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Industrial Agglomeration and Economic Development

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Abstract

The paper outlines a static equilibrium model, which analyses the economic development in a two-country case by considering interregional migration in R&D-sectors. The effects of migration and firm decisions on both industrial agglomeration and economic development will be shown: lock-in-effects and free market entry will lead to a concentration of firms. In addition, the consideration of fundamental and secondary research activity leads to a higher number of firms and products by means of cost reduction and spillover effects. The resulting demand of unskilled and skilled labor will be met by sectoral and interregional migration. This reinforces the concentration of economic activity and leads to a higher degree of specialization and economic development.

The formation of single equilibria is shown under consideration of exogenous shocks: diminishing transportation cost will turn economies, originally equally endowed and with the same economic structure, to spatial concentration and uneven economic development.

JEL classifaction: D5; O1; R0

Keywords: Economic geography, Factor mobility, Regional growth theory, R&D, Learning by doing, Spillover effects.

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1. Introduction

The first appreciable industrialization and urbanization process in parts of Europe can be dated to the 19th century. Technological progress was necessary to produce sufficient agricultural crops allowing people to concentrate and human activity to specialize: while in Europe the share of urban population increased from 20% in 1850, to 52% in 1950 and nowadays to 75%, in the united states a rise form 3% in 1800 to over 60% in 1950 and 77 % in the last years was observed (Fujita and Thisse 2002). The urbanization process was accompanied by a relatively constant pattern of different sizes of cities and economic areas and their spatial distribution[1]. The respective population share living in urban centers relatively to the total population is quite low (e.g. New York ca. 7%) and laterly declining.

On the contrary, the economic and urban development in nearly whole Latin America and Asia did not start until the last century. In the majority of these countries, economic activity is concentrated to few agglomerations absorbing a huge part of the total population and attracting more and more labor force from structurally backward regions as Mexico City in Latin America or Manila in Asia. As a result, there are core regions of industrial and urban activities[2], which can hardly be destabilized by the tightening negative social, ecological and economical impact. A distribution and/or size rule of urban cities as mentioned for Europe and the USA is not to be found in the developing countries.

How can the coexistence of these different patterns of industrialization and urbanization be explained?

The traditional models of the neo classic are not able to give a satisfactory reply. These kinds of models try to explain economic development and international labor division by a set of comparative cost advantages due to factor distribution and resource allocation as well as constant returns of scale. Generally there is a 2x2x2 trade model: two regions produce two goods by using two immobile input factors. Interregional trade leads to a factor price convergence and to regional specialization. The same result can be obtained by a model with at least one mobile input factor producing one homogenous product. Using comparative cost advantages as a main source for regional specialization, the loss or the abolition of them should lead to a disintegration of these concentrations: in the beginning of the 20th century all of the ten biggest cities in the USA emerged as seaports. Although the importance of water transport has

[1] Fujita, Krugman and Venables (1999) show for the United States that in 1991 40 cities had a population share of more than one million, 20 cities of more than two millions and 9 cities, Houston in Texas was a little bit to small, of more than four million people.

[2] Elizondo and Krugman (1995) analyze the impact on developing countries by pursuing different trade policies.

permanently depleted, most of them remained important, see Fujita and Mori (1996) and Krugman (1993). Therefore neo classic models cannot explain persistent development of industrial and urban concentration characterized by uneven pay of factors and regional inequalities.

However, it seems to be more fruitful to have a closer look to the cost of spatial interaction, increasing returns, inter-industrial linkages and different labor supplies when discussing industrial and urban concentrations.

Developing countries are confronted with a higher degree of scale economies, lower transaction and communication costs and a higher elasticity of rural population towards urban migration than in 19th century as industrialization and urbanization began in Europe and the USA.[3] The increased profitability of firms due to mass production and the reduction of transportation cost can be used as an explanation of the emergence of huge industrial und urban agglomerations in the third world countries serving for the international market.

To what extent core regions and cities either are specialized in their production pattern or account with a diversified range of industrial activities depends on the same factors.

If industries are in a top-down or bottom-up correlation or dependent on specific factors/natural resources, then agglomeration with a high degree of specialization results[4]. The manufacturing belt in northeast and parts of the Midwest during the first part of the 20th century (Krugman (1991a)) or nowadays the so-called factory cities as Toyota City in Japan, Armonk (IBM) in the USA or Wolfsburg (VW) in Germany are examples for a strong specialization and vertical intra-industrial linkages. Accordant to a study from Duranton and Puga (2000) in 1992 the first eight of the most specialized firms in the USA can be assigned to the tobacco, leather and petroleum industry. To nearly the same results leads a further look of industry branches, and especially the non-productive industries, which are dependent on a specific human qualification or computer network as the financial district in London or the Silicon Valley in California.

At the same time there are cities and conurbations without important branches and with a multiplicity of different firm activities. Due to the fact that several industries do not have any inter-industrial linkages or are about to develop new ideas, diversified cities are characterized by emerging innovative firms and a high share of headquarters and provision of services,

[3] Puga (1998) shows in a two-region-model the development of urban concentrations due to interregional migration and points to the importance of a high elasticity of labor supply for the urbanization of developing countries.
[4] Venables (1996) and Puga und Venables (1996) model input-output structures to show specific industrial agglomerations.

Duranton and Puga (2001a, 2001b). Congruously, cities like Cincinnati, Atlanta and New York present a high diversification share.[5]

Therefore it depends on the point of view when answering the questions if cities or core regions are specialized or not: a metropolis can be a huge agglomeration of economic activity or a conglomeration of several industrial concentrations. But the processes leading to urban and industrial concentrations are the same: technological progress, closer networking of industrial activities, diminishing transport and communication costs and a higher labor pool due to migration increase the incentives to spatial and economic concentration. Furthermore economic development through innovations and cost reduction is positively influenced in industrialized regions with a higher level of research activity. Circular processes arise leading to core regions and cities with a high share of urban and industrial activities, where economic development fosters further prosperity, and to structurally backward regions. Therefore, differences in the degree of these effects seem to have a major impact on industrialization and can explain distinctive urbanization patterns.

This paper analyses the process of industrial agglomerations and economic development in two countries. The structure of the paper is described as follows: in the second chapter a static total equilibrium model will be presented and discussed. The results of numerical simulations and the impacts on long run equilibria will be given in chapter 3. A summary of the paper and an outlook are stated in chapter 4. Further equations and equilibrium conditions as well as specific details for parameters and the numeric simulation are listed in the appendix.

2. A static equilibrium model

The model is based on a microeconomic funded theory, which relies on the concept of monopolistic competition from Spence (1976) and Dixit and Stiglitz (1977) and the adaptation on regional economics from Krugman (1991b, 1991c) and Krugman and Venables (1995). In addition, the use of intermediate goods in the manufacturing sector is considered. This is in line with the models among others like Fujita and Thisse (2002) as well as Fujita, Krugmann und Venables (1999).[6] Costs of spatial interaction are modeled as iceberg costs, Samuelson (1954). There will be a publicly financed R&D sector providing fundamental research to firms and reducing costs on a firm level: this impact will augment the number of

[5] Measured as an inverse hirshman-herfindahl index, see Duranton und Puga (2000).
[6] An overview of the theoretical treatments on regional economics is given by Grafts and Venables (2001). The empirical stand is shown in Overman, Redding and Venables (2001).

locally operating firms and therefore the supply of goods. Leading to similar results, a learning-by-doing approach is introduced to incorporate the effects of a higher regional share of manufacturing labor on economic development. To keep it analytically tractable both approaches will be examined separately due to its impacts on economic developments and compared to a model without regional research activity as formalized in Puga (1999). Due to the assumption of increasing scale returns and the consideration of research activity impacts on industries, monetary and technological external effects as mentioned by Scitovsky (1954) can be analyzed within one framework. Preferences of consumers are expressed by a love-of-variety assumption.

2.1. Agglomeration and research activity

The paper outlines a static equilibrium model, which analyses the economic development in a two-country case by considering additionally interregional migration in R&D-sectors. The effects of firm decisions and migration on both industrial agglomeration and economic development will be analyzed as well as regional research activity. A crucial role is accredited to the spillover effect due to applicability of interregional research and is therefore a main focus in this paper.

The interaction of economies of scale, costs of transportation and migration are decisive for the location of industry. Due to Hirschmann (1958) there are *pull* and *push forces* leading to core periphery structure or even pattern of industrialization: manufacturing firms are able to use intermediate goods more cheaply and face a greater demand towards their products where other firms and consumers are concentrated (cost and demand linkages). Further agglomeration will occur. At the same time competition in product and factor markets rises with the number of locally operating firms. These neoclassical forces work against agglomeration and the emergence of core periphery structures. Therefore the pattern of industrialization and urbanization depends on the one hand on the presence and on the strength of these pull and push forces. On the other hand the role of *migration* is considered to have a strong impact on the formation of agglomeration. While sectoral migration is a mayor factor for intraregional firm location, interregional migration affects the country as a whole. Both types of migration will be taken into account and differences in either nominal or real wage rates are entailed by higher fluctuation of labor. The effects on agglomeration and economic development are distinctive: manufacturing firms can attract a higher share of labor force from other sectors by offering a higher nominal wage rate pushing toward further industrial agglomeration. If this leads to a widening of interregional wage gaps, which is not responded by factor movement due to migration restriction, firms may consider a production dislocation to the structurally backward region/country and weaken industrial concentration. If not or in the case of free factor movement, agglomeration is even more encouraged as seen in many core cities in developing countries.

As an extension to the discussed static equilibrium models in literature, R&D as an import source of technological change and productivity growth and its spillover effects on regions/industries will be introduced. The outcome of the R&D sector is determined solely by factor mobility of skilled labor. Factor mobility in multiregional endogenous growth and agglomeration models as modeled by Walz (1996), Baldwin and Forslid (2000), Black and Henderson (1999) or Martin and Ottaviano (2001) are analyzed dynamically: following the endogenous growth theory of Romer (1990) and Grossman and Helpman (1991) permanent product innovation in the R&D sector will lead to a higher number of products and firms and hence to higher growth rates[7]. In this paper the treatment of R&D and research activity is distinctive but leads to the same results: research outcome reduces costs on a firm level and will augment the number of locally operating firms and products leading to higher economic development. Depending on whether there is fundamental or secondary research (Aghion and Howitt (1998)), the implications on the firm costs are modeled differently.

Average production costs

Fundamental research as measured by R&D outcome is supposed to reduce fix costs on a firm level and hence the average production costs leading to a lower break even point and to a higher market entry of firms. Referring to a empirical study about costs and productivity in the automobile production from Fuss and Waverman (1992), the impact from technical change, measured as stock of R&D[8], to the average unit production costs would have been for the U.S. -0.8%, for Japan -2.7% and for Canada -0.3% per annum over a period of 1970-84 and for Germany -1.1% per annum for 1970-80.

Total factor productivity

The same study shows an increase of total factor productivity, measured as a ratio of output to aggregate inputs, of 1.3% for U.S., 3.0% for Japan and 1.3% for Canada per annum over a period of 1970-84 and for Germany 1.3% per annum for 1970-80. Following Fuss and Wa-

[7] In the case of Black and Henderson (1999) human capital accumulation and knowledge spillover as mentioned in Lucas (1998) fuels urban growth.

[8] Constructed by converting annual R&D expenditure to a real capital stock. Fuss and Waverman (1992) set a benchmark R&D stock for 1967 and normalized it to one arguing that the then available technology for Germany and Japan could be represented by the R&D stock in the U.S..

verman (1992) this increase can be attributed to R&D, to scale economies and capacity utilization. Therefore, secondary research (e.g. learning by doing) leading to a higher productivity of input factors should consider the implication of R&D as well as quality and process improvements due to a high share of manufacturing fabrication. As a result, secondary research will reduce variable costs enabling firms to generate higher short run profits.

In the literature there is a distinction between *local* and *global spillover effects* when considering the implementation of research results (Martin and Ottaviano (1997)). On the one side the availability and applicability of research outcomes can be restricted locally: blueprints cannot be transferred and applied to other regions due to its specific use or property rights provoking and strengthen uneven development in the world. But on the other side reengineering and/or imitation of imported products or increased interchange of human capital and ideas can raise the degree of interregional research spillovers and therefore the likelihood for economic prosperity of developing countries.

2.2. Model structure

Let us consider a world with two economies, i = 1,2, with identical endowments of mobile and immobile factors of production. Considering the mobile factors, there will be a distinction between unqualified and qualified workers, L_i and m_i, where the first are mobile between sectors within an economy, the second between the two economies. The shares of the immobile factors land, B_i, and capital, K_i, will be the same in each country and will be fixed. Both countries have the same technology and firms are able to engage in both agriculture and manufacture. Within the manufacturing sector, intermediate goods will be needed for industrial production. Gross country trade with industrial goods will be subject to transportation costs. In addition, there will be state financed research and development in each country. The research results will have an impact on either the fixed cost or the variable cost on a firm level. All consumers have the same preferences and are time indifferent.
Steady state equilibria will be considered. Further development of equations and equilibrium conditions are shown in the appendix.

Agriculture

In the agricultural sector, s = R, there is perfect competition and constant economies of scale. The homogenous agricultural good, y_i, can be traded without transportation cost. The production is supposed to take the form of a Cobb-Douglas production function using land, B_i, and unqualified labor, $L_{i,R}$: $F_{i,R}(L_{i,R}, B_i) = L_{i,R}{}^{\theta} B^{(1-\theta)}$, with θ as a partial production elasticity of unqualified work and B_i = B.

The nominal wage rate paid in the agricultural sector will be obtained by the first derivation with respect to unqualified labor:

$$w_{i,R} = F'_{i,R}(L_{i,R}, B) = \theta L_{i,R}{}^{\theta-1} B^{(1-\theta)} . \quad (1)$$

Considering that unqualified workers can be employed by the agricultural sector as well as the manufacturing sector, equation (1) can be rewritten as:

$$w_{i,R} = F'(L_i - L_{i,U}, B) = \theta(L_i - L_{i,U})^{\theta-1} B^{(1-\theta)} , \quad (1.1)$$

with $L_{i,U}$ as unqualified labor employed in the industrial sector. If there is a constant share of L_i in economy i, the agricultural payoff will be determined by the industrial factor demand: the higher the share of labor in manufacturing, the higher the productivity and therefore the payoff in the agricultural sector. A profit condition[9] can be used to express agricultural gains as a function of the price of the agricultural good, $p_{i,R}$, nominal wages, $w_{i,R}$, and land endowment, B:

$$R_i(p_{i,R}, w_{i,R}, B) = \max\{p_{i,R} y_i - w_{i,R} L_{i,R} - zaB \mid y_i \le g(L_{i,R}, B)\}, \quad (2)$$

where za is the cost for agricultural land use. Equation (2) can be rewritten using $p_{i,R}$ =1 to:

$$R_i(1, w_{i,R}, B) = Br_i(w_{i,R}) , \quad (2.1)$$

with $r_i(w_{i,R})$ as maximized profit per unit land.

Manufacture

In the industrial sector, s = U, we assume monopolistic competition and increasing returns of scale. Input factors for the industrial goods are an aggregate of intermediate goods, CES_i, with a production share of μ and unqualified workers, $L_{i,U}$, with $(1-\mu)$:

$$Q_i = L_{i,U}{}^{1-\mu} CES_i{}^{\mu} , \quad (2)$$

with $CES_i = \left(\sum_{j=1}^{2} \int_{h \in N_j} x_{j,i}^{\rho} dh \right)^{1/\rho}$ for $0 < \rho \le 1$ and i = 1,2. The aggregate supply is therefore a Cobb-Douglas and a CES production function with ρ as a degree of product differentiation and N_i as the number of firms operating in economy i.

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[9] See Puga (1999).

It is convenient for the analysis of the cost distribution on the input factors and the price setting to argue on microeconomic levels. The cost function as an optimizing result of cost minimizing under fixed output for an individual firm in country i can be written as:

$$C_i(k) = q_i^{\mu} w_{i,U}^{\;1-\mu}\left(\alpha_i + \beta_i x_i(k)\right), \qquad (3)$$

with q_i as the price index and $w_{i,U}$ as the nominal wage rate paid in the industrial sector. The cost of producing industrial goods can be divided into a fix part α_i and a variable part, β_i [10], where $x_i(k)$ is the output of firm k in country i. Increasing returns of scale are responsible for the firms producing a single, heterogeneous product in the steady state equilibrium. So $x_i(k)$ also means the produced amount of good k in country i.

Due to the assumption of monopolistic competition, on the one hand firms are price setter and are therefore able to raise prices above marginal cost, but on the other hand they have to compete in markets. Therefore price setting leads to:

$$p_i = \frac{\beta_i}{\rho} q_i^{\;\mu} w_{i,U}^{\;1-\mu}, \qquad (4)$$

with $(1/\rho)$ as a constant mark-up factor. The short term profits of a firm determined by free entry in markets are calculated as:

$$\pi_i(k) = \frac{p_i}{\sigma}\left(x_i - x^{bep}\right), \qquad (5)$$

with σ >1 as the elasticity of substitution between goods and $x^{bep} = \alpha_i(\sigma - 1)/\beta_i$ as the break-even output, where in the long run profits are zero. The elasticity of substitution is assumed to be identical in both countries.

Government: Research activity and taxation

The public R&D-sector, s = F, operates, as the agricultural sector, under the assumption of constant economies of scale. Qualified labor, m_i, and a constant capital stock, K_i, are used as input factors in the R&D sector. For a Cobb-Douglas production assumption we get:

$$R\&D_i = A m_i^{\iota} K_i^{1-\iota}, \qquad (6)$$

with ι as the partial supply elasticity of the qualified work and A as a constant technical parameter. The research output $R\&D_i$ in equation (6) will be available to firms in country i without charging a fee.

[10] Picard and Thisse (2002) presume that production occur solely under the consideration of variable cost and underscore the assumption of monopolistic competition as an essential push factor towards agglomeration.

To finance the R&D-sector in economy i, a lump sum tax, τa, on taxable income and therefore on consumption is imposed:

$$\tau a Y_i = w_{i,H} m_i + rkK_i \,, \tag{7}$$

where $w_{i,H}$ as the nominal wage rate for qualified work in country i and rk as a global constant interest rate. So equation (7) means also, that there is a resource transfer from consumption to research.

a.) Fundamental Research: R&D

The research level in country i will solely be determined by the output of the R&D-sector. Depending on the availability of non-locally research, each country account with:

$$FE_i = R\&D_i + \Gamma R\&D_j \,, \tag{8}$$

for $i \neq j$. The spillover effect is best expressed by $\Gamma \in [0,1]$: a global effect by $\Gamma = 1$ means that both countries transfer research from the other region without loosing application and no redundancy. By $\Gamma = 0$ country's research level is determined by its own research activity. As mentioned before, fundamental research will reduce fixed cost on the industry level:

$$FE_i = 1/\alpha_i \,, \tag{9}$$

the higher the level of research, the higher the fixed cost reduction.

b.) Secondary research: Learning-by-doing

In addition to the R&D-sector, the learning-by-doing impact by its labor participation in the manufacturing sector, $L_{i,U}$, is also considered to determine the research level in each economy:

$$FE_i = \frac{L_{i,U}}{L_i}\Theta_i + \Gamma \frac{L_{j,U}}{L_j}(1-\Theta_i) \,, \tag{8.1}$$

for $i \neq j$ and $\Theta_i = R\&D_i / \sum_{j=1}^{2} R\&D_j$. Analogously, $\Gamma \in [0,1]$ measures the availability and redundancy of non-regional research. Equation (8.1) determines the level of the variable cost[11]:

$$FE_i = 1/\beta_i \,. \tag{9.1}$$

[11] Rouvinen (1999) analyses the effects of R&D spillovers on cost and production structures of finish manufacturing firms and show a slight variable cost reduction associated with R&D spillovers.

Representative consumer

The representative consumer is supposed to have a time invariant, identical preference towards goods produced in both countries. The utility is described by a love-of-variety preference: the higher the number of goods, the higher the utility. Preferences therefore are best described by a Cobb-Douglas function using the agricultural numéraire good, $y_i = 1$, and an aggregate of industrial consumer goods, VU_i, as input factors. The aggregate itself is a CES function of the heterogeneous goods:

$$V_i = 1^{1-\gamma} VU_i^{\gamma}, \tag{10}$$

with $VU_i = \left(\sum_{j=1}^{2} \int_{h \in N_j} x_{j,i}^{\rho} dh \right)^{1/\rho}$ und γ as the consumption share of the industrial products. The degree of product differentiation, ρ, will be identical for both regions. The first order condition leads to the indirect utility function:

$$V_i = 1^{-(1-\gamma)} q_i^{-\gamma} Y_i^{*}, \tag{11}$$

where $Y_i^{*} = (1-\tau a)Y_i - e_0$ is the available income after taxation and the cost of margin subsistence. The price index for the industrial products q_i is the same for consumers and the producers due to analytical reasons.

In addition to the optimization rule in equation (11), there is a migration condition for the qualified workers:

$$q_i^{-\gamma} Y_i^{*} = q_j^{-\gamma} Y_j^{*}, \tag{12}$$

for $i \neq j$. Equation (12) changes, if the decision for migration depends on real wage rate differences:

$$q_i^{-\gamma} w_{i,H} = q_j^{-\gamma} w_{j,H} \quad . \tag{12.1}$$

2.3. General equilibrium conditions

Due to the assumption of increasing economies of scale, each good is produced by a single firm located in one region. Total demand of one good will be composed of consumer and producer demand from both countries. Demand allocation for good z on both aggregates, VU_i and CES_i, in economy i is therefore:

$$x_i(z) = p_i(z)^{-\sigma} \left(e_i q_i^{(\sigma-1)} + e_j q_j^{(\sigma-1)} \tau^{(1-\sigma)} \right), \tag{13}$$

for $j \neq i$. Iceberg transportation cost has to be considered while doing interregional trade: only a fraction of goods produced in country j and requested in country i will be met by local demand. Parts of the traded quantity melt away, i.e. units ($\tau_j \geq 1$) in region j shrink to one unit in region i. Price $p_i(z)$ is the producer price of the firms and will be listed as the f*ree-on-board* price (FOB). The price index for the bundle of industrial goods in country i can be written as:

$$q_i = \left[\int_{h=N_i} \left(p_{i,i}(h)\right)^{(1-\sigma)} dh + \int_{h \in N_j} \left(p_{j,i}(h)\tau_{j,i}\right)^{(1-\sigma)} dh \right]^{1/(1-\sigma)}, \tag{14}$$

for $j \neq i$. In each country the price index depends on the local prices, which on their part depend on the FOB-prices and the local transportation cost. The total expenditure, e_i, is composed of the consumer and producer expenditure on industrial products and can be specified for country i as:

$$e_i = \gamma(1-\tau a)\left(w_{i,U} L_i + Br_i + w_{i,H} m_i + rkK_i - e_0 + \int_{h \in N_i} \pi_i(h) dh \right) + \mu \int_{h \in N_i} C_i(h) dh .^{12} \tag{15}$$

The first part of equation (15) stands for the net expenditure of the consumers, while the second part describes the share of cost spending from firms.

The remaining part of cost spending $(1-\mu)$ will be dispended demanding labor. According to shepard's lemma differentiating equation (3) with respect to the wage rate one gets:

$$L_{i,U} = (1-\mu) \int_{k \in N_i} C_i(k) dk / w_{i,U} . \tag{16}$$

Demand towards qualified work can be calculated using the differential of equation (6) in respect to the wage rate. Normalizing the capital stock, $K_i = K = 1$, yields to:

$$m_i = ((1/\iota) w_{i,H})^{1/(\iota-1)} . \tag{17}$$

Steady-State Equilibrium

Both economies are characterized by an initial equilibrium. Exogenous shocks like diminishing transport costs will lead to transition phases, where regions and sectors are marked by fluctuation of firms and labor. The adjustment process can be stated as mentioned by Puga (1999) as:

[12] Due to the lump-sum taxation of consumer income for financing wages of skilled work, equation (15) reduces to: $e_i = \gamma\left(w_{i,U} L_i + Br_i - e_0 + \int_{h \in N_i} \pi_i(h) dh \right) + \mu \int_{h \in N_i} C_i(h) dh$; see appendix part c.

$$\dot{n}_i = \lambda_1 \pi_i (n_1, n_2) \text{ and} \tag{18}$$

$$\dot{m}_i = \lambda_2 w_{i,H} (m_1, m_2)\,, \tag{19}$$

for i=1,2, with $\dot{n}_i$ und $\dot{m}_i$ as the derivatives for the quantity of firms and labor due to the adjustment time while reaching a steady state equilibrium, λ_1 und λ_2 as positive constants and n_i as well as m_i as static variables. The share of employed labor in the manufacturing and agricultural sector is determined by the industrial demand and will not be quoted as an explicit adjustment process.

For a steady state equilibrium to occur, it is necessary that there is no incentive for further outsourcing of production and migration. Therefore both countries have a static share of firms and labor:

$$\frac{\partial \pi_i}{\partial n_i} \leq 0 \text{ and } \frac{\partial \varpi_{i,H}}{\partial m_i} \leq 0\,, \tag{20}$$

for i=1,2.

From equation (20) follows that in a steady state equilibrium firms are not able to make profits through free market entry, $\pi_i(k) = 0$ in equation (7), and that firms are producing at the break even level:

$$x_i = x_i^{bep} = \alpha_i (\sigma - 1) / \beta_i\,. \tag{21}$$

The number of firms in country i will be endogenously determined by equation (16):

$$n_i = \frac{L_{i,U} w_{i,U}}{(1-\mu) w_{i,U}^{(1-\mu)} q_i^{\mu} \alpha_i \sigma}\,. \tag{22}$$

The model and the equilibrium conditions are described by equations (1) to (22).

3. Equilibrium analysis: Industrial Agglomeration and economic development

The model to present is a static equilibrium model. After introducing exogenous shocks, i.e. diminishing transport cost, into the model, conditions and types of equilibria will be analyzed. It will be shown that single steady state equilibria exist. The range of transport costs for a stable symmetric and asymmetric distribution of industrial activity is presented and analyzed. In particular, there is a special interest on the equilibrium properties and parameters used to determine economic behavior. The procedure follows the one discussed by Fujita, Krugman und Venables (1999) and is best described by answering two questions: (1) When and under which conditions is an asymmetric dispersion of economic activity a stable equilibrium? (2) When and under which conditions is a symmetric equilibrium dissolved towards agglomeration? Answering the second question does not mean that agglomeration results. In fact there exists a range of transport costs, in which both types of industrial distribution can arise[13]. In the following, there is a logical sequence of industrialization: starting from an initial symmetric equilibrium there is a single determined transport cost value from which a symmetric equilibrium switches to the formation of industrial clusters and structurally backward regions.[14]

3.1. Fundamental research: R&D

The starting point is an initial equilibrium with an identical distribution of input factors. Both countries are characterized by equal industrial and research activity subject to high transport cost, $\tau = 3$. The spillover effect of research is supposed to be same in both regions and measured with $\Gamma = 0{,}5$: 50% of regional research is not applicable in the other country or, named differently, redundant. Industrial agglomeration and economic development are now being analyzed by looking at steady state equilibria while transport costs are diminishing. While figure 1 shows the share of industrial activity, $s_i = n_i /(n_i + n_j)$ for $i \neq j$, figure 2 presents the total number of firms, n_i. In order to analyze the importance of the chosen model, the results of a numeric simulation without modeling R&D activity (i.e. dash slight lines) are shown in the figures as well.[15]

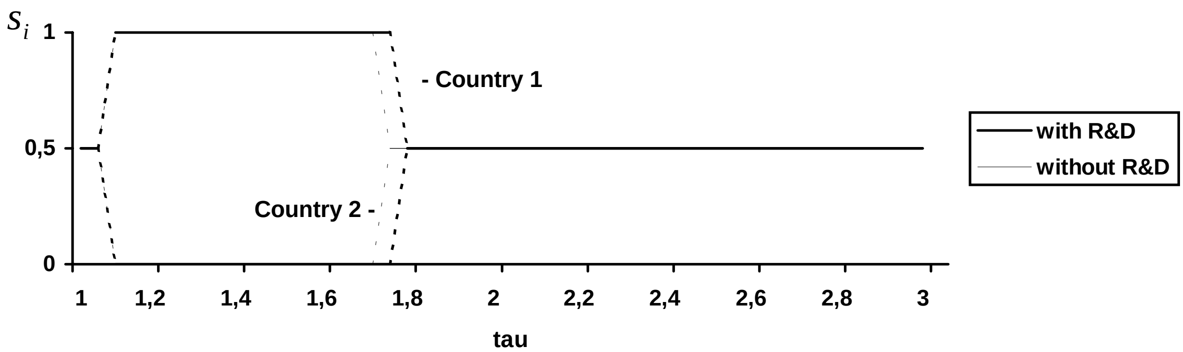

Figure 1: Shares of industries

[13] In most treatments concerning the new economic geography a tomahawk-bifurcation is mentioned: the critical value for transport cost, which instable a symmetric distribution, is lower than the one which leads to an asymmetric equilibrium. The graphical presentation looks like a prehistorically tomahawk (Fujita, Krugman und Venables (1999)), see figure F1 in appendix f.

[14] In the course of advanced industrialization a restructuring of industrial fabrication and a higher share of economic activity in the periphery can result. The respective transport cost value can be calculated by stating that an asymmetric equilibrium remains stable as long as there is no incentive of firms to relocate production.

[15] This simulation corresponds to a static equilibrium model without interregional migration presented and discussed by Puga (1999).

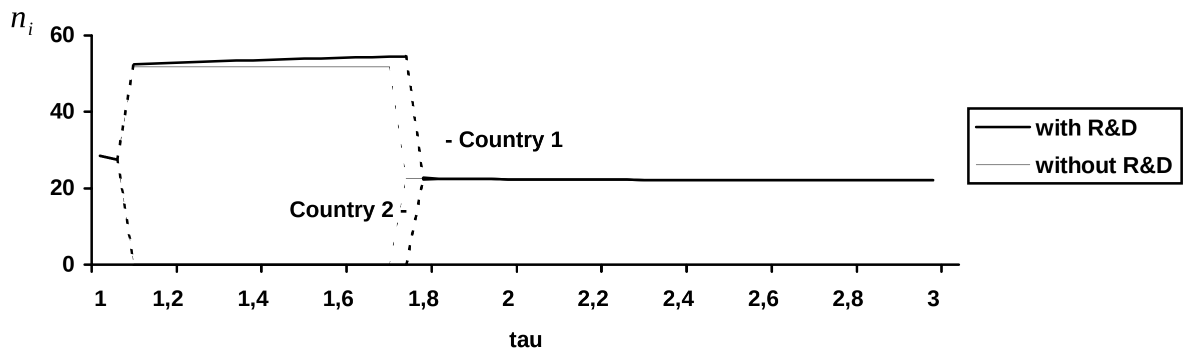

Figure 2: Number of firms

Diminishing transport costs lead to an interference of the equilibrium in both countries. There will be a temporal process in which firms react to short run profits and workers to higher wage rates. The symmetric equilibrium still remains stable: neoclassical forces in respect to factor and price markets are strong enough to overcome the mentioned agglomeration forces (*cost* and *demand linkages*). From equation (22) and the price index, equation (14), follows that a higher number of firms in a country leads to higher wages and to a lower price index and therefore works against a core-periphery structure. Furthermore, no incentive for industrial concentration will be given due to an identical level of fundamental research in both countries. The slight increasing number of firms operating in both countries is a result of the lower price index[16], meanwhile the equal initial distribution of input factors remains.

A further reduction of transport cost inevitably leads to a dislocation of industrial production and to a grouping of research activity on the basis of the growing lock in effects: in core regions intermediate goods can be less costly used as input factors, equation (3) in combination with equation (13), and a higher demand for industrial products, equation (15), can be stated. These cost and demand linkages are responsible for the concentration of industrial activity in country 1. Reaching a critical value for the transport cost, $\tau_{krit} = 1{,}76$[17], the symmetric equilibrium breaks down in favor of an asymmetric distribution in country 1. The transition phase is characterized by erratic dislocation of total industrial activity[18]. In contrast to an approach without modeling R&D, industrialization under the consideration of research activity will occur earlier and is characterized by a higher number of firms and products both during the transition and agglomeration phase, figure 2. Two niveau effects have to be men-

[16] From equation (22) follows theoretically that the number of firms increase as the price index falls and factor input remains constant. Economically argued, a lower price index leads to a cheaper use of intermediate goods in industrial production. Due to the fact that in long run equilibria the break-even output remains unchanged, short run profits leads to a higher number of operating firms.

[17] Corresponds to the value generated by numerical simulation.

[18] The process of industrialization can be in principle both gradual and discontinuous: in Puga (1999) the third derivation of the profit function due to regional shares is responsible for the course of industrialization.

tioned: firstly, there is an agglomeration effect due to increasing returns of scale on industry level which result to higher number of firms in concentrations. Secondly, a regional grouping of research leads to a comparative cost advantage and therefore to a higher incentive for agglomeration, hence to a higher share of industrial activity. Thus industrialization and R&D cause each other and yield to economic development.

The additional labor demand for firms in country 1 will be met by attracting unqualified workers form the agricultural to the manufacturing sector. The reverse happens in country 2: due to the assumption of full employment there is an increase of unqualified labor in the agriculture absorbing the labor force released in the industrial sector. The resulting difference in nominal wages, equation (1.1), leads through labor demand, equation (15), to circular processes, which yield to a complete concentration of economic activity in country 1 while at the same time country 2 converges to an agricultural hinterland. In figure (3) and (4) nominal and real wage gaps of unqualified labor are shown.

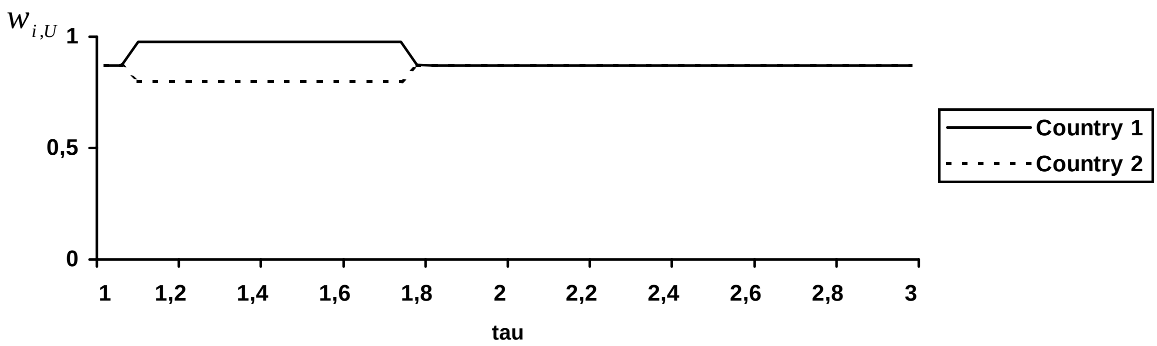

Figure 3: Nominal wage rate; Unqualified work

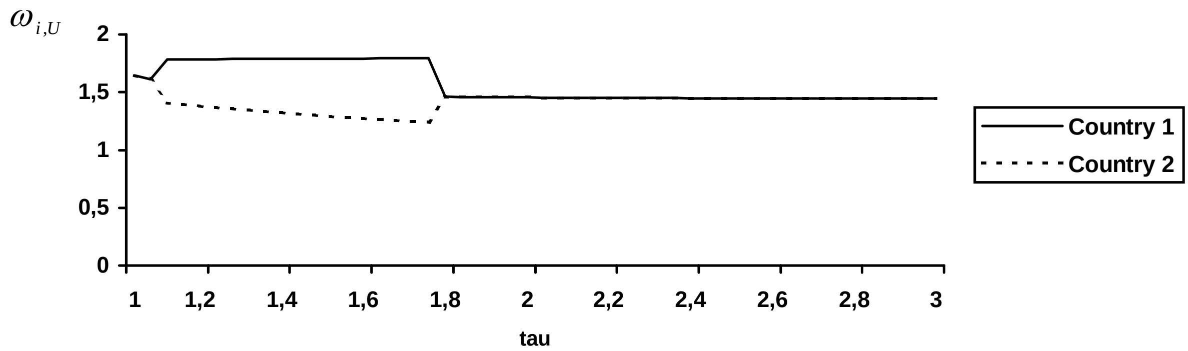

Figure 4: Real wage rate; Unqualified work

The nominal discrepancy does not change during the agglomeration phase. A further attraction of labor into the manufacturing sector is not possible.[19] However, there is an improve-

[19] The maximal share of unqualified worker employed in the manufacturing sector, without affecting primary supply with agricultural goods and therefore individual utility, depends on the consumer share of agricultural goods, γ , and the elasticity of unqualified work, θ , in the agricultural sector, see appendix part d.

ment in the real wage rate in country 2, see figure 4, and therefore a shrinking of the real wage gap. The reason for this can be explained by the different development of the regional price indices: during complete asymmetric concentration of industrial activity only the price index in the periphery is affected by a further reduction of transport cost. Imported goods subject to transport cost are getting cheaper leading to a lower price index and therefore to a raise of the real wage rate in country 2.

Sectoral and interregional migration will lead to a convergence of wages in both countries. While the nominal wage rate for unqualified labor is equalized through sectoral fluctuation of labor within one country, the migration condition, equation (12.1), leads to a convergence of real wages for qualified labor between countries. The participation of the R&D sector in both regions depends on the economic development: the higher the share of industrial production and manufactured goods, the lower the price index and the higher the incentive for skilled work to migrate.[20] A grouping of research activities in one region itself has a positive impact on economic development because of the reduced cost leverage effect. Thus industrialization and the supply of R&D results cause each other and yield to economic development.

> ***Proposition 1:*** Industrial agglomeration and economic development reinforce each other: there are circular processes leading to a core-periphery structure.

The international migration of qualified work starts during the first stages of industrialization and leads through a higher degree of research activity to lower fix costs in country 1. Therefore profits for settled and potential firms are generated. Due to free market entry, this yields to a higher number of firms operating in country 1: higher levels of economic development and a concentration of industrial activity characterize the transition phase from a symmetric equilibrium to an asymmetric dislocation of industry. Further agglomeration yields to a gradual increase of skilled work in country 2 by means of the mentioned different development of the regional price indices. As a result, the number of firms is reduced, but the asymmetric agglomeration remains stable, see figure 2.

In figure (5) and (6) nominal and real wages of skilled work are shown.

[20] Alonso-Villar (2002) introduces an „education market“ to increase the share of skilled work in agglomerations.

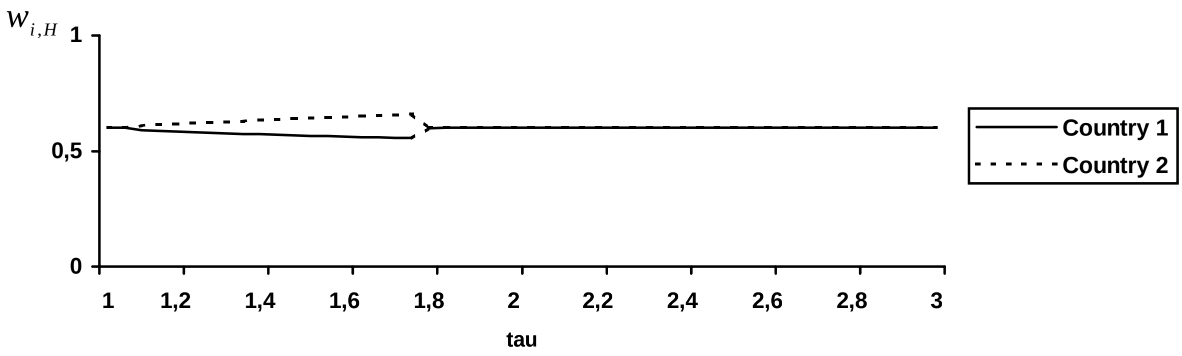

Figure 5: Nominal wage rate, Qualified work

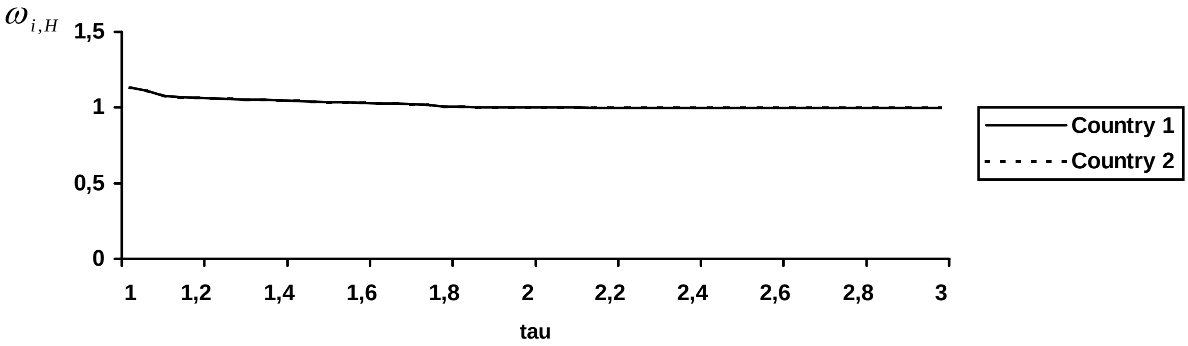

Figure 6: Real wage rate, Qualified work

An interesting point to mention is the contrary development of nominal wages of skilled labor due to the economic development, see figure 5: a higher research activity in the industrialized country is accompanied by a lower wage rate and hence a lower productivity. In the case of the U.S. Segerstrom (1998) shows in an empirical survey covering a time period from 1965 to 1989 a constant patent rate registration even though there has been a labor increase in R&D by half a million. Segerstrom (1998) outlines the fact that research results are increasingly harder to obtain and therefore outputs stagnate despite enormous efforts.[21]. In accordance with this view the decreasing productivity and the lower wages can be explained. Due to the migration condition, equation (12.1), the real wages rates in both countries do not diverge, figure 6.

Impact of spillover effects on economic development

Figure 7 shows the impacts of different spillover effects on industrialization and economic development.

[21] Furthermore Segerstrom (1998) criticizes the often mentioned scale effect when modeling research activity: a higher number of employed work yields to a higher R&D level and therefore to higher growth rates. But at least in the beginning of industrialization scale effects in research activity will matter and affect economic development.

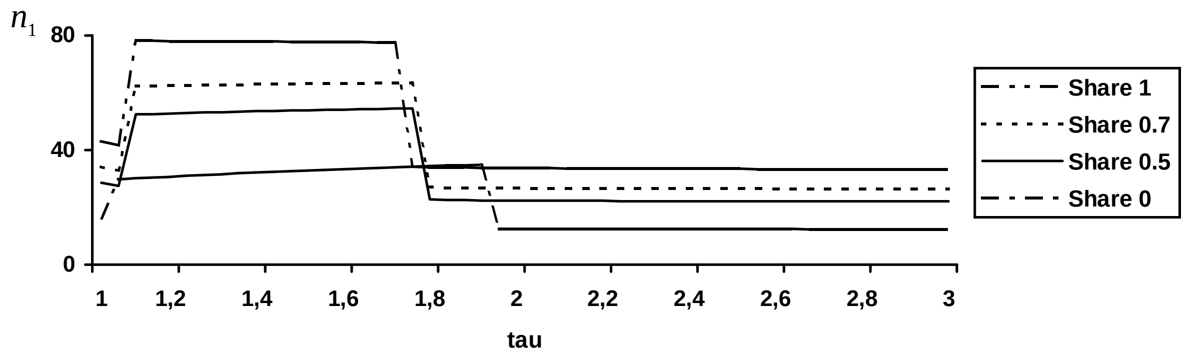

Figure 7: Spillover effect: Number of firms in country 1

Dependent on to the degree of regional applicability of R&D results, $\Gamma \in [0,1]$, there are distinctive agglomeration processes: higher degrees of spillover effects decelerate industrialization because both countries benefit in the same way from a higher access to research results. Regional comparative cost advantages due to restricted applicability are losing their importance for promoting local agglomeration.[22]

> ***Proposition 2:*** The higher the degree of spillover effects in R&D, the more industrial agglomeration is delayed: the regional importance of research activity as a pull force towards regional industrialization vanishes with increasing international access and applicability of research.

However the agglomeration phases and therefore economic development are characterized by a higher number of firms because of lower cost level due to a higher transferability of R&D and its impacts: the highest niveau effect on economic development and a constant number of firms during agglomeration can be notified by a global spillover effect, $\Gamma = 1$.

> ***Proposition 3:*** Economic development depends positively on regional R&D activities and on their spillover effects.

In the course of further concentration, agglomeration and the number of firms are less affected the higher the spillover effect and therefore the lower the impact of R&D relocation is due to the asymmetric change of the price indexes.

---

[22] The derivation of the critical transport cost value due to Γ should be negative, $\partial\tau_{krit} / \partial\Gamma < 0$. The identical value for the critical transport cost, $\tau_{krit} = 1{,}76$, for $\Gamma = 0{,}5$ and $\Gamma = 0{,}7$ is a matter of the chosen number of iteration steps in the numerical simulation.

3.2. Secondary research: Learning-by-doing

Considering a learning-by-doing approach and assuming the same initial conditions and a spillover effect of $\Gamma = 0{,}5$ for both countries as discussed above, the impact on industrial agglomeration and economic development is the same. In fact, there will be an additional agglomeration impulse when considering the share of unqualified labor in manufacturing. A faster economic development as result of a higher industrial and research activity in the manufacturing and R&D sector can be observed, see figure 8 and 9.

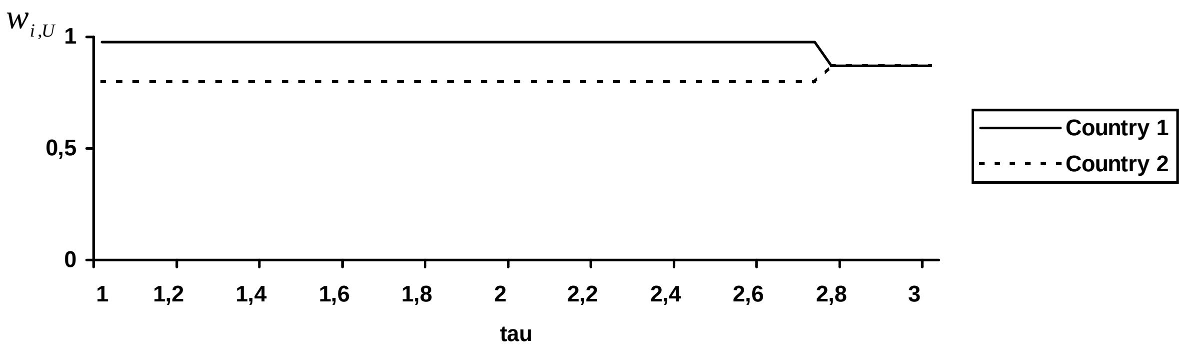

Figure 8: Nominal wage rate; Unqualified work

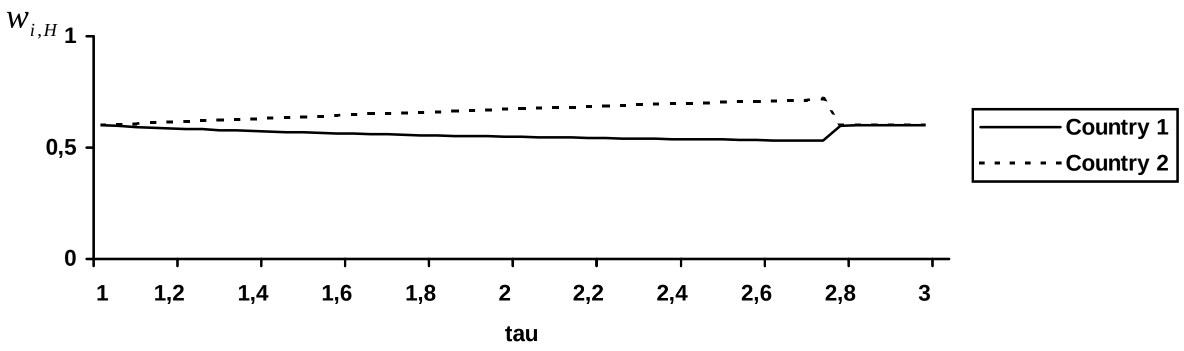

Figure 9: Nominal wage rate; Qualified work

The divergence of nominal wage rates respectively to unqualified and qualified labor represents the formation of a core periphery structure. The circular process leading to industrial agglomeration and uneven economic development starts earlier and with higher amplitudes with regard to the number of firms and products than in the case of fundamental research. An increase of total factor productivity due to a higher share of industrial and research participation in core region seems to be a major pull force.

Proposition 4: Increase of total factor productivity fosters industrial agglomeration and economic development leading to a higher number of firms and a higher research level.

Impact of spillover effects on economic development

In Figure 10 the effects of different spillover effects on the formation of asymmetric equilibria can be seen. As mentioned in the case of fundamental research and expressed in proposition 2: the higher the degree of spillover effects in R&D, the more industrial agglomeration is delayed.

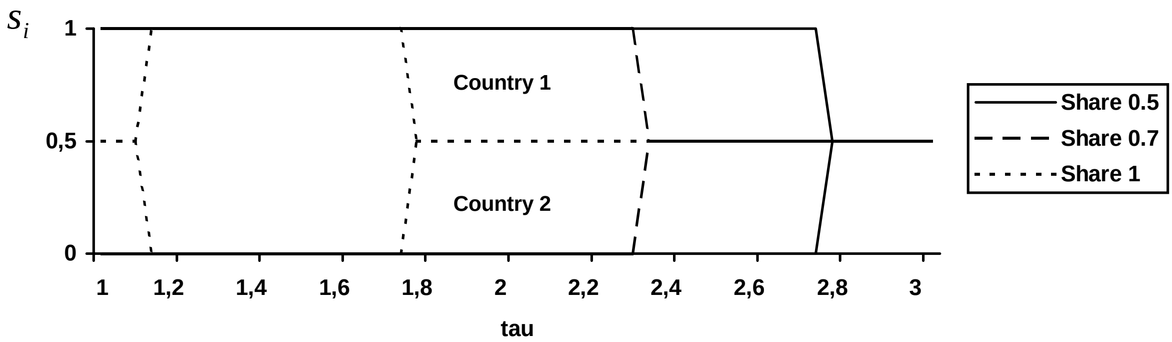

Figure 10: Spillover effect; Industry shares

Interestingly, for a spillover effect of $\Gamma = 1$ there is an additional critical value of transport cost from which a symmetric distribution reappears. This finding corresponds to figure 1. In contrast, for $\Gamma = 0{,}5$ and $\Gamma = 0{,}7$ the resulting lock-in-effects are too strong to destabilize a once established agglomeration.

4. Conclusion

To summarize this paper the industrialization phases can be solely attributed to firm and migration decisions and are localized by fostering economic development. In particular spillover effects of regional R&D are crucial to the beginning and the course of industrialization: the higher the respective applicability and transferability of research the greater the impact on the firm costs and therefore the higher the resulting variety of products due to an increasing number of firms. Relating to the example of the industrialization of the asiatic tigers in the last century, a consequent pursuance of an export oriented policy combined with a unilaterally opening for foreign imports was able to generate a sustainable economic development in that region[23]. Beneath high saving rates and educational spending, the spillover of foreign knowledge due to the use of imported intermediate and their adaptation in domestic production was decisive. By increased trade and a higher international division of labor the western industrialized countries were able to compensate their losses in the share of labor intensive production. The fastest economic development in south-east Asia was thereby achieved in the early phases of industrialization (World Bank (1994)).

It turns out to be increasingly essential for developing countries to gain access to knowledge capital and research results for an upgrade of their local industries: the greater the access towards R&D and their local adaptation, the higher the possibility for an stronger economic activity in distinctive sectors. Industrialization and R&D can yield to circular processes during the early stages of economic development. The resulting stagnation period in the model can be seen in most developed countries in these days with no notable economic development and very low growth rates.

These kinds of theoretical models yield to very insightful results concerning regional development questions. By an adequate concretization and formalization problems targeting sustainable economic development and migration flows can be theoretically analyzed and normative statements derived: questions concerning the optimal size of sustainable cluster formation and their promotion and supervision by public authorities (Norman und Venables (2002)) are not restricted to a local context. Solutions and political advisory to confront the increasing migration pressure from poor to rich countries, as mentioned by Lundborg und Segerstrom (2002), are required. The cutback of restriction of factor mobility due to the increased economic integration and the further political EU enlargement demands for clear statements as to economic impacts, Ottaviano und Thisse (2002).

[23]Puga and Venables (1998, 1999) analyze the economic impacts of different trade policy. They conclude that a liberal policy is always preferable to a strategy of import substitution.

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Mathematical Appendix

The derivation of the discussed equations for a two region model as well as further information due to numerical simulation will be given in the mathematical appendix.

a.) Decision making of an individual firm

Costfunction

Each firm k faces the following decision making problem:

$$\text{Min } C_i^s(k) = (1 - a^s - b^s - \sum_{r=0}^{S} c^{r,s}) w_{i,s} LA_{i,s} + a^s rkK_{i,s} + b^s zaB_{i,s} + \sum_{r=0}^{S} c^{r,s} q_{i,r} CES_{i,r}, \quad \text{(a.1)}$$

$$\text{s.t.} \qquad Q_i^s = f(z^s) = (LA_{i,s})^{(1-\varphi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s})} (K_{i,s})^{\chi^s} (B_{i,s})^{\varphi^s} \prod_{r=0}^{S} (CES_{i,r})^{\mu^{r,s}},$$

$$z^s \geq 0, \; v^s \geq 0$$

for i = 1, 2. The input vector z consist of $LA_{i,s} = L_{i,s} + m_{i,s}$, $B_{i,s}$ and $K_{i,s}$, the aggregate of intermediate goods is described by $CES_{i,r} = \sum_{j=1}^{M} \int_{h \in N_j} x_{j,i}^r dh$ and v is used as a vector for the individual shares: a^s, b^s and c^s.

With the use of $C_i^s(k) = \lambda Q_i^s$ the distribution of the firm k costs on the input factors as part of the optimization problem can be described as:

$$w_{i,s} L_{i,s}(k) \equiv w_{i,s} L_{i,s} = C_i^s \frac{(1 - \varphi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s})}{(1 - a^s - b^s - \sum_{r=0}^{S} c^{r,s})}, \quad \text{(a.2)}$$

$$rkK_i^s(k) \equiv rkK_i^s = C_i^s \chi^s / a^s, \quad \text{(a.3)}$$

$$zaB_i^s(k) \equiv zaB_i^s = C_i^s \varphi^s / b^s, \quad \text{(a.4)}$$

$$q_i^s CES_i^s(k) \equiv q_i^s CES_i^s = C_i^S \mu^{r,s} / c^{r,s}. \quad \text{(a.5)}$$

The solution gives the ***costfunction*** of firm k: (a.6)

$$C_i^s(k) = Q_i^s(k) \left(\frac{w_i (1 - a^s - b^s - \sum_{r=0}^{S} c^{r,s})}{(1 - \varphi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s})} \right)^{(1-\varphi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s})} \left(\frac{rka^s}{\chi^s} \right)^{\chi^s} \left(\frac{zab^s}{\varphi^s} \right)^{\varphi^s} \prod_{r=0}^{S} \left(\frac{q_i^r c^{r,s}}{\mu^{r,s}} \right)^{\mu^{r,s}}.$$

Due to the assumption of symmetry the individual shares of firm k will match with the sector specific shares in the optimum:

Agriculture, s = R with $\mu^s = \chi^s = 0$ and constant scale economies:

$$C_i^R(k) = y_i w_{i,R}{}^{(1-\varphi^R)} za^{\varphi^R} , \tag{a.7}$$

respectively with $\theta = (1-\varphi^R)$:

$$C_i^R(k) = y_i w_{i,R}{}^{\theta} za^{1-\theta} , \tag{a.7.1}$$

Industry, s = U with $\varphi^s = \chi^s = 0$ and increasing scale economies:

$$C_i^U(k) = (\alpha + \beta(x_i)) w_{i,U}{}^{(1-\mu)} q_i{}^{\mu} , \tag{a.8}$$

Research and Development, s=F with $\mu^s = \varphi^s = 0$ and constant scale economies:

$$C_i^F(k) = (R \,\&\, D_i) w_{i,H}{}^{(1-\chi^F)} rk^{\chi^F} , \tag{a.9}$$

respectively with $\iota = (1-\chi)$:

$$C_i^F(k) = (R \,\&\, D_i) w_{i,H}{}^{\iota} rk^{(1-\iota)} . \tag{a.9.1}$$

Price-setting, short run profits and labor demand

The profit for individual manufacturing firm k can be written as:

$$\pi_i^U(k)(x_{i,k}, p_{i,k}) = p_{i,k} x_{i,k}(p_{i,k}) - C_i^U(k) \tag{a.10}$$

Each firm faces price competition. The first derivation of equation (a.10) due to the price, $\partial \pi_i^U(k) / \partial p_{i,k}$, will lead to the maximizing producer price:

$$p_{i,k} = \frac{1}{\rho} c_{i,k}^{U\ \mathrm{var.}} , \tag{a.11}$$

where $1/\rho$ is a constant mark-up factor over marginal costs. Under consideration of equation (a.8) and the assumption, that in the long run equilibrium all manufacturing firms will set the same price, equation (a.11) can be rewritten to:

$$p_i = \frac{1}{\rho} \beta_i q_i{}^{\mu} w_{i,U}{}^{1-\mu} , \tag{a.11.1}$$

or for the case of fundamental research, $\beta = \rho$,to:

$$p_i = q_i{}^{\mu} w_{i,U}{}^{1-\mu} . \tag{a.11.2}$$

Substitution of equation (a.8) and (a.11.1) into (a.10) the condition for short run profits can be described as:

$$\pi_i(k) = \frac{p_i}{\sigma}\left(x_i - x_i^{bep}\right), \tag{a.12}$$

with $\rho = (\sigma - 1)/\sigma$ and $x_i^{bep} = \alpha_i(\sigma - 1)/\beta_i$ as the break even output for a long run equilibrium.

The aggregate demand for unqualified work of firms in sector U will be obtained by differentiating the cost function equation (a8) due to the nominal wage:

$$L_{i,U} = \frac{\partial C_i^U}{\partial w_{i,U}} = \frac{\partial \left[\int_{k \in N_i} C_i^U(k) dk \right]}{\partial w_{i,U}}. \tag{a.13}$$

And therefore:

$$L_{i,U} w_{i,U} = (1 - \mu) \int_{k \in N_i} C_i(k) dk\,. \tag{a.13.1}$$

The demand for the qualified work will be financed through lump sum income taxation:

$$m_i w_{i,H} = \tau a(Y_i - e_0) - rkK_i\,, \tag{a.14}$$

or under consideration of the income:

$$Y_i = w_{i,U} L_i + Br(w_{i,R}) + w_{i,H} m_i + rkK_i + \int_{h \in N_i} \pi_i(h) dh\,, \tag{a.15}$$

equation (a.14) can be rewritten to:

$$m_i w_{i,H} = \frac{\tau a}{(1 - \tau a)} \left(w_{i,U} L_i + Br(w_{i,R}) - e_0 + \int_{h \in N_i} \pi_i(h) dh \right) - rkK_i\,. \tag{a.14.1}$$

b.) Decision making of a representative consumer

A representative consumer of region i face the following optimization problem:

$$Max V_i = \prod_{s=0}^{S} (VU_i^s)^{\gamma^s}\,, \tag{b.1}$$

$$\text{s. t.} \qquad (1 - \tau a)(Y_i - \sum_{s=0}^{S} e_0^s) = \sum_{s=0}^{S} d^s q_i^s VU_i^s$$

$$v^s \geq 0$$

for i = 1, 2 and $s \neq F$. The term $VU_i^s = \sum_{j=1}^{2} \left[\int_{h \in N_j} (x_{j,i}^s(h))^\rho dh \right]^{1/\rho}$ is an aggregate of consumption goods, v is as a vector of the individual shares, d^s and $\sum_{s=0}^{S} \gamma^s = 1$.

The optimal budget allocation due to consumption products of one sector, s = z, can be stated as:

$$q_i^z VU_i^z = (1-\tau a)(Y_i - \sum_{s=0}^{S} e_0^s)\gamma^z / d^z \, . \qquad \text{(b.2)}$$

The optimization leads to the indirect utility function of consumer i:

$$V_i = (1-\tau a)(Y_i - \sum_{s=0}^{S} e_0^s)\prod_{z=0}^{S}\left(\frac{d^z}{\gamma^z}(q_i^z)\right)^{(-\gamma^z)} \, . \qquad \text{(b.3)}$$

In the optimum the individual shares will match with the sector specific shares, $d^z = \gamma^z$. Normalizing the price of the agricultural output to one, $q_i^R = 1$, the indirect utility function can be written as:

$$V_i = 1^{-(1-\gamma)} q_i^{-\gamma} Y_i^* \, , \qquad \text{(b.3.1)}$$

with $$Y_i^* = (1-\tau a)(Y_i - e_0) \qquad \text{(b.4)}$$

as the disposable income.

c.) General equilibrium

Due to the proposition of increasing returns, each good is solely produced by a unique firm in one region, whereas the demand will be in both regions. In this section the total demand of consumers and producers for good z produced in Region j will be calculated:

$$x_i^{Ges.}(z) = \sum_{j=1}^{2} x_{i,j}^{\Pr od.}(z) + \sum_{j=1}^{2} x_{i,j}^{Kon.}(z) \, . \qquad \text{(c.1)}$$

for j = 1, 2.

Demand of producers

In the optimization problem of the manufacturing firms the first order condition was that a share of μC_j is used for the purchase of the intermediate aggregate:

$$\text{Max. } CES_j = \sum_{j=1}^{2}\left[\int_{h\in N_j}(x_{j,j}(h))^{\rho} dh\right]^{\frac{1}{\rho}} \qquad \text{(c.2)}$$

$$\text{s. t.} \quad \mu C_j = \sum_{j=1}^{2} p_{j,j}\left[\int_{h\in N_j}(x_{j,j}(h))dh\right],$$

with $p_{j,j}(h) = p_{j,j}$: in equilibrium each producer sets the same price.

Demand of consumers

In the optimization problem of representative consumer the first order condition was that a share income γ is used for the purchase of the manufacturing goods:

$$\text{Max. } VU_j = \sum_{j=1}^{2}\left[\int_{h\in N_j}(x_{j,j}(h))^{\rho}\,dh\right]^{\frac{1}{\rho}} \qquad \text{(c.3)}$$

$$\text{s. t.} \qquad \gamma Y_j^* = \sum_{j=1}^{2} p_{j,j}\left[\int_{h\in N_j}(x_{j,j}(h))dh\right].$$

Total demand

Substituting the two optimization solutions form equation set (c.2) and (c.3), $x_j^{Prod.}(z)$ and $x_j^{Kon.}(z)$, into equation (c.1) total demand of good z can be written as:

$$x_i^{Ges.}(z) = \sum_{j=1}^{2}\left[p_{i,j}(z)^{-\sigma}\tau_j^{1-\sigma}\mu C_j q_j^{\sigma-1}\right] + \sum_{j=1}^{2}\left[p_{i,j}(z)^{-\sigma}\tau_j^{1-\sigma}\gamma Y_j^* q_j^{\sigma-1}\right],$$

or:

$$x_i(z) = \sum_{j=1}^{2}\left[p_{i,j}(z)^{-\sigma}\tau_j^{1-\sigma}q_j^{\sigma-1}e_j\right], \qquad \text{(c.4)}$$

with

$$q_j = \left[\sum_{j=1}^{2}\left[\int_{h\in N_j}((p_{j,j}(h)\tau_{j,j})^{(1-\sigma)}dh\right]\right]^{1/(1-\sigma)} \qquad \text{(c.5)}$$

as the price index and

$$e_j = \gamma Y_j^* + \mu C_j \qquad \text{(c.6)}$$

as the cumulative expenditures of good z.

Under consideration of equation (b.4) and (a15) the equation (c.6) can be rewritten as:

$$e_j = \gamma(1-\tau a)\left(w_{j,U}L_j + Br(w_{j,R}) + w_{j,H}m_j + rkK_i - e_0 + \int_{h\in N_j}\pi_j(h)dh\right) + \mu\int_{h\in N_j}C_j(h)dh, \qquad \text{(c.6.1)}$$

or respectively with equation (a.14.1) to:

$$e_j = \gamma(1-\tau a)\begin{pmatrix} w_{j,U}L_j + Br(w_{j,R}) + rkK_i - e_0 + \int_{h\in N_j}\pi_j(h)dh + \\ \frac{\tau a}{(1-\tau a)}(w_{j,U}L_j + Br(w_{j,R}) - e_0 + \int_{h\in N_j}\pi_j(h)dh) - rkK_i \end{pmatrix} + \mu\int_{h\in N_j}C_j(h)dh,$$

$$e_j = \gamma\left(w_{j,U} L_j + Br(w_{j,R}) - e_0 + \int_{h\in N_j} \pi_j(h)dh \right) + \mu \int_{h\in N_j} C_j(h)dh \,. \qquad \text{(c.6.2)}$$

There will be no transportation costs within regions, $\tau_{i,i} = 1$. Equation (c.4) therefore is:

$$x_i(z) = p_{i,i}(z)^{-\sigma}\left(e_i q_i^{(\sigma-1)} + e_j q_j^{(\sigma-1)}\tau^{(1-\sigma)}\right), \qquad \text{(c.4.1)}$$

with

$$q_i = \left[\int_{h=N_i} \left(p_{i,i}(h)\right)^{(1-\sigma)} dh + \int_{h\in N_j} \left(p_{j,i}(h)\tau_{j,i}\right)^{(1-\sigma)} dh \right]^{1/(1-\sigma)} \qquad \text{(c.5.1)}$$

for $j \neq i$ and $e_i = \gamma((1-\tau a)Y_i - e_0) + \mu C_i$ for i= 1, 2.

d.) Symmetric equilibrium shares of unqualified workers

Under consideration of long run equilibrium equations (a.13.1) can be sated as $L_U w_U = (1-\mu)npx^{bep}$ using $x^{bep} = 1$ and $\pi = 0$. To calculate the symmetric equilibrium share of workers employed in agriculture and industry substitution of equation (a.13.1) into equations (c.6.2), (c.5.1) and (c.4.1) leads to:

$$e = \gamma\left(w_U L_U + L_R^{\theta} K^{1-\theta} + n\pi\right) + \frac{\mu}{1-\mu} wL_U \,, \qquad \text{(e.1)}$$

$$q = \left[\frac{L_U}{1-\mu} w_U^{\,1-\sigma(1-\mu)} (1+\tau^{1-\sigma}) \right]^{1/(1-\sigma(1-\mu))} , \qquad \text{(e.2)}$$

and

$$w_U^{\,\sigma(1-\mu)} = q^{\sigma(1-\mu)-1} e(1+\tau^{1-\tau}) \,. \qquad \text{(e.3)}$$

After substitution of equation (e.1) and equation (e.2) into equation (e.3) the condition for the equilibrium industrial wage is:

$$w_U = \frac{\gamma}{1-\gamma} \frac{L_R^{\,\theta}}{L_U} \,. \qquad \text{(e.4)}$$

The economy will be in a stable equilibrium when the nominal wage in the agriculture sector, $w_R = \theta L_R^{\,\theta-1}$, equation (3) matches with equation (e.4):

$$L_U = \frac{\gamma}{\theta(1-\gamma)+\gamma} \qquad \text{(e.5)}$$

and $$1 - L_U = L_R = \frac{\theta(1-\gamma)}{\theta(1-\gamma)+\gamma}. \qquad \text{(e.6)}$$

e.) Numerical Simulation and the choice of parameters

The numerical simulation was calculated in Gauss and be requested. The parameters were set to $\mu = 0{,}6$, $\sigma = 6$, $\iota = 0{,}6$, $\gamma = 0{,}3$ and $\theta = 0{,}8$. In the case of fundamental the parameter β_i is normalized to $\beta_i = \rho = (\sigma - 1)/\sigma$. The technology parameter for the R&D sector was set for fundamental research to A=4 and for secondary research to A=3,2. The elasticity of the rural population can be calculated as: $\eta = \frac{1-\gamma}{\gamma}\frac{\theta}{1-\theta}$. The spillover effect is measured by $\Gamma \in [0,1]$.

Due to the numerical simulation, the same methodology is used as mentioned in Puga (1998, 1999): based on prior determined number of operating firms, N_i, the price index, q_i, and nominal wages, $w_{i,U}$, of unqualified work can be calculated for a short run equilibrium. On the same time the share of qualified and unqualified work, $L_{i,U}$ and m_i, in both regions and sectors can be determined. Subsequently the number of firms is varied as long as equation (20) is satisfied: in a long run equilibrium there will be no further incentive for firms to fluctuate and labor to migrate.

f.) Multiple Equilibria:

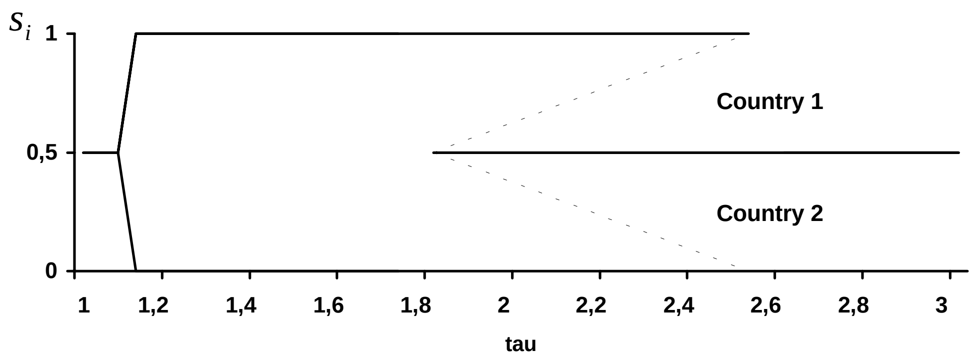

Figure F1: Fundamental research; Tomahawk-bifurcation

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