The Role of Technological Spillovers in an Uneven Subsidy Competition Game

Rainald Borck
University of Munich and DIW Berlin

Hyun-Ju Koh*
University of Munich

Michael Pflüger
University of Passau and IZA Bonn

14th March 2008

Preliminary Version

Abstract

Previous works on regional competition in the presence of agglomeration economies showed that locational hysteresis is strong enough to tie industry to the agglomerated region even if regions start to compete over the industry core. Regions with an initially larger share of industry did not suffer from a relocation of firms. This paper elaborates two new aspects. First, the inclusion of technological spillovers into the model à la Martin and Rogers (1995) leads to an additional stable equilibrium where all industry is agglomerated in the less populated region. Second, we show that industry allocation resulting from a regional competition game is not necessarily efficient from a global perspective. In fact, an inefficient allocation of industry, where all firms are located in the small region can persist. We conclude that regional policies supporting the dissemination of technological spillovers are not socially desirable per se. For the case where all industry is agglomerated in the large region, strong localization economies will benefit residents of both regions. However, for the case where agglomeration occurs in the small region, strong intra-industry spillovers either detain or support to restore an efficient allocation of industry.

JEL classification: F12; F15; H25; H73; R12
Keywords: agglomeration; asymmetric regions; subsidy competition; spillovers

*Corresponding author.Phone:+49 2180 2889; fax:+49 2180 3128.
Author's adress: Department of Economics, University of Munich, Ludwigstr.28/Vgb.III, 80539 Munich, Germany. E-mail adress: hyunju.koh@lrz.uni-muenchen.de

1 Introduction

The role of path dependency and hysteresis effects are inherent in economic geography models which deal with the location of production in space. These models are characterized by a range of parameters in which multiple equilibria exist and where history or firms' expectations rather than fundamentals determine which spatial equilibrium is selected.[1] Redding et al. (2007) show that history matters and give evidence for the existence of such multiple stable equilibria. They find that temporary shocks like the division of Germany after World War II have permanent effects on industry location by showing that the German air hub shifted from Berlin to Frankfurt after the division and that there is no evidence that this shift is only temporary. Krugman (1991a) gives anecdotal evidence for persisting agglomeration patterns which continue to exist although the initial factors to cause this agglomeration have vanished over time. Moreover, as Rauch (1993) already pointed out, the importance of the result that history matters for the location of industry lies in the fact that history does not ensure to choose the most efficient outcome.

The existence of multiple equilibria is also of political interest as temporary regional policy interventions can trigger a permanent shift of industry location thereby affecting welfare of immobile factors. Previous literature has thereby focused mainly on tax competition in the presence of hysteresis effects. While Ludema and Wooton (2000) focus on the effects of economic integration on the intensity on tax competition within an oligopoly model, Andersson and Forslid (2003), Baldwin and Krugman (2004) and Borck and Pflüger (2006) apply an economic geography framework à la Forslid and Ottaviano (2003) with monopolisitic competition and unskilled immobile and skilled mobile labor.[2] Irrespective of the applied famework they all reach to the same conclusion that the existence of agglomeration economies alters the basic predictions of the traditional tax competition literature. Once industry is agglomerated in one region, firms in the agglomerated region realize an agglomeration rent which can be taxed without triggering an immediate outflow of capital.[3] Baldwin and Krugman (2004) as well as Borck and Pflüger (2006) thereby work with a three stage tax competition game starting out from

[1]See Baldwin et al. (2003) on the role of history and expectations for the determination of equilibrium.

[2]This type of economic geogrphay model has been named footloose entrepreneur model (FE model) by Baldwin et al. (2003).

[3]Location hysteresis and the emergence of taxable rents due to agglomeration economies has been identified by Kind et al. (2000).

an agglomerated equilibrium[4] and show that the core region prevents a relocation of firms by limit taxing the periphery. Tax competition is a one sided affair since the core region is constrained in the choice of its optimal tax rate whereas the periphery being aware that it will never induce a relocation can set its unconstrained tax rate. However, whereas these studies mainly focus on the comparison between traditional tax competition model predictions and results obtained from a tax competition game in an economic geography framework for the case where regions are equal-sized, the possibility of asymmetrically sized regions competing over the industry core in the presence of agglomeration economies and the question about the overall desirability of agglomeration when regions differ in size remained rather neglected except for Ottaviano and van Ypersele (2005).[5] They find that similar to the results of Baldwin and Krugman (2004) and Borck and Pflüger (2006) firms in the agglomerated region will never relocate towards the (smaller) periphery, i.e. the peripheral region is unable to affect location of firms. Additionally they show, that the larger region will host a larger share of industry and that tax rates will be higher than tax rates in the smaller region.

Appyling a new simple agglomeration model where endogenous asymmetry of regions can arise due to technological spillovers we show first, that although inefficient from a global perspective, being agglomerated in the smaller region constitutes a stable locational equilibrium. Starting from such an industry allocation we show further that even though regional governments start to compete over the industry core, restoring a globally efficient allocation of industry is not necessarily achieved.[6] This sort of inefficiency could not arise neither in Baldwin and Krugman (2004) who assume an equal amount of the immobile factor in each region nor in Ottaviano and van Ypersele (2005) who show that the smaller region never hosts a larger share of industry than the large region. Furthermore, whereas

[4]Borck and Pflüger (2006) additionally assess the effects of starting out from an equilibrium with partial agglomeration.

[5]Also Bucovetsky (1991), who analyzes asymmetric tax competition between regions of different size and finds that Nash equilibrium tax rates will be higher in the larger jurisdiction and that residents of the smaller jurisdiction will be better off than those in the larger jurisdiction. However, the analysis builds on a traditional tax competition model which neglects the existence of agglomeration economies and hence the possibility that initially symmetric regions can end up to become asymmetric due to mechanisms that are endogenous to the model.

[6]An example of the real world where a relocation of industry was prevented by granting subsidies can be found in 1997 where Volkswagen AG received a subsidy in order to safeguard employment in the German State Saxony(Oman (2000)).

a relocation of industry never occurred in the aforementioned studies it becomes possible in our model that even if regions are symmetric in size all industry relocates towards the challenging region. Finally, due to quasi-linear utility functions which remove the income effect on industrial varieties we are able to conduct the welfare analysis as well as the subsidy competition game on the basis of indirect utility functions in contrast to Baldwin and Krugman (2004) and Borck and Pflüger (2006).

We establish a new agglomeration model by including intra- and inter-industry spillovers into the model by Martin and Rogers (1995). The first to include technological spillovers into an economic geography framework has been Ulltveit-Moe (2007) who assesses the effects of intra- and inter-industry spillovers on the effectiveness of different regional policies in a FE model. She finds that a policy enforcing a symmetric allocation of industry is related to higher welfare costs than a policy based on direct income transfers if intra-industry spillovers exceed inter-industry spillovers.

We include external scale economies into an economic geography framework not only because Neary (2001) explicitly criticizes the absence of knowledge spillovers in economic geography models but rather because of compelling empirical evidence for the existence of knowledge spillovers. Whereas most economic geography models which are characterized by internal scale economies highlight the role of market size for geographic concentration, the empirical literature has also focused on the role of external scale economies such as localization economies (Marshall-Arrow-Romer externalities[7]). Jaffe et al. (1993) as well as Audretsch and Feldman (1996) find evidence for spillovers within the same industry to be geographically localized. Also recent work by Devereux et al. (2007) shows that firms of a specific industry respond to subsidies only if the region already hosts a critical share of the respective industry. In our model workers become more productive while working in the agglomerated industrial sector. Moreover, the enhanced productivity spills over to the other local production sector resulting in a higher wage for all workers employed in the agglomerated region.

The paper is organized as follows. Section 2 presents the extended model and derives the long run locational equilibria first assuming equal sized regions and then allowing

[7]This expression has been introduced by Glaeser et al. (1992) who refer to the work of Marshall (1890), Arrow (1962) and Romer (1986) and who find that regional diversity rather than regional specialization promotes knowledge spillovers. For a detailed survey on technological spillovers see Audretsch and Feldman (2004) as well as Rosenthal and Strange (2004).

for asymmetric region size. The section ends with the welfare analysis in the symmetric region size case. Section 3 analyzes the outcomes of an uneven subsidy competition game for the general case where region may also differ in size. Section 4 concludes.

2 The Model

2.1 Basic Set Up

The model builds on Martin and Rogers (1995). The world consists of two regions $i = 1, 2$ which are symmetric in their preferences and technology. There are two sectors. An industrial sector (M) characterized by increasing returns, monopolistic competition and iceberg trade costs produces a composite of industrial varieties. Spatial distance is modeled using iceberg trade costs denoted as $\tau \geq 1$, implying that $\frac{1}{\tau}$ per unit of an imported variety melts away in transit. To consume one unit of a variety produced abroad more than one unit has to be shipped. The perfectly competitive traditional sector (A) produces a homogenous good under constant returns to scale. The A-good which is taken as the numéraire good and hence, its price normalizes to one, $p_i^A = 1$, is produced in both regions and is traded without costs across regions. Furthermore, there are two input factors, capital and labor. While labor is immobile across region and employed in both sectors, capital can move freely across regions and is employed in the industrial sector only. However, capital owners are assumed to be immobile which implies that the reward of capital is repatriated to the region of origin. We denote $s_k \equiv K_1/K$ as the share of world capital owned by capital owners residing in region 1 with $K = K_1 + K_2 = 1$. Analogously, $s_n \equiv n_1/n$ denotes the share of capital employed in region 1 (the share of firms located or alternatively the mass of varieties produced in region 1) with $n = n_1 + n_2 = K = 1$. The share of workers in region 1 is denoted as $s_l \equiv L_1/L$, with $L = L_1 + L_2 = 1$.

2.2 Preferences and Demand

In each region there are $L_i + K_i$ households, where each household supplies one unit of its factor endowment. The representative household derives utility from consuming a range of differentiated industrial goods and a traditional good. The preferences are represented by a two tier utility function, where the upper tier function is quasi-linear which eliminates the income effect on the industrial good and the lower tier utility function is of the CES form. The upper tier utility function reads

$$U_i(A_i, M_i) = \alpha \ln M_i + A_i - \alpha[\ln \alpha - 1], \quad \text{with} \quad 0 < \alpha < y_i. \tag{1}$$

We assume $0 < \alpha < y_i$ to assure that both types of goods are consumed. $\alpha[\ln \alpha - 1]$ is a constant which will cancel out when deriving the indirect utility function. A_i denotes consumption of the numéraire good and α the amount of income spent on the composite good M_i which consists of all differentiated varieties v of the industrial good

$$M_i = \left(\int_0^{n_i} m_{ii}(v)^{\frac{\sigma-1}{\sigma}} dv + \int_{n_i}^{n_i+n_j} m_{ji}(v)^{\frac{\sigma-1}{\sigma}} dv \right)^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1, \quad i \neq j. \tag{2}$$

m_{ii} denotes consumption of a variety produced domestically and m_{ji} denotes consumption of a variety produced abroad. The constant elasticity of substitution between any two varieties is denoted by σ. The budget constraint of a representative household reads

$$\int_0^{n_i} p_i(v) m_{ii}(v) dv + \int_{n_i}^{n_i+n_j} \tau p_j(v) m_{ji}(v) dv + A_i = y_i, \tag{3}$$

where p_i and p_j denote the producer prices of a respective variety and $\tau \geq 1$ iceberg trade costs. y_i denotes income of the respective household. Solving the utility maximization problem yields the following demand functions, $m_{ii}(v)$, $m_{ji}(v)$, M_i and A_i and indirect utility V_i

$$M_i = \alpha / P_i, \qquad A_i = y_i - \alpha, \tag{4}$$
$$m_{ii} = \alpha p_i(v)^{-\sigma} P_i^{\sigma-1}, \qquad m_{ji} = \alpha p_j(v)^{-\sigma} P_i^{\sigma-1},$$

$$P_i \equiv [n_i p_i^{1-\sigma} + n_j p_j^{1-\sigma}]^{\frac{1}{1-\sigma}}, \tag{5}$$

$$V_i = y_i - \alpha \ln P_i, \tag{6}$$

where P_i denotes the cost-of-living index in region i which takes symmetry of producer prices already into account.

2.3 Production

Since the model is symmetric we will henceforth derive the expressions for the home region only. The corresponding expression for the foreign regions are analogous.

2.3.1 Traditional Sector

The A-good is produced using labor as the only input according to $q_i^A = (1+\mu s_n)L_i^A$, where L_i^A is labor input and q_i^A is output. μs_n captures inter-industry spillovers, with $\mu > 0$. The higher the mass of industrial firms producing in region i, the higher is the marginal productivity of labor and the more units of the A-good can be produced with a given labor force. Due to perfect competition labor is paid its marginal product. Hence, from $p_i^A q_i^A = w_i L_i^A$ and $q_i^A = (1+\mu s_n)L_i^A$ with $p_i^A = 1$ we get $w_i = 1+\mu s_n$.[8]

2.3.2 Industrial Sector

The representative firm in region i produces one variety using one unit of capital (the fixed input requirement) and $1/(1+\gamma s_n)$ units of labor according to the total cost function

$$TC_i = \left(\frac{1+\mu s_n}{1+\gamma s_n}\right)q_i + r_i \tag{7}$$

where r_i denotes the capital's reward rate and q_i firm's output in region i. Intra-industry spillovers γ enter via the variable input requirement affecting the cost structure of each single firm. Producing close to other industrial firms generates some kind of knowledge spillovers among workers employed in the industrial sector which lower firm's variable costs. By assuming intra-industry spillovers to be stronger than inter-industry spillovers, $\gamma > \mu$, we account for the fact that spillovers are more intense within the same industry than between different industries, i.e. spillovers increase industry specific skills of a worker more than general skills which is in line with empirical evidence.[9] The profit function of the representative firm in region i is given by

$$\Pi_i = \left(p_i - \frac{1+\mu s_n}{1+\gamma s_n}\right)q_i - r_i, \tag{8}$$

where

$$q_i = m_{ii}(L_i + K_i) + \tau m_{ij}(L_j + K_j) \tag{9}$$

denotes the market clearing condition for a domestic variety, i.e. output produced equals total demand (domestic and export demand). (8) uses the familiar result that mill pricing

[8] Note that contrary to previous economic geography models which assume that the immobile factor earns the same reward irrespective of whether employed in the concentrated or in the peripheral region we allow for a higher wage rate in the region where industry is agglomerated.

[9] See Bottazzi and Peri (2003).

in the Dixit Stiglitz monopolistic competition model is optimal for firms,[10] i.e. the per unit producer price is identical on the two markets. Trade costs are fully borne by consumers. Therefore, part of the demand in (9) is indirect due to transport losses. Maximizing producer profit gives the mill price of each variety.

$$p_i = \frac{\sigma}{\sigma - 1}\left(\frac{1+\mu s_n}{1+\gamma s_n}\right). \tag{10}$$

Since firms are identical each producer charges the same price which consists of a constant mark up over marginal costs (since producers face a constant elasticity of substitution), the wage rate and intra-industry spillovers. Higher concentration of firms lowers the variable input requirement, which in turn lowers the production costs and allows for a lower profit maximizing producer price.

Using the zero pure profit condition and applying mill prices from (8) yields the break even output q_i of a firm

$$q_i = r_i(\sigma - 1)\left(\frac{1+\gamma s_n}{1+\mu s_n}\right). \tag{11}$$

2.4 Short Run Equilibrium

In the short run capital is immobile. Hence, for a given allocation of capital and labor across regions, the reward for capital in each region is determined using firm's optimal producer prices (10) and market clearing (9) together with the demand functions (5). Since the reward for capital is equal to operating profits[11] it follows from (10) and (11) $p_i q_i = r_i \sigma$ and hence operating profits are given by $r_i = (p_i q_i)/\sigma$.

$$r_1 = \frac{\alpha}{\sigma}\left(\frac{s_l + s_k}{s_n + (1-s_n)\phi(\frac{p_2}{p_1})^{1-\sigma}} + \frac{\phi((1-s_l)+(1-s_k))}{s_n + (1-s_n)(\frac{p_2}{p_1})^{1-\sigma}}\right), \tag{12}$$

$$r_2 = \frac{\alpha}{\sigma}\left(\frac{\phi(s_l + s_k)(\frac{p_2}{p_1})^{1-\sigma}}{s_n + (1-s_n)\phi(\frac{p_2}{p_1})^{1-\sigma}} + \frac{((1-s_l)+(1-s_k))(\frac{p_2}{p_1})^{1-\sigma}}{s_n\phi + (1-s_n)(\frac{p_2}{p_1})^{1-\sigma}}\right), \tag{13}$$

where $\phi \equiv \tau^{1-\sigma}$ is the level of trade freeness, with $0 < \phi \leq 1$. Replacing $(\frac{p_2}{p_1})^{1-\sigma}$ by χ the capital reward rates in the two regions read

$$r_1 = \frac{\alpha}{\sigma}\left(\frac{s_l + s_k}{s_n + (1-s_n)\phi\chi} + \frac{\phi((1-s_l)+(1-s_k))}{s_n + (1-s_n)\chi}\right), \tag{14}$$

[10] This is due to the constant markup, or more precisely due to the constant elasticity of substitution (see Dixit and Stiglitz (1977)).

[11] To start producing a variety one unit of capital is needed. Hence, the price of one unit of capital will be bid up until it is equal to operating profits.

$$r_2 = \frac{\alpha}{\sigma}\left(\frac{\phi(s_l + s_k)\chi}{s_n + (1 - s_n)\phi(\frac{p_2}{p_1})^{1-\sigma}} + \frac{((1 - s_l) + (1 - s_k))\chi}{s_n\phi + (1 - s_n)\chi}\right), \tag{15}$$

where

$$\chi \equiv (\frac{p_2}{p_1})^{1-\sigma} = \left(\frac{1 + \mu(1 - s_n)}{1 + \mu s_n}\frac{1 + \gamma s_n}{1 + \gamma(1 - s_n)}\right)^{1-\sigma} \equiv (\chi_\mu)^{1-\sigma}(\chi_\gamma)^{1-\sigma}. \tag{16}$$

Note that with a quasi-linear upper tier utility function all income effects on the industrial good are eliminated.

2.5 Long Run Equilibrium

In the long run where capital is mobile the relocation of firms is driven by differentials in capital's nominal reward according to the ad-hoc migration equation [12]

$$\dot{s_n} = (r_1 - r_2)(1 - s_n)s_n, \tag{17}$$

which reveals that there are two types of locational long-run equilibria, where a long run equilibrium is defined as a situation where capital no longer moves across regions. Either each region hosts an equal share of industry (symmetric interior equilibrium, where $(r_1 - r_2) = 0$ or industry is agglomerated in one single region (a so called core-periphery equilibrium) at $s_n = 0$ or $s_n = 1$. Which equilibrium will prevail depends on the relative strength of the agglomeration force and the dispersion forces which depend on the level of trade costs. For low trade costs firms will agglomerate in one region, whereas at high trade costs a dispersed allocation of firms arises. The different locational equilibria emerging for different trade costs are depicted in Figure 1 for the case where regions are of equal size.

[12] See Baldwin et al. (2003) for an extended discussion on the ad-hoc migration equation.

$\sigma = 4; \gamma = 1; \alpha = 0.5; \mu = 0.5; s_k = s_l = 0.5$

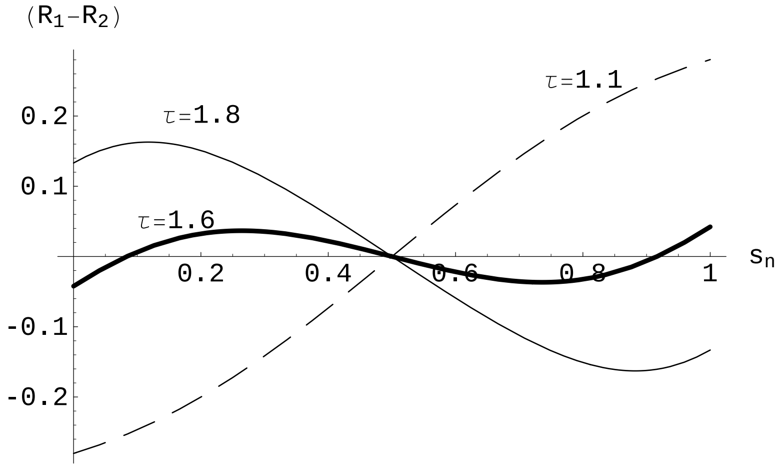

Figure 1: Locational Equilibria

A symmetric equilibrium is stable for intermediate and high trade costs. Starting from $s_n = 1/2$ and increasing region 1's industry share lowers the capital reward gap $(r_1 - r_2)$ implying that firms will have an incentive to move back to region 2. A core-periphery outcome is stable for low and intermediate trade costs but unstable for high trade cost. Furthermore, for intermediate trade costs all three allocations, $s_n = 0$, $s_n = 1/2$ and $s_n = 1$ constitute stable equilibria.

2.5.1 Symmetry Breaking

To assess the stability of the different long-run equilibria we derive the market break point denoted by ϕ^B which is the threshold level of trade freeness above which the symmetric equilibrium becomes unstable inducing a shift of industry towards one single region. The formal condition for an equilibrium to be stable is given by

$$\frac{d(r_1 - r_2)}{ds_n}|_{s_n=\frac{1}{2}} < 0, \quad (18)$$

i.e. the symmetric equilibrium is stable if the slope of the capital reward gap curve is negative at $s_n = 1/2$ (see Figure 1). Setting (18) equal to zero and solving for ϕ gives

$$\phi^B = \frac{4 + 6\mu - 4\mu\sigma + \gamma(4\sigma + \mu - 2) - 2\sqrt{2}\sqrt{(\gamma - \mu)(\sigma - 1)(4 + \mu(4 + \gamma - 2\sigma) + 2\gamma\sigma)}}{(2 + \gamma)(2 + \mu)} \quad (19)$$

Figure 2 depicts the stability of long run equilibria for $\alpha = \mu = s_k = s_l = 0.5; \sigma = 4; \gamma = 1$. The model exhibits a subcritical pitchfork.[13] As soon as ϕ exceeds the critical break

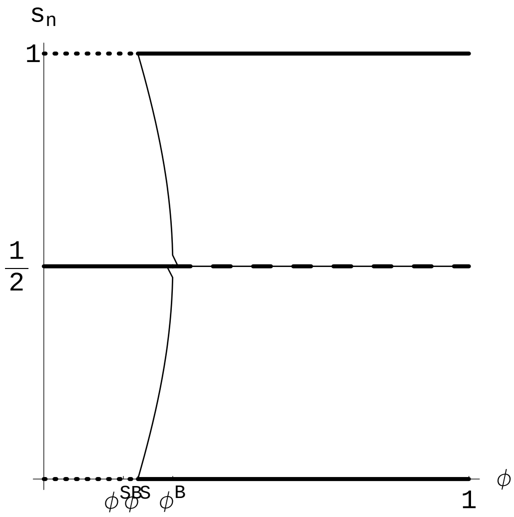

Figure 2: Bifurcation I

point the only stable equilibrium is the core-periphery outcome. The market break point depends positively on the elasticity of substitution, negatively on intra-industry spillovers and positively on inter-industry spillovers.[14] A higher elasticity of substitution (a decline in consumers' love for variety) implies lower economies of scale at the firm level and lower price markups of industrial firms. In order to break even firms have to pay less to capital owners, the reward for capital falls as σ increases. This effect rather supports a dispersed equilibrium even for higher levels of trade freeness. To understand the effect of intra-and inter-industry spillovers on the level of the break point it seems helpful to first identify the different agglomerative and deglomerative forces of the model on the basis of (14) and (15).[15] Intra-industry spillovers, the agglomeration force of the model, operate through the production costs of the single firm. A higher industry share in region 1 lowers the variable input requirement due to intra-industry spillovers[16] which increases operating profits and hence r_1 inducing a further capital inflow towards region 1. Therefore, as intra-industry spillovers become stronger increasing thereby the tendency for firms to

[13] Straightforward calculations show that at $s_n = 1/2$ and $\phi = \phi^B$, $\partial^2(r_1 - r_2)/\partial(s_n)^2 = 0$ holds. It can be shown numerically that $\partial^3(r_1 - r_2)/\partial(s_n)^3 > 0$ is fulfilled for $\gamma > \mu$.

[14] The corresponding expressions for $\frac{\partial\phi^B}{\partial\gamma} < 0$, $\frac{\partial\phi^B}{\partial\mu} > 0$ and $\frac{\partial\phi^B}{\partial\sigma} > 0$ are rather messy which prevents a straightforward determination of the sign. However, for our parameter specifications the figures in the appendix confirm the above stated directions of change.

[15] The formal exposition is left to the appendix.

[16] Since we assume that $\gamma > \mu$.

cluster, the range of trade freeness levels at which the symmetric equilibrium remains to be a stable equilibrium declines.

The local competition effect and inter-industry spillovers both support a dispersed allocation of industry. The first describes the tendency of firms to produce in regions with only few competitors. Starting from a symmetric allocation of industry, an increasing share of industry in region 1 drives down positive operative profits in that region and hence also r_1 as long as trade is not completely free, which will in turn discourage other firms to start their production in that region.

The second dispersion force works through the worker's wage rate. An increase in the share of industry in region 1 lowers variable costs but due to inter-industry spillovers which increases the productivity of workers, the wage paid to workers in the core is μ higher than the wage paid in the periphery. Higher production costs in turn lower firm's operating profit in region 1 and thus also r_1 which discourages further firms to start producing in region 1. As a consequence, strong inter-industry spillovers increase the range of trade freeness levels at which the symmetric equilibrium is stable. Figure 3 depicts the forces in dependence of the level of trade freeness for $\sigma = 4$ and $\alpha = 0.5$.

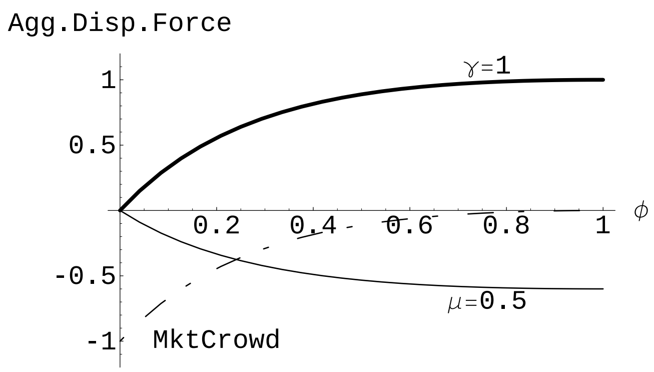

Figure 3: Agglomeration/Dispersion Forces

The market crowding effect is strongest when trade costs are high and becomes weaker as the economy becomes more and more integrated until it finally vanishes at $\phi = 1$. Hence, whereas location becomes irrelevant with regard to the market crowding effect this is not true for intra- and inter-industry spillovers. Both forces, the agglomerative and dispersive spillover force become stronger with ongoing trade integration and persist even if both regions are fully integrated.

2.5.2 Sustain Point and agglomeration rent

To assess the stability of the core-periphery equilibria we derive the level of trade freeness up to which a core-periphery equilibrium can be sustained. At the point where the level of trade freeness is equal to the sustain point level, the difference in capital reward rates equals zero and all firms agglomerated in one region are just indifferent between staying or relocating. Hence, solving $(r_1 - r_2) \,|_{s_n=1} = 0$ for ϕ yields

$$\phi^S = \frac{(\frac{1+\gamma}{1+\mu})^\sigma \left(1 + \mu - \sqrt{(1+\mu)^2 - (1+\gamma)^2 (\frac{1+\mu}{1+\gamma})^{2\sigma}}\right)}{1+\gamma}. \tag{20}$$

Stronger intra-industry spillovers increase the tendency to agglomerate thereby lowering ϕ^S meaning that the core-periphery outcome can be sustained even for low levels of trade freeness. The opposite holds for the case where inter-industry spillovers increase. An increase in the elasticity of substitution will increase ϕ^S meaning that a core-periphery outcome becomes unstable even for relatively high levels of trade freeness as the willingness of the consumer to substitute industrial varieties increases.[17] Moreover, the overlap between the sustain and market break point depicted in Figure 3 reflects the range of levels of trade freeness at which both types of equilibria, the symmetric as well as the core-periphery outcome are stable. A sufficiently large shock in expectations could lead the economy from one stable equilibrium to the other without any change in the level of trade freeness or spillovers.

Once the level of trade freeness exceeds the sustain point firms in the core region earn an agglomeration rent which is defined as the firm's loss if it relocates from region i to region j given that all other firms stay in region i. (21) shows the agglomeration rent for the case where region 1 hosts the core.

$$(r_1 - r_2)\Big|_{s_n=1} = \frac{\alpha}{\sigma}\left[2 - \left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}\left(\frac{[(1-s_k)+(1-s_l)]}{\phi} + (s_k + s_l)\phi\right)\right]. \tag{21}$$

Moreoever, the corresponding Figure 4 shows that location does not become irrelevant as the economy becomes fully integrated.

To summarize the results of the analysis so far, we find that extending the FC[18] model by including technological spillovers results in multiple stable equilibria in contrast to

[17] The corresponding figures can be found in the appendix.

[18] The model by Martin and Rogers (1995) has been named as the footloose capital model (FC model) by Baldwin et al. (2003).

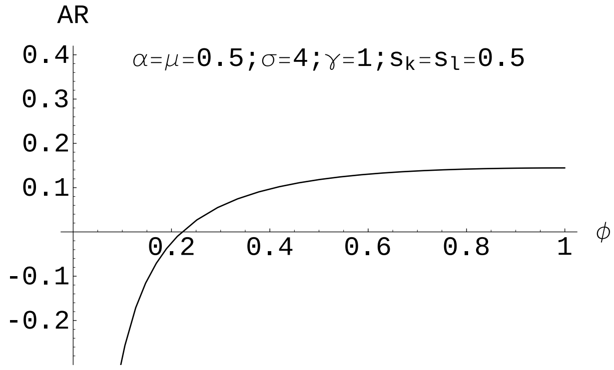

Figure 4: Agglomeration rent

the standard FC model where the symmetric allocation is the only stable equilibrium.[19] This also implies that the standard FC model exhibits no break and sustain point contrary to our model. In our model, both threshold levels now depend on the strength of intra-industry and inter-industry spillovers. Moreover, the agglomeration rent does not approach zero as trade becomes free, i.e. location does not become irrelevant as the level of trade freeness approaches one.

2.6 The model with asymmetric country size

So far the analysis assumed regions to be equally endowed with the immobile factor which enabled us to compare the extended model to the symmetric FC model without spillovers. This section applies the model for the general case which allows for differences in region size. Recall that capital moves in search of the highest nominal reward where the capital reward rates are given by (14) and (15). We assume that regions are equally rich in capital, i.e. each region owns half of the world capital stock $s_k = 1/2$ and do only differ in the number of workers, where region 1 is the larger region, $s_l > 1/2$. In contrast to the FC model without spillovers described in Baldwin et al. (2003) and used by Ottaviano and van Ypersele (2005)[20] where the larger region always hosts the larger share of industry [21] the model with intra-industry spillovers and asymmetric country size exhibits multiple

[19] see Baldwin et al. (2003).

[20] They apply a quadratic quasi-linear utility function based on the model by Ottaviano et al. (2002).

[21] In fact, for high trade costs the interior asymmetric equilibrium, where the larger region hosts a larger industry share is stable whereas for low trade costs all industry will be agglomerated in the larger region. See Baldwin et al. (2003) as well as Ottaviano and van Ypersele (2005).

stable core periphery equilibria. For low levels of trade freeness an interior equilibrium where the larger region hosts more than half of the total industry is stable. However, for high levels of trade freeness both, the core in the large region as well as the core in the small region are stable equilibria (see also Figure 15 in the appendix.). Hence, the new feature of the asymmetric model follows from the existence of multiple stable corner equilibria. It allows for the possibility that the entire industry is concentrated in the smaller region despite the fact that firms could earn a higher agglomeration rent if all industry were located in the larger region (see Figure 5). To motivate the existence of

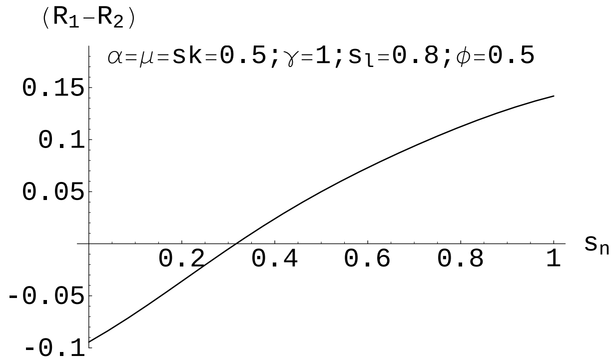

Figure 5: Asymmetric Region Size

this equilibrium we assume that there exists some kind of coordination failure[22] (absence of rational expectations i.e. lack of information or any kind of costs that hinders firms to relocate) which make firms unable or not willing to commit to relocate.[23] Nevertheless, from a global efficiency point of view it is always more efficient to have the industry core situated in the large region, since then a larger share of households would benefit from a lower cost-of-living index and from higher remuneration.[24]

[22]see Baldwin et al. (2003) as well as Krugman (1991b) who discuss the role of expectations in the choice of equilibria.

[23]Note that without this assumption it becomes difficult to justify the existence of multiple equilibria at all. In fact, Krugman (1991a) states that rather rational expectations are hard to justify since they call for a degree of information and sophistication that is rather unreasonable (Krugman (1991a), p.29).

[24]A formal proof can be found in the appendix.

2.7 Welfare Analysis in the Symmetric Region Case

In order to identify whether conflicts between resident of different regions arise due to the reallocation of industry we first derive the indirect utility functions for the different groups (workers and capital owners in region 1 and 2). Noting that income E is either capital income or labor income w_i indirect utility of capital owners and workers read

$$V_{K_i} = -\alpha \ln P_i + max\{r_1, r_2\}, \qquad V_{L_i} = -\alpha \ln P_i + w_i, \tag{22}$$

where the wage for workers w_i is either $(1 + \mu s_n)$ in region 1 or $(1 + \mu(1 - s_n))$ in region 2, respectively. Since the producer price of every single industrial variety produced in the same country is identical the price index of region i can be written as

$$P_1 = [s_n p_1^{1-\sigma} + (1 - s_n)\phi p_2^{1-\sigma}]^{\frac{1}{1-\sigma}}, \qquad P_2 = [s_n \phi p_1^{1-\sigma} + (1 - s_n) p_2^{1-\sigma}]^{\frac{1}{1-\sigma}}, \tag{23}$$

where

$$p_1 = \frac{\sigma}{\sigma - 1}\left(\frac{1 + \mu s_n}{1 + \gamma s_n}\right), \qquad p_2 = \frac{\sigma}{\sigma - 1}\left(\frac{1 + \mu(1 - s_n)}{1 + \gamma(1 - s_n)}\right). \tag{24}$$

We take regional welfare as the unweighted sum of indirect utilities of capital owners and workers residing in the respective region,

$$W_1 = s_l V_{L_1} + s_k V_{K_1}, \qquad W_2 = (1 - s_l)V_{L_2} + (1 - s_k)V_{K_2}. \tag{25}$$

The figures below depict regional welfare for $\alpha = 0.5, \sigma = 4$ and $\mu = 0.5$, where we find a conflict between regions to be unambiguous for weak intra-industry spillovers and high trade costs. This result changes if we allow for strong intra-industry spillovers and low trade costs. Figure 6 represents the case where trade costs are high and intra-industry spillovers weak. Residents of one region unambiguously lose due to higher consumer prices and lower wages as the share of industry in their region declines whereas residents of the agglomerating region experience a welfare increase since they save on transport cost when purchasing industrial varieties and earn a higher wage rate. On the contrary, the effects of a reallocation of firms on regional welfare for strong intra-industry spillovers and low trade costs is ambiguous as shown in Figure 7. Starting from $s_n = 0$, an increase in the number of firms in region 1 initially decreases welfare of *both* groups. The intuition is as follows. At $s_n = 0$ residents in region 1 also benefit from an agglomeration in region 2, since consumer prices are low due to high spillovers. If trade costs are sufficiently low, the benefit from lower producer prices exceeds the cost of importing industrial goods. But as

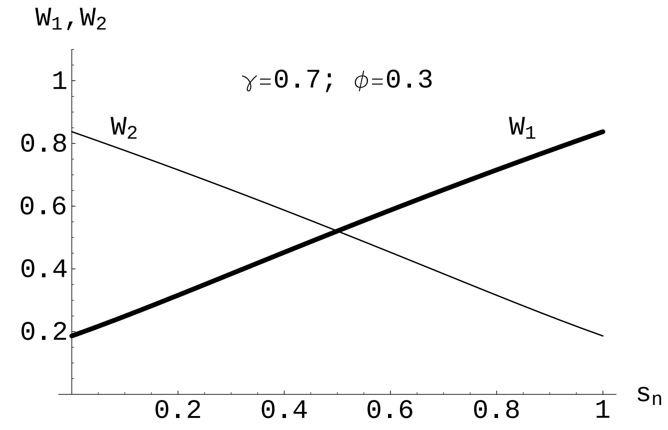

Figure 6: Regional Welfare I

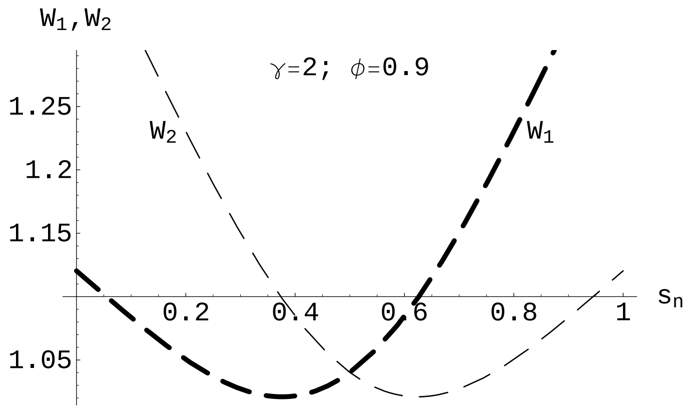

Figure 7: Regional Welfare II

more and more firms move away from the core, the gains from intra-industry spillovers decline, producer prices increase thereby hurting households of both regions. Thus we conclude that there is an unambiguous regional conflict if trade freeness is low and intra-industry spillovers weak. However, for certain parameter values factor owners of both regions might be hurt by a reallocation of industry.

To find out whether the arising location pattern is socially desirable i.e. to find out whether there is too much or too little agglomeration we compare the social planner's choice of industry allocation to the market outcome. Since conflicting interests among residents of different regions make the Pareto criterion unapplicable we apply a utilitarian concept where the utilitarian social welfare function is the unweighted sum of household's indirect utilities, $W^{soc} = \sum_{i=1}^{2} W_i$. With quasi-linear utility functions the marginal utility of income is identical among agents such that redistribution of income does not affect aggregate welfare.[25] In the first best case the price distortion in the industrial sector is removed and capital owners are paid lump sum transfers financed through lump sum taxes such that production and consumption as specified above remain unchanged. In the second best case, the social planner takes market prices as given and only decides over the allocation of industry. First best and second best social welfare function differ only by constant (the mark up $\frac{\sigma}{\sigma-1}$) within the price indices P_i. Since, this constant is independent from the industry share the optimal location structure chosen by the social planner will be identical in the first best and second best case.[26] For computational ease we will conduct the analysis using the second best social welfare function. In the symmetric region case $s_l = s_k = 1/2$ the social welfare function in the second best case then reads

$$W^{soc} = -\alpha \ln[P_1 P_2] + 1 + \frac{\mu}{2} + \frac{2\alpha}{\sigma}, \tag{26}$$

where P_1 and P_2 are given by (23) and (24). Figure 8 depicts the social welfare function plotted against the industry share for different levels of trade freeness. While partial

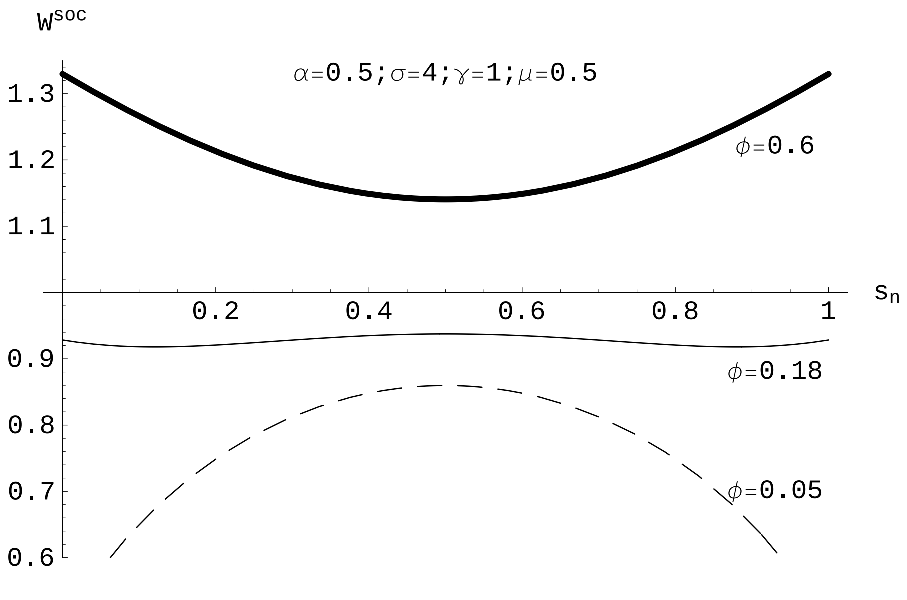

Figure 8: Social Welfare

agglomeration is never optimal for the social planner a symmetric allocation is chosen

[25]See Pflüger and Südekum (2007) and Baldwin et al. (2003).

[26]The first best social welfare level however, will be higher than the second best social welfare level due to the price distortion. For a detailed discussion on the social welfare function with quasi-linear preferences see Pflüger and Südekum (2007).

at low levels of trade freeness and a core periphery equilibrium at high levels of trade freeness. We denote ϕ^{SB} as the level of trade freeness at which the social planner is just indifferent between implementing a symmetric or a concentrated allocation of industry, i.e. which solves $W^{soc}_{s_n=\frac{1}{2}} = W^{soc}_{s_n=1} = W^{soc}_{s_n=0}$. Comparing this level with ϕ^B allows us to detect whether the market outcome is socially desirable. It turns out that for our parameter restrictions the social break point lies below the market breakpoint[27]

$$\phi^{SB} < \phi^B, \tag{27}$$

which reveals that for low levels of trade freeness the market exihibits under-agglomeration (see also Figure 2). Contrary to Pflüger and Südekum (2007) who analyze the social desirability of agglomeration using a FE model and find that the market equilibrium exhibits over-agglomeration for high trade costs and under-agglomeration for low trade costs, the order of the two threshold levels here is reversed. In the social optimum the switch from a symmetric to an agglomerated equilibrium occurs at a lower level of trade freeness than in the market outcome. This result is driven by the additional externality that arises if we allow for intra-industry spillovers next to the pecuniary externality. Firms internalize neither of the externalities into their location decision. The pecuniary externality which acts through the cost-of-living index increases the tendency of the social planner to implement a symmetric equilibrium while the presence of intra-industry spillovers increases the tendency to choose a concentrated allocation. The location of the social break point reveals that the negative effect of losing industry and hence incurring transport costs on imported varieties is alleviated through the depressing effect of agglomeration on industrial goods prices.

3 Subsidy Competition

3.1 The model with exogenous subsidies (taxes)

As already emphasized in section 2.6 the model for asymmetric region size exhibits two stable core periphery equilibria. For the case where all industry is located in the small region we assumed that firms are unable to coordinate such that this industry allocation is a stable equilibrium. This assumption is necessary for the following analysis. In this section we are interested in the outcome of an uneven subsidy competition game in the

[27]The full expression for ϕ^{SB} is available upon request. See Appendix for a graphical exposition.

presence of technological spillovers. We will conduct the analysis for the case where trade costs are sufficiently low such that industry is agglomerated in one region.

Governments of each region maximizing welfare of local residents use subsidies to influence capital owners' decision where to employ their capital. The core region as well as the periphery both have an interest to retain/attract firms since being the core region increases welfare of immobile factors residing in the core region through the cost-of-living effect and through the inter-industry spillover wage effect. In order to derive analytical expressions for the different subsidy levels we model subsidies in their simplest form and assume that subsidies enter as a direct payment thereby increasing capital owners' income.[28] This modeling choice implies, that the capital reward rate as well as the number of varieties in the economy are both unaffected which simplifies the analysis. Capital (firms) now moves to the region which offers the highest post-subsidy capital reward rate, $r_i^s = r_i + z_i$. The no-delocation-condition then reads

$$r_1^s = r_2^s, \tag{28}$$

where subsidies z_i are financed through a regional lump sum tax on laborers' and capital owners' endowment

$$z_1 s_n = T_1(s_k K^w + s_l L^w), \qquad z_2(1 - s_n) = T_2((1 - s_k)K^w + (1 - s_l)L^w). \tag{29}$$

Note that the subsidy paid to capital owners solely aims at attracting capital. There is no public good which enters household's utility.[29] Thus, government expenditure and therefore tax revenue are both zero once the region becomes the periphery. Plugging in the price indices using (23) and (24) as well as the post-subsidy capital reward rates from (28) and wage rates into the regional welfare functions yields welfare of region i for the case where it hosts the industry core and for the case where region i is the periphery

$$W_1(z_1, z_2)\Big|_{s_n=1} = \frac{\alpha}{\sigma} - \frac{\alpha(1+2s_l)}{2} \ln\left(\frac{(1+\mu)\sigma}{(1+\gamma)(\sigma-1)}\right) + s_l(1+\mu) - \frac{z_1}{2} \tag{30}$$

$$W_1(z_1, z_2)\Big|_{s_n=0} = \frac{\alpha}{\sigma} - \frac{\alpha(1+2s_l)}{2} \left[\ln\left(\frac{(1+\mu)\sigma}{(1+\gamma)(\sigma-1)}\right) + \frac{1}{1-\sigma} \ln\phi\right] + s_l + \frac{z_2}{2} \tag{31}$$

[28]This modeling choice is legitimate given that direct subsidy payments targeted at attracting industry seem to be common practice as in the latest example of Nokia.

[29]In contrast to Andersson and Forslid (2003) or Baldwin and Krugman (2004) where tax revenue is used for public good provision we abstract from the benefits that result from higher public good provision and concentrate on the direct benefits that result from hosting the industry core, i.e. higher wages and lower cost of living index.

$$W_2(z_1,z_2)\Big|_{s_n=0} = \frac{\alpha}{\sigma} - \frac{\alpha(3-2s_l)}{2}\ln\left(\frac{(1+\mu)\sigma}{(1+\gamma)(\sigma-1)}\right) + (1-s_l)(1+\mu) - \frac{z_2}{2} \quad (32)$$

$$W_2(z_1,z_2)\Big|_{s_n=1} = \frac{\alpha}{\sigma} - \frac{\alpha(3-2s_l)}{2}\left[\ln\left(\frac{(1+\mu)\sigma}{(1+\gamma)(\sigma-1)}\right) + \frac{1}{1-\sigma}\ln\phi\right] + (1-s_l) + \frac{z_1}{2}. \quad (33)$$

These welfare functions are linear in the subsidy levels as depicted in Figure 9 for $\alpha = \mu = s_k = 0.5; \sigma = 4; \gamma = 1; \phi = 0.7; s_l = 0.6$. Whereas welfare of a peripheral region is

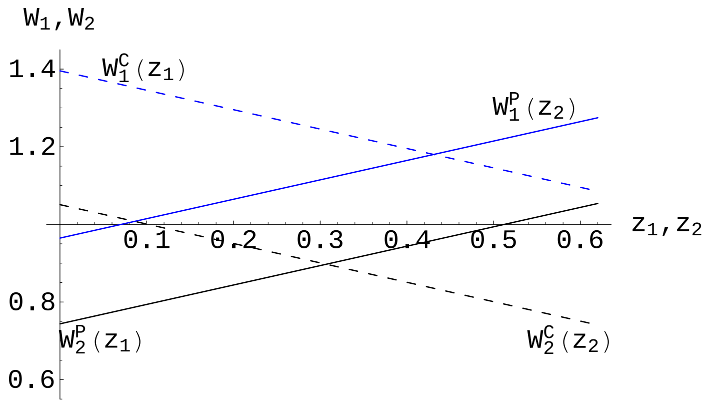

Figure 9: Core/Periphery Regional Welfare

increasing in the subsidy level offered in the core region, it decreases in its own subsidy level as soon as it hosts the industry core. This is due to the fact that capital owners own half of the world capital stock and subsidies are financed regionally.

For reasons of comparability we adopt the same game structure as Baldwin and Krugman (2004) and apply a three stage game.[30] The government of the core region sets its subsidy level in the first, the periphery sets its level in the second stage. In the third stage firms choose their location of production dependent on the subsidized capital reward rates.[31] Production and consumption take place as described in the model in the preceding section. We will start out from a long-run equilibrium in which all firms are

[30]The reasoning follows a strategic entry deterrence game as described in Spence (1977) or Dixit (1980).

[31]Due to the discontinuity of each government's reaction function a simultaneous move game is not applicable. If the challenger sets its level given the level of the core region it would have no incentive to deviate. But the core then would wish to set a different (lower) subsidy level given the subsidy level of the challenging region. If it does so, the challenging region would again have an incentive to deviate and to steal the core. A pure Nash equilibrium therefore does not exist (see Baldwin et al. (2003)).

located in region 2. Initially, subsidy levels and therefore taxes are zero in both regions. Moreover, we continue to assume that each region has an equal share of immobile capital owners, $s_k = 1/2$, but not necessarily an equal share of immobile workers. We therefore allow for asymmetries in region size in terms of the number of workers and allow for the possibility that the core region 2 is smaller than the periphery, $\frac{1}{2} \leq s_l < 1$. Hence, in contrast to Borck and Pflüger (2006) and Baldwin and Krugman (2004) we want to allow for a situation where the initial factors (e.g. market size) that once caused this agglomeration disappeared but where the agglomeration still continues to exist, i.e. firms continue to produce in the smaller region implying that the allocation of industry remains to be globally inefficient in the sense that less households benefit from agglomeration economies than possible. Differences in region size are only allowed to the extent to which welfare of the smaller core region, $W_2^C(z_1, z_2) \equiv W_2\big|_{s_n=0}$ still exceeds the welfare level in the periphery case, i.e. $W_2^P(z_1, z_2) \equiv W_2\big|_{s_n=1}$ such that the outcome of the subsidy competition game does not become trivial.[32]

In stage one the government of the core region (Govt 2) decides whether to defend and keep the industry core by offering a high enough subsidy payment to capital owners of both regions or to set its subsidy level equal to zero thereby risking to lose all industry. In stage two the government of the peripheral region (Govt 1) then decides on whether to induce a relocation of the industry core by offering a high enough subsidy such that each firm finds it worthwhile to delocate towards region 1 or, to stay out of the competition by setting a subsidy equal to zero and leaving the allocation of industry unchanged. We begin with the derivation of the subsidy levels which are necessary to determine the outcome of the game. Due to agglomeration forces which lead to a lumpiness of the mobile factor, Govt 1 in the second stage will not achieve any movement of capital if it chooses a subsidy level too low. In terms of the economic geography literature, Govt 1 has to offer a subsidy level that is at least as high as the agglomeration rent that each industrial firm earns in the core region. Therefore, once Govt 1 has decided to attract the core it has to set a subsidy high enough such that a firm located in region 2 becomes just indifferent between staying in the core or delocating towards region 1 given that all other firms were to stay in region 2. Hence, the agglomeration rent in region 2 is defined as the difference between the capital reward rate in region 2 and region 1 for the case where all industry is located

[32] Otherwise the benefits of hosting the industry core in the form of lower living costs and higher wage rates would not suffice for the government of the core region to engage in a costly subsidy competition.

in region 2. The capital reward rates evaluated at $s_n = 0$ are given by

$$r_2^s\big|_{s_n=0} = z_2 + \frac{2\alpha}{\sigma}, \tag{34}$$

$$r_1^s\big|_{s_n=0} = z_1 + \left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}\left(\frac{s_k+s_l}{\phi} + [(1-s_k)+(1-s_l)]\phi\right). \tag{35}$$

Therefore, the subsidy level offered to each firm has to be at least as high as $z_1^{min}(z_2)$, which we denote as the threshold or minimum subsidy level at which the agglomeration rent in region 2, denoted by AR, just becomes zero.

$$AR = (r_2^s - r_1^s)\Big|_{s_n=0} = \frac{\alpha}{\sigma}\left[2 - \left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}\left(\frac{s_k+s_l}{\phi} + [(1-s_k)+(1-s_l)]\phi\right)\right] + (z_2 - z_1), \tag{36}$$

where AR is increasing in intra-industry spillovers and region size and decreasing in inter-industry spillovers.[33] Setting $AR = 0$ and solving for z_1 using $s_k = \frac{1}{2}$ yields

$$z_1^{min}(z_2) = \frac{\alpha}{\sigma}\left[2 - \frac{(\frac{1+\gamma}{1+\mu})^{1-\sigma}(1+2s_l-(2s_l-3)\phi^2)}{2\phi}\right] + z_2. \tag{37}$$

Any subsidy level falling below this level will fail to induce a relocation of firms. Moreover, $z_1^{min}(z_2)$ has to be higher, the higher the agglomeration rent in region 2 and since z_1^{min} depends on the subsidy level set by the core region in stage one it also has to be higher the higher z_2. For Govt 1 to engage in the competition the welfare level after having attracted all industry by offering a high enough subsidy has to exceed the welfare level for the case where region 1 remains the periphery. Hence, using the condition for an engagement of Govt 1, $W_1^C(z_1, z_2) > W_1^P(0, z_2)$, we are able to derive the maximum subsidy level from which on Govt 1 will no longer be willing to attract the core. We denote the subsidy level which solves $W_1^P(0, z_2) = W_1^C(z_1, z_2)$ as z_1^{max}. Using (30) and (31) yields

$$z_1^{max}(z_2) = 2\mu s_l + \frac{\alpha(1+2s_l)}{1-\sigma}\ln\phi - z_2. \tag{38}$$

The first term in (38) captures the potential *wage income effect* on the immobile factor. As soon as region 1 hosts the core, the remuneration for workers in region 1 will be μ higher than the remuneration in the periphery. Moreover, this total wage income effect will be larger the higher the share of workers residing in region 1. The second term

[33] See appendix for analytical expressions.

captures the *net trade cost saving or cost-of-living effect* which acts through the price index prevailing in the respective region.[34] This term is positive since $\sigma > 1$ and $\ln\phi < 0$. Hosting the industry core implies that residents save on trade costs since all firms are located in their region. This trade cost saving effect will be the higher the lower the level of trade freeness ϕ[35] and the lower the elasticity of substitution σ, i.e. the higher the love for variety. Moreover, a high share of workers in region 1 additionally enhances the effect. Finally, the last term expresses the *foregoing subsidy effect* of attracting all industry and becoming the core region. Since capital income is repatriated to the region of origin and subsidies are financed via regional taxes, each capital owner residing in the periphery benefits from a subsidy distributed in the core region. Thus, z_2 denotes the foregone subsidy payment of each of region 1's capital owners once the core becomes located in their region. The higher z_2 set in the first stage, the lower will be z_1^{max}, i.e. the lower will be the willingness of Govt 1 to attract the core. As soon as the minimum subsidy level is at least as high as the maximum level, i.e. for any $z_1^{min}(z_2) \geq z_1^{max}(z_2)$ Govt 1 will not try to attract the core by setting a positive subsidy level, since the subsidy necessary to attract the core is so high such that the gain from attaining the core is lower than the cost of attracting all capital.

In stage one, if Govt 2 decides to defend its core the only subsidy level at which she can achieve this, is a subsidy level at which Govt 1 in stage two will no longer be willing to snatch the core. That implies that Govt 2 has to set its subsidy level such that inducing a relocation becomes too costly for the periphery region. We denote this level as z_2^d, where d indicates Govt 2's decision to defend. Then, z_2^d is the subsidy level at which $z_1^{min}(z_2) = z_1^{max}(z_2)$ holds and is given by

$$z_2^d = \frac{1}{2}\left\{2\mu s_l + \frac{\alpha(1+2s_l)}{1-\sigma}\ln\phi - \frac{\alpha}{\sigma}\left[2 - \frac{(\frac{1+\gamma}{1+\mu})^{1-\sigma}(1+2s_l-(2s_l-3)\phi^2)}{2\phi}\right]\right\} \tag{39}$$

This subsidy level necessary to maintain the industry core will be higher, the higher Govt 1's willingness to steal the core and the lower the cost of inducing a relocation. Having derived the subsidy levels for our further analysis, we will begin to solve the different stages and identify the outcomes of this game.

[34]Due to symmetric spillovers both regions benefit from high intra-industry spillovers through lower prices. Hence, any disparity in consumer prices between core and periphery stems from trade costs only.

[35]But note that we consider only cases for high levels of trade freeness, i.e. for levels of trade freeness where a CP-equilibrium arises.

3.2 Equilibria of the Game

3.2.1 Stage One: Periphery's Decision

Given the subsidy level set in the first stage, Govt 1 in stage two decides on whether to snatch the core or to remain the periphery according to the following decision rule

$$z_1 = \begin{cases} z_1^{min}(z_2) & \text{if} \quad W_1^C(z_1, 0) > W_1^P(0, z_2), \\ 0 & \text{otherwise.} \end{cases}$$

Clearly whether Govt 1 decides to enforce a relocation by setting a subsidy level equal to z_1^{min} depends on the subsidy level set by the core government in the first stage. The higher the subsidy level set in stage one the higher will be the cost of snatching the core in stage two.

3.2.2 Stage Two: Core's Decision

Govt 2 in stage one foresees the implication of its choice on the choice of Govt 1's in the following stage and decides on whether to maintain the industry core by setting $z_2 = z_2^d$ or to set a subsidy level $z_2 \neq z_2^d$. Govt 2's decision can thereby be divided into three cases.

Case 1. Core is unconstrained and can even levy a tax on firms, $z_2^d < 0$
In this case the agglomeration rent prevailing in the core is so high such that Govt 2 could even levy a tax on firms without triggering a relocation. Hence, compared to the unconstrained optimum with $z_i = 0$ welfare in the core will be higher as compared to the unconstrained optimum.

Case 2. Core faces no risk of delocation, $z_2^d = 0$
For $z_2^d = 0$ the agglomeration rent prevailing in the core is high enough such that Govt 2 need not offer a positive subsidy payment to firms to deter the periphery from snatching the core. Hence, the core is able to set a subsidy level equal to the unconstrained optimum level, $z_2 = 0$.
The outcomes of Case 1. and Case 2. are summarized in the following Proposition:

Proposition 1. *Govt 2 will always set $z_2 = z_2^d$ and maintain all industry as soon as the level of subsidy necessary to prevent a relocation is non-positive, i.e. $z_2^d \leq 0$. By implication setting $z_2 \neq z_2^d$ implies that $z_2^d > 0$.*

Proof of Proposition 1. Suppose z_2^d were non positive, i.e. the subsidy level which is necessary to induce Govt 1 to abstain from setting a nonzero subsidy level is equal to or even less than zero. Since $W_2^C(0, z_2)$ is strictly decreasing in z_2 this implies $W_2^C(0, z_2^d) \geq W_2^C(0,0)$ for $z_2^d \leq 0$. Moreover, since $W_2^C(0,0) - W_2^P(0,0) = (1-s_l)\mu - \frac{(3-2s_l)}{2(\sigma-1)} \ln \phi > 0$ and therefore $W_2^C(0, z_2^d) \geq W_2^P(0,0)$ for $z_2^d \leq 0$ Govt 2 will set a subsidy level equal to z_2^d and never set a subsidy level which is below[36] or above this level since it will neither risk a relocation of industry nor will it forgo higher welfare by setting a subsidy level higher than necessary to induce firms to stay. By implication if Govt 2 sets $z_2 \neq z_2^d$, then z_2^d must be positive. □

Hence, we can state that for $z_2^d \leq 0$ a relocation of firms will not occur since AR is high enough to deter Govt 1 from setting a positive subsidy level. Govt 2 thereby does not experience a welfare loss. In fact, if $z_2^d < 0$ Govt 2 is even better off compared to the unconstrained optimum whereas Govt 1 will be worse off compared to the unconstrained optimum where $z_i = 0$. This follows from $W_1^P(0, z_2)$ which is increasing in z_2. The case where $z_2^d \leq 0$ will only occur if AR is sufficiently high such that the cost of stealing the core exceeds Govt 1's willingness to offer a subsidy payment, i.e. if $z_1^{min} \geq z_1^{max}$.

Case 3. Relocation becomes possible, $z_2^d > 0$

If however Govt 2 has to offer a positive subsidy level to induce firms to stay in region 2 it may be able to defend the industry core but not necessarily willing to do so. It will set a subsidy level according to the following decision rule

$$z_2 = \begin{cases} z_2^d & \text{if} \quad W_2^C(0, z_2^d) \geq W_2^P(z_1^{min}(0), 0), \\ 0 & \text{otherwise.} \end{cases}$$

Hence, if Govt 2 by setting $z_2 = 0$ rather than $z_2 = z_2^d$ declares not to defend the industry core this will definitely cause a relocation of firms towards region 1 since z_2^d being positive implies $z_1^{min}(0) - z_1^{max}(0)$ to be negative and therefore $W_1^C(z_1, 0) > W_1^P(0, z_2)$. In case of losing the core, welfare in region 2 will be $W_2^P(z_1^{min}(0), 0)$. On the other hand, if she rather decides to set a nonzero subsidy level she will retain all industry and the corresponding payoff will be $W_2^C(0, z_2^d)$. Hence, for the case where $z_2^d > 0$, Govt 2 will only decide to set a nonzero subsidy level if $W_2^C(0, z_2^d) - W_2^P(z_1^{min}(0), 0) \geq 0$. Plugging in the respective

[36] A subsidy level less than this level, i.e. a higher tax rate would induce firms to relocate without Govt 1 offering them any payment since the agglomeration rent in region 2 has decreased to an extent such that the only stable equilibrium will be the one where all industry is located in region 1.

subsidy levels z_2^d and z_1^{min} from (39) and (37) into (32) and (33), respectively yields

$$W_2^C(0, z_2^d) - W_2^P(z_1^{min}(0), 0) = \frac{1}{8}\Bigg\{ \underbrace{4\mu(2-3s_l)}_{\text{net wage income effect}} + \underbrace{\frac{2\alpha(6s_l-5)}{\sigma-1}\ln\phi}_{\text{net cost-of-living effect}} \underbrace{-\frac{\alpha}{\sigma}\left[4-\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}\left(\frac{1+2s_l}{\phi}+(3-2s_l)\phi\right)\right]}_{\text{opportunity cost of hosting the industry core}}\Bigg\} \quad (40)$$

The net wage income effect consists of the wage income effect on workers in region 2 who earn a higher wage than workers in region 1 and the effect of the potential wage income effect μs_l for the case that industry relocates. The latter enters z_2^d through $z_1^{max}(z_2)$ whereas the first enters directly through $W_2^C(z_1, z_2)$. Depending on the relative strength of the wage income effect in region 2 and region 1 the net effect will enter with a positive or negative sign. The net cost-of-living effect acts in a similar way. On the one hand the impact of trade freeness ϕ enters through z_2^d. The higher the potential transport cost saving effect which occurs if region 1 succeeds in attracting the core, the higher the subsidy level necessary to prevent a relocation, i.e. the higher z_2^d. This effect tends to lower $W_2^C(z_1, z_2)$ especially if s_l is large. On the other hand, ϕ also enters $W_2^P(z_1, 0)$, i.e. the higher the imminent loss caused by a relocation of industry towards region 1, the lower will be $W_2^P(z_1, 0)$, the more likely it becomes that region 2 will defend the industry core. Thus, whether the net cost-of-living effect enters with a positive sign thereby increasing Govt 2 willingness to retain the core depends on the relative strength of the trade cost saving effect in region 2 and region 1. Finally, the last term in (40) expresses the opportunity cost of hosting the industry core. In case of retaining the industry core Govt 2 does not only incur the direct costs of defending, z_2^d but also the cost of the foregoing subsidy payment from region 1. The larger AR the higher will be the necessary subsidy level for Govt 1 to attract the core and hence, the higher the potential repatriation externality for Govt 2 in case she becomes the periphery.

Note that even if regions are of equal size, it cannot be assured that the core always defends the core as opposed to Baldwin and Krugman (2004). For $s_l = 1/2$ condition (40) reads

$$W_2^C(0, z_2^d) - W_2^P(z_1^{min}(0), 0)\big|_{s_l=\frac{1}{2}} = \frac{1}{4}\mu - \frac{\alpha}{2(\sigma-1)}\ln\phi - \underbrace{\left(\frac{\alpha}{2\sigma} - \frac{\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}(1+\phi^2)}{4\sigma\phi}\right)}_{\frac{1}{4}z_1^{min}(0)}. \quad (41)$$

The first two terms are unambiguously positive, i.e. the positive wage income as well as the positive transport cost saving effect increase core's willingness to prevent a relocation. But still, the repatriation externality (the foregone subsidy payment) $-\frac{1}{4}z_1^{min}(0)$ lower Govt 2's willingness to defend the industry core. Thus we conclude that irrespective of whether region 2 is of equal size or even smaller than region 1, Govt 2 will find it worthwhile to set a nonzero subsidy level as long as the wage income effect on workers employed in the core region as well as the cost-of-living index prevailing in the core are sufficiently high and the (opportunity) costs of retaining the core are sufficiently low. Contrary to Baldwin and Krugman (2004) where, due to the assumption of symmetric region size, retaining the industry core was always more attractive than becoming the periphery, in our model the decision in Case 3. whether to defend or not cannot be determined a priori. Therefore, to analyze how region size and intra-industry spillovers influence Govt 2's decision whether to defend or not, we map the condition when to set $z_2 = z_2^d$ in the s_l, γ space. The line in Figure 10 then shows s_l, γ-combinations at which $W_2^C(0, z_2^d) = W_2^P(z_1^{min}(0), 0)$ holds. For all s_l, γ-combinations above the line Govt 2 will

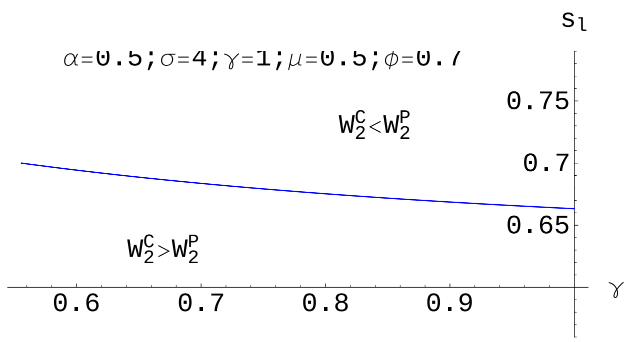

Figure 10: Govt 2's Decision

abstain from defending the core, whereas at all s_l, γ-combinations on and below the line the core will remain in region 2. The first thing to note is that the slope is negative, i.e. the line is decreasing in the intensity of intra-industry spillovers. This negative relationship between region 1's size s_l and γ appears to be counterintuitive at the first glance, since one would expect that larger intra-industry spillover will rather increase Govt 2's willingness to defend the core. However, the negative relationship consists of two effects. On the one hand, z_2^d decreases as γ increases.[37] The subsidy level necessary to defend the core

[37] The analytical expressions are left to the appendix.

is lower the higher intra-industry spillovers since they increase the agglomeration rent in the core thereby also lowering the cost of maintaining the core. Hence, indirect utility of the core region increases in γ. On the other hand, as $z_1^{min}(0)$ increases with γ this implies that welfare in the periphery case. This stems from the immobility of capital owners and with it the repatriation of capital income. A subsidy paid in the core region causes a positive externality on immobile capital owners residing in the periphery since half of the capital employed in region i accrues to capital owners of the other region. Moreover, since the subsidy is financed through a regional tax on immobile residents of the subsidizing region, they gain from a subsidy paid in the other region without bearing the financing costs. This externality effect dominates the subsidy-saving effect irrespective of region size, implying that $\frac{\partial\left(W_2^C(0,z_2^d)-W_2^P(z_1^{min}(0),0)\right)}{\partial\gamma}$ is unambiguously negative for our parameter restrictions.

The role of inter-industry spillovers on Govt 2's decision is however ambiguous. Since μ increases the positive wage income effect of *both* the core and the periphery region, higher inter-industry spillovers will only increase the set of s_l, γ-combinations at which Govt 2 will set a nonzero subsidy level provided that the number of workers in region 2 is not too low. The intuition is that, as the willingness of Govt 1 to attain the core z_1^{max} and thus also the cost of maintaining the core z_2^d increase in response to higher μ this tends to lower $W_2^C(z_2^d)$ and hence Govt 2's willingness to retain the core. On the other hand, inter-industry spillovers have an attenuating effect on AR and thus also on the cost of attracting all industry z_1^{min}. This again has two effects. On the one hand it increases z_2^d which in turn lowers W_2^C making an effort by Govt 2 less likely. On the other hand, a lower z_1^{min} entails a lower repatriation externality thereby decreasing welfare in the periphery case and hence increasing the attractiveness for Govt 2 to maintain the core. It can be shown that the last mentioned effect dominates the effect of a low z_1^{min} on z_2^d. Still the overall effect is ambiguous due to the first two direct wage income effects.

So far we have assessed the role of intra- and inter-industry spillovers in Govt 2's decision whether to hold on to the core or to allow a relocation. Whereas in Case 3. high intra-industry spillovers lower Govt 2's willingness to maintain the core and thereby encourage a relocation of firms towards the large region which would restore an allocation that is efficient from a global perspective, high enough intra-industry spillovers may also prevent a relocation of firms (Case 1. and Case 2.) and therefore prevent an efficient allocation. What remains to be identified is how each region fares at the end of the game.

In Case 1. and Case 2. ($z_2^d \leq 0$) the core region will not experience a welfare loss just as residents in region 1 will not experience a welfare gain, since $W_2^C(z_2^d) - W_2^C(0,0) \geq 0$ and $W_1^P(z_2^d) - W_1^P(0,0) \leq 0$ for $z_2^d \leq 0$. For Case 3. where industry relocation cannot be excluded a priori we obtain two welfare scenarios. If $W_2^C(z_2^d) - W_2^P(z_1^{min}(0)) \geq 0$ holds, Govt 2 defends the core and residents of region 2 will unambiguously experience a welfare decline due to costly competition whereas households in region 1 experience an unambiguous welfare gain[38] compared to the initial welfare levels, where $z_i = 0$. However, for the case where relocation is inevitable and $(z_1, z_2) = (z_1^{min}(0), 0)$, region 1 experiences a welfare gain, $W_1^C(z_1^{min}(0), 0) > W_1^P(0,0)$ after snatching the core but what cannot be unambiguously determined is whether the new periphery region, i.e. region 2 will be worse or better off after the relocation of industry. The welfare differential in region 2 for the case where industry production changes its location reads

$$\begin{aligned} W_2^P(z_1^{min}(0), 0) - W_2^C(0,0) = & \underbrace{\frac{\alpha}{\sigma} - \frac{(\frac{1+\gamma}{1+\mu})^{1-\sigma}(1 + 2s_l + \alpha(3 - 2s_l)\phi^2)}{4\sigma\phi}}_{\frac{1}{2}z_1^{min}} \\ & - (1 - s_l)\mu + \underbrace{\frac{(3 - 2s_l)}{2(\sigma - 1)}\ln\phi}_{<0}, \end{aligned} \tag{42}$$

where the sign is ambiguous. On the one hand, a relocation of industry induced by a nonzero subsidy level set by Govt 1 imposes a positive externality on capital owners' income in the new periphery. Half of the subsidy payment promised to industrial firms by Govt 1 accrues to capital owners of region 2 thereby increasing $W_2^P(z_1^{min}(0), 0)$. On the other hand, region 2 loses all industry thereby suffering from a lower wage rate and a higher price index which is expressed by the second and last expression in (42). Hence, region 2 will be worse off compared to the unconstrained optimum if the repatriation externality falls out rather low.

3.3 Results and Discussion

This section summarizes the most important results and compares them to the results of the previous literature. There are two outcomes of the subsidy competition game which are summarized below

[38] $\frac{\partial W_2^C(0,z_2)}{\partial z_2} < 0$ and $\frac{\partial W_1^P(0,z_2)}{\partial z_2} > 0$.

Result 1 *In contrast to Baldwin and Krugman (2004) and Ottaviano and van Ypersele (2005) industry relocation constitutes an additional outcome next to the 'core remains the core' outcome. Moreover, both outcomes of the game arise irrespective of whether the core is of equal or even smaller size than the periphery.*

The choice of the core region whether to maintain the industry core or not thereby depends on whether the positive effects of hosting the core (cost-of-living and wage income effect) exceed both the costs of maintaining the core which consist of foregoing a subsidy payment from the other region and the direct costs of paying a subsidy to firms. By implication of Result 1 a globally inefficient allocation[39] can persist even if regions of asymmetric size start to compete over the industry core. Region size influences the outcome but is not the decisive parameter for the decision to defend the core. In fact, for certain parameter values it becomes possible that even though the core region is smaller in terms of number of workers it might still set a nonzero subsidy level which prevents Govt 1 from stealing the core. This result can neither occur in Andersson and Forslid (2003) nor in Baldwin and Krugman (2004) or Borck and Pflüger (2006) since they restrict their analysis to the symmetric region size case. Persisting global inefficiency is also a new outcome of the regional competition game compared to already existing studies on regional competition between regions of different size.

For $z_2^d > 0$ fierce subsidy competition commands a subsidy payment to industrial firms from the core government to prevent a relocation of firms. Contrary to this case, Govt 2 always sets the subsidy level necessary to deter the periphery from snatching the core and does not experience a welfare loss if $z_2^d \leq 0$. In fact, for $z_2^d < 0$, the agglomeration rent is high enough such that the core region is able to subsidize less and even levy a tax on industrial firms without inducing an outflow of firms. This result is summarized as follows

Result 2 *For parameter values which yield $z_2^d < 0$, Govt 2 is even better off compared to the unconstrained optimum where $z_i = 0$. It will be worse off compared to the unconstrained optimum if Govt 2 sets $z_2^d > 0$ in order to retain all industry.*

[39] From the previous section we know that the social planner will always implement a core-periphery allocation earlier than the market $\phi^{SB} < \phi^{B}$. From this it follows that for high levels of trade freeness we can exclude a dispersed allocation to be more efficient than a concentrated allocation. Moreover, as shown in the appendix a globally efficient allocation is the one where the larger region hosts a larger share of industry (due to symmetric spillovers across regions).

The case where $z_2^d < 0$ is in stark contrast to Andersson and Forslid (2003) where tax rates on the mobile factor in the agglomerated equilibirum are distorted downwards[40] and also to Baldwin and Krugman (2004) where the core experiences a welfare loss compared to the unconstrained optimum. Whereas tax competition is unambiguously harmful in Baldwin and Krugman (2004) and Borck and Pflüger (2006) for residents of the core region but not for residents of the periphery, regional competition may now also affect welfare in the periphery. Hence, an ultimate opinion about the general desirability of regional competition in our framework cannot be agreed upon. In Case 1. the core region is even better off compared to the unconstrained optimum since it can levy a lump sum tax on the mobile factor. The resulting tax revenue is thereby redistributed to local (core) residents. However, capital owners in the periphery whose capital is employed in the core region suffer from a welfare decline due to the tax on capital compared to the unconstrained optimum. Furthermore, when evaluating the desirability of regional competition from a global perspective we have seen that as long as size differences are not too large an inefficient allocation of industry from a global perspective can persist although regions start to compete over the industry core. But for large enough size differences and weak agglomeration rents in the smaller core region, a globally efficient allocation can be restored if competition among regional governments is allowed for.

Result 3 *The Role of Intra-Industry Spillovers*

The role of intra-industry spillovers in an uneven subsidy competition game is however ambiguous. On the one hand the existence of intra-industry spillovers extends the possible outcomes of this subsidy game. In contrast to Ottaviano and van Ypersele (2005) who also consider unequal region size in a regional competition game but where due to their modeling choice only interior asymmetric equilibria and a one sided core periphery equilibrium (core located in the large region) constituted the only stable equilibria, our modeling approach exhibits an additional stable equilibrium. Since intra-industry spillovers exceed inter-industry spillovers it becomes possible that for high levels of trade freeness the industry core is located in the smaller region. Firms in the industry core realize an agglomeration rent which is predominantly determined by the cost-saving intra-industry spillovers and the level of trade freeness. We have seen that if this agglomeration rent is sufficiently high (e.g. due to very strong intra-industry spillovers) such that $z_i^d \leq 0$

[40] Additionally taxes on the immobile factor in Andersson and Forslid (2003) are distorted upwards.

then all industry will stay in the smaller region without the need for a subsidy payment. On the other hand, for the case where the government would need to offer a positive subsidy payment to induce firms to stay, i.e. for $z_i^d > 0$ strong intra-industry spillovers now discourage the maintenance of the industry core in region 2. The higher the intensity of intra-industry spillovers γ the lower must be the difference in region size if the core region is to set a subsidy level equal to z_i^d. This effect stems from the positive repatriation externality which is absent in Andersson and Forslid (2003), Baldwin and Krugman (2004) and Borck and Pflüger (2006) since they assume capital to move with its owner. In our model high intra-industry spillover will increase the minimum subsidy level that also accrues partly to capital owners residing in the other region. As long as $z_i^{min}(0) < z_i^{max}(0)$ this will imply that the initial core region experiences an outflow of firms but also that the utility loss is alleviated through the positive externality on capital owners' income.

Result 4 *Region Size and Capital/Labor ratio*

Borck and Pflüger (2006) conclude that the larger region (defined as the region hosting a larger industry share) has higher tax rates and a higher capital/labor ratio as opposed to Bucovetsky (1991) who measures region size as the number of the immobile factor (population) and who assumes that regions exogenously differ in the number of their immobile population. In this case, the larger region will have a higher equilibrium tax rate but a lower capital/labor ratio. In contrast to Borck and Pflüger (2006) we distinguish between regions of symmetric size and regions symmetric in industry. While the first refers to the number of immobile factor (capital owners + workers), the latter is concerned with the share of industry in each region.[41] For the case where smaller region 2 prevents a relocation of firms towards region 1, the capital/labor ratio in the small region will be larger and not smaller as predicted in Bucovetsky (1991). The reason lies in the fact that industry is not necessarily located in the larger region, which is in contrast to Bucovetsky (1991) where the larger region is also richer in capital in equilibrium.

Finally, what turns out to be handy is that contrary to Baldwin and Krugman (2004) or Borck and Pflüger (2006) we do not need to rely on an arbitrarily chosen objective function and functional forms. By means of the indirect utility functions we are able to derive analytical and for the most part interpretable expressions.

[41]Hence, in our model regions can be symmetric in size and asymmetric in industry but can never be symmetric in industry and asymmetric in size at the same time in equilibrium.

4 Conclusion

Previous works on regional competition in the presence of agglomeration forces concluded that the resulting locational hysteresis is strong enough to tie industry to the agglomerated region even if regions start to compete over the industry core. Regions with an initially larger share of industry did not suffer from a relocation of firms. In fact, due to the resulting taxable rents, governments of the agglomerated region were able to impose higher tax rates on firms compared to tax rates in the less agglomerated region. It was thereby assumed that regions either were equally sized[42] or that one region was larger in terms of the immobile factor as in Ottaviano and van Ypersele (2005). In this case the larger region hosted a larger share of industry irrespective of the level of trade costs. This paper however has elaborated two aspects. In contrast to Ottaviano and van Ypersele (2005) our model with technological spillovers now allows for stable core equilibria with the agglomeration being located in the less populated region. This new feature of the model enabled us to analyze the effects of regional competition for the asymmetric size case next to the symmetric region size case. We have thereby shown that regional competition can have ambiguous effects on social welfare and does not ensure that the resulting allocation is efficient from a global perspective. In fact, an inefficient allocation of industry, where all firms are located in the small region implying that less households benefit from a low cost-of-living index and higher wages can persist although regions start to compete over the industry core. All this leads us to the conclusion that policies supporting the dissemination of technological spillovers are not socially desirable per se. For the case where all industry is agglomerated in the large region, strong localization economies will indeed benefit residents of both regions through lower producer prices which decrease the costs of purchasing differentiated varieties. However, for the case where agglomeration occurs in the smaller region, strong intra-industry spillovers either detain to achieve an efficient firm allocation or support to restore an efficient allocation of industry depending on the parameter values.

[42] Asymmetry between regions emerged endogenously through demand and supply linkages.

Appendices

A Local Stability

A.1 Social and Market Break Point

We restrict ourselves to a graphical exposition and show that $\phi^{SB} - \phi^{B}$ is non positive for our parameter specifications ($\gamma > \mu$ and $\sigma > 1$).

$$\gamma = 1;\ \mu = 0.5$$

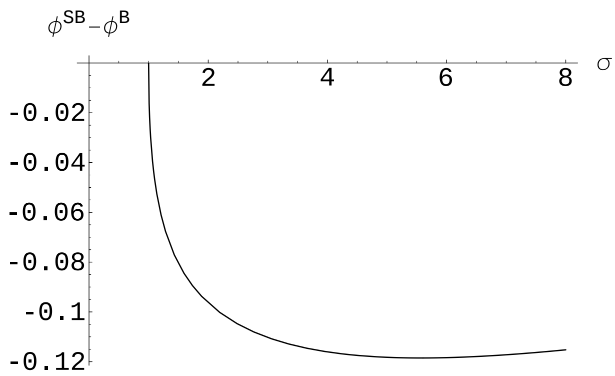

Figure 11: Social and Market Breakpoint

A.2 Market Break Point and Sustain Point: Comparative Statics

Since the partial derivatives of the break and sustain point with respect to γ, μ and σ are rather messy we restrict ourselves to numerical and graphical exposition to illustrate the direction of change. We begin with the impact of intra-industry spillovers on ϕ^{B} and ϕ^{S}. Figure 12 shows that for our parameter restrictions $\gamma > \mu$ and $\sigma > 1$ ($\sigma = 4$) the partial derivative of the break point is negative implying that the break point shifts left as γ increases (solid curve). In the same manner the sustain point also decreases in response to an increase in γ (thick solid curve), where $\mu = 0.1$ is the underlying parameter value for these curves. The effect of γ on ϕ^{B} and ϕ^{S} becomes even stronger if the difference between inter-and inter-industry spillovers is low. These cases are depicted through the

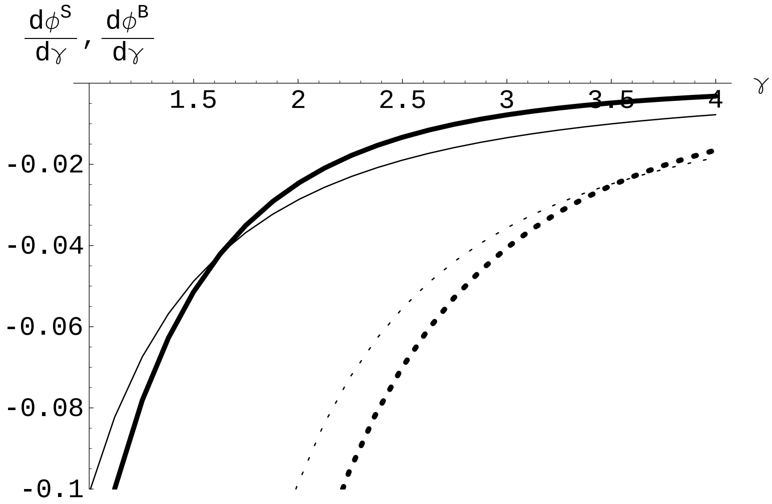

Figure 12: Effect of intra-industry spillovers

dashed thick for the sustain point and the dashed solid curve for the market break point where the underlying parameter values is now given by $\mu = 0.9$. Figure 13 shows the impact of inter-industry spillovers on ϕ^B and ϕ^S. For our parameter restrictions $\gamma > \mu$ and $\sigma > 1$ the market break point and the sustain point will both increase in response to an increase in inter-industry spillovers, the partial derivative being positive.

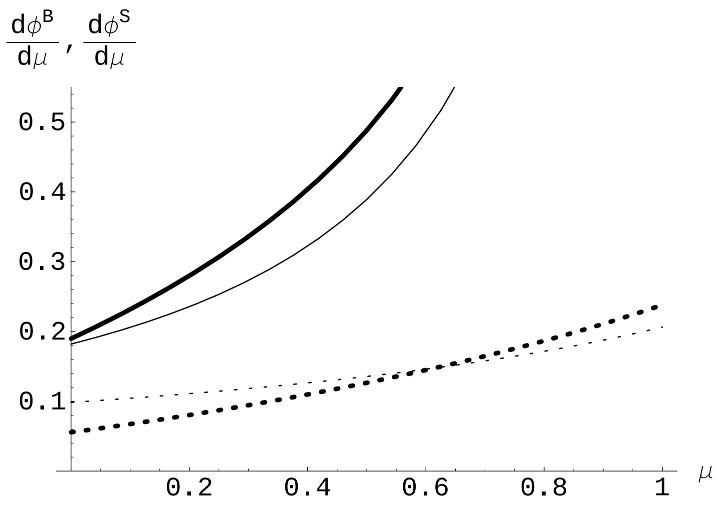

Figure 13: Effect of inter-industry spillovers

Again, the effect of inter-industry spillovers on ϕ^B and ϕ^S will be stronger the lower the difference between both spillovers. Accordingly, $\gamma = 1$ is the underlying parameter value of (thick) solid curves, whereas the (thick) dashed curves are plotted for $\gamma = 2$. Finally Figure 14 illustrates the direction of change of ϕ^B and ϕ^S induced by an increase in σ, the constant elasticity of substitution.

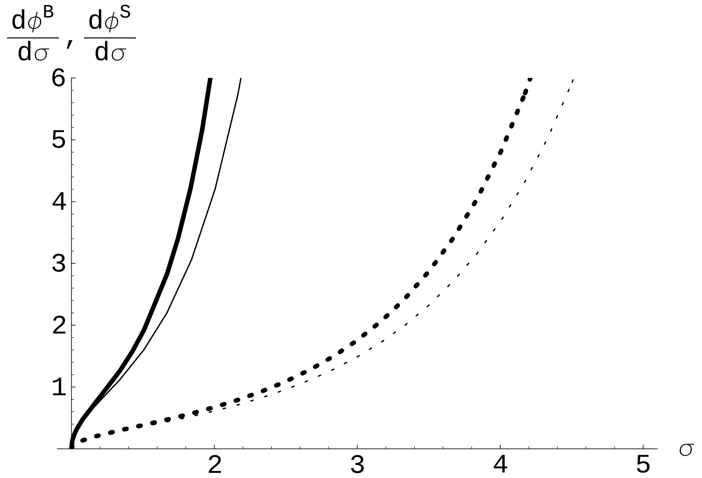

Figure 14: Effect of σ

Both threshold levels shift to the right as the elasticity of substitution increases indicating lower market power of each single firm. With an increase in the market break point the symmetric allocation becomes stable for higher levels of trade freeness while the corner outcomes become unstable already for high levels of trade freeness. The degree of change is larger the larger the difference between the two spillover intensities.

B Locational Forces

The locational forces are obtained by evaluating the different forces at $s_n = \frac{1}{2}$ for the symmetric region case, i.e. $s_l = s_k = \frac{1}{2}$.

1. Intra-Industry Spillovers

To isolate the intra-industry spillover force we differentiate the capital reward gap with respect to s_n holding fixed the market crowding effect (the direct effect of the industry share on r_i) and inter-industry spillovers.

$$\left.\frac{d(r_1 - r_2)}{ds_n}\right|_{s_n=\frac{1}{2},\mu=0} = \frac{\partial(r_1 - r_2)}{\partial\chi_\gamma}\frac{\partial\chi_\gamma}{\partial s_n} = -\frac{32\alpha\gamma(1-\sigma)}{(2+\gamma)\sigma}\frac{\phi}{(1+\phi)^2} > 0. \tag{43}$$

This expression is positive for our parameter specifications and captures the agglomerative intra-industry spillover force.

2. Inter-Industry Spillovers

The deglomerative inter-industry spillover force is derived in as similar manner as the agglomeration force. Holding fixed the market crowding effect and intra-industry spillovers yields the inter-industry spillover force

$$\left.\frac{d(r_1 - r_2)}{ds_n}\right|_{s_n=\frac{1}{2},\gamma=0} = \frac{\partial(r_1 - r_2)}{\partial\chi_\mu}\frac{\partial\chi_\mu}{\partial s_n} = \frac{32\alpha\mu(1-\sigma)}{(2+\mu)\sigma}\frac{\phi}{(1+\phi)^2} < 0. \tag{44}$$

which is unambiguously negative.

3. Market Crowding Effect Formally the market crowding effect works through the direct effect of s_n on R_1 in (13). Holding fixed inter-and intra-industry spillovers yields the isolated market crowding effect

$$\left.\frac{\partial(r_1 - r_2)}{\partial s_n}\right|_{s_n=\frac{1}{2},\mu=\gamma=0} = -\frac{8\alpha}{\sigma}\frac{(-1+\phi)^2}{(1+\phi)^2} \leq 0. \tag{45}$$

which is unambiguously non-positive.

C The model for asymmetric region size

$\alpha = \mu = s_k = 0.5; \sigma = 4; \gamma = 1; s_l = 0.6$

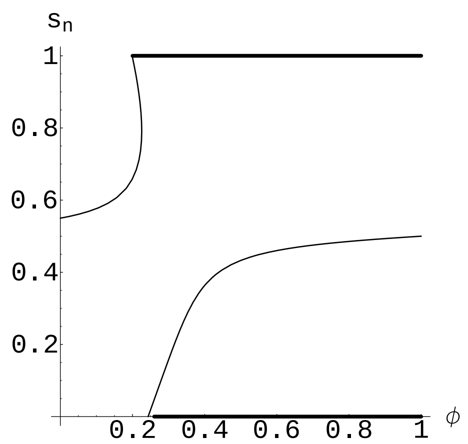

Figure 15: Bifurcation II

Depending on the level of trade freeness the corner equilibria with $s_n = 1$ or $s_n = 0$ or stable interior asymmetric equilibria (upper curve) arise. There is still an overlap where two different types of equilibria namely $s_n = 1$ and $0.5 < s_n < 1$ turn out to be both stable for low levels of trade freeness.

D Subsidy Competition

D.1 Agglomeration Rent

$$\frac{\partial AR}{\partial \mu} = -\frac{\alpha(\frac{1+\gamma}{1+\mu})^{-\sigma}(\sigma-1)(1+2s_l+(3-2s_l)\phi^2)}{2(1+\mu)\sigma\phi} < 0, \tag{46}$$

$$\frac{\partial AR}{\partial \gamma} = \frac{\alpha(\frac{1+\gamma}{1+\mu})^{-\sigma}(\sigma-1)(1+2s_l+(3-2s_l)\phi^2)}{2(1+\mu)\sigma\phi} > 0, \tag{47}$$

$$\frac{\partial AR}{\partial s_l} = -\frac{\alpha\frac{1+\gamma}{1+\mu}^{-\sigma}(1-\phi^2)}{\sigma\phi} < 0. \tag{48}$$

D.2 Govt 2's Decision

D.2.1 The role of intra-industry spillovers

Show that indirect utility of the core region increases in γ: Intuitively, since $\frac{\partial z_1^{min}}{\partial \gamma} > 0$ and $\frac{\partial z_1^{max}}{\partial \gamma} = 0$ it follows from the definition of z_2^d that $\frac{\partial z_2^d}{\partial \gamma}$ must be positive. , i.e.

$$\frac{\partial W_2^C(0, z_2^d)}{\partial \gamma} = \frac{\alpha(3-2s_l)}{2(1+\gamma)} + \frac{\alpha(\frac{1+\gamma}{1+\mu})^{-\sigma}(\sigma-1)(1+2s_l+(3-2s_l)\phi^2)}{8\sigma\phi(1+\mu)} > 0 \tag{49}$$

is unambiguously positive for our parameter restrictions.
Welfare in the periphery case increases in γ as $z_1^{min}(0)$ increases with γ (repatriation effect), i.e.

$$\frac{\partial W_2^P(z_1^{min}(0), 0)}{\partial \gamma} = \frac{\alpha(3-2s_l)}{2(1+\gamma)} + \frac{\alpha(\frac{1+\gamma}{1+\mu})^{-\sigma}(\sigma-1)(1+2s_l+(3-2s_l)\phi^2)}{4\sigma\phi(1+\mu)} > 0 \tag{50}$$

is also unambiguously positive.
Hence it follows that

$$\frac{\partial\big(W_2^C(0, z_2^d) - W_2^P(z_1^{min}(0), 0)\big)}{\partial \gamma} = -\frac{\alpha(\frac{1+\gamma}{1+\mu})^{-\sigma}(\sigma-1)(1+2s_l+(3-2s_l)\phi^2)}{8\sigma\phi(1+\mu)} < 0 \tag{51}$$

is unambiguously negative for our parameter restrictions.

D.3 The role of inter-industry spillovers

$$\frac{\partial[W_2^C(z_2^d) - W_2^P(z_1^{min})]}{\partial\mu} = \underbrace{\frac{1}{2}(2-3s_l)}_{\geq 0 \text{for} s_l<\frac{2}{3}} - \underbrace{\frac{\alpha(1-\sigma)\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}[1+2s_l+(3-2s_l)\phi^2]}{8\sigma\phi(1+\mu)}}_{>0} \tag{52}$$

The difference will only be unambiguously positive for $s_l < \frac{2}{3}$. On the hand μ increases W_2^C through $(1-s_l)\mu$. On the other hand, μs_l increase z_1^{max} and hence also z_2^d which lowers W_2^C.

$$\frac{\partial W_2^C}{\partial\mu} = (1-s_l) - \frac{\alpha(3-2s_l)}{2(1+\mu)} - \frac{1}{2}\frac{\partial z_2^d}{\partial\mu} \tag{53}$$

Whereas $\frac{\partial z_2^d}{\partial\mu}$ is unambiguously positive (see below) the sign of $\frac{\partial W_2^C}{\partial\mu}$ remains indeterminate. The last term in (52) is positive and captures the effect of higher inter-industry spillovers on Govt 2 willingness to maintain all industry, W_2^C through z_2^d, and on the welfare in case of losing the core to region 1, W_2^P. First, μ decreases AR which lowers z_1^{min} and increases z_2^d thereby lowering W_2^C.

$$\frac{\partial z_1^{min}}{\partial\mu} = -\frac{(\sigma-1)\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}[1+2s_l+(3-2s_l)\phi^2]}{2\sigma(1+\mu)\phi} < 0 \tag{54}$$

and is unambiguously negative, while

$$\frac{\partial z_2^d}{\partial\mu} = s_l + \frac{\alpha(\sigma-1)\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}[1+2s_l+(3-2s_l)\phi^2]}{4\sigma(1+\mu)\phi} > 0 \tag{55}$$

is unambiguously positive. Second, lower z_1^{min} entails a lower repatriation externality thereby decreasing welfare in the periphery case and hence increasing the attractiveness for Govt 2 to maintain the core.

$$\frac{\partial W_2^P}{\partial\mu} = -\frac{\alpha}{\sigma}\left[\frac{(3-2s_l)}{2(1+\mu)} + \frac{\alpha(\sigma-1)\left(\frac{1+\gamma}{1+\mu}\right)^{1-\sigma}[1+2s_l+(3-2s_l)\phi^2]}{4\sigma\phi(1+\mu)}\right] \tag{56}$$

is unambiguously negative for our parameter specifications.

D.4 Efficient industry allocation

In order to show that global welfare is higher when all industry is located in the larger region we compare the sum of regional welfare for the case where the core is located in the large region with the sum of regional welfare for the case where the small region hosts the core.

$$\sum_{i=1}^{2} W_i\big|_{s_n=1,z_i=0} - \sum_{i=1}^{2} W_i\big|_{s_n=0,z_i=0} = \frac{(2s_l-1)[\mu(\sigma-1)-\alpha ln\phi]}{\sigma-1} \quad (57)$$

is unambiguously positive for $s_l > \frac{1}{2}$.

References

F. Andersson and R. Forslid. Tax competition and economic geography. *Journal of Public Economic Theory*, 5(2):279–303, 04 2003.

K. Arrow. Economic welfare and the allocation of resources for invention. In R. Nelson, editor, *The Rate and Direction of Inventive Activity*. Princeton University Press, 1962.

D. B. Audretsch and M. P. Feldman. R&d spillovers and the geography of innovation and production. *The American Economic Review*, 86(3):630–640, June 1996.

D. B. Audretsch and M. P. Feldman. Knowledge spillovers and the geography of innovation. In J. V. Henderson and J. F. Thisse, editors, *Handbook of Regional and Urban Economics*. 2004.

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

R. E. Baldwin, R. Forslid, P. Martin, G. Ottaviano, and F. Robert-Nicoud. *Economic Geography And Public Policy*. Princeton University Press, 2003.

R. Borck and M. Pflüger. Agglomeration and tax competition. *European Economic Review*, 50(3):647–668, April 2006.

L. Bottazzi and G. Peri. Innovation and spillovers in regions: Evidence from european patent data. *European Economic Review*, 47(4):687 –, August 2003. ISSN 00142921.

S. Bucovetsky. Asymmetric tax competition. *Journal of Urban Economics*, 30(2):167–181, September 1991.

M. P. Devereux, R. Griffith, and H. Simpson. Firm location decisions, regional grants and agglomeration externalities. *Journal of Public Economics*, 91(3/4):413 – 435, 2007. ISSN 00472727.

A. Dixit. The role of investment in entry-deterrence. *Economic Journal*, 90(357):95–106, March 1980.

A. K. Dixit and J. E. Stiglitz. Monopolistic competition and optimum product diversity. *American Economic Review*, 67(3):297–308, June 1977.

R. Forslid and G. I. Ottaviano. An analytically solvable core-periphery model. *Journal of Economic Geography*, 3(3):229–240, July 2003.

E. L. Glaeser, H. D. Kallal, J. A. Scheinkman, and A. Shleifer. Growth in cities. *The Journal of Political Economy*, 100(6, Centennial Issue):1126–1152, December 1992.

A. B. Jaffe, M. Trajtenberg, and R. Henderson. Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics*, 108 (3):577–98, August 1993.

H. J. Kind, G. Schjelderup, and K. H. Ulltveit-Moe. Competing for capital in a 'lumpy' world. *Journal of Public Economics*, 78(3):253–274, November 2000.

P. Krugman. *Geography and Trade*. MIT Press, 1991a.

P. Krugman. History versus expectations. *The Quarterly Journal of Economics*, 106(2): 651–667, May 1991b.

R. D. Ludema and I. Wooton. Economic geography and the fiscal effects of regional integration. *Journal of International Economics*, 52(2):331–357, December 2000.

A. Marshall. *Principles of Economics*. Macmillan, London, 1890.

P. Martin and C. A. Rogers. Industrial location and public infrastructure. *Journal of International Economics*, 39(3-4):335–351, November 1995.

J. P. Neary. Of hype and hyperbolas: Introducing the new economic geography. *Journal of Economic Literature*, 39(2):536–561, June 2001.

C. Oman. *Policy Competition for Foreign Direct Investment: A study of Competition among Governments to Attract FDI*. OECD Development Centre, 2000.

G. Ottaviano, T. Tabuchi, and J.-F. Thisse. Agglomeration and trade revisited. *International Economic Review*, 43(2):409–436, May 2002.

G. I. Ottaviano and T. van Ypersele. Market size and tax competition. *Journal of International Economics*, 67(1):25–46, September 2005.

M. Pflüger and J. Südekum. Integration, agglomeration and welfare. *Journal of Urban Economics*, 2007.

J. E. Rauch. Does history matter only when it matters little? the case of city-industry location. *The Quarterly Journal of Economics*, 108(3):843–67, August 1993.

S. J. Redding, D. M. Sturm, and N. Wolf. History and industry location: Evidence from german airports. *CEP Discussion Paper*, No809:1–35, 2007.

P. M. Romer. Increasing returns and long-run growth. *The Journal of Political Economy*, 94(5):1002–1037, October 1986.

S. S. Rosenthal and W. C. Strange. Evidence on the nature and sources of agglomeration economies. In J. V. Henderson and J. F. Thisse, editors, *Handbook of Regional and Urban Economics*. 2004.

M. A. Spence. Entry, capacity, investment and oligopolistic pricing. *Bell Journal of Economics*, 8(2):534–544, Autumn 1977.

K. H. Ulltveit-Moe. Regional policy design: An analysis of relocation, efficiency and equity. *European Economic Review*, 51(6):1443–1467, August 2007.