Economic Development and Agglomeration: Research Activity and Tax Competition in a Static Equilibrium Model*

Kurt Adolf Hafner**

May 2004

Department of Economics; University of Bamberg, Germany

Abstract

The paper outlines a static equilibrium model, which analyses the economic development in a two-country case by considering international 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 international migration. This reinforces the concentration of economic activity and yields to a higher degree of specialization and economic development. Furthermore, strategic income taxation enables governments to foster industrial agglomeration and to promote national research activity. Hence, countries face international tax competition while competing for skilled labor.

*JEL-Classification: O1, R1, F22, C7
Keywords: Economic Geography, Agglomeration, International Migration, Regional Growth Theory, Spillover-Effect, Tax Competition.

*I would like to thank Johannes Schwarz, University of Bamberg. Financial support from the Deutsche Forschungsgemeinschaft is gratefully acknowledged.

**Graduiertenkolleg: „Märkte und Sozialräume in Europa“, Lichtenhaiderstr. 11, 96034 Bamberg, Germany; email: kurt.hafner@sowi-uni.bamberg.de
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 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. The respective population share living in urban centers relatively to the total population is quite low (e.g. New York ca. 7%) and lately 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 for example. As a result, there are core regions of industrial and urban activities, 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? Can regional policies such as different trade policies or fiscal measures account for regional inequalities or do we have to rely on comparative cost advantages?

While the impact of pursing different trade policies reaching from import substitution to trade liberalization on developing countries’ economic development and prosperity is widely studied2, trade policies cannot explain the existence of uneven urbanization and industrialization. As described, economic activity in Latin America as well as in Asia concentrates on huge agglomerations although the pursing of trade policies was quite different for a long period in the last century.

---

1 To what extend cities in its turn are specialized or diversified is discussed by Duranton and Puga (2000, 2001a, 2001b).
Indeed, developing countries do have an incentive to use fiscal policy to foster industrialization and to attract mobile factors by offering favorable conditions such as low taxes. It is widely believed that further economic integration such as the intended creation of a free trade area for all American countries or the enlargement of the EU to 25 countries in May 2004 leads to painful adjustment processes within the core and periphery countries. Without tax harmonization for example, mobile factors will locate to regions where taxes are low and/or the provision of public goods is high. Hence, periphery countries may decrease their tax rates leading to an inward flow of mobile factors and pushing local economic development at the cores’ expense. As a result, all countries would adopt the same tax rates leading to “a race to the bottom” and to a sub-optimal provision of public goods as predicted by the standard tax competition literature (Wilson 1999). Increasing tax competition as a result of further economic integration is more likely to give way for a tax harmonization than to account for the asymmetric formation and development of industrial agglomeration.

Moreover, none of the traditional neoclassical models are able to give a satisfactory answer: These kinds of models try to explain asymmetric industrialization 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. 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 permanently depleted, most of them remained important, see Fujita and Mori (1996) and Krugman (1993). Therefore, neoclassical models cannot explain persistent development of industrial and urban concentration characterized by uneven pay of factors and regional inequalities.

Hence, in order to deal with uneven economic development and to create the possibility for the periphery to catch up with the core, it is not enough to rest on trade policy, fiscal measures and comparative cost advantages. It seems to be more fruitful to have a closer look on the cost of spatial interaction, increasing returns, inter-industrial linkages, different labor supplies and research activity when discussing industrial and urban concentrations.

In the last century developing countries were 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 the 19th century when industrialization and urbanization began in Europe and the USA. The increased profitability of firms due to mass production, the reduction of transportation cost as well as a massive rural exodus can be used as an expla-

---

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.
nation of the emergence of huge industrial und urban agglomerations in the developing coun-
tries serving international markets.
In fact, the processes leading to urban and industrial concentrations are the same for all coun-
tries: technological progress, closer networking of industrial activities, diminishing transport
and communication costs and a higher labor pool due to international migration increase the
incentives to spatial and economic concentration. Circular processes arise leading to core
regions 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 might be the
reason for distinctive industrialization patterns.

The structure of the paper is described as follows. In the next section basic intuition and some
stylized facts about industrial agglomerations, research activity and tax competition will be
given. Section 3 presents a two-country model. Section 4 shows and discusses the impacts on
steady state equilibria when analyzing research activity and international migration. Adding
strategic tax-setting and introducing a limited tax game enriches the story in section 5. A
summary of the paper and an outlook are stated in section 6. Further equations and equilib-
rium conditions as well as specific details for parameters and the numeric simulation are listed
in the appendix.

2. Agglomeration, Research Activity and Tax Competition

When talking about agglomerations and their lock-in-effects, one inevitably comes
across the concept of Marshallian externalities (Marshall (1890)): mass production, the avail-
ability of specialized input services and the formation of highly skilled labor as well as the
production of new ideas are crucial in the formation of industrial clusters (Fujita and Thisse
(2002)). These effects are decisive for cumulative agglomeration processes to take place even
when considering strategic tax competition.

Agglomeration

The interaction of economies of scale, costs of transportation and migration are deci-
sive for the location of industry. With reference 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 major 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 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 outsourcing 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.

**Research Activity**

Another source that pushes industrial agglomeration and fuels economic development is R&D-activity as the main cause of technological change and productivity growth. In general, innovation rates are higher and positively influenced in industrialized regions with high levels of research activity leading to faster economic development than in structurally backward regions. Hence, if the outcome of R&D is determined largely by skilled labor, then the cutback of the restrictions on factor mobility is decisive. The higher education system, complemented by immigration of highly skilled labor from abroad, might be an important indicator questioning the attractiveness of regions, OECD (2003).  


---

4 Comparing the higher education system in the OECD countries for example, the flows of university graduates are higher in the European Union than in the United States: while the EU award 36% of science and engineering (S&E) university degrees of all S&E degrees given by the OECD countries in 2000, the USA account for only 24%. Considering Ph.D. degrees in S&E, the gap even widens: 50% in the EU and 27% in the USA, OECD (2003). This underlines the importance of the EU as an attractive region for immigration.
will lead to a higher number of products and firms and hence to higher endogenous growth rates. In static context the treatment of R&D is distinctive but leads to the same results: research outcome will reduce 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 firm costs have to be modeled differently.

**Average Production Costs:**
Fundamental research as measured solely by R&D outcome is supposed to reduce fix costs on a firm level and hence the average production costs due to its long term character. The likely result is a lower break-even-point for settled firms and a higher market entry of competitors. Referring to an 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, 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 Waverman (1992) this increase can be attributed to R&D, to scale economies and capacity utilization. Leading to a higher productivity of input factors, secondary research interpreted as learning-by-doing should consider the implication of R&D results as well as quality and process improvements due to a high share of manufacturing production. Therefore, the impact of secondary research is supposed to be on variable costs leading to a cost reduction on a firm level.

Moreover, the implementation of research results and its impact on agglomerations depends to a great extent on the kind of technological spillover. Following Martin and Ottaviano (1997), there is a distinction between local and global spillover effects of R&D implementation. On the one hand, the availability and applicability of research outcomes can be restricted locally: blueprints cannot be transferred and applied to other regions due to their specific use or property rights, strengthening the inequality between regions even further. But on the other hand,

---

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

6 It is 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.A.
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. Hence, a crucial role is accredited to technological spillover effects while analyzing economic development.

**Tax Competition**

Considering the impacts of tax competition on international mobile factors and agglomeration, one raises the question: does national tax policy push economic prosperity and does it lead to a higher share of industrial production by controlling international mobile factor flows? While capital moves to regions where taxes are low and risk adjusted profits are high, the migration decision of labor takes account of taxes, wages and provision of public goods among others. The mentioned “race to the bottom” result of the standard tax competition literature does only apply to mobile capital and in a perfect competition and constant return modeling. Indeed, things are different in models of the new economic geography\(^7\) and/or with labor as the mobile taxable factor (Borck and Pflüger (2004), Anderson and Forslid (1999)). For skilled labor to migrate, countries may have to raise, not to lower tax rates in order to account for a higher public good provision or to offer higher wage proposals. Tax competition may then yield to an outcome with sub-optimal tax rates, which are too high from a social perspective. Again, tax harmonization will be taken into account. Furthermore, if skilled labor is largely employed in research activity, the effect on R&D and its impact on firms have to be considered as well.

3. 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 (1991a, 1991b) 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 Venables (1996), Fujita, Krugman und Venables (1999) as well as Fujita and Thisse (2002).\(^8\) 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

---

\(^7\) Krugman and Baldwin (2004) show first “a race to the top” and then “to the bottom” as economic integration goes further.

\(^8\) A good 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).
number of 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 and its spillover effects 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. In order to analyze strategic tax-setting and to introduce a limited tax game in section 5, the model follows Baldwin et al. (2003) and Baldwin and Krugman (2004).

3.1. 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 fixed or variable costs 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 \( L_{i,R} \) as input factors: \( F_{i,R}(L_{i,R}, B_i) = L_{i,R}^{\theta} B^{(1-\theta)} \), with \( \theta \) as the partial production elasticity of unqualified labor 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:

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

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

\[
w_{i,R} = F'_{i,R}(L_i - L_{i,U}, B) = \theta (L_i - L_{i,U})^{\theta-1} B^{(1-\theta)}, \tag{1.1}
\]

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 solely 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 \( B \):

\[
R_i(p_{i,R}, w_{i,R}, B) = \max\{p_{i,R}y_i - w_{i,R}L_{i,R} - zaB|y_i \leq g(L_{i,R}, B)\}, \tag{2}
\]

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

\[
R_i(1, w_{i,R}, B) = Br_i(w_{i,R}), \tag{2.1}
\]

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 \( \mu \), and unqualified labor \( L_{i,U} \), with \( (1 - \mu) \):

\[
Q_i = L_{i,U}^{1-\mu} CES_i^\mu, \tag{2}
\]

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

It is convenient for the analysis of cost distribution and price setting to argue on micro- economic levels. The cost function as an optimizing result of cost minimizing for an individual firm in country \( i \) can be written as:

\[
C_i(k) = q_i^\mu w_{i,U}^{1-\mu} (\alpha_i + \beta_i x_i(k)),
\]

(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 \( \alpha_i \) and a variable part \( \beta_i \), where \( x_i(k) \) is the output of firm \( k \) in country \( i \). Increasing returns of scale are responsible for firms to produce a single, heterogeneous product in the steady state equilibrium. So \( x_i(k) \) also stands for the produced amount of good \( k \) in country \( i \).

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

\[
p_i = \frac{\beta_i}{\rho} q_i^\mu w_{i,U}^{1-\mu},
\]

(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:

\[
\pi_i(k) = \frac{p_i}{\sigma} (x_i - x_i^{\text{bep}}),
\]

(5)

with \( \sigma >1 \) as the elasticity of substitution between goods and \( x_i^{\text{bep}} = \alpha_i (\sigma - 1)/ \beta_i \) as the break-even-output. 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 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 function we get:

\[
R \& D_i = A m_i^{i} K_i^{1-i},
\]

(6)

with \( i \) as the partial supply elasticity of 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 $\alpha_i$ on taxable income and therefore on consumption is imposed:

$$\alpha_i Y_i = w_{i,t} m_i + rK_i,$$  \hspace{1cm} (7)

where $w_{i,t}$ is the nominal wage rate for qualified work in country i and $rK$ is a global constant interest rate. Hence, equation (7) states, that there is a resource transfer from immobile factors, who have to carry the tax burden, to factors employed in the R&D sector.

\textbf{a.) Fundamental Research: R&D}

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

$$FE_i = R & D_i + \Gamma R & D_j,$$  \hspace{1cm} (8)

for $i \neq j$. The spillover effect is best expressed by $\Gamma \in [0,1]$: a global spillover effect $\Gamma = 1$ means, that both countries transfer research from each other without losing application and 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:

$$\alpha_i = 1/ FE_i.$$  \hspace{1cm} (9)

\textbf{b.) Secondary Research: Learning-By-Doing}

Both the R&D-sector and the labor participation in the manufacturing sector $L_{i,U}$ is considered by a learning-by-doing approach in order to determine the secondary research level in country i:

$$FE_i = \frac{L_{i,U}}{L_i} \Theta_i + \Gamma \frac{L_{j,U}}{L_j} (1 - \Theta_i),$$  \hspace{1cm} (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-locally research. Equation (8.1) determines the level of the variable cost:

$$\beta_i = 1/ FE_i.$$  \hspace{1cm} (9.1)

\textbf{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 $VU_i$. The aggregate itself is a CES function of the heterogeneous goods:

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

(10)

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

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

(11)

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

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

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

(12)

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

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

(12.1)

### 3.2. 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:

$$x_i(z) = p_i(z)^{-\sigma} \left( \epsilon_i q_i^{(\sigma-1)} + \epsilon_j q_j^{(\sigma-1)} \right)^{\frac{1+\epsilon}{\sigma}},$$

(13)

for $j \neq i$. Iceberg transportation costs have 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 $i$. $p_i(z)$ is the producer price of the firms and will be listed as the free-on-
board price (FOB). The price index for the bundle of industrial goods in country i can be written as:

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

(14)

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

\[
e_i = \gamma (1 - \tau a) \left( w_{i,U} L_i + Br_i + w_{i,H} m_i + rK_i + \int_{h=N_i} \pi_i(h) dh \right) + \mu \int_{h=N_i} C_i(h) dh. \quad (15)
\]

The first part of equation (15) stands for the net expenditure of the consumers, while the second part describes the share of firms’ cost spending. The remaining part of cost spending \((1 - \mu)\) will be dispended towards labor demand. According to Shepard’s Lemma, differentiating equation (3) with respect to the wage rate leads to:

\[
L_{i,U} = (1 - \mu) \int_{k=N_i} C_i(k) dk / w_{i,U}. \quad (16)
\]

Qualified labor demand can be calculated using equation (7) and aggregated total income,

\[
Y_i = w_{i,U} L_i + Br(w_{i,R}) + w_{i,H} m_i + rK_i + \int_{h=N_i} \pi_i(h) dh.
\]

Rearrangement leads to:

\[
m_i = \left( \frac{\tau a_i}{(1 - \tau a_i)} \right) \left( w_{i,U} L_i + Br(w_{i,R}) + \int_{h=N_i} \pi_i(h) dh \right) - rK_i / w_{i,H}. \quad (17)
\]

**Steady-State Equilibrium**

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

\[\text{Due to the lump-sum taxation of consumer income in order to finance R&D input factors, equation (15) reduces to: } e_i = \gamma \left( w_{i,U} L_i + Br_i + \int_{h=N_i} \pi_i(h) dh \right) + \mu \int_{h=N_i} C_i(h) dh; \text{ see appendix part c).} \]
\[ \dot{n}_i = \dot{\lambda}_i \pi_i (n_1, n_2) \text{ and } \]
\[ \dot{m}_i = \dot{\lambda}_2 w_{i,H} (m_1, m_2), \]
for i=1,2, with \( \dot{n}_i \) und \( \dot{m}_i \) as the derivatives for the quantity of firms and skilled labor with respect to the adjustment time while reaching a steady state equilibrium, \( \dot{\lambda}_i \) and \( \dot{\lambda}_2 \) as positive constants and \( n_i \) as well as \( m_i \) as static variables. The share of unskilled labor in the manufacturing and agricultural sector is determined by 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 skilled labor:

\[ \frac{\partial \pi_i}{\partial n_i} \leq 0 \text{ and } \frac{\partial \sigma_{i,H}}{\partial m_i} \leq 0, \]
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:

\[ x_i = x_i^{bep} = \alpha_i (\sigma - 1) / \beta_i. \]

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

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

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


Results of the static equilibrium model will now be presented and discussed. After introducing exogenous shocks, i.e. diminishing transport cost, to the model, equilibrium conditions and steady state equilibria will be analyzed. In particular, there is a range of transport cost values, where either a symmetric or asymmetric distribution of industrial activity as a stable equilibrium results. 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 agglomera-
tion? Answering the first question does not mean that an agglomeration outcome emerges. In fact, there are transport costs, where both types of industrial distribution can arise. However, 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.

To keep things simple, governments will not engage in strategic tax-setting in order to influence the course of industrialization. Therefore, input factors in the R&D sector are supposed to be paid either by their marginal product or by a constant rate. Normalizing the capital stock to one, factor payment for skilled labor will be $w_{i,\mu} = Am_{i}^{1}$ and for capital $r$. Hence, this leaves no room for strategic tax rates and tax competition.

4.1. Fundamental Research: R&D

We consider 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, $\tau = 3$. Spillover effect of research is supposed to be same in both regions and measured by $\Gamma = 0.5$: 50% of regional research is not applicable or redundant. 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 compare, the results of a numeric simulation of a model without R&D activity (i.e. dash slight lines) are shown in the figures as well.

![Figure 1: Shares of Industries](image)

12 Generally known as a Tomahawk-bifurcation: the graphical presentation looks like a prehistorically tomahawk (Fujita, Krugman und Venables (1999)), see figure F1 in appendix f).

13 In the course of advanced industrialization (i.e further decline of transport costs) a restructuring of industrial production and therefore 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.

14 This value corresponds to a static equilibrium model without interregional migration presented and discussed by Puga (1999).
Figure 2: Number of Firms

Diminishing transport costs may lead to an interference of the equilibrium in both countries. However, if transport costs are high, the symmetric equilibrium remains stable. Neoclassical forces as push forces in to factor and price markets are strong enough to predominate the mentioned agglomeration forces (cost and demand linkages): it is not profitable for firms to cluster when delivering markets in the periphery is too costly. Moreover, no incentive for industrial concentration will be given due to equal research activity in both countries. As a result, the initial distribution of input factors and the symmetric equilibrium remain unchanged, while there is a slight increase in the number of firms in both countries due to a lower price index\(^{15}\), see figure 2.

Further diminishing of transport cost leads inevitably to a dislocation of industrial production and to a grouping of research activity: in core regions intermediate goods can be now used less costly as input factors, equation (3) in combination with equation (13), and firms face a higher demand for industrial products, equation (15). These cost and demand linkages are strong enough to dissolve the symmetric equilibrium leading to a concentration of industrial activity and to a migration of skilled labor in country 1. Reaching a critical value for the transport cost \(\tau_{krit} = 1,76\)\(^{16}\), 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\(^{17}\). In contrast to a model without R&D, industrialization will occur earlier and is characterized by a higher number of firms and products both during the transition and the agglomeration phase, figure 2. Two niveau effects have to be mentioned: firstly, there is an agglomeration effect due to increasing returns of scale on industry level which lead to a

---

\(^{15}\) From equation (22) follows that when factor input remains constant the number of firms increase as the price index falls. Economically argued, a lower price index leads to a cheaper use of intermediate goods in industrial production and to short run profits. Due to the fact that in long run profits are zero and the break-even-output is unchanged, there is a higher number of firms.

\(^{16}\) Corresponds to the value generated by numerical simulation.

\(^{17}\) In Principle, the process of industrialization can be gradual and discontinuous. In Puga (1999) the third derivation of the profit function with respect to regional shares is responsible for the course of industrialization.
higher number of firms. Secondly, as a result of inward migration of skilled, a regional group-
ing of research leads to a comparative cost advantage and therefore to a higher incentive for agglomeration, hence to a higher share of industrial activity.

The additional unskilled labor demand of firms in country 1 will be met by offering higher wages leading to sectoral migration. The contrary happens in country 2: due to the loss of industry shares and the assumption of full employment, the labor force release in the industrial sector have to be absorbed by the agricultural sector pushing nominal wage rates down, equation (1.1). Hence, the resulting gap in nominal wages reinforces agglomeration in country 1 through a higher expenditure share, equation (15). In figure 3.a) and 3.b) nominal and real wages of unskilled labor are shown.

a) Nominal Wages  
b) Real Wages

![Figure 3: Wage Rates: Unskilled Labor](image)

The nominal wage gap does not change during the agglomeration phase because further attraction of unskilled labor by the manufacturing sector is not possible. However, there is an improvement in the real wage rate in country 2, see figure 3.b), and a shrinking of the real wage gap: 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 nominal wage rates for unqualified labor are equalized through sectoral fluctuation within countries, the migration condition, equation (12.1), leads to a convergence of real wages for qualified labor between countries.

As mentioned, the uneven development of the regional price indices during the first stages of industrialization opens a real wage gap. International migration of skilled labor occurs and

---

18 The maximal share of unqualified labor employed in the manufacturing sector, without affecting primary supply with agricultural goods and therefore individual utility, depends on the consumer share of agricultural goods $y$ and the elasticity of unqualified work $\theta$ in the agricultural sector, see appendix part d).
augments the participation in the R&D sector in country 1. Hence, a higher degree of research activity lowers fix costs on firm level and generates short run profits for settled and potential firms. Due to free market entry assumption, this yields to a even higher number of firms in country 1 and to cumulative processes. The transition phase toward an asymmetric equilibrium is characterized by a ongoing migration flow of skilled labor and an increasing share of research activity in country 1 fostering further economic development and concentration. Nominal as well as real wage rates are presented for skilled labor in figure 4.a) and 4.b).

![Nominal Wages and Real Wages](image)

Figure 4: Wage Rates: Skilled Labor

An interesting point to mention is the contrary development of nominal wages of skilled labor due to the economic development, see figure 4.a): a higher research activity in the industrialized country is accompanied by a lower productivity and hence a lower wage rate. In the case of the United States, 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. 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 4b). Further agglomeration yields to a gradual increase of skilled work and hence nominal wages in country 2 by means of the asymmetric development of the price indices. As a result, the number of firms is reduced - lower research activity decreases comparative cost advantage - but the asymmetric agglomeration remains stable, see figure 2.

The share of research activity 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 labor to migrate.19 A grouping of research activities in one country itself

---

19 Alonso-Villar (2002) introduces an „education market“ to increase the share of skilled work in agglomerations.
has a positive impact on economic development due to cost leverage effects. 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.

**Impact of Spillover Effects on Economic Development**

Figure 5 shows the impacts of different spillover effects on industrialization and economic development.

![Figure 5: Spillover Effect: Number of Firms in Country 1](image)

Dependent on to the degree of regional spillover effects of R&D results, $\Gamma \in [0,1]$, there are distinctive agglomeration processes: high 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.\(^{20}\)

**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.

\(^{20}\) The derivation of the critical transport cost value due to $\Gamma$ 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 and parameters in the numerical simulation.
However, agglomeration and economic development are characterized by a higher number of firms, the stronger the spillover effects are: the highest niveau effect of economic development can be notified by a global spillover effect, $\Gamma = 1$.\footnote{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.}

**Proposition 3:** Economic development depends positively on regional research activities and on their spillover effects.

### 4.2. Secondary Research: Learning-By-Doing

Considering learning-by-doing and assuming the same initial conditions as well as 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. An earlier formation of agglomeration as result of a higher industrial and research activity in the manufacturing and R&D sector can be observed. The divergence of nominal wage rates respectively to unskilled and skilled labor in figure 6.a) and 6.b) represents the formation of the core periphery structure.

![Graph](figure6.png)

Figure 6: Nominal Wage Rates: Unskilled and Skilled Labor

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. As described, this leads to higher sectoral and international migration opening up nominal wage gaps. Hence, an increase of total factor productivity as a result of a higher share of industrial and research participation in the 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 7 effects of different spillover effects on the formation of asymmetric equilibria are given. 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.

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.

**5. Government Taxation and Tax Competition**

Now we consider a more active role for state activity to foster local industrial agglomeration and to promote national economic development. In the last section government taxation was limited to raise lump sum taxes in order to finance research activity: qualified labor was paid by its marginal product while the factor payment for capital was held constant. At any time there was a well balanced state budget and no strategic effect on industrial agglomeration had to be considered.

Countries may now raise their taxes on income in order to attract mobile factors from abroad by offering higher factor payments. A greater inflow of skilled labor in the R&D sector will increase national R&D and hence - by free market entry - the number of settled firms. There-
fore, a strategic tax policy can foster economic development and yield to higher industry shares.

This section is organized as follows: after a further specification of the government objective function and its tax policies, we analyze separately the two kinds of equilibria, which we discussed throughout section 4, and rest solely on fundamental research activity, equation (8) and (9). In the case of a symmetric equilibrium, states are not primarily interested in changing their status quo: governments maximize their utility function by choosing an optimal tax rate either in a cooperative or non-cooperative way. In a core periphery situation, the structurally backward country may have an incentive to reverse the industrialization process and to snatch industry shares from the core country by setting a strategic tax rate. In order to anticipate this possibility by the core country, a limited tax game will be introduced and analyzed.

**Government Objective Function**

As before, the government uses its inland revenue due to lump sum income taxes, \( \tau \alpha Y_i \), to finance research activity in the R&D-sector, \( w_i, m_i + rkK_i \). Within a country, an income tax raise and its redistribution as factor payments do not change the total factor income.\(^{22}\) However, there is an income transfer towards international mobile factors at the immobile factors’ expense.\(^{23}\) Hence, government decision making in choosing the right tax rate is ambivalent. On the one hand, governments have to consider that individual utility is obviously reduced by imposing taxes. On the other hand, a higher tax revenue and its use for the provision of public goods (i.e. higher research activity) favors at first glance qualified labor, but also the country as a whole through a higher number of locally operating firms and cheaper products.

The utility function for the government can therefore be stated as:

\[
WE_i(G_i, C_i) = G_i^{\psi_i}C_i^{1-\psi_i},
\]

for \( i=1,2 \) and with \( G_i = \tau \alpha Y_i / q_i \) as provision of public goods, \( C_i = (1-\tau \alpha Y_i / q_i) \) as consumption of a representative consumer after taxation and \( \psi_i \) as a public good preference in country \( i \). Rearranging equation (23) leads to:

---

\(^{22}\) It is supposed, that international mobile factors spent their income and getting taxed in the country, where they are employed (origin principle in tax theory). So there are no factors repatriating earnings and GDP and GNP do not differ in this model, see Baldwin et al. (2003).

\(^{23}\) Due to the assumption of a constant capital stock as well as an unchanging interest rate, capital factor income does not alter and a higher tax revenue is only redistributed to qualified labor.
With reference to the migration decision of qualified labor, the migration condition, equation (12), can be rewritten as:

\[
\frac{q_i^{-\tau} (1 - \tau_i) (Y_i^{\text{ind}})}{q_j^{-\tau} (1 - \tau_j) (Y_j^{\text{ind}})} = 1.
\]  

(12.2)

Qualified labor takes into account taxes, the price level and individual factor income. Bearing in mind that factor income for qualified labor is the nominal wage rate financed through lump sum taxation, \( Y_i^{\text{ind}} = w_{i,H} = (\tau_i Y_i - rK_i) / m_i \), and \( Y_i \) is stated as aggregated income in country \( i \), \( Y_i = w_{i,U} L_i + Br(w_{i,R}) + w_{i,J} m_i + rK_i + \int_{h \in N_i} \pi_i(h)dh \), equation (12.2) can be transformed to:

\[
\frac{q_i^{-\tau} \tau_i Y_i^{\text{GDP}} / m_i}{q_j^{-\tau} \tau_j Y_j^{\text{GDP}} / m_j} = 1,
\]

(12.3)

for \( i \neq j \) and \( Y_i^{\text{GDP}} = w_{i,U} L_i + Br(w_{i,R}) + \int_{h \in N_i} \pi_i(h)dh \) as GDP.24

**Optimal Tax Rate-Setting**

Following Baldwin et al. (2003), one way to find the optimal tax rate for a symmetric outcome is first to assume that all factors are immobile (i.e. migration condition equation (12) does not apply) and to calculate the first best tax rate. Afterwards, factor mobility will be allowed in order to show whether the result does change or not.

To start with, the term \((Y_i / q_i)\) in equation (23) is a parameter and does not vary with different tax rates. It is then easy to derive from equation (23) that the first best tax rate is \( \tau_i^* = \psi_i \); the tax rate to set in order to finance the public good provision equals the preference for that good.

Asserting that the first best tax rate is a symmetric equilibrium, preference for the public good therefore has to be the same in both countries, \( \psi_1 = \psi_2 = \psi \). The next step is to allow for

---

24 Note that GDP consists only of the factor income of unqualified labor, \( w_{i,U} L_i + Br(w_{i,R}) \), and the short run profits, \( \int_{h \in N_i} \pi_i(h)dh \): factor income of qualified labor and capital financed through income taxation does not count.
factor mobility, equation (12.3). If country 1 does not want to deviate from the first best solution nor does country 2, \( \tau^* = \psi \) would be a symmetric Nash equilibrium with an equal share of mobile factors, \( m_1 = m_2 = 1/2 \). However, if one country has an incentive to deviate by setting a higher tax rate in order to obtain a higher share of mobile factors and to raise the number of firms and goods, the first best solution cannot be a Nash equilibrium. In this case we rely upon numerical simulations.

To see if the first best solution is a Nash equilibrium, the government utility function has to be mechanically differentiated. Equation (23.1) can be facilitated by using two sub-functions, 

\[
\psi^\tau \tau = \left( \tau^\psi \left( 1 - \tau^\psi \right)^{1-\psi} \right)
\]

and 

\[
g[m] = (Y/q),
\]

and dropping country indexes: 

\[
WE = g[m]f[\tau].
\]

Total differentiation and evaluation of the derivative at the first best tax rate leads to the same result as shown by Baldwin et al. (2003):

\[
\frac{dWE}{d\tau} = \frac{d(\tau^\psi (1 - \tau^\psi)^{1-\psi})}{d\tau} \left| \frac{Y}{q} + \left( \psi^\psi (1 - \psi)^{1-\psi} \right) \frac{d(Y/q)}{d\tau} \right|_{m=1/2}.
\] (24)

Due to the optimal tax rate, the first term in equation (24) is zero. Hence, the sign of 

\[
\frac{dWE}{d\tau}
\]

depends only on the second term. Using the definition of \( Y \) one gets by application of the quotient rule:

\[
\frac{d(Y/q)}{d\tau} = \left( L \frac{dw_{L}}{dn} + B \frac{dr(w_{R})}{dn} dL_{R} - Y \frac{dq}{q} \frac{dL}{dn} \right) Z + \frac{w_{He}}{q} \left( 1 + \frac{m}{w_{He}} \frac{dw_{He}}{dm} \right) \frac{dm}{d\tau},
\] (25)

where \( \frac{d(rK)}{d\tau} \) and \( \frac{d(\int \pi(h)dh)}{d\tau} \) are zero and \( Z = \frac{dn}{dFE} \frac{dFE}{dm} \frac{dm}{d\tau} \). Derivatives are evaluated at the supposed symmetric equilibrium.

A further look on equation (25) leads by comparative static to the following conclusion:

\[
\frac{dm}{d\tau} > 0; Z > 0; \frac{d(w_{L})}{dn} > 0; \frac{dr(w_{R})}{dn} dL_{R} < 0; \frac{dq}{dn} < 0; \varepsilon_{w_{L,m}} = \frac{m}{w_{He}} \frac{dw_{He}}{dm} = -1.
\] (26)

All other things constant, a higher tax rate leads to an increase of qualified labor due to the migration condition. Hence, an increase in skilled labor increases the number of firms and therefore decreases the agricultural profit share per unit land and the price index. Finally, the elasticity of skilled wages with respect to skilled labor is negative.\(^{25}\) The negative effect of the agricultural profit rate does not outweigh the other effects due to a tax increase. As a result,

\(^{25}\) For further discussion see appendix e).
is positive and therefore \(\frac{dY}{dq} \cdot d\tau\) as well: countries have an incentive to deviate from the first best solution by raising higher tax rates in order to get a higher utility. Hence, the symmetric first best solution is not a Nash equilibrium.

Indeed, numerical simulation shows that the optimal tax rate approaches one: a nearly 100 percent income transfer from immobile factors to qualified labor.\(^{26}\) Government cares about the provision of public goods as well as the consumption of a representative consumer, equation (23). An income transfer from one group to another group does not affect the consumption as a whole, so governments can raise their utility by increasing taxes providing more public goods (i.e. higher research activity) while consumption expressed by a representative consumer remains unaffected.

We therefore have to rearrange the state utility function in order to care for those who have to carry the tax burden. Remember that although all factor income groups get taxed, a redistribution of the tax revenue to factors employed in the R&D-sectors causes a real tax burden just for unqualified labor \(L\). So equation (23) has to be changed to:

\[
\frac{WE_i (G_i, C_{i,L})}{\tau_i} = \left(1 - \tau_i \right) Y_i^{GDP} / q_i.
\]

The model in this chapter is described by the equations (1) to (22) as well as the state equation (27) and the migration condition (12.2).

5.1. Symmetric Equilibrium: Prisoner’s Dilemma

We assume a symmetric equilibrium with equal industry shares and identical factor endowments in both countries, which is usually the case for high transportation costs. Furthermore, countries do not have a primary interest to change the status quo. In order to set an optimal tax rate, governments maximize their utility functions taking the tax rate of the counterpart as a constant. In general, governments can choose a cooperative or a non-cooperative way in doing so. If one of these two strategies leads to a Nash equilibrium, the corresponding tax rate as a market outcome will be observed. The resulting equilibrium might not be pareto-efficient: although there is no incentive to deviate solely, there could be a solution resulting in higher utilities for both countries. This situation is best described by the prisoner’s dilemma.

\(^{26}\) See figure F2 in appendix f).
In the first case, countries can cooperate and governments set identical tax rates. In doing so, there is no additional migration, equation (12.3), and therefore no change in industry shares. The status quo is being preserved and both countries remain symmetric. Figure 8 shows the development of state utility functions, equation (27), for tax rate values, $\tau \in [0,1]$, considering different public good preferences.

The higher the preference for public goods in a country, the more to the right is the shift of the utility function: governments increase their utility (i.e. the utility of the country) by higher tax rates providing more public goods. Hence, if there is a preference for a high research level, $\psi \uparrow$, states have to increase taxes on income in order to finance R&D activity and to raise their utility. The peak of the utility functions corresponding to different preferences in figure 8 therefore characterize the optimal tax rate with the highest utility level, as shown numerically in table 1:

<table>
<thead>
<tr>
<th>$\psi$</th>
<th>$WE_1^*$</th>
<th>$\tau^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>40.018</td>
<td>0.11</td>
</tr>
<tr>
<td>0.2</td>
<td>34.933</td>
<td>0.25</td>
</tr>
<tr>
<td>0.3</td>
<td>33.962</td>
<td>0.43</td>
</tr>
<tr>
<td>0.4</td>
<td>37.389</td>
<td>0.67</td>
</tr>
<tr>
<td>0.5</td>
<td>54.503</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 1: Cooperation: Optimal tax rates; $\tau = 3$

As a result, the optimal tax rate increases with stronger preference for public goods. But the public good preference should not be too high: reaching a value of 0.5 the resulting tax rate approaches one leaving no room for further analysis.
Numerical simulation shows, that the optimal tax rates in table 1 are valid for different values of transport costs, but that the utility level increases the lower the transport costs are due to the decreasing prize index.

Analyzing a non-cooperative situation, we concentrate on a preference value of $\psi = 0.3$ and assume that both counterparts know their optimal tax rate and their resulting utility values if both would cooperate. A coordinated tax setting to be a stable Nash equilibrium demands that there is no incentive to deviate in order to achieve a higher utility. Fixing the tax rate of country 1 on the optimal value presented in table 1, $\tau_1^* = 0.43$, and varying country’s 2 tax rate, $\tau_2 \in [0,1]$, figure 9 shows a range of tax rate values with a higher utility for country 2 than for country 1.

More precisely, the highest utility level, $WE_2^{*\text{dev}} = 34.147$, can be obtained for country 2 by setting a tax rate of $\tau_2^{*\text{dev}} = 0.49$. Comparing this with table 1 leads to the conclusion, that country 2 gains by setting a higher tax rate and attracting more qualified labor (i.e. $\tau_2 \in [0,1]$, $\tau_2^{*\text{dev}} = 0.49$). This would result in a higher share of industry activity for country 2 at country 1’s expense.

Of course the same strategic behavior can be conceded to country 1. Hence, both countries would have an incentive to deviate from the coordinated solution taking the tax rate of the counterpart as a constant. This results in a non-coordinated symmetric Nash equilibrium, where both countries have the same industry and factor shares but a lower utility than in the coordinated strategy. Table 2 shows the prisoner’s dilemma in form of the utility values, $WE_1; WE_2$.

![Figure 9: Non-Cooperation: Strategic Tax-Setting; $\tau = 3$](image)
Proposition 5: Tax competition in a symmetric equilibrium results in an income tax rate that is too high from a social perspective: coordinated tax setting such as tax harmonization would lead to lower income taxes and to higher state utilities.

Proposition 5 remains valid for values of transport costs and public good preferences, which lead to a symmetric outcome and to a strategic tax setting.

5.2. Agglomeration and Limited Tax Game

Considering a core periphery situation, the structurally backward country may have an incentive to gain industry shares from the industrialized country by setting a strategic tax rate. If this results in a higher tax yield relatively to the core country, offering higher wages leads qualified labor to inward migration and therefore to a higher research activity. Reducing or reversing the comparative advantage of the industrialized country of having a higher research level, firms begin to shift their production towards the structurally backward country. In doing so, they benefit not only from the increasing share of R&D activity, but also from the wage discrepancy. Hence, reinforcing circular processes, which were once responsible for the creation and development of the core periphery situation, would lead to a catch up of the structurally backward country up to a reverse of the industrialization process. However, the core country could be aware of the strategic tax setting of its counterpart: it would choose its optimal tax rate in order to offset the effects on migration and production outsourcing and to retain the core periphery situation.

Following Baldwin and Krugman (2004) and Baldwin et al. (2003), this results in a limited tax game: the core country sets its optimal tax rate, $\tau_1$, in the first stage, the periphery country chooses its tax rate, $\tau_2$, in the second stage. In the third stage, migration and production decision will be taken by the market participants until both economies reach steady state equilibria.

Ignoring tax competition, industrialized countries are in general characterized by a higher tax burden than developing countries in order to finance public goods. This might be the result of

<table>
<thead>
<tr>
<th>Country 1 \ Country 2</th>
<th>$\tau_1 = 0.43$</th>
<th>$\tau_1 = 0.49$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33.962;33.962</td>
<td>33.597;34.147</td>
</tr>
<tr>
<td>$\tau_1 = 0.49$</td>
<td>34.147;33.597</td>
<td>33.783;33.783</td>
</tr>
</tbody>
</table>

Table 2: Prisoner’s Dilemma, $\psi = 0.3; \tau = 3$
a higher need and/or a higher preference of the public: rich voters tend to desire more public spending and are willing to carry a higher tax burden than poor voters in developing countries. Therefore, governments in rich countries have to consider a higher public good preference while optimizing their tax rate setting. As a result, the tax rate increases the higher the preference for public goods, see Table 1. To cover this fact, we have to assume that the core country has a higher preference towards public good spending than the structurally backward country.²⁷

We assume an asymmetric equilibrium with industrial agglomeration in country 1 (i.e. a relative industry share of one, $s_1 = 1$) and agricultural hinterland in country 2 ($s_2 = 0$), which is usually the case when transportation costs are low. In solving this tax game, the last stage is solved first, followed by the first stage considering the beforehand solution:

(1) The tax decision of country 2, equation (27), is solved first assuming the optimal tax rate of country 1 as given, $\tau_2 = \tau_1^*$.  

(2) Taking into account the solution derived in (1), country 1 tries to offset the effect of country 2’s strategic tax rate on migration and therefore on firm decision keeping the migration condition unchanged, equation (12.3).

As a benchmark, a cooperation situation as in the previous section is given, where countries do not have an interest in changing their status quo. Assuming different public good preferences for both countries, numerical simulation shows that each country sets its optimal tax rate $\tau_i^*$ according to $\psi_i$, as discussed in the symmetric case. Figure 10 shows state utility for $\psi_1 = 0.3$ and $\psi_2 = 0.2$ while considering low transport costs, $\tau = 1.1$. The optimum for both countries under the condition of cooperation and maintaining the status quo can be reached by setting $\tau_1^* = 0.43$ and $\tau_2^* = 0.25$, see also table 1.

²⁷ As shown in chapter 3, both the nominal and the real wages for unqualified labor are higher in the core than in the periphery. Considering unqualified labor as a median voter, core countries are therefore richer.
Solving the tax game step (1) numerically and using the same parameter values as in figure 10, country 2 takes the optimal tax rate of country 2 as a constant, $\tau_{2} = 0.43$, and vary its tax rate in order to attract migration and provoke production outsourcing.\(^{28}\) While figure 11.a) shows state utility, the absolute number of firms is shown in figure 11.b).

Figure 11: Core-Periphery: Deviation of Country 2; $\tau = 1.1$

Note that the utility function as well as the corresponding number of firms is discontinuous: reaching a value of $\tau_{2}^{dev} = 0.67|\tau_{1}^{*} = 0.43$ massive inward migration of qualified labor\(^{29}\) leads to a dislocation of firms - figure 11.b) - attracting even more firms and qualified labor. As a result, the industrialization course is reversed with industrial agglomeration in country 2 and agricultural production in country 1 (i.e. $s_{1} = 0$ and $s_{2} = 1$). Although the highest utility level $WE_{2}^{*} = 44.99$ for country 2 is at $\tau_{2}^{*} = 0.19$, deviation by setting $\tau_{2}^{dev} = 0.67|\tau_{1}^{*} = 0.43$

---

\(^{28}\) The whole range of tax rate values is shown in order to give full description of the impacts of deviation. However, only tax rates greater than $\tau_{2} = 0.25$ can lead to inward migration and therefore to a structural change of the status quo.

\(^{29}\) While there is a continuous flow of qualified labor from country 1 to country 2 as wages increase due to higher tax rates in country 2, reaching $\tau_{2}^{dev*}$ results in a jump of inward migration.
and being industrialized would raise utility to $WE_2^{dev} = 46.42$. Hence, country 2 would prefer to raise its tax rate in order to get the core, $WE_2^{dev} > WE_2^*$. 

Taking this into account, tax game step (2) is solved by country 1 in such a way that the effect of higher wage proposals offered by country 2 on migration decision is neutralized. In doing so, country 1 has to raise its tax rate in order to offer higher wages and to keep the migration condition unchanged. Equation (12.2) can be rearranged to:

$$\tau_1^{dev} = 1 - (1 - \tau_2^{dev})/\Omega^{CP}, \quad (28)$$

with $\Omega^{CP} = w_{1,1} / q_{1}^{r} / w_{2,1} / q_{2}^{r}$ as the real wage gap, where the core periphery equilibrium remains unchanged. Considering $\tau_1^{dev}$ as an optimal response to $\tau_2^{dev}$, country 1 has to be sure that there is no more incentive left for country 2 to an even higher tax rate: if not, country 1 has to solve step (2) again, considering country 2’s new strategic tax rate. Step (2) will be repeated as long as country 2 gains the core and rises utility by increasing its tax rates, $WE_2^{dev} > WE_2^*$, or until country 1 finds it worthwhile to surrender the core and to rest on agricultural production. Figure 12 shows the stylized decision problem for country 1.

![Figure 12: Tax Game: Decision Problem of Country 1](image)

The diagram in figure 12 reproduces the choices for country 2 in remaining underdeveloped (lower utility curve) or in gaining the core and being industrialized (upper utility curve). Country 1’s decision problem is such that it has to raise its tax rate to a level where country 2 is indifferent between $\tau_2^{dev}$ as a strategic tax rate to get the core and $\tau_2^*$ as an optimal tax rate to refrain from tax competition and to maintain the status quo. Having identified country’s 2 deviation tax rate, which corresponds to the same utility value as in the case without...
deviation, equation (28) determines the tax rate of country 1 in order to remain industrialized, $\tau_{1}^{\text{dev}}$. Finally, country 1 has to verify if it is worthwhile keeping the core:

$$\text{WE}_{1}^{\text{dev}} \geq \text{WE}_{1}^*,$$

(29)

where $\text{WE}_{1}^*$ corresponds to an optimal utility value imposed when being agricultural hinterland. If equation (29) is not fulfilled, country 1 would resign the core and set $\tau_{1}^*$ producing solely agricultural goods.

Indeed, numerical simulations prove that country 1 has to raise tax rates from $\tau_{1}^*$ to $\tau_{1}^{\text{dev}}$ in order to keep the core and to prevent country 2 from being industrialized taking into account equation (29). Hence, instead of deviation and engaging in the tax game, country 2 would rest on $\tau_{2}^*$ as the best response to $\tau_{1}^{\text{dev}}$, see figure 11.32 Additionally, as economies get closer (i.e. in terms of diminishing transportation costs), the core country has to increase its tax rate to a still higher extent.

**Proposition 6**: Tax competition in a strategic tax game and further reduction of transportation costs forces industrialized countries to increase their tax rates in order to maintain the status quo and to prevent migration and production outsourcing to occur.

### 6. Conclusion

To summarize, industrialization can be solely attributed to firm and migration decisions and is characterized by uneven economic development. In particular, spillover effects of regional R&D are crucial to the beginning and to the course of industrialization: the higher the respective applicability and transferability of research result, the greater the impact on the firm costs and therefore the higher the number of firms and products. Once industrialization has taken place, circular processes will lead to further economic development and will strengthen agglomerations.

Relating to the example of the industrialization of the Asian Tigers in the last century, a consequent pursuance of an export oriented policy combined with a unilateral opening for foreign imports was able to generate a sustainable economic development in that region33. Beside high saving rates and educational spending, the spillover of foreign knowledge due to the use of imported intermediates and their adaptation in domestic production was decisive. Only by

---

32 See appendix c) for numerical results when considering the same assumptions as in figure 11.
33Puga and Venables (1998, 1999) analyze the economic impacts of different trade policy. They conclude that a liberal trade policy is always preferable to a strategy of import substitution.
increased trade and further international division of labor 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)). The resulting stagnation period as predicted by the model can be seen in most developed countries in these days with no notable economic development and low growth rates.

It turns out to be increasingly essential for developing countries to gain access to knowledge and human capital as well as research results to upgrade their local industries: the greater the access towards R&D and skilled labor, the higher the possibility for stronger participation in world markets and sustainable economic development.

Increasing tax competition as a direct consequence of further economic integration forces countries to raise their taxes in order to keep the status quo and to prevent migration of skilled labor. If countries are equal in their industry shares, the outcome will be income tax rates that are too high from a social perspective. If not and in the case of a core periphery consideration, core countries may want to offset the effect of periphery’s strategic tax rate on production location and migration flows by raising their tax rates. Hence, in both cases the standard result of a “race to the bottom” does not apply. Moreover, tax rate-setting is not only constrained by tax competition but also by the extent of economic integration: as economies and markets get closer it may be worthwhile not to engage in strategic tax games and to set a socially optimized tax rate.

As outlined by Krugman and Baldwin (2004), during the first stages of European integration (1950-1970), average taxes were raised in all participating countries but to a higher extent by the industrialized core nations such as Germany or France than by the less industrialized Mediterranean countries or Ireland. It is hard to say whether increased economic integration and further political enlargement of the EU lead to tax harmonization within member countries. But the analysis shows, that at least for symmetric countries the adoption of common tax rates would be a desirable outcome in controlling migration flows. However, further analyses for political advise are required in order to confront the increasing migration pressure from poor to rich countries (Lundborg und Segerstrom (2002)) as well as the cutback of factor mobility restrictions (Ottaviano und Thisse (2002)).
Literature


Mathematical Appendix

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

a.) Decision-Making of an Individual Firm

Cost Function

Each firm $k$ faces the following decision making problem:

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

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

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

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 $CES_{i,r} = \sum_{j=1}^{M} \int x^{j_s} dh$ and $v$ is used as a vector for the individual shares: $a^s, b^s$ and $c^s$.

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

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

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

$$zaB_{i,s}(k) \equiv zaB_{i,s} = C_i^k \phi^s / b^s, \quad (a.4)$$

$$q_{i,s} CES_{i,s}(k) \equiv q_{i,s} CES_{i,s} = C_i^k \mu^{r,s} / c^{r,s}. \quad (a.5)$$

The solution gives the cost function of firm $k$:

$$C_i^k(k) = Q_i^s(k) \left(1 - a^s - b^s - \sum_{r=0}^{S} c^{r,s}\right) \left(\frac{1 - \phi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s}}{1 - \phi^s - \chi^s - \sum_{r=0}^{S} \mu^{r,s}}\right) \left(rk\right)^{\phi^s} \left(z_{ab}\right)^{\phi^s} \prod_{r=0}^{S} \left(q_{i,s} c^{r,s} / \mu^{r,s}\right)^{\phi^s}. \quad (a.6)$$
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 $\mu^r = \chi^r = 0$ and constant scale economies:

$$C_i^R(k) = y_i w_{i,R}^{(1-\phi^r)} z \alpha^r,$$

(a.7)

respectively with $\theta = (1 - \phi^r)$:

$$C_i^R(k) = y_i w_{i,R}^\theta z \alpha^{1-\theta},$$

(a.7.1)

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

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

(a.8)

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

$$C_i^F(k) = (R & D_i) w_{i,ii}^{(1-\chi^r)} r k^r_i,$$

(a.9)

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

$$C_i^F(k) = (R & D_i) w_{i,H}^{i} r k^{1-\mu}. $$

(a.9.1)

**Price-Setting, Short Run Profits and Labor Demand**

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

$$\pi_i^U(x_{i,k}, p_{i,k}) = p_{i,k} x_i^k (p_{i,k}) - C_{i,k}^U,$$

(a.10)

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

$$p_{i,k} = \frac{1}{\rho} C_{i,k}^{U,\text{var}},$$

(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:

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

(a.11.1)

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

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

(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:

$$\pi_i(k) = \frac{p_i}{\sigma} (x_i - x_i^{\text{bep}}),$$

(a.12)
with $\rho = (\sigma - 1) / \sigma$ and $x_i^{bp} = \alpha_i (\sigma - 1) / \beta_i$ as the break-even-output for a long run equilibrium.

The aggregate demand for unqualified work in sector U will be obtained by differentiating the cost function equation (a.8) with respect to the nominal wage:

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

And therefore:

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

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

$$m_i w_{i,U} = \bar{w}_i Y_i - rK_i . \quad (a.14)$$

With consideration of total income:

$$Y_i = w_{i,U} L_i + Br(w_{i,L}) + w_{i,M} m_i + rK_i + \int_{h \in N_i} \pi_i (h) dh , \quad (a.15)$$

equation (a.14) can be rewritten to:

$$m_i w_{i,U} = \frac{\bar{w}_i}{(1 - \bar{w}_i)} \left( w_{i,U} L_i + Br(w_{i,L}) + \int_{h \in N_i} \pi_i (h) dh \right) - rK_i . \quad (a.14.1)$$

**b.) Decision Making of a Representative Consumer**

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

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

s. t. \hspace{0.5cm} (1 - \bar{w}) Y_i = \sum_{s=0}^{S} d^s q^s_i VU_i^s

$$v^s \geq 0$$

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


The optimal budget allocation relative to consumption goods of one sector, \( s = z \), can be stated as:

\[
q_i^z V U_i^z = (1 - \alpha)Y_i \frac{d^z}{\gamma^z}. \tag{b.2}
\]

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

\[
V_i = (1 - \alpha)Y_i \prod_{z=0}^{S} \left( \frac{d^z}{\gamma^z} (q_i^z) \right)^{(-\gamma)} . \tag{b.3}
\]

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, \( q_i^y = 1 \), the indirect utility function can be written as:

\[
V_i = 1^{-(1-\gamma)} q_i^{-\gamma} Y_i^* , \tag{b.3.1}
\]

with \( Y_i^* = (1 - \alpha)Y_i \) \( \tag{b.4} \)

as the disposable income.

c.) General Equilibrium

due to the assumption of increasing returns, each good is solely produced by a unique firm in one region, whereas demand will be in both regions. Total demand of consumers and producers for good \( z \) produced in Region \( j \) can be stated as:

\[
x_i^{total}(z) = \sum_{j=1}^{2} x_i^{prod}(z) + \sum_{j=1}^{2} x_i^{con}(z) . \tag{c.1}
\]

for \( j = 1, 2 \).

Demand of Producers

As derived for the optimization problem of manufacturing firms, a share of \( \mu C_j \) is used for the purchase of the intermediate aggregate:

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

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

with \( p_{j,i}(h) = p_{j,i} : \) each producer sets the same price in a steady state equilibrium.
**Demand of Consumers**

As derived for the optimization problem of representative consumer, a share of income $\gamma$ is used for the purchase of the manufacturing goods:

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

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

**Total Demand**

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

\[
x_j^{\text{total}}(z) = \sum_{j=1}^{2} \left[ p_{i,j}(z)^{-\sigma} \tau_j^{1-\sigma} C_j q_j^{\sigma} \right] + \sum_{j=1}^{2} \left[ p_{i,j}(z)^{-\sigma} \tau_j^{1-\sigma} \gamma Y_j^* q_j^{\sigma} \right],
\]

or:

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

with

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

as the price index and

\[e_j = \gamma Y_j^* + \mu C_j \quad (c.6)\]

as the cumulative expenditures of good $z$.

Under consideration of equation (b.4) and (a.15), equation (c.6) can be rewritten as:

\[e_j = \gamma(1-\alpha) \left( w_{j,I} L_j + Br(w_{j,R}) + \int_{h \in N_j} m_j + rK_i + \int_{h \in N_j} \pi_j(h) dh \right) + \mu \int_{h \in N_j} C_j(h) dh, \quad (c.6.1)\]

or respectively with equation (a.14.1) to:

\[e_j = \gamma(1-\alpha) \left( \frac{\alpha}{1-\alpha} \left( w_{j,U} L_j + Br(w_{j,R}) + \int_{h \in N_j} \pi_j(h) dh - rK_i \right) \right) + \mu \int_{h \in N_j} C_j(h) dh, \]
\[ e_j = \gamma \left( w_{jL} L_j + Br(w_{jR}) + \int_{h \in N_j} \pi_j(h) dh \right) + \mu \int_{h \in N_j} C_j(h) dh. \]  

(c.6.2)

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

\[ x_i(z) = p_{i,i}(z)^{-\sigma} \left( e_i q_i^{(\sigma-1)} + e_j q_j^{(\sigma-1)} e^{(1-\sigma)} \right), \]

with

\[ q_i = \left[ \int_{h \in N_j} (p_{i,i}(h))^{(1-\sigma)} dh + \int_{h \in N_j} (p_{j,i}(h) e_j)^{(1-\sigma)} dh \right]^{\gamma/(1-\sigma)}, \]

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

**d.) Symmetric Equilibrium Shares of Unqualified Labor**

Considering a steady state equilibrium, equations (a.13.1) can be sated as \( L_U w_U = (1 - \mu) n p x^{b,p} \). Normalizing \( x^{b,p} = 1 \) and \( \pi = 0 \), the symmetric equilibrium share of workers employed in agriculture and industry can be calculated by substitution of equation (a.13.1) into equation (c.6.2), (c.5.1) and (c.4.1). This leads to:

\[ e = \gamma \left( w_{iL} L_i + L_i^{\theta} K^{1-\theta} + n \pi \right) + \frac{\mu}{1 - \mu} w_L L_U, \]  

(d.1)

\[ q = \left[ \frac{L_U}{1 - \mu} w_{U}^{1-\sigma(1-\mu)} (1 + \tau^{1-\sigma}) \right]^{\gamma/(1-\sigma(1-\mu))}, \]

(d.2)

and

\[ w_{U}^{\sigma(1-\mu)} = q^{\sigma(1-\mu)-1} e(1 + \tau^{1-\sigma}). \]

(d.3)

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

\[ w_U = \frac{\gamma L_R^{\theta}}{1 - \gamma L_U}. \]

(d.4)

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

\[ L_U = \frac{\gamma}{\theta(1 - \gamma) + \gamma} \]

(d.5)

and

\[ L_R = \frac{\theta(1 - \gamma)}{\theta(1 - \gamma) + \gamma}. \]

(d.6)
Government Taxation and Tax Competition

**Optimal Tax Rate-Setting: Without International Migration**

Optimizing equation (23):

\[
\max_{\tau} \quad WE_i (G_i, C_i) = \left( \frac{Y_i}{q_i} \right) (\tau a_i^\eta (1-\tau a_i)^{1-\eta}), \quad (e.1)
\]

under the assumption of no international factor mobility, this leads to:

\[
\frac{dWE_i}{d\tau a_i} \bigg|_{\eta=0} = \left( \frac{Y_i}{q_i} \right) (\psi \tau a_i^\eta - \tau a_i^\eta - \tau a_i^{\eta-1} (1-\psi) (1-\tau a_i)^{\eta-1}) = 0. \quad (e.2)
\]

Rearranging equation (e.2), it turns out that the first best tax rate equals public good preference:

\[
\left( \frac{Y_i}{q_i} \right) (1-\tau a)^{-\eta} \tau a^\eta \left( \psi \tau a_i^\eta (1-\tau a_i) - (1-\psi) \right) = 0,
\]

\[
\psi \tau a_i^\eta - \psi - 1 + \psi = 0,
\]

\[
\tau a_i = \psi. \quad (e.3)
\]

**Optimal Tax Rate-Setting: With International Migration**

In order to analyze the effect of a tax change on aggregated income, \(\frac{d(Y/q)}{d\tau a}\), and therefore on state utility, equation (23), differentiation of

\[
Y = w_u L + Br(w_k) + w_m r + rK + \int_{h=N} \pi(h) dh
\]

at the supposed symmetric equilibrium yields to:

\[
\frac{d(Y/q)}{d\tau a} = \frac{L d(w_u)}{q dn} Z + \frac{B d(rK)}{q dL_r} Z + \frac{w_u dm}{q d\tau a} + \frac{m dw_m}{q dm d\tau a} - \frac{Y dq}{q^2 dn} Z, \quad (e.4)
\]

or:

\[
\frac{d(Y/q)}{d\tau a} = \left( \frac{L d(w_u)}{q dn} + \frac{B d(rK)}{q dL_r} - \frac{Y dq}{q^2 dn} \right) Z + \frac{w_u dm}{q dm d\tau a} \left( 1 + \frac{m dw_m}{w_m dm} \right) d\tau a, \quad (e.4.1)
\]

where \(\frac{d(rK)}{d\tau a}\) and \(\frac{d(\int \pi(h) dh)}{d\tau a}\) are zero and

\[
Z = \frac{dn dFE dm}{dFE dm d\tau a}.
\]

A further look on equation (e.4) leads to the following conclusions:

1. \(Z > 0\): a tax increase leads to an inflow of qualified labor and by equation (6) in combination with equation (8) or (8.1) to a higher research level and hence to a higher number of firms, equation (22). The sign of \(Z\) is therefore positive.
(2) $\frac{d(w_U)}{dn} > 0$: a higher number of firms results in higher demand of unqualified labor, equation (16), and therefore in a higher wage rate. The sign of this term is also positive.

(3) $\frac{dr(w_R)}{dL_R} \frac{dL_R}{dn} < 0$: a higher number of firms results in a higher share of unqualified labor employed in manufacture and in a loss of labor shares in agriculture, $L_R = L - L_U$. The effect on the agricultural profit rate per unit land, $r(w_R)$, is negative because of the resulting higher wages in agriculture, equation (1.1).

(4) $\frac{dq}{dn} < 0$: a higher number of firms decrease the price index, equation (14).

(5) $\varepsilon_{w_{m,m}} = \frac{m}{w_{m}} \frac{d w_{m}}{dm} = -1$: when all other things equal, a one percent increase in skilled labor decreases wage rates by one percent.

(6) $\frac{dm}{d\tau} > 0$: a tax increase raises the incentive to migrate, equation (12) in combination with equation (7).

The last two statements (5) and (6) will be derived analytically:

(5) Wage elasticity respectively to qualified labor:

$$\varepsilon_{w_{m,m}} = \frac{m}{w_{m}} \frac{d w_{m}}{dm} = \frac{m}{w} \left(-\frac{\tau a Y - r K}{m^2}\right),$$

by the use of equation (7), $w_{m}m = \tau a Y - r K$. Re-substitution of equation (7) yields to:

$$\varepsilon_{w_{m,m}} = \frac{m}{w} \left(-\frac{mw}{m^2}\right) = -1.$$

(6) Total differentiation of the migration condition, equation (12.3), using two sub-functions, $f[\tau a] = \tau a$ and $g[m] = \frac{q_1^{-\gamma} (Y_1^{GDP})/m_1}{q_2^{-\gamma} \tau a_2 (Y_2^{GDP})/m_2}$, and evaluation at the supposed symmetric equilibrium by holding the tax rate of the counterpart constant gives:

$$g[1/2] \frac{\partial f[\tau a]}{\partial \tau a} d\tau a + f[\tau a] \frac{\partial g[m]}{\partial m} dm = 0,$$

or

$$\frac{dm}{d\tau a} = -\frac{g[1/2]}{\frac{\partial g[m]}{\partial m} \tau a}.$$ (e.5)
Rearranging \( g(m) = A \frac{1-m_1}{m_1} \) by the use of \( m_2 = 1 - m_1 \) and with \( A = \frac{q_1 \gamma (Y_1^{\text{GDP}})}{q_2 \gamma (Y_2^{\text{GDP}})} \) as a mathematical substitute, equation (e.5) can be written to:

\[
\frac{dm}{d\tau} \bigg|_{m=\psi} = - \frac{A}{m^2 \psi} m^2 = \frac{1}{4\psi} > 0 .
\]

To summarize, the negative effect of the agricultural profit rate, \( \frac{dr(w_r)}{d\tau} < 0 \), does not overweight the other effects due to a tax increase. Hence, the sign of \( \frac{d(Y/q)}{d\tau} \) is positive and therefore the sign of \( dWE / d\tau \): the first best solution, \( \tau = \psi \), cannot be a Nash equilibrium.

**Numerical Results for the Limited Tax Game:**

Assuming \( \psi_1 = 0.3 \) and \( \psi_2 = 0.2 \) as well as \( \tau = 1.1 \), Table e.1) present numerical results for country 1’s decision problem assuming:

<table>
<thead>
<tr>
<th>( \tau = 1.1 )</th>
<th>Step (1)</th>
<th>Step (1)</th>
<th>Step (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau_{a_1} )</td>
<td>No Deviation</td>
<td>0.43</td>
<td>Deviation</td>
</tr>
<tr>
<td></td>
<td>No Deviation</td>
<td>0.44676</td>
<td>Deviation</td>
</tr>
<tr>
<td></td>
<td>No Deviation</td>
<td>0.46405</td>
<td>Deviation</td>
</tr>
<tr>
<td>( \tau_{a_2} )</td>
<td>0.19</td>
<td>0.067</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>0.19</td>
<td>0.69</td>
<td>0.19</td>
</tr>
<tr>
<td>( WE_1 )</td>
<td>51.814</td>
<td>41.866</td>
<td>51.911</td>
</tr>
<tr>
<td>( WE_2 )</td>
<td>44.985</td>
<td>46.419</td>
<td>45.09</td>
</tr>
</tbody>
</table>

Table e.1: Decision Problem of Country 1

As mentioned, in setting \( \tau_{a_2} \text{dev} = 0.67\tau_{a_1}^* = 0.43 \) country 2 could gain the core, reach a higher utility level than to remain underdeveloped, \( WE_2 \text{dev} = 46.419 > WE_2^* = 44.985 \), and leave country 1 as an agricultural hinterland. Hence, equation (28) indicate, that country 1 have to set \( \tau_{a_1} \text{dev} = 0.447 \) in order to offset the effect on migration, but leaving room to country 2 for further deviation by setting \( \tau_{a_2} \text{dev} = 0.69\tau_{a_1} \text{dev} = 0.447 \). Again, country 2 would choose to deviate and would still be better off, \( WE_2 \text{dev} = 45.647 > WE_2^* = 45.09 \). Repeating tax game step (2) leads to \( \tau_{a_1} \text{dev} = 0.464 \) as an optimal response for country 1 and to an end of the tax game: country 2 could still get the core by \( \tau_{a_2} \text{dev} = 0.72\tau_{a_1} \text{dev} = 0.464 \) but being industrialized
would lead to a lower utility than to abstain from strategic tax setting and to rest on 
\( \tau d_2^* = 0.19 \), \( WE_2^{dev} = 44.402 < WE_2^* = 45.194 \). Therefore, if country 1 sets in the first stage 
\( \tau d_1^{dev} = 0.464 \), country 2 has in the second stage no more incentive to deviate. Finally, the
established solution has to comply with equation (29) in order to be reasonable outcome: in fact, its worthwhile for country 1 to engage in strategic tax-setting and to remain industrialized, because state utility for country 1 in case of deviation of country 2 and losing the core is always lower than \( WE_i^{dev} = 51.962 \).

f.) Steady State Equilibrium: Figures

Multiple Equilibria:

![Graph showing multiple equilibria](image)

Figure F1: Fundamental research; Tomahawk-bifurcation

Symmetric Tax Rate-Setting: Preferences for Public Goods

![Graph showing symmetric tax rate-setting](image)

Figure F2: Cooperation: Government taxing; \( \tau = 3 \)
g.) Numerical Simulation and the Choice of Parameters

The numerical simulation was calculated in Gauss and can 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 $\beta_i$ 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 $\Gamma \in [0,1]$.

Respectively 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 labor can be calculated for a short run equilibrium. On the same time the share of qualified and unqualified work in manufacture, $m_i$ and $L_{i,U}$, in both countries 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. Respectively to government taxation and tax competition in chapter 4, tax rates are set first, followed by migration and production decision taken by market participants until economies reach steady state equilibria.