Agglomeration, Migration and Tax Competition

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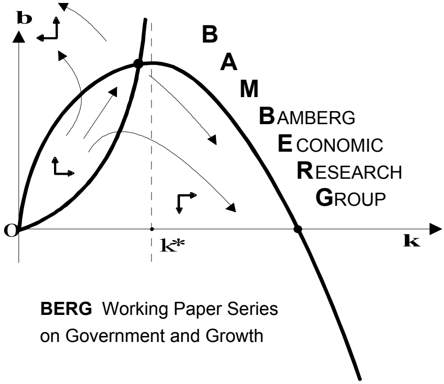

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Abstract

This paper focuses on tax competition and international migration in R&D sectors as agglomeration forces and trade restrictions are present. Economic integration forces industrialized countries to adapt their tax rates in order to keep their industrial status quo. Unlike the often discussed "race to the bottom" result, taxes are increased and the provision of public goods is maintained. It is also proven that taxes that redistribute between mobile and immobile labor lead to a tax burden that favors mobile labor. As integration continues, the cutback of factor mobility restrictions supports economic development in industrialized countries at the expense of structurally backward regions.

JEL-Classifaction: F12, F22, H73, R12

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1. Introduction

It is widely believed that further economic integration such as the enlargement of the EU to 25 countries through the integration of Central and Eastern European countries in May 2004 will lead to painful adjustment processes within core and periphery countries. While some fear for the maintenance of large welfare states others are concerned about remaining competitive and losing industry shares as economies grow together. Considering tax competition of example, mobile factors are generally assumed to locate to regions where taxes are low and/or the provision of public goods is high. Periphery countries therefore may decrease taxes in order to attract mobile factors pushing local economic development at the cores' expense. As a result, all countries would adapt 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, (e.g. Wilson, 1999). Following this line of argumentation, national tax policy is therefore limited to lowering taxes as tax competition increases in economically integrating regions. The overall provision of public goods would then decline towards the lowest level of provision within member countries and governments would be reduced to interfering in market failures. Hence, should the European Community consider tax harmonization to maintain social welfare? If not, should the cutback of factor mobility restriction be reversed as analyzed in Ottaviano and Thisse (2002) or, according to Lundborg and Segerstrom (2002), taxes be imposed in order to control such factor flows?

While capital is more likely to move 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 amongst other considerations. When factor owners move with their factors, countries may have to raise, not lower national tax rates in order to account for a high provision of public goods and to increase the country's attractiveness to inward migration. Hence factors move to countries even when income taxes are high or about to be increased. Highly educated labor in R&D sectors for example is empirically shown to be more mobile between countries than unskilled labor.[1] In order to maintain their research level governments in economically integrating regions are willing to prevent outward migration of skilled labor by offering higher wage proposals. A tax that redistributes between mobile and immobile factors leads to a tax burden that discriminates against immobile factors. Tax competition may then yield an outcome with sub-optimal tax rates, which are too high from a social perspective.

[1] For surveys on the mobility of skilled labor see Shields and Shields (1989) as well as Pedersen (1996).

Hence, as soon as factor owners move with their factors and income is spent in the host country, the standard tax competition result of a "race to the bottom" does not hold.

Moreover, considering industrial agglomeration and its lock in effects, factors may stick to regions even under a high tax burden. The point is that within industrial cluster agglomeration rents can be taxed without provoking an outflow of input factors or a loss of industry shares. While there is no inherent incentive of clustering in the standard tax competition (perfect competition, constant return of scale), tax competition in the new economic geography literature do account for the location of industry and factor mobility in the presence of agglomeration forces. Baldwin and Krugman (2004) show first "a race to the top" among core countries and later, as integration continues, also among the periphery countries. They underline their findings by empirical observation of the average total and corporate tax rates during the European integration process (1965-1994). In Anderson and Forslid (2003) a small redistribution between mobile and immobile factor shares due to a coordinated tax increase on mobile factors between countries may lead to a catastrophic agglomeration with all industry and skilled labor concentrated. There isn't even a need for an international tax difference in order to cause such agglomerations. Baldwin et al. (2003) show amongst other things that tax competition on mobile factors will result in the first best tax rate when factor owners move with their factors and governments are concerned about the mobile factor. In that context, tax competition would not harm social welfare. In short, things are different in models with agglomeration forces and with labor as the taxable mobile factor. There is no simple "race to the bottom" and no need for tax harmonization as a single straightforward solution. Consequently, this paper focuses on the interaction of agglomeration forces, factor mobility of labor and taxation, as trade liberalization and diminishing migration costs force countries to compete for industry shares as well as for input factors.

The structure of the paper is described as follows. Basic intuition about industrial agglomerations, migration flows and tax competition are presented in the below section. In section 3 we turn to a static two-country model. The results of numerical simulation are given in section 4 in order to show the impacts of tax competition and trade integration on steady state equilibria. Section 5 concludes. Specific details about parameters and numeric simulation as well as analytical derivation are listed in the appendix.

2. Agglomeration, Migration and Tax Competition

In order to cope with tax competition and international migration in the presence of agglomeration forces and economic integration we first introduce an agglomeration model with Marshallian externalities[2] and then add public goods and taxation.

To start with, we assume a Walrasian sector (agriculture) and a Dixit-Stiglitz monopolistic competition sector with increasing returns of scale and vertical linkages (manufacturing). Following Hirschmann (1958) cost and demand linkages arise as firms are able to use intermediate goods more cheaply and face a greater demand for their products where other firms and consumers are concentrated. This leads to circular causality and to self-enforcing agglomeration. At the same time competition in product and factor markets increases with the number of locally concentrated firms. Such neoclassical forces as well as the existence of trade costs and the need to deliver immobile consumers work against spatial concentration of industry. Hence, the trade off between these centripetal and centrifugal forces determines the pattern of industrialization and the distribution of mobile factors between countries. As usual, industrial agglomeration occurs when trade costs are at an intermediate level, whereas at high and at low trade costs industrial activity is more likely to be equally distributed. All corresponding key features as outlined and discussed by Baldwin et al. (2003) are present: agglomeration via the home-market effect, demand and cost linkages, endogenous asymmetry, catastrophic agglomeration, locational hysteresis or path-dependency, hump-shaped agglomeration rents, and multiple long run equilibria.

In order to analyze international migration and to study the effect of tax competition and trade liberalization on migration flows and economic development, we assume that skilled labor is solely employed in a public R&D sector such as the higher education sector.[3] Furthermore, if research activity is determined by the flow and input of skilled labor, the effect on R&D output and its impact on firms are also important. It is assumed that firms' costs are reduced by the presence of fundamental research[4] and therefore by the amount of skilled labor

[2] For Marshall (1890) "mass production, the availability of specialized input services and the formation of highly skilled labor as well as the production of new ideas are crucial for the formation of industrial clusters", see (Fujita and Thisse, 2002).

[3] According to the OECD (2003) basic research activity can be broken down into higher education, government, private non-profit and business enterprises. In the last few years the expenditure as a percentage of GDP within the public financed sectors was significantly higher on higher education than on government research for the OECD as well as for the EU. We therefore focus on higher education.

[4] Fuss and Waverman (1992) show in an empirical study of costs and productivity in the automobile sector the impact of technical change – as measured by the stock of R&D – on average unit production costs. Unit production costs would have been reduced due to technical change on average for the US by -0.8%, for Japan by -2.7% and for Canada by -0.3% per annum for the period 1970-84 and for Germany by -1.1% per annum from 1970 to 1980.

used in the R&D sector. This idea is derived from Ottaviano (2001) and Forslid (1999), where a "footloose entrepreneur" is required as a fixed input to produce one single variety of industrial goods and location of industry is driven by real wage difference. However in this paper immigration of skilled labor leads via R&D to a lower break-even-point for firms. Firm location therefore is affected by higher market entry due to short run profits. Again, self-enforcing processes arise where a higher number of clustered firms leads to a real wage gap and therefore to further immigration. Hence, in determining economic development factor mobility restriction and migration costs of skilled labor have to be considered as well. We are not interested in different technological spillover effects and their impact on industry and factor distribution as analyzed by Martin and Ottaviano (1997) and Hafner (2004). As recent studies such as from Feldman and Florida (1994) show, innovations are more likely to cluster in regions where R&D–oriented firms and universities are established, and that their diffusion to structurally backward regions is slow. As such regions become more attractive further concentration of firms and mobile factors occurs, pushing a region's capacity to innovate and grow. Since the location of innovation matters for industrial agglomeration we assume a time-invariant symmetric diffusion rate.

Fundamental research is provided at no cost for firms and there is no discrimination between settled and potential firms within countries. Hence, income taxes are imposed in order to provide research activity as a public good and therefore to finance factors employed in the R&D sector. Taxes are levied on mobile as well as on immobile factors, and income is spent in the host country, where factors are employed and being taxed ("origin principle" in tax lexicon). There are no factors repatriating earnings and GDP and GNP do not differ. Having introduced public goods and factor taxation, we have to be specific about government objectives. In principle governments can be concerned about a representative consumer and adopt its objectives (Benthamite objectives), they can be concerned about a specific group and choose objectives by a median voter (Non-Benthamite objectives) or they can maximize their own utilities (Leviathan governments). As we will see, impacts on migration flows and economic development are quite different.

Finally, taxation of mobile factors in the presence of agglomeration and integration forces depends heavily on the kind of initial equilibrium. Circular causality due to cost and demand linkages as well as migration flows is responsible for industrial activity either being equally distributed between countries or fully concentrated. Hence, it is not possible to analyze partial agglomeration and tax competition as in Borck and Pflüger (2004). In a symmetric equilibrium strategic taxation may lead to a slight shift in mobile factors and industry shares between countries. In a core periphery situation agglomeration rents can be taxed by the core countries, but the periphery do have an incentive to engage in strategic tax-setting in order to gain industry shares. The general procedure for both equilibria is that we first analyze a cooperation case with no tax-setting deviation and then introduce tax competition as a non-cooperation game.

3. A Static Equilibrium Model

The model relies on the concept of monopolistic competition from Spence (1976) and Dixit and Stiglitz (1977), and its adaptation to regional economics by Krugman (1991a, 1991b) and Krugman and Venables (1995). Additionally, vertical linkages among firms like in Venables (1996), Fujita, Krugman und Venables (1999), Puga (1999) and Fujita and Thisse (2002) are assumed. Traded industrial goods are subject to iceberg trade costs as proposed by Samuelson (1954). In order to define government utility function and therefore the provision of public goods, we follow Baldwin et al. (2003) and Baldwin and Krugman (2004).

3.1. Assumptions

Consider a world with two economies, i = 1,2, with identical endowments of mobile and immobile factors of production. There is a distinction between unskilled and skilled labor, respectively L_i and m_i, where the first is mobile between sectors within an economy and the second between countries. The share of the immobile factor - land B_i - is assumed to be fixed and the same in each country. Both countries have the same technology and there are three sectors: agriculture, manufacturing and R&D.

Agriculture is a Walrasian sector with perfect competition and constant economies of scale. The homogenous agricultural good y_i can be traded without trade costs. Production is supposed to follow a Cobb–Douglas production function using land B_i and unqualified labor $L_{i,R}$ as input factors, whereas R is the index for the agricultural sector. Considering that unskilled labor can be employed by the agricultural sector as well as by the manufacturing sector, the nominal wage rate paid in the agricultural sector with respect to unskilled labor can be written as $w_{i,R} = F^{'}(L_i - L_{i,U}, B) = \theta(L_i - L_{i,U})^{\theta-1} B^{1-\theta}$, with $L_{i,U}$ as unqualified labor employed in the industrial sector (index U), θ as the partial production elasticity of unqualified labor and $B_i = B$. Following Puga (1999), a profit condition 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:

$$R_i(p_{i,R}, w_{i,R}, B) = \max\{p_{i,R} y_i - w_{i,R} L_{i,R} - zaB \,|\, y_i \leq g(L_{i,R}, B)\}, \qquad (1)$$

where za is the cost for agricultural land use. Equation (1) can be rewritten using $p_{i,R} = 1$ as $R_i(1, w_{i,R}, B) = Br_i(w_{i,R})$, with $r_i(w_{i,R})$ as maximized profit per unit of land in country i.

Monopolistic competition and increasing returns of scale are assumed for the industrial sector. In addition to unskilled labor $L_{i,U}$, an aggregate of intermediate goods CES_i is used as input factors in industrial production. Aggregate supply follows a Cobb–Douglas functional form and a CES production function with ρ as the degree of product differentiation and N_i as the number of firms operating in country i:

$$Q_i = L_{i,U}{}^{1-\mu} CES_i{}^{\mu}, \; CES_i = \left(\sum_{j=1}^{2} \int_{h \in N_j} x_{j,i}^{\rho} dh \right)^{1/\rho}, \qquad (2)$$

with μ as the partial production elasticity of intermediate goods. The quantity of the produced good i in country j is denoted by $x_{j,i}$. The cost-function of a single firm in country i can be calculated as $C_i(k) = (\alpha_i + \beta\, x_i(k)) q_i^{\mu} w_{i,U}{}^{1-\mu}$, where q_i is the price index and $w_{i,U}$ is the nominal wage rate paid in the industrial sector. Production costs of a single variety by firm k in country i is divided into a fixed part α_i and a variable part β, which does not differ between countries. Due to the assumption of increasing returns of scale, $x_i(k)$ also stands for the produced amount of good k in country i. Firms are price setters and are therefore able to raise prices above the marginal cost: $p_i = (1/\rho)\beta\, q_i{}^{\mu} w_{i,U}{}^{1-\mu}$, with $(1/\rho)$ as a constant markup factor. The short term profits of a firm, determined by free entry into markets, are calculated as:

$$\pi_i(k) = \frac{p_i}{\sigma}\left(x_i - x_i^{bep}\right), \qquad (3)$$

with $\sigma = 1/(1-\rho) > 1$ as the elasticity of substitution between goods and $x_i^{bep} = \alpha_i(\sigma - 1)/\beta$ as the break-even output. In the long-run, profits are zero.

The public R&D sector uses skilled labor m_i as the input factor. Under the assumption of decreasing economies of scale, perfect competition and a Cobb Douglas functional term, research output in country i can be written as $R\&D_i = m_i^{\iota}$, with $\iota < 1$ as the partial production elasticity of skilled labor. The overall research level in country i is solely determined by the compounded output of the R&D sectors. Depending on the availability of research results from abroad, each country has a relative share of fundamental research:

$$FE_i = \frac{R\&D_i + \Gamma R\&D_j}{\phi}, \; \alpha_i = A / FE_i \tag{4}$$

for j=1,2, $j \neq i$ and $\phi = \sum_{h=1}^{2} R\&D_h$. The technological spillover effect is best expressed by $\Gamma \in [0,1]$: a global spillover effect $\Gamma = 1$ means that both countries transfer research results to each other without losing application and redundancy. By $\Gamma = 0$, a country's research level is determined by its own research activity. As discussed, fundamental research reduces fixed costs α_i at the firm level, whereas A is a constant technical parameter. Therefore a higher research level FE_i leads to lower fixed costs and by equation (3) to higher short run profits.

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

$$\tau a_i Y_i = w_{i,H} m_i, \tag{5}$$

where $w_{i,H}$ is the nominal wage rate for skilled labor in country i. Taxable income can be traced back to factor income of unskilled and skilled labor, as well as to gains resulting from agriculture and manufacturing:

$$Y_i = w_{i,U} L_i + w_{i,H} m_i + Br_i(w_{i,R}) + \int_{h \in N_i} \pi_i(h) dh. \tag{6}$$

Substituting and rearranging equation (5) in equation (6) yields to $Y_i^{GDP} = (1 - \tau a_i) Y_i$, with $Y_i^{GDP} = w_{i,U} L_i + Br_i(w_{i,R}) + \int_{h \in N_i} \pi_i(h) dh$. Note that GDP consists only of factor income of unqualified labor, agricultural gains and short run profits: within a country an income tax and its redistribution as factor payments do not change the total factor income.

The utility function for a government with Benthamite objectives can be stated as:

$$WE_i\,(G_i, CR_i) = G_i^{\psi_i} CR_i^{1-\psi_i}, \; G_i = \tau a_i Y_i / q_i, \; CR_i = (1 - \tau a_i) Y_i / q_i, \tag{7}$$

with ψ_i as the public good preference in country i. G_i is the provision of public goods – equation (5) – and $CR_i = (1-\tau a_i)Y_i / q_i$ is the consumption of a representative consumer after taxation. 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 higher tax revenue and its expenditure on the provision of public goods (i.e. higher research activity) favors at first glance input factors in the R&D sector, but also benefits the country as a whole because of a higher national research output. Rearranging equation (7) leads to: $WE_i = (Y_i / q_i)\left(\tau a_i^{\psi_i}(1-\tau a_i)^{1-\psi_i}\right)$.

The representative consumer is assumed to have time-invariant, identical preferences towards goods produced in either country. Love of variety preferences are usually modeled by a Cobb–Douglas functional term using the agricultural good y_i, an aggregate of industrial consumer goods VU_i and public goods G_i. The aggregate itself is a CES function of the heterogeneous consumption goods:

$$V_i = y_i^{1-\gamma-\psi_i} VU_i^{\gamma} G_i^{\psi_i}, \; VU_i = \left(\sum_{j=1}^{2} \int_{h \in N_j} x_{j,i}^{\rho} dh \right)^{1/\rho}, \tag{8}$$

with γ as the consumption share of the industrial products. Optimization leads to the indirect utility function: $V_i = [Y_i \tau a_i^{\psi_i}(1-\tau a_i)^{(1-\psi_i)}]1^{-(1-\gamma-\psi_i)} q_i^{-\gamma}$. Note that the first part of the indirect utility function describes exactly equation (7) in nominal terms. In optimizing state utility, the indirect utility function of a representative consumer is maximized as well. For analytical reasons, the price index for the industrial products q_i is the same for consumers and producers.

Skilled labor takes into account local tax rates, the price level and nominal wage rates as well as migration costs τb_i. Hence, the migration condition of skilled labor can be written as:

$$\frac{q_i^{-\gamma}(1-\tau a_i)(1-\tau b_i)(w_{i,H})}{q_j^{-\gamma}(1-\tau a_j)(1-\tau b_j)(w_{j,H})} = 1 \tag{9}$$

for j=1,2 and $j \neq i$.

3.2. General Equilibrium Conditions

Owing to the assumption of increasing economies of scale, each good is produced by a single firm located in a single region. Total demand for one good produced in country i will be composed of consumer and producer demand from both countries:

$$x_i(z) = p_i(z)^{-\sigma}\left(e_i q_i^{(\sigma-1)} + e_j q_j^{(\sigma-1)}\tau^{(1-\sigma)}\right), \tag{10}$$

for j=1,2 and $j \neq i$. Iceberg trade costs are considered when undertaking interregional trade; 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:

$$q_i = \left[\int_{h=N_i}\left(p_{i,i}(h)\right)^{(1-\sigma)}dh + \int_{h\in N_j}\left(p_{j,i}(h)\tau_{j,i}\right)^{(1-\sigma)}dh\right]^{1/(1-\sigma)}, \tag{11}$$

for j=1,2 and $j \neq i$. In each country, the price index depends on local prices, which in turn depend on FOB prices and local trade costs. Total expenditure e_i is composed of consumer and producer expenditure on industrial products and can be specified for country i as:

$$e_i = \gamma\left(w_{i,U}L_i + Br_i + \int_{h\in N_i}\pi_i(h)dh - MC_i\right) + \mu\int_{h\in N_i}C_i(h)dh\,, \tag{12}$$

with $MC_i = \tau b_i w_{i,H}(m_i - m_{i,0}) \geq 0$ as total migration costs for net immigration of skilled labor, whereas $m_{i,0}$ represents the original endowment of skilled labor. Note, that if there is a net emigration of skilled labor, $m_i - m_{i,0} < 0$, migration costs for country i will be zero. Due to the assumption of lump-sum taxation, factor income from the R&D sector does not enter in equation (12). The first part of equation (12) stands for the net expenditure of consumers, while the second part describes the share of firms' cost spending. The remaining part of cost spending, $(1-\mu)$, will be directed towards unskilled labor demand. According to Shepard's Lemma, differentiating the cost-function with respect to the wage rate leads to:

$$L_{i,U} = (1-\mu)\int_{k\in N_i}C_i(k)dk / w_{i,U}\,. \tag{13}$$

Given the tax rate [equation (7)] and the nominal wage [equation (9)], skilled labor demand can be calculated using equation (5) and $Y_i^{GDP} = (1-\tau a_i)Y_i$:

$$m_i = (\frac{\tau a_i}{(1-\tau a_i)} Y^{GDP}) / w_{i,H} . \tag{14}$$

3.3. Steady State Equilibrium

Both economies are characterized by an initial equilibrium. Exogenous shocks such as trade liberalization, the cutback of factor mobility restrictions or strategic tax-setting lead to transition phases where countries and sectors are marked by fluctuations in firms and labor. Following Puga (1999), the adjustment process can be stated as:

$$\dot{n}_i = \lambda_1 \pi_i (n_1, n_2) \text{ and } \dot{m}_i = \lambda_2 \varpi_{i,H} (m_1, m_2) , \tag{15}$$

with $\dot{n}_i$ and $\dot{m}_i$ as the derivatives for the quantity of firms and skilled labor with respect to the adjustment time whilst reaching a steady-state equilibrium, λ_1 und λ_2 as positive constants, and n_i as well as m_i as static variables. $\varpi_{i,H}$ is the real wage rate of skilled labor in country i. The share of unskilled labor in the manufacturing and agricultural sectors is determined by industrial demand and will not be included in an explicit adjustment process.

For steady-state equilibrium to be stable, it is necessary that there is no incentive for further fluctuation of firms or further migration. Therefore, both countries have a static share of firms and skilled labor if

$$\frac{\partial \pi_i}{\partial n_i} \leq 0 \text{ and } \frac{\partial \varpi_{i,H}}{\partial m_i} \leq 0 : \tag{16}$$

a higher number of firms and skilled labor doesn’t lead to higher profits nor real wages within a country.

From equation (16) it follows that in steady state equilibrium firms are not able to make any profits through free market entry: $x_i = x_i^{bep} = \alpha_i (\sigma - 1) / \beta$ in equation (3). The number of firms in country i will be endogenously determined by equation (13):

$$n_i = \frac{L_{i,U} w_{i,U}}{(1-\mu) w_{i,U}{}^{(1-\mu)} q_i{}^{\mu} \alpha_i \sigma}. \tag{17}$$

The model and the equilibrium conditions are described by equations (1)–(17). Steady state equilibria will be considered.

4. Government Taxation and Tax Competition

The model cannot be solved analytically and therefore we have to rely on numerical simulation. The problems arise with Dixit-Stiglitz monopolistic competition, CES utility, and iceberg trade costs which make such models unsolvable due to the discussed circular causalities. Ignoring tax competition for a moment and assuming that neither migration costs nor factor mobility restrictions exist, migration is therefore only driven by its productivity and differences in the price index. Hence, without any strategic tax-setting behavior government taxation is reduced to pay skilled labor by its marginal product. Figure 1 plots the share of industry against diminishing trade costs while migration costs are zero. The technical diffusion Γ is assumed to be symmetric and at a value of 0.5.

Within high and very low trade costs there is a symmetric equilibrium with an equal industry share of 0.5 in both countries. At an intermediate level of trade costs circular causality arise leading to a catastrophic agglomeration in country 1, whereas country 2 degrades to an agricultural hinterland. However, there is a range of trade costs between values of 2.6 and 1.8 with multiple equilibria due to path dependency which may lead either to full agglomeration or to symmetric distribution in industrial activity. Therefore, introducing an even more strategic role of government taxation does not alter the complexity.

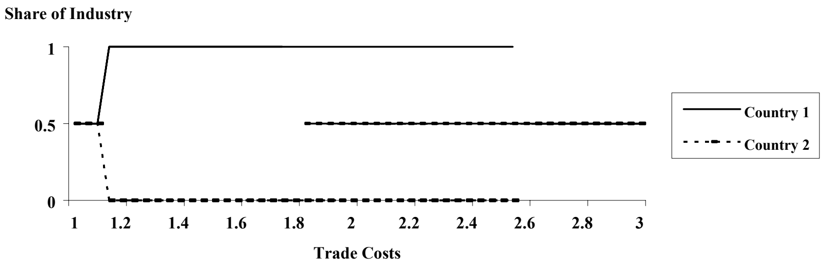

Figure 1: Multiple Equilibria: Tomahawk-Bifurcation

After further inspection of the government objective function and its tax policies, we analyze separately the impact of tax-setting on the two different steady state equilibria. 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 as proposed by Baldwin and Krugman (2004) will be introduced. Therefore, in order to analyze the effect of strategic tax-setting on industry shares and factor flows in economically integrating regions we focus on trade liberalization and the cutback of factor mobility restrictions in terms of diminishing migration costs.

4.1. Optimal Tax-Setting

Following Baldwin et al. (2003), one way to find the optimal tax rate for a symmetric equilibrium is to first assume that all factors are internationally immobile (i.e. migration condition equation (9) does not apply) and to calculate the first best tax rate. Afterwards, factor mobility is allowed for in order to show whether the result changes or not.

To start with, the term (Y_i / q_i) in equation (7) is a parameter and does not vary with different tax rates. It is then easy to derive from equation (7) that the first best tax rate is $\tau a_i^* = \psi_i$: the tax rate in order to finance the public good provision equals the preference for that good.

Assuming 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 factor mobility by equation (9). If country 1 does not want to deviate from the first best solution nor does country 2, $\tau a^* = \psi$ would also be a Nash equilibrium with an equal share of mobile factors, $m = m_1 /(m_1 + m_2) = 1/2$. 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 on numerical simulations.

To ascertain whether the first best solution is a Nash equilibrium, the government utility function has to be mechanically differentiated. Equation (7) can be facilitated by dropping country indexes and using two sub-functions, $g[m] = (Y / q)$ and $f[\tau a] = \left(\tau a^{\psi} \; (1 - \tau a \;)^{1-\psi} \;\right)$, to: $WE = g[m]f[\tau a]$. By setting the first best tax rate, total differentiation and evaluation at the supposed symmetric equilibrium leads to same result as shown by Baldwin et al. (2003):

$$\frac{dWE}{d\tau a} = \left.\frac{d(\tau a^{\psi}(1-\tau a)^{1-\psi})}{d\tau a}\right|_{\tau a=\psi} \frac{Y}{q} + \left.\left((\psi^{\psi}(1-\psi)^{1-\psi})\frac{d(Y/q)}{d\tau a}\right)\right|_{m=1/2}. \tag{18}$$

Due to the optimal first best tax rate, the first term in equation (18) is zero. Hence, the sign of $dWE/d\tau a$ depends only on the second term. Using the definition of Y [equation 6] one gets by application of the quotient rule:

$$\left.\frac{d(Y/q)}{d\tau a}\right|_{m=1/2} = \left(\frac{L}{q}\frac{dw_U}{dn} + \frac{B}{q}\frac{dr(w_r)}{dL_r}\frac{dL_r}{dn} - \frac{Y}{q^2}\frac{dq}{dn}\right)Z + \frac{w_H}{q}\left(1+\frac{m}{w_H}\frac{dw_H}{dm}\right)\frac{dm}{d\tau a}, \tag{19}$$

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

A further look at equation (19) and the equation set (1)-(17) leads by comparative statics to the following conclusion:

$$\frac{dm}{d\tau a} > 0;\ Z > 0;\ \frac{d(w_U)}{dn} > 0;\ \frac{dr(w_R)}{dL_R}\frac{dL_R}{dn} < 0;\ \frac{dq}{dn} < 0;\ \varepsilon_{w_H,m} = \frac{m}{w_H}\frac{dw_H}{dm} = -1. \tag{20}$$

All other things constant, a higher tax rate leads to an increase in skilled labor due to the migration condition. Hence, an increase in skilled labor increases the number of firms, Z > 0, and therefore increases unskilled nominal wages, decreases the agricultural profit share per unit of land and the price index. Finally, the elasticity of skilled wages with respect to skilled labor is negative.[5] The negative effect of the agricultural profit rate does not overweight the other effects. As a result, $d(Y/q)/d\tau a$ is positive and therefore $dWE/d\tau a$ also: countries have an incentive to deviate from the first best solution by raising tax rates in order to achieve a higher utility. Hence, the symmetric first best solution is not a Nash equilibrium.

[5] More details about the derivatives in equation (20) are listed in appendix B.

Indeed, numerical simulations show that the optimal tax rate approaches one: a nearly 100 percent income transfer from immobile factors to qualified labor. By equation (7), governments are concerned about the provision of public goods as well as the consumption of a representative consumer. An income transfer from one group to another group does not affect consumption as a whole – GDP remains unchanged – therefore 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 account 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 for the immobile factors. Hence, we change equation (7) to:

$$WE_i\ (G_i, CL_i) = G_i^{\psi_i} CL_i^{1-\psi_i},\ G_i = \tau a_i Y_i / q_i,\ CL_i = (1-\tau a_i) Y_i^{GDP} / q_i, \tag{21}$$

with CL_i as the consumption of unskilled labor as well as of owners of agricultural and industrial gains. The government objective function in equation (21) is now described by a median voter model and its adoption of the specific consumer tastes of the immobile factors.

4.2. Symmetric Equilibrium: Prisoner's Dilemma

We assume a symmetric equilibrium with equal industry shares and identical factor endowments in both countries when trade costs are high - $\tau = 3.0$ - as well as $\Gamma = 0.5$, which means that 50% of regional research is not applicable or redundant. Furthermore, between equally industrialized countries it is assumed that neither migration costs nor factor mobility restrictions exits, $\tau b = 0$.

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 either a cooperative or a non-cooperative way of doing so. If one of these two strategies leads to a stable equilibrium, the corresponding tax rate as a market outcome can 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 with the prisoner's dilemma.

In the first case, countries can cooperate and governments set therefore identical tax rates. In doing so, there is no additional migration and therefore no change in industry shares. The status quo is preserved and both countries remain symmetric. Figure 2 shows the development of state utility functions [equation (21)] for tax rate values, $\tau a \in [0,1]$, with respect to different public good preferences.

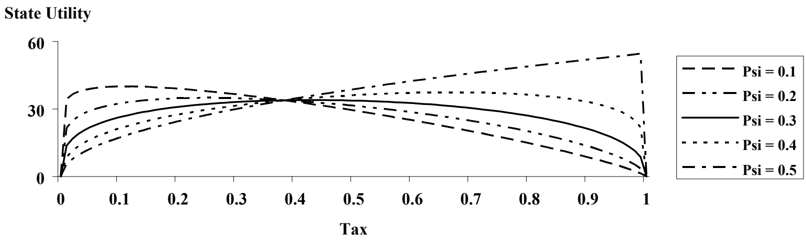

Figure 2: Symmetric Equilibrium: Coordinated Tax-Setting

The higher the preference for public goods in a country, the more the utility function shifts to the right: governments increase their utility by raising tax rates providing more public goods. Hence, if there is a high public good preference, $\psi \uparrow$, countries are about to increase income taxes in order to finance R&D activity and to raise their utility. The peaks of the utility functions corresponding to different preferences in Figure 2 therefore characterize the optimal tax rate. As a result, the optimal tax rate increases the stronger the preference for public goods. However, public good preference should not be too high: reaching a value of 0.5 the resulting optimal tax rate approaches one and therefore leaves no room for further analysis. Numerical simulations show, that the optimal tax rates in Figure 2 are valid for different values of trade costs.

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 were to cooperate. In order for a coordinated tax-setting to be a stable equilibrium it is required that there is no incentive to deviate. Fixing the tax rate of country 1 at the optimal value presented in Figure 2, $\overline{\tau a_1^*} = \tau a^{*coop.}$, and varying country's 2 tax rate, $\tau a_2 \in [0,1]$, Figure 3 shows a range of tax rate values with a higher utility for country 2 than for country 1.

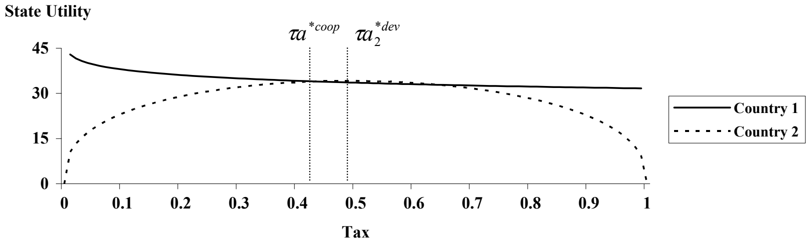

Figure 3: Symmetric Equilibrium: Strategic Tax-Setting

More precisely, a higher utility level can be obtained for country 2 by setting the optimal deviation tax rate τa_2^{*dev} instead of $\tau a^{*coop.}$. Hence, country 2 gains by deviation - $WE_2^{*coop}\Big|_{\psi=0.3} < WE_2^{*dev}\Big|_{\psi=0.3}$ - and attracts more qualified labor in national research activity. As a result, the share of industry in country 2 would increase 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 by setting a higher tax rate. Due to the initial assumptions that both countries are symmetric, this results in a non-coordinated symmetric Nash equilibrium, where both countries set identical but higher tax rates than in the coordinated strategy. However, these symmetric tax rates are not optimal. Hence, such a prisoner's dilemma leaves both countries worse off while their industrial status quo remains unchanged. The resulting redistribution of higher income tax revenue favors skilled labor at the expense of unskilled labor.

> ***Proposition 1:*** 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 therefore to a lower tax burden for unskilled labor.

Proposition 1 remains valid for values of trade costs and public good preferences as long as there is an initial symmetric equilibrium.

4.3. 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 relative to the core country, offering higher wages leads qualified labor to inward migration and therefore to a higher research activity. Reducing or reversing the industrialized country's comparative advantage of having a high research level, firms begin to shift their location towards the structurally backward country. In doing so, they benefit not only from the increasing share of R&D activity, but also from the unskilled 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. 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) this can be analyzed by a limited tax game: the core country sets its optimal tax rate τa_1 in the first stage whereas the periphery country chooses its tax rate τa_2 in the second stage. In the third stage, migration and production occur until both economies reach steady state equilibria.

Industrialized countries are general characterized by a higher tax burden than developing countries in order to finance public goods. This might be the result of a higher need and/or higher preferences by 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, as seen in Figure 2. To allow for this fact, we have to assume that the core country has a higher preference towards public good spending than the structurally backward country.[6]

We assume an asymmetric equilibrium with industrial agglomeration in country 1 and agricultural hinterland in country 2. To keep things simple, we first assume that there are no migration costs, $\tau b_1 = \tau b_2 = 0$. This simplification will be relaxed later on. In solving this tax game, the last stage is solved first, and the first stage is solved last:

(1) The tax decision of country 2 [equation (21)] is solved first assuming the optimal tax rate of country 1 as given, $\tau a_2^{*dev} \big| \tau a_1^*$.

[6] As a general result in these kind of models, nominal and real wages for unqualified labor are higher in the core than in the periphery. Considering unqualified labor as a median voter and bearing in mind that a lump sum income tax and its redistribution do not change GDP, core countries are indeed richer than the periphery.

(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 flows and on firm location keeping the migration condition unchanged [equation (9)].

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 τa_i^* according to ψ_i, as discussed for the symmetric case. The optimum for both countries under the condition of cooperation and maintaining the status quo is obtained by setting $\tau a_1^{*coop} = 0.43$ and $\tau a_2^{*coop} = 0.25$ for $\psi_1 = 0.3$ and $\psi_2 = 0.2$ respectively. Trade costs are assumed at a value of $\tau = 1.1$.

Solving the tax game step (1) numerically and using the same parameter values as in Figure 3, country 2 takes the optimal tax rate of country 2 as a constant, $\overline{\tau a_1^{*coop}} = 0.43$, and varies its tax rate in order to attract skilled labor and provoke firms dislocation.[7] While Figure 4a) shows state utility, the absolute number of firms is shown in Figure 4b).

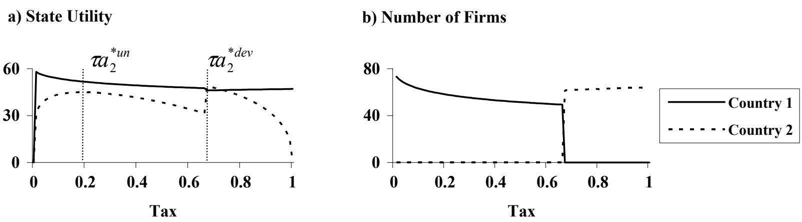

Figure 4: Core-Periphery: Deviation of Country 2

Note that the utility function as well as the corresponding number of firms is discontinuous: reaching a value of $\tau a_2^{*dev} = 0.67 \big| \tau a_1^{*coop} = 0.43$ massive inward migration of qualified labor[8] leads to a dislocation of firms - Figure 4b) - 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. In Figure 4a) there are two relevant tax rates for country 2: while the first tax rate $\tau a_2^{*un} = 0.19$ represents the optimum for remaining agricultural

[7] The whole range of tax rate values is shown in order to give a full description of the impacts of tax deviation. However, only tax rates greater than $\tau a_2^{*coop} = 0.25$ can lead to inward migration and therefore to a structural change in the status quo.

[8] While there is a continuous flow of skilled labor from country 1 to country 2 due to higher tax rates and therefore higher wage proposals in country 2, reaching τa_2^{*dev} results in a jump in inward migration.

hinterland, the second tax rate characterizes deviation by setting $\tau a_2^{*dev} = 0.67$ and being industrialized.[9] However, country 2 would prefer to raise its tax rate in order to get the core, $WE_2^{*dev} > WE_2^{*un}$.

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 decisions is neutralized. In doing so, country 1 has to increase its tax rate in order to offer higher wages and to keep the migration condition unchanged. Equation (9) can be rearranged to:

$$\tau a_1^{eq} = 1 - (1 - \tau a_2^{nd}) / \Omega^{CP} \tag{22}$$

with $\Omega^{CP} = \dfrac{w_{1,H} / q_1^{-\gamma}}{w_{2,H} / q_2^{-\gamma}}$ as the real wage gap of skilled labor. As long as country 1 is willing to keep the real wage rate gap Ω^{CP} unchanged by choosing a strategic tax rate itself, the core periphery equilibrium remains stable. Considering τa_1^{dev} as an optimal response to $\tau a_2^{*dev} \big| \tau a_1^{*}$, country 1 has to be sure that there is no 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 could gain the core and raise utility by increasing its tax rates, $WE_2^{*dev} > WE_2^{*un}$, or until country 1 finds it worthwhile to surrender the core and to rely on agricultural production. Figure 5 shows the stylized decision problem for country 1.[10]

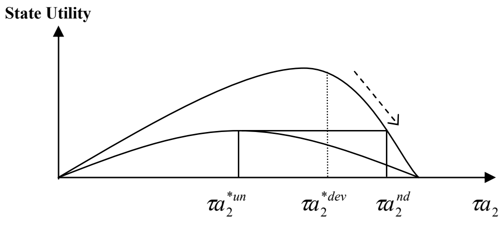

Figure 5: Tax Game: Decision Problem of Country 1

The diagram in Figure 5 reproduces the choices for country 2 in either remain underdeveloped (lower utility curve) or gain the core and be 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

[9] At the same time that industry shares switch from country 1 to country 2, preferences for public goods have to be such adjusted that country 2 - being industrialized - now has the higher preference towards public goods.

[10] Note the difference to the model analyzed by Baldwin and Krugman (2004), where the periphery has to lower tax rates in order to attract mobile factors.

between τa_2^{nd} as a strategic tax rate to get the core and τa_2^{*un} as an optimal tax rate to refrain from tax competition and to remain underdeveloped. Having identified country's 2 deviation tax rate τa_2^{nd}, which leads to the same utility value as in the case with no deviation, equation (22) determines the tax rate of country 1 in order to remain industrialized, τa_1^{eq}. Finally, country 1 has to ascertain whether it is worthwhile keeping the core:

$$WE_1^{eq} \geq WE_1^{*un}, \tag{23}$$

where WE_1^{*un} corresponds to an optimal utility value imposed when being agricultural hinterland. If equation (23) is not fulfilled, country 1 would give up the core and set τa_1^{*un} producing solely agricultural goods. But as long as we assume that both countries have the same share of immobile factors, the potential to be core or periphery country is the same for both. Hence, the utility curves plotted in Figure 5 also apply for country 1. In any case, the periphery can only attract skilled labor to such an extent that the industrialization process is reversed by setting a higher tax rate than the core. Therefore, the core country's tax rate τa_1^{eq} is lower than τa_2^{nd}. As Figure 5 shows keeping the core and engaging in tax competition is always the better choice for country 1 than losing the core, $WE_1^{eq} > WE_2^{*un}$.

Indeed, numerical simulations prove that country 1 has to raise tax rates up to τa_1^{eq} in order to keep the core and to prevent country 2 from being industrialized. Hence, instead of deviation and engaging in the tax game, country 2 would keep τa_2^{*un} as the best response to τa_1^{eq}.

> ***Proposition 2:*** Tax competition in a strategic tax game forces industrialized countries to increase their tax rates in order to maintain the status quo. In pushing their comparative cost advantage of higher research activity industrialized countries prevent migration and production outsourcing from occurring.

Trade Liberalization

Additionally, numerical simulations also show that as economies become closer (i.e. in terms of trade liberalization), the core country has to increase its tax rate to an even higher extent favoring therefore skilled labor at the expense of unskilled labor.

Figure 6 shows the development of tax rates - τa_1^{eq} and τa_2^{*un} - on the right scale as well as the real wage gap between skilled and unskilled labor within countries on the left scale. As integration continues (from $\tau = 1.1$ to $\tau = 1.08$), tax competition forces country 1 to increase its tax rates leaving unskilled labor worse off relative to skilled labor. Additionally, by losing skilled labor to the core country, the wages of skilled labor in the periphery also increase, although tax rates remain unchanged. Therefore the real wage ratio of skilled to unskilled labor rises in country 2 but to a lower extent than in country 1.

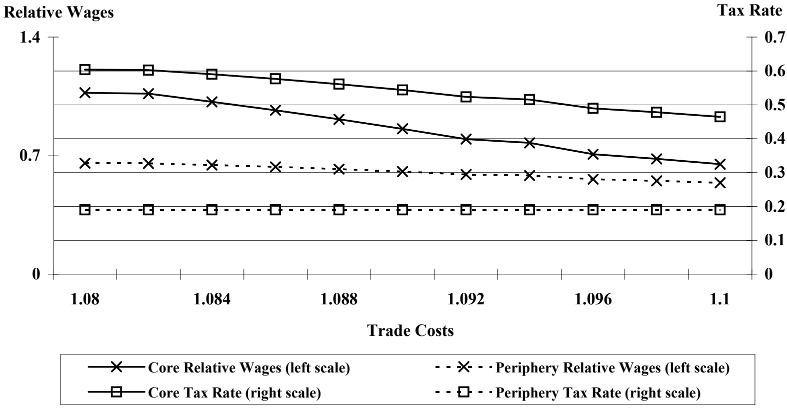

Figure 6: Trade Liberalization: Relative Wages and Tax Rates

> ***Proposition 3:*** Tax competition in industrial countries leads to a higher tax burden for immobile factors than for mobile factors. As integration continues skilled labor is always favored at the expense of unskilled labor.

Asymmetric Migration Costs

We now turn to migration costs. To analyze the effects of strategic tax-setting on factor flows we assume that only immigration of skilled labor from the periphery to the core have to consider migration costs and is therefore taken into account by equation (9), whereas vice versa no migration costs occur. Or to put it differently, one can imagine factor mobility restrictions as quotas or qualitative requirements imposed by the industrialized countries in order to control such migration flows. Once migration takes place, monetary costs such as physical movement, the inclusion in social systems and even money transfers to relatives are taken into account when analyzing the effect on national income and consumption.

Figure 7 plots equilibrium tax rates τa_1^{eq} and τa_2^{*un} on the right scale and the number of firms in the core country on the left scale against diminishing migration costs (from $\tau b_1 = 0.1$ to $\tau b_1 = 0$). Firstly, the higher the migration costs are, the higher the tax rate is set by the core country: the core country has to increase nominal wages in order to compensate for migration costs and therefore raise the incentive for skilled labor to immigrate. This results in higher income tax rates in the core country. In contrast, the tax rate chosen by the periphery as an agricultural hinterland remains unchanged. Secondly, such migration costs are sunk costs to the industrialized countries: the share of imposed taxes used as a wage compensation for the occurred migration costs is lost for overall national consumption [equation (12)] and does not enter national accounts. As a consequence, the core's number of firms and products partly determined by national consumption spending is reduced the higher the migration costs are, as can be seen on the left scale in Figure 7.

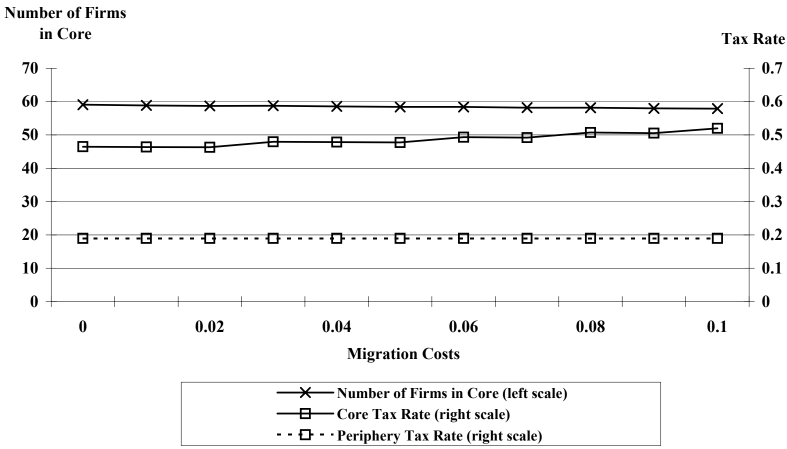

Figure 7: Tax Competition and Asymmetric Migration Costs

Proposition 4: The cutback of migration costs in the presence of tax competition pushes economic development in industrialized countries at the expense of structurally backward regions. As a result, the brain drain of skilled labor hurts periphery countries whereas core countries gain.

5. Conclusion

Increasing tax competition as a direct consequence of further economic integration forces countries to adapt their taxes in order to keep the status quo and to prevent outward 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 situation, core countries offset the effect of strategic tax-setting by the periphery on production location and migration flows by higher incentives and may therefore increase their tax rates. Hence, in both cases the standard result of a "race to the bottom" does not apply. Moreover, if factor owners move with their factors and account for public goods governments are more likely to augment the provision of such goods. In increasing the attractiveness of the country, mobile factors immigrate even though higher income taxes are levied.

As outlined above, tax-setting is not only constrained by tax competition but also by the extent of economic integration. As economies and markets grow together it may be worthwhile for periphery countries to not engage in strategic tax-setting but to set a socially optimized tax rate. As factor mobility restrictions are relaxed, periphery countries suffer a brain drain towards core countries and lose skilled workforce as the valuable input for self-determining economic development. In contrast, those countries with a high share of industrial and economic activity partly based on the presence of such mobile factors are not about to lose industry shares and are therefore willing to offer higher incentives in order to keep the status quo. If this is financed or subsidized by an income tax that redistributes between mobile and immobile factors, tax competition in economically integrating regions ends up as a higher tax burden for unskilled labor in core countries. As integration continues skilled labor is always favored at the expense of unskilled labor.

As outlined by Baldwin and Krugman (2004), during the first stages of European integration, average taxes were increased in all participating countries but to a higher extent in the industrialized core nations such as Germany or France than in the lesser industrialized Mediterranean countries or in Ireland. It is difficult to say whether increased economic integration and further political enlargement of the EU should be accompanied by tax harmonization within member countries. Our analysis shows that at least for symmetric countries the adoption of common tax rates would be a socially desirable outcome for controlling migration flows. Particularly as countries with fairly similar levels of institutional and economic development has implemented full factor mobility of people inside their territories according to the Schengen agreements of 1985 and 1991. However, if countries are different in size and economic power a temporary factor mobility restrictions for qualified labor may serve as an adequate migration policy option for prospective members not for core members. Therefore, Central and Eastern European countries are more likely to profit from factor mobility restrictions imposed by the former EU countries at the first stages of economic integration. In preventing the described brain drain towards the rich countries in the EU, such countries sustain at least the opportunity for self determined growth. And, partly due the fact that the majority of their workers have vocational trainings and are probably as well qualified as the overall average in Germany as outlined in DIW (31/2001), this augments the incentive for foreign direct investments and production outsourcing as another potential source of growth.

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Appendix

Specific details for parameters and numerical simulation as well as further information about the derivatives in equation (20) are listed in the appendix.

(A) The Choice of Parameters and Numerical Simulation

The numerical simulation is calculated in Gauss and can be requested from the author. The parameters are set to $\mu = 0.6$, $\sigma = 6$, $\iota = 0.6$, $\gamma = 0.3$ and $\theta = 0.8$. The parameter β is normalized to $\beta = \rho = (\sigma - 1)/\sigma$. The technology parameter for firms' fix costs is set to $A = 1/8$. The technological spillover effect is $\Gamma = 0.5$. Total factor endowment of unskilled and skilled labor is assumed to be the same for both countries.

The methodology used for numerical simulation follows Baldwin et al. (2003) and Puga (1999). In order to analyze the impact of government taxation on economic development and industrial agglomeration tax rates are set first, followed by migration and production decisions until economies reach steady state equilibria. Based on the prior determined number of operating firms N_i and the price index q_i, the nominal wages $w_{i,U}$ of unskilled labor can be calculated for a short-run equilibrium. Concurrently, as tax rates have been set the share of unskilled labor in manufacturing $L_{i,U}$ as well as of skilled labor m_i in R&D can be calculated. Subsequently, the number of firms is varied and migration and production decisions adjusted until equation (16) is satisfied. In a long-run equilibrium there is no further incentive for firms to fluctuate or for labor to migrate.

(B) Optimal Tax-Setting

In order to analyze the effect of a tax change on taxable income Y [equation (6)] and therefore on state utility [equation (7)], differentiation of (Y/q) with respect to τa at the supposed symmetric equilibrium yields to:

$$\left.\frac{d(Y/q)}{d\tau a}\right|_{m=1/2} = \left(\frac{L}{q}\frac{dw_U}{dn} + \frac{B}{q}\frac{dr(w_r)}{dL_r}\frac{dL_r}{dn} - \frac{Y}{q^2}\frac{dq}{dn}\right)Z + \frac{w_H}{q}\left(1 + \frac{m}{w_H}\frac{dw_H}{dm}\right)\frac{dm}{d\tau a}, \tag{19}$$

where $\dfrac{d(\int \pi(h)dh)}{d\tau a}$ is zero and $Z = \dfrac{dn}{dFE}\dfrac{dFE}{dm}\dfrac{dm}{d\tau a}$.

A further look at equation (19) leads to the following conclusions:

(1) $\frac{dm}{d\tau a} > 0$: A higher tax rate leads to a higher inflow of skilled labor. Substituting equation (5) in equation (9) and total differentiation by using two sub-functions $f[\tau a] = \tau a_1$ and $g[m] = \frac{q_1^{-\gamma}(1-\tau b_1)Y_1^{GDP} / m_1}{q_2^{-\gamma}\tau a_2(1-\tau b_2)Y_2^{GDP} / m_2}$ at the supposed symmetric equilibrium by holding the tax rate of the counterpart constant leads to:

$$g[1/2]\frac{\partial f[\tau a]}{\partial \tau a}d\tau a + f[\tau a]\frac{\partial g[m]}{\partial m}dm = 0 \text{ or } \frac{dm}{d\tau a} = -\frac{g[1/2]}{\frac{\partial g[m]}{\partial m}\tau a}. \qquad \text{(B.1)}$$

Rearranging $g[m]$ by the use of $m = m_1/(m_1 + m_2)$ and with $D = \frac{q_1^{-\gamma}(1-\tau b_1)Y_1^{GDP}}{q_2^{-\gamma}\tau a_2(1-\tau b_2)Y_2^{GDP}}$ leads to $g[m] = D\frac{1-m}{m}$. Equation (B.1) can be calculated as:

$$\left.\frac{dm}{d\tau a}\right|_{\tau a=\psi} = -\frac{D}{-\frac{D}{m^2}\psi} = \frac{m^2}{\psi} = \frac{1}{4\psi} > 0. \qquad \text{(B.2)}$$

(2) Z > 0: A higher tax leads to an increase of skilled labor [equation (B.2)] and therefore to a higher research output. The availability of research results is restricted by the technological spillover effect: a shift of skilled labor from abroad also increases the national research level [equation (4)]. Hence, fix costs at firm level are reduced - $\alpha = A/FE$ - leading by equation (17) to a higher number of firms. The sign of Z is therefore positive.

(3) $\frac{d(w_U)}{dn} > 0$: Z > 0 leads to a higher demand for unqualified labor in the industrial sector and raises therefore nominal wages for unskilled labor.

(4) $\frac{dr(w_R)}{dL_R}\frac{dL_R}{dn} < 0$: Z > 0 results in a higher share of unqualified labor employed in manufacturing and therefore in a loss of labor shares in agriculture: $L_R = L - L_U$.

Higher wages in the agricultural sector due to increased productivity of unqualified labor lead to a lower profit rate per unit of land $r(w_R)$ by equation (1).

(5) $\frac{dq}{dn} < 0$: Z > 0 decreases the price index [equation (11)] as more firms and products are concentrated within countries.

(6) $\varepsilon_{W_H,m} = \frac{m}{w_H}\frac{dw_H}{dm} = -1$: All other things constant, a one percent increase in skilled labor decreases wage rates by one percent. Wage elasticity with respect to skilled labor and the use of equation (5) can be stated as:

$$\varepsilon_{W_H,m} = \frac{m}{w_H}\frac{dw_H}{dm} = \frac{m}{w_H}\left(-\frac{\tau a Y}{m^2}\right). \tag{B.3}$$

Re-substitution of equation (5) in equation (B.3), the wage elasticity can then be written as:

$$\varepsilon_{W_H,m} = \frac{m}{w_H}\left(-\frac{m w_H}{m^2}\right) = -1. \tag{B.4}$$

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