\text{pop}} = 1/2$). Section 5.1 discusses ex-ante asymmetric regions. In the symmetric Nash equilibrium, the provided level has the expected correlations. It increases with μ, because manufactured goods gain more weight in the individuals' preferences. The indirect effect, and accordingly the competition for industrial firms, gets the stronger the higher ϕ. Therefore, the provided level increases in trade freeness, too. The elasticity of substitution σ has a negative effect on the equilibrium provision of infrastructure, because the output elasticity of infrastructure $1/(\sigma - 1)$ decreases with σ.

In this case, free-riding will not occur, because the trade costs are too high to waive local industry. In contrast, the regions prefer to invest in infrastructure in order to attract industry from the foreign region.

Corner Nash equilibria particularly require that the periphery does not prefer to deviate. It may prefer to deviate from the corner solution of zero infrastructure provision if any positive value of infrastructure provision exists that ensures a higher utility than the corner solution does. There are two possible candidates that may be beneficial for the periphery. It either provides the optimal level for an interior solution or it provides a very high level of infrastructure that attracts all industry from the core.

Corner solutions only exist if trade freeness is sufficiently high. The intuition for this finding is that both regions try to free-ride on the expenses of the other region if the trade costs are sufficiently low, since the costs of setting up local industry exceed the costs of importing manufactured goods from the foreign region.

In decentralized equilibrium we may distinguish three scenarios, with respect to the trade freeness. First, if trade costs are very high, i.e., if $\phi < 0.1748$, only a stable symmetric Nash equilibrium with dispersion of industry exists. Second, for medium trade costs no Nash equilibrium in pure strategies exists at all.[8] Third, if trade freeness is high, i.e., if $\phi > 0.2832$, only corner Nash equilibria with a core-periphery pattern occur. The first case is depicted in Fig. 2, the second in Fig. 3, the third in Fig. 4. These figures show the reaction curves of both regions and – provided that they exist – their intersection points, that is the Nash equilibria. Furthermore, full agglomeration lines where the entire industry is located in either region are also shown. Not surprisingly,

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[8] Since payoff functions W_j are continuous in X_H and X_F, according to the theorem of Glicksberg (1952) a mixed strategy equilibrium exists provided that the choice of infrastructure is restricted to a compact subset of $\Re_0^+$.

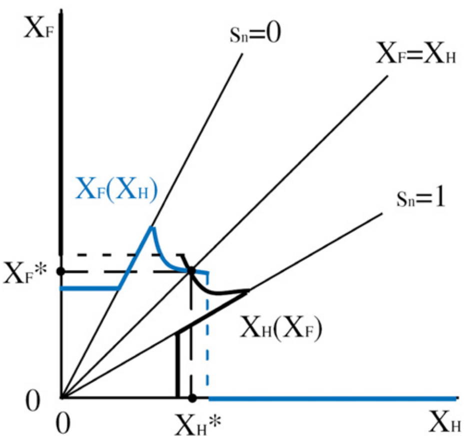

Fig. 2. Interior Nash equilibrium at low trade freeness.

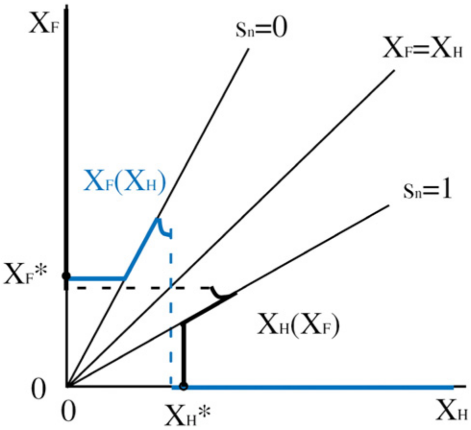

Fig. 4. Corner Nash equilibria at high trade freeness.

regions do not increase infrastructure investment further when the industry is already completely located on their territory. The periphery without any industry does not invest at all. Moreover, if the other region provides a really large quantity of public goods, attracting industry is so costly that the region refrains from investing.

The shape of the reaction curves can be easily explained. Starting at low infrastructure investment of region *F*, region *H* invests as much as necessary to attract all manufacturing firms and to become the core. When the other region increases investment further, region *H* must also increase investment in order to prevent capital flight. If a certain investment level of region *F* is achieved, this strategy becomes too costly. Region *H* now reduces investment, leading to industry dispersion. A further increase in region *F*'s investment ultimately exterminates any incentive to supply infrastructure. As a consequence, region *H* does not supply infrastructure at all. For region *F*, the same reasoning applies. As can be seen from the figures, the higher trade freeness is, the smaller the area is where both regions supply infrastructural goods and where industry is dispersed.

For low trade freeness (Fig. 2), reactions curves intersect once in the interior, for medium trade freeness never (Fig. 3), for high trade freeness (Fig. 4) two times at the axes. Furthermore, since in an interior equilibrium the reaction curve of region *H* is steeper than the reaction curve of region *F*, this equilibrium is locally stable, i.e., adjustment along the reaction curves ultimately leads to the equilibrium.

4. Centralization

A central government endowed with fiscal authorities may levy taxes on both regions symmetrically but distribute infrastructure asymmetrically. Furthermore, the central government internalizes the externalities that regions impose on each other. Again, workers and capital owners in both regions are taxed in order to finance infrastructure. The objective of the federal government is to maximize the sum of workers' utility in both regions:

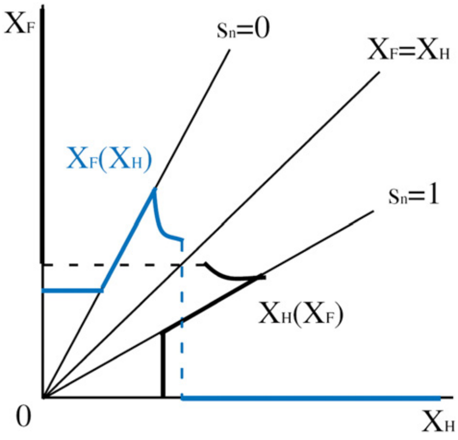

Fig. 3. Non-existence of Nash equilibrium at medium trade freeness.

$$\max_{X_H,X_F} \quad W \equiv L_H + L_F + n\bar{R} - X_H - X_F - (K_H + L_H)\mu \ln(P_H) - (K_F + L_F)\mu \ln(P_F) \quad \text{s.t. } (14). \tag{25}$$

To solve this problem, we assume again equally sized regions, i.e. $s_{\text{pop}} = 1/2$.

Proposition 2. *Symmetric distribution of infrastructure is optimal for low trade freeness, i.e., if* $\phi < 7 - 4\sqrt{3} \approx 0.0717$. *Otherwise, a corner solution with either all infrastructure in region H or region F is optimal. Independent of trade costs, the optimum aggregate infrastructure investment is*

$$X_H + X_F = \frac{\mu N}{\sigma - 1}. \tag{26}$$

Proof. See Appendix B. □

For high trade freeness, manufacturing goods produced in one region can be consumed in both regions at low costs. Hence the federal government concentrates infrastructure in one region in order to maximize the aggregate productivity in the manufacturing sector. In this case the gain in aggregate productivity is higher than the rise of expenses on trade costs.

For low trade freeness, the federal government distributes infrastructure equally with the consequence of low aggregate productivity in order to minimize overall trade costs. The savings on trade costs due to the equalized distribution of manufacturing plants dominates the potential gain in aggregate productivity.

Comparing optimal infrastructure investment with the outcome of fiscal competition, differences occur with respect to the level and the distribution of infrastructure investment depending on the trade costs. A comparison of the critical trade costs values given in the pervious propositions yields immediately:

Proposition 3. ***(a)*** *For medium trade freeness, i.e., for* $0.1748 < \phi < 0.2832$, *the allocation of infrastructure cannot be determined consistently by decentral authorities.*

(b) *A decentralized federation oversupplies public infrastructure if trade costs are high, i.e., if* $\phi < 0.1748$ *(where infrastructure investment is fully equalized). For high trade freeness, i.e., for* $\phi > 0.2832$, *decentralization leads to undersupply.*

(c) *When trade costs fall, a decentralized federation changes too late from full equalization of infrastructure investment and dispersed industry locations to a core-periphery pattern.*

For medium trade freeness, both jurisdictions would alternately overbid and underbid each other. As a result, a decentralized federation does not even come to a solution for the allocation problem. For more extreme trade costs, decentral authorities provide infrastructural goods consistently, but never efficiently.

The central government provides always $X_H+X_F=\mu N/(\sigma-1)$ on aggregate. However, in the decentralized case each of the two regions provides $\mu N/[2(\sigma-1)(1-\phi)]$ if the full equalization equilibrium applies. If a core-periphery pattern arises, the core region provides infrastructure $\mu N/[2(\sigma-1)]$. The intuition for those results is as follows: For low trade freeness it is crucial to have industry located nearby, therefore the negative externality from competing for industry dominates the positive externality due to the public input characteristic of infrastructure and the regions overprovide infrastructure in decentralized equilibrium. As the trade costs fall below a critical value, importing manufactured goods becomes cheap enough to waive local industry. This strategy allows the saving of the costs of setting up infrastructure by indirectly using the foreign one. Using infrastructure without contributing to the costs of providing it represents a free-riding externality, which now leads to underprovision. Furthermore, if the industry is located in one region, the core is able to skim off agglomeration rents, and thus reduces its effort to reduce production costs.

Comparing decentralization and centralization with respect to the distribution of infrastructure an inefficiency arises for the range of trade freeness between 0.0717 and 0.2832, because corner solutions occur in the centralized economy already for lower trade freeness than in the decentralized economy. Choosing a corner solution without local industry a single region benefits from increasing aggregate productivity only to the extent weighted by the trade freeness. Therefore, the productivity gain it takes into account is smaller than the aggregate productivity gain the federation faces as a whole. Moreover, the increase in trade costs of the region that loses all industry is higher than the average increase in trade costs, since the other region saves trade costs. Both effects imply that the federal government chooses corner solutions already for a lower trade freeness than the single regions do in Nash equilibrium.

5. Extensions

Assuming symmetry and pure public goods greatly simplifies the analysis, but our results are much more general. They will qualitatively hold in reasonably more complex circumstances.

5.1. Asymmetric regions

Asymmetry in population size does not fundamentally change the mechanisms or the results. Although it is not possible to obtain analytical results, by way of numerical analysis it can be shown that the comparison of decentral and central states leads to similar results as in a state with equally sized regions.[9] First, for low trade freeness, in a decentralized federation both regions provide public infrastructure and the aggregate level of investment is too high. However, due to the home-market effect, a disproportional high share of industry is located in the larger region even if both provide the same amount of public inputs. For high trade freeness, decentralization leads again to agglomeration and undersupply. Of course corner solutions with only one region providing infrastructure already take place for lower trade freeness than for ex ante symmetric regions. Second, in the process of trade integration a decentralized federation changes too late from dispersion of infrastructure investment and industry locations to a core-periphery pattern. However, asymmetry is an additional source of inefficiency. For low trade freeness, competition for mobile firms forces both the smaller and the larger region strongly to supply public infrastructure. As a result, the difference in public investment in an interior Nash equilibrium is too small. A central planner would increase investment in the larger region and simultaneously reduce expenditure in the smaller region.

5.2. Congestion costs

Of course, there could be congestion costs that act against the efficiency of agglomeration. One possibility to take those into account is to assume that infrastructure entails usage costs that increase with the local amount of firms (see Sinn, 1997). This relationship can be defined by the following cost functions:

$$Cost(X_H)=\left[1+\alpha\left(\frac{s_n}{0.5}-1\right)\right]X_H \quad \text{and}$$

$$Cost(X_F)=\left[1+\alpha\left(\frac{(1-s_n)}{0.5}-1\right)\right]X_F,$$

where $\alpha, 0\leq\alpha\leq 1$, represents the parameter of congestion. For $\alpha=0$ as well as for symmetric industry distribution ($s_n=0.5$) there is no congestion, the price of infrastructure provision remains unity as before. The higher α and the larger the asymmetry of industry distribution, the stronger the congestion. For full agglomeration the price of infrastructure in the core region becomes $1+\alpha$. The implied utility for symmetric distribution of infrastructure is the same as in the absence of congestion. Comparing welfare with and without congestion when regions are of the same size, one can easily show that the critical value of trade freeness where agglomeration becomes efficient increases with α. Considering the Nash equilibrium congestion costs entail an additional externality. While the marginal utilities of infrastructure in both regions are not affected by the congestion costs, the marginal costs of infrastructure provision are increasing in the stock of regional infrastructure and the congestion parameter α. Hence, for low trade freeness the pressure for equalization of infrastructure levels is strengthened. However, for sufficiently high trade freeness one may still expect corner solutions, i.e. full agglomeration, to arise. When deciding on whether or not to provide infrastructure a region contrasts the cost savings of not providing infrastructure to the utility loss of not having local industry and accordingly, having to import all industrial goods. Compared to the scenario without congestion costs the costs savings have risen, whereas the utility loss has not changed. Hence, corner solutions may already occur for lower trade freeness than without congestion costs. Regarding the efficiency of aggregate infrastructure provision the resulting overprovision in case of low trade freeness may be alleviated, since a region exerts not only a negative effect on the other region when investing in infrastructure by attracting industry but also a positive effect by decreasing the costs of infrastructure and accordingly the tax burden in the foreign region. The result of underprovision in the case of low trade-freeness, however, is still valid, since congestion costs do not arise in the periphery where all industry has left to the core. Obviously, the assumption of congestion costs may only act as an additional externality as long as both regions have some local industry that is as long as interior solutions arise.

6. Conclusion

Global markets become more and more integrated and trade costs are falling. We have shown that this phenomenon alters

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[9] Numeric simulations can be provided on request.

significantly the implications of public input competition. When trade costs are sufficiently low, it becomes favorable for regions to import industrial goods instead of providing infrastructure. Thus some regions may prefer to quit the competition for industry by providing better infrastructure. Those regions become voluntarily the periphery and specialize in the agricultural sectors. However, this free-riding behavior of some regions results in an inefficiently low level of aggregate infrastructure whereas the asymmetric distribution of infrastructure and industry is desirable from the welfare perspective.

Since externalities arise as long as trade is possible, a centralized provision of infrastructure is always welfare-improving. For low trade costs this means that the overall level of infrastructure should be subsidized. Thus our model implies that regional policies should subsidize infrastructure in core regions in order to achieve the efficient level of aggregate infrastructure. Moreover, from an efficiency point of view industrial concentration should already be implemented for higher trade costs than it is the outcome of regional competition. This is in sharp contrast with the European Union's regional policy which aims at enhancing regional integration and at the same time subsidizes public infrastructure in peripheral regions. A trade-off between aggregate efficiency and regional cohesion arises as it was already demonstrated in other models of the New Economic Geography (see Martin, 1999).

Our model focuses on the effects of fiscal competition on infrastructure provision and industrial distribution. It neglects all effects of information asymmetries between central and decentral authorities which would make the case for decentralization. Moreover, our model features only one industrial sector with industry-specific infrastructure. Our results could be translated into a world with several industrial branches where efficient agglomeration means that various industrial sectors cluster in different regions. This is a tendency we observe in federations all over the world.

Acknowledgements

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Appendix A. Proof of Proposition 1

We analyze first candidates for interior Nash equilibria. From the first-order conditions (22) for $s_{\text{pop}}=1/2$ and $0<s_n<1$ we derive the potential equilibria in the interior:

$$X_{H_1}=X_{F_1}=\frac{\mu N}{2(1-\phi)(\sigma-1)},$$

$$X_{H_2}=\frac{\mu N}{(\sigma-1)}\left(\frac{1+\phi+\sqrt{1-2\phi-3\phi^2}}{4\phi(\phi+1)}\right),$$

$$X_{F_2}=\frac{\mu N}{(\sigma-1)}\left(\frac{1}{1+\phi+\sqrt{1-2\phi-3\phi^2}}\right),$$

$$X_{H_3}=\frac{\mu N}{(\sigma-1)}\left(\frac{1+\phi-\sqrt{1-2\phi-3\phi^2}}{4\phi(\phi+1)}\right),$$

$$X_{F_3}=\frac{\mu N}{(\sigma-1)}\left(\frac{1}{1+\phi-\sqrt{1-2\phi-3\phi^2}}\right).$$

Note that the second and third solutions are only defined for $\phi\le 1/3$. Calculating the second derivatives and the cross derivatives gives

$$\frac{\partial^2 W_H}{\partial X_H^2}=\left[\frac{\mu N}{2(1-\sigma)}\right]\frac{X_F(X_F-2\phi X_H)}{X_H^2(X_F-\phi X_H)^2},$$

$$\frac{\partial^2 W_F}{\partial X_F^2}=\left[\frac{\mu N}{2(1-\sigma)}\right]\frac{X_H(X_H-2\phi X_F)}{X_F^2(X_H-\phi X_F)^2},$$

$$\frac{\partial^2 W_H}{\partial X_H\partial X_F}=\frac{\mu N\phi}{2(1-\sigma)(X_F-\phi X_H)^2},$$

$$\frac{\partial^2 W_F}{\partial X_F\partial X_H}=\frac{\mu N\phi}{2(1-\sigma)(X_H-\phi X_F)^2}.$$

For $X_F=X_H$, the second-order condition $\partial^2 W_j/\partial X_j^2\le 0$ is only fulfilled for $\phi\le 1/2$. For the asymmetric candidates, the second-order conditions $\partial^2 W_H/\partial X_H^2\le 0$ and $\partial^2 W_F/\partial X_F^2\le 0$ require $4\phi^2+2\phi-1\ge 0$, i.e. $\phi\ge 0.309017$.

The symmetric equilibrium is locally stable if the reaction curve $X_H(X_F)$ is steeper than $X_F(X_H)$, i.e., if

$$-\frac{\partial^2 W_H/\partial X_H^2}{\partial^2 W_H/(\partial X_H\partial X_F)}<-\frac{\partial^2 W_F/(\partial X_F\partial X_H)}{\partial W_F/\partial X_F^2}\Leftrightarrow\frac{2\phi-1}{\phi}<\frac{\phi}{2\phi-1},\quad(27)$$

which is satisfied for $\phi<1/3$.

It can be easily shown that for both asymmetric solutions there exists one region which would gain from abandoning public infrastructure investment completely. Thus, the asymmetric solutions do not present Nash equilibria.

When one single region deviates from the symmetric solution and does not provide public infrastructure, the gain for this region is

$$\frac{\mu N\{1+(1-\phi)\ln(\phi)-(1-\phi)\ln[(1+\phi)/2]\}}{2(1-\phi)(\sigma-1)},$$

which is positive if and only if $\phi>0.1748$. A single upwards deviation, i.e., a strong increase in investment which makes the deviating region core, pays only if $\phi>0.4492$. Hence, already for $\phi>0.1748$ a symmetric Nash equilibrium does not exist.

Now, we consider corner solutions. If one region, say region *F*, does not supply infrastructural goods, region *H* maximizes regional welfare W_H by choosing $X_H=\mu N/[2(\sigma-1)]$ (which fulfills the second-order conditions for *H*). If region *F* deviates by supplying infrastructure according to the reaction curve given above it gains

$$\frac{\mu N}{4\phi(\sigma-1)}\left\{\sqrt{1-4\phi}-1-\phi\ln(4)-2\phi\ln(\phi)+2\phi\ln\left[\frac{\left(\phi^2-1\right)\left(\sqrt{1-4\phi}-1\right)}{\phi\left(\sqrt{1-4\phi}+1\right)}\right]\right\},$$

which is positive if and only if $\phi<0.25$. If region *F* deviates upwards, i.e., if it supplies X_F^{Agg} which makes it the core, it gains

$$-\frac{\mu N}{4\phi(\sigma-1)}\left[1+\phi^2+2\phi\ln(2\phi)-2\phi\ln\left(\frac{1+\phi^2}{\phi}\right)\right],$$

which is positive for $0.2203<\phi<0.2832$. Hence, for $\phi<0.2832$ a corner Nash equilibrium does not exist.

As a consequence, for $0.1748<\phi<0.2832$ single deviations rule out any equilibrium.

Appendix B. Proof of Proposition 2

In order to solve the optimization problem (25) for $s_{\text{pop}} = 1/2$, we determine separately interior solutions and corner solutions, compare the implied welfare levels, and, finally, choose the strategy which leads to the highest welfare level.

For infrastructure investment that implies $0 < s_n < 1$, the first-order conditions are

$$1 = \frac{\mu N}{\sigma - 1}\frac{1}{X_H}\left(2 + \frac{X_H\phi}{X_F - \phi X_H} - \frac{X_H}{X_H - \phi X_F}\right),$$
$$1 = \frac{\mu N}{\sigma - 1}\frac{1}{X_F}\left(2 + \frac{X_F\phi}{X_H - \phi X_F} - \frac{X_F}{X_F - \phi X_H}\right).$$

There are exactly three solutions for regional infrastructure investments. One solution that implies full equalization of regional infrastructure, that is a ratio $\chi_1 = 1$ and absolute levels:

$$X_{H_1} = X_{F_1} = \frac{\mu N}{2(\sigma - 1)}.$$

The trace and the determinant for this symmetric solution are

$$\text{trace}_{\chi_1} = -\frac{4(\sigma - 1)[1 + \phi(\phi - 4)]}{\mu N(1 - \phi)^2},$$

$$\det_{\chi_1} = \frac{4(\sigma - 1)^2[1 + \phi(\phi - 6)]}{\mu^2 N^2(1 - \phi)^2}.$$

Hence, for $\phi < 3 - 2\sqrt{2} \approx 0.1715$ the determinant is positive (and the trace negative), and, therefore, this symmetric solution is a maximum.

Besides this symmetric solution, there are two asymmetric solutions that imply regional infrastructure ratios $\chi_{2,3}$, with $\chi_3 < \chi_1 < \chi_2$, which are only defined for $\phi \le 3 - 2\sqrt{2}$. However, using continuity one can easily show that those two solutions are minima.

In order to obtain candidates for corner solutions, we set without loss of generality X_F to zero. This implies a first-order condition for X_H

$$\frac{\mu N}{X_H(\sigma - 1)} - 1 = 0,$$

and, thus, $X_H = \mu N/(\sigma - 1)$ (the second-order condition is obviously fulfilled).

The difference in welfare between the corner solution and an interior symmetric allocation of infrastructure is

$$\frac{\mu N}{2(\sigma - 1)}[\ln(16) + \ln(\phi) - 2\ln(1 + \phi)],$$

which is positive if and only if $\phi > 7 - 4\sqrt{3}$.

Appendix C. Generalized output elasticity of infrastructure

If we allow for a general output elasticity of infrastructure $\delta > 0$ the production function is

$$Q_j = X_j^{\delta} L_j \leftrightarrow c = X_j^{-\delta}$$

Solving for the long-run distribution of industry gives

$$s_n = \frac{s_{\text{pop}}}{\left(1 - \phi\chi^{\delta(\sigma - 1)}\right)} - \frac{\phi\left(1 - s_{\text{pop}}\right)}{\left(\chi^{\delta(\sigma - 1)} - \phi\right)};\ \text{where } \chi = \frac{X_H}{X_F}$$

and a local price indices

$$\ln(P_H) = \frac{1}{1 - \sigma}\ln\left[\frac{X_H^{\delta(\sigma - 1)}X_F^{\delta(\sigma - 1)}s_{\text{pop}}\left(1 - \phi^2\right)}{X_F^{\delta(\sigma - 1)} - \phi X_H^{\delta(\sigma - 1)}}\right] + \ln\left(\frac{\sigma}{\sigma - 1}\right) + \frac{1}{1 - \sigma}\ln(n)$$

$$\ln(P_F) = \frac{1}{1 - \sigma}\ln\left[\frac{X_H^{\delta(\sigma - 1)}X_F^{\delta(\sigma - 1)}\left(1 - s_{\text{pop}}\right)\left(1 - \phi^2\right)}{X_H^{\delta(\sigma - 1)} - \phi X_F^{\delta(\sigma - 1)}}\right] + \ln\left(\frac{\sigma}{\sigma - 1}\right) + \frac{1}{1 - \sigma}\ln(n).$$

Using the indirect utility functions for the decentralized case we get first-order conditions:

$$1 = \frac{\mu\delta N}{2X_H}\frac{X_F^{\delta(\sigma - 1)}}{\left(X_F^{\delta(\sigma - 1)} - \phi X_H^{\delta(\sigma - 1)}\right)}$$
$$1 = \frac{\mu\delta N}{2X_F}\frac{X_H^{\delta(\sigma - 1)}}{\left(X_H^{\delta(\sigma - 1)} - \phi X_F^{\delta(\sigma - 1)}\right)}$$

which imply an infrastructure provision in case of the full equalization equilibrium

$$X_H = X_F = \frac{\mu\delta N}{2(1 - \phi)}$$

Determinant and trace are given by

$$\det = \frac{(1 - \phi)(1 - \phi - 2\delta\phi(\sigma - 1))}{\mu^2 N^2\delta^2}$$

$$tr = -\frac{2(1 - \phi + \delta\phi(1 - \sigma))}{\mu N\delta}.$$

The trace is negative if $\phi < \frac{1}{1 + \delta(\sigma - 1)}$, the determinant positive if $\phi < \frac{1}{1 + 2\delta(\sigma - 1)}$. When setting $\delta = \frac{1}{\sigma - 1}$ we get the same results as above. Infrastructure has diminishing returns if $0 < \delta < 1$. If this is the case the full equalization equilibrium is stable even for high trade freeness, whereas it gets unstable already for low trade freeness if increasing returns to infrastructure (*i.e.* $\delta > 1$) are presumed.

The federal government faces first-order conditions:

$$1 = \frac{\mu\delta N}{X_H}\left[2 + \frac{\phi X_H^{\delta(\sigma - 1)}}{\left(X_F^{\delta(\sigma - 1)} - \phi X_H^{\delta(\sigma - 1)}\right)} - \frac{X_H^{\delta(\sigma - 1)}}{\left(X_H^{\delta(\sigma - 1)} - \phi X_F^{\delta(\sigma - 1)}\right)}\right]$$
$$1 = \frac{\mu\delta N}{X_F}\left[2 + \frac{\phi X_F^{\delta(\sigma - 1)}}{\left(X_H^{\delta(\sigma - 1)} - \phi X_F^{\delta(\sigma - 1)}\right)} - \frac{X_F^{\delta(\sigma - 1)}}{\left(X_F^{\delta(\sigma - 1)} - \phi X_H^{\delta(\sigma - 1)}\right)}\right]$$

which imply an infrastructure provision

$$X_H = X_F = \mu\delta N.$$

Determinant and trace are given by

$$\det = \frac{1 + \phi^2 - 2\phi(1 + 2\delta(\sigma - 1))}{(\phi - 1)^2\mu^2 N^2\delta^2}$$

$$tr = -\frac{2\left[1 + \phi^2 - 2\phi(1 + \delta(\sigma - 1))\right]}{(\phi - 1)^2\mu N\delta}.$$

The trace is negative for $\phi < 1 + \delta(\sigma - 1) \pm \sqrt{\delta^2(1-\sigma)^2 + 2\delta(\sigma - 1)}$, the determinant positive for $\phi < 1 + 2\delta(\sigma - 1) \pm 2\sqrt{\delta^2(1-\sigma)^2 + \delta(\sigma - 1)}$. Setting $\delta = \frac{1}{\sigma - 1}$ the same results as above are obtained. Moreover the lower δ the later it becomes efficient to distribute infrastructure asymmetrically. Hence, the symmetric provision of infrastructure is efficient up to a higher trade freeness for diminishing returns to infrastructure than it is for increasing returns.

Appendix D. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.regsciurbeco.2009.04.003.

References

Andersson, F., Forslid, R., 2003. Tax competition and economic geography. Journal of Public Economic Theory 5, 279–303.

Baldwin, R.E., Krugman, P., 2004. Agglomeration, integration and tax harmonisation. European Economic Review 48, 1–23.

Baldwin, R.E., Forslid, R., Martin, P., Ottaviano, G.I.P., Robert-Nicoud, P., 2003. Economic geography and public policy. Princeton University Press, Princeton.

Barro, R.J., 1990. Government spending in a simple model of endogenous growth. Journal of Political Economy 98, 103–125.

Bénassy-Quéré, A., Gobalraja, N., Trannoy, A., 2007. Tax and public input competition. Economic Policy 50, 385–430.

Borck, R., Pflüger, M., 2006. Agglomeration and tax competition. European Economic Review 50, 647–668.

Borck, R., Caliendo, M., Steiner, V., 2007. Fiscal competition and the composition of public spending: theory and evidence. Finanzarchiv (Public Finance Analysis) 63, 264–277.

Brühlhart, M., 2001. Evolving geographic concentration of European manufacturing industries. Weltwirtschaftliches Archiv (Review of World Economics) 137, 215–243.

Bucovetsky, S., 2005. Public input competition. Journal of Public Economics 89, 1763–1787.

Dixit, A., Stiglitz, J.E., 1977. Monopolistic competition and optimum product diversity. American Economic Review 67, 297–308.

Dupont, V., Martin, P., 2006. Subsidies to poor regions and inequalities: some unpleasant arithmetic. Journal of Economic Geography 6, 223–240.

Egger, H., Falkinger, J., 2006. The role of public infrastructure and subsidies for firm location and international outsourcing. European Economic Review 50, 1993–2015.

Ellison, G., Glaeser, E.L., 1999. The geographic concentration of industry: does natural advantage explain agglomeration. American Economic Review 89, 311–316.

Ezcurra, R., Pascual, P., Rapun, M., 2006. The dynamics of industrial concentration in the regions of the European Union. Growth and Change 37, 200–229.

Fujita, M., Krugman, P., Venables, A.J., 1999. The spatial economy. Cities, regions, and international trade. InMIT Press, Cambridge.

Gabe, T.M., Bell, K.P., 2004. Tradeoffs between local taxes and government spending as determinant of business location. Journal of Regional Science 44, 21–41.

Glicksberg, I.L., 1952. A further generalization of the Kakutani fixed point theorem with application to Nash equilibrium points. Proceedings of the American Mathematical Society 3, 170–174.

Keen, M., Marchand, M., 1997. Fiscal competition and the pattern of public spending. Journal of Public Economics 66, 33–53.

Kind, H.J., Knarvik, K.H.M., Schjelderup, G., 2000. Competing for capital in a lumpy world. Journal of Public Economics 78, 253–274.

Krugman, P., 1991. Increasing returns and economic geography. Journal of Political Economy 99, 483–499.

Ludema, R.D., Wooton, I., 2000. Economic geography and the fiscal effects of regional integration. Journal of International Economics 52, 331–357.

Martin, P., 1999. Public policies, regional inequalities and growth. Journal of Public Economics 73, 85–105.

Martin, P., Rogers, C.A., 1995. Industrial location and public infrastructure. Journal of International Economics 39, 335–351.

Martin, P., Ottaviano, G.I.P., 1999. Growing locations: industry location in a model of endogenous growth. European Economic Review 43, 281–302.

Midelfart-Knarvik, K.H., Overman, H.G., 2002. Delocation and European integration: is structural spending justified? Economic Policy 17, 321–359.

Morrison, C.J., Schwartz, A.E., 1996. State infrastructure and productive performance. American Economic Review 86, 1095–1111.

Ottaviano, G., Thisse, J.-F., 2004. Agglomeration and economic geography. In: Henderson, J.V., Thisse, J.-F. (Eds.), Handbook of regional and urban economics, vol. 4. Elsevier, Amsterdam, pp. 2563–2608.

Ottaviano, G.I.P., van Ypserle, T., 2005. Market size and tax competition. Journal of Internalional Economics 67, 25–46.

Pereira, A.M., Andraz, J.M., 2007. Public investment in transportation infrastructures and industry performance in Portugal. Journal of Economic Development 32, 1–20.

Pflüger, M., 2004. A simple, analytically solvable Chamberlinian agglomeration model. Regional Science and Urban Economics 34, 565–573.

Robert-Nicoud, F., Sbergami, F., 2004. Home-market vs. vote-market effect: location equilibrium in a probabilistic voting model. European Economic Review 48, 155–179.

Sinn, H.-W., 1997. The selection principle and market failure in systems competition. Journal of Public Economics 66, 247–274.