SEZ, Regional Development and Disparity
-multiple equilibria through labor market frictions in a neoclassical model of regional growth and development

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Abstract

In some developing countries a lot of economic privileges were given to Special Economic Zones (SEZ). These privileges facilitated international integration. Opening for international investors boosted economic growth in these regions. Hence, a strong regional disparity developed. In this theoretical paper we would like to contribute to this discussion by taking a closer look on the interdependencies of regional development: In a neoclassical model of regional growth and development with imperfect labor markets (other than in NEG model) we will show five effects of regional development: 1. Regional development can in deed be driven by international integration via FDI, exports, and technological catching up. 2. This process of rapid regional growth in some regions will happen by causing income disparity between regions. 3. As we obtain multiple equilibria and path dependence there is no symmetry in economic development when all regions introduce identical conditions some times later. 4. Early development of the privileged regions and the resulting advantages cannot be compensated by just giving identical conditions to lagging regions later on; history matters. 5. Historical disadvantages sometimes can be compensated by government activities.

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JEL Classification: F15, J61, J64, O14, O18, O33, O40, R58

1 International integration and regional growth and agglomeration

The effects of trade and economic *integration* have been discussed in a number of papers within the framework of New Regional Growth Theory. Eaton and Kortum (2001) follow a quality ladder model with endogenous innovation and trade and analyze the effect of lower geographic barriers on trade, research and productivity growth. Baldwin and Forslid (2000a) look at stabilizing or destabilizing effects of integration, while Baldwin and Forslid (2000b) introduce scale economies and imperfect competition into the R&D and financial intermediation sectors of a Romer-Grossman-Helpman endogenous growth model.

Baldwin and Martin (2003) show that the relation between growth and agglomeration depends crucially on capital mobility between regions. To some extent this model is a variation of the type of approach close to Baldwin (1999), Baldwin, Martin and Ottaviano (2001) and Martin and Ottaviano (1999). The first two papers analyze models of growth and agglomeration without capital mobility. In contrast to Baldwin (1999), who uses an exogenous growth model, Baldwin and Martin (2003) consider endogenous growth. Baldwin, Martin and Ottaviano (2001), who study the case of global technology spill-over, present a model of growth and agglomeration with perfect capital mobility in the context of North-South income divergence.

Only a small number of approaches to New Regional Growth Theory allow for endogenous growth and migration as a driving force of agglomerations. Even if the connection between growth and migration seems very obvious, only few papers have appeared. Walz (1996), Puga (1999), Baldwin and Forslid (2000a), Black/Henderson (1999b), Fujita and Thisse (2002,Ch.11), and recently Kondo (2004) introduced this link. The basic framework of these models is again monopolistic competition and increasing returns to scale, combined with an endogenous growth process often close to Romer (1990) and Grossman/Helpman (1991 ch. 3).

For a developing country, access to relevant production factors, international spill-over and externalities through technologies and infrastructure are relevant determinants of growth and development.[1] While the idea of NEG basically works through increasing returns to scale, monopolistic competition, market size and pecuniary externalities, the idea in this paper is somehow different. Within a neoclassical model, externalities are technical and information externalities in the imitation process. Market imperfection is located in the labor market. Nonseparability of growth, urbanization and regional agglomeration have combined interactions. The main reason why firms are located in a certain region is the access and proximity to international technologies and a pool of human capital. Informational spill-overs lead to more efficient production for clustered firms than for isolated producers. In the discussion of this process Glaeser et al (1992) points to the distinction between Jacobs (1969) and MAR (Marshall-Arrow-Romer) externalities. MAR externalities focus on knowledge spill-over processes

[1] See e.g. Fujita/Thisse (2002 ch.11), Bottazzi/Peri (1999) or Kelly/Hageman (1999).

between firms of the same industries. MAR externalities were discussed first by Marshall (1890 [1920]) and Arrow (1962). Starting with Romer (1986) this kind of spill-over process plays a crucial role in many models of the new growth theory. Jacobs externalities are not industry specific, but more of a general type. They occur between firms which do not need to be in the same industry cluster. From an empirical point of view both externalities seem to matter. Glaeser et al. (1992) found evidence for Jacobs externalities while Black/Henderson (1999a) and Kelly/Hagemann (1999) identified MAR externalities.

Taking these ideas of international spill-over and externalities as the point of departure section 2 develops a neoclassical model of growth for a single backward region. In order to elaborate the interaction between migration, agglomeration, technology spill-over from FDI, and development, we are focusing on the macro mechanics of development, rather than concentrating on sophisticated micro foundations. This model will be so stylized and simplified that a region can be modeled with four equations. While 3 equations are taken from neoclassical standard approaches the fourth equation covers labor market frictions modeled by an imperfect matching process. By introducing labor market frictions and uncertainty in the migration process we obtain a multiple equilibrium solution. Section 3 adds a second region to define a developing country where human capital is mobile between the regions and identifies multiple equlibria. Section 4 analyzes the endogenous formation of regions if international transaction costs non-symmetrically change in the regions and human capital can migrate between regions. We will show five effects of mutually dependent regional development, agglomeration and disparity: 1. Regional development can in deed be driven by international integration via FDI, exports, and technological catching up. 2. This process of rapid regional growth and agglomeration in some regions will happen on cost of other regions, causing regional income disparity. 3. With the existence of multiple equilibria the process of gradual and sequential introduction of international integration of different regions is highly path dependent. Section 5 discusses the implications of path dependency.

2 A four equation model of regional growth

The stylized macro model proposed in this section consists of two regions in which an international traded final good is produced with immobile land, regionally mobile human capital and internationaly mobile real capital. Due to positive externalities, inflowing FDI induce imitation and hence productivity growth. Mobile human capital can migrate according to wage arbitrage. The regional government can influence the economy by changing international transaction costs (transport costs as well as barriers to trade), and by providing the public infrastructure required for imitation. The economy under consideration is a small region i integrated into the world economy. The region is located in a developing country and characterized by a technological gap compared to leading industrialized countries.

Final output: The final output sector uses land L_i international capital flowing into the region as FDI K_i and labor N_i to produce a homogeneous final good X_i. Based on the small country assumption and integration of regional goods markets into world markets, the production function of the final good can be regarded as Findlay's *foreign exchange production function*[2]. Hence X_i is a production value function measured in international prices. With the concept of the *foreign exchange production function* the aggregate production value function stands for a continuum of industries characterized by different factor intensities valuated in given international prices. Each level of output value indicates a full specialization in the industry characterized by the corresponding factor intensity. A change in output value and hence factor intensity indicates a switch of specialization pattern towards another industry. As international capital is the only real capital in the production process, the final output sector is owned by international investors. The inflowing international capital is fully depreciated during the period of influx.[3]. The production of the final good takes place under perfect competition and constant economies to scale and is described by a Cobb–Douglas technology

$$\begin{aligned} X_i &= \omega_i L_i^{\alpha} K_i^{\beta} N_i^{1-\alpha-\beta}, \\ with \quad \omega_i &= A_i/A \end{aligned} \tag{1}$$

where A_i is the regional level of technology and A is the technology level of the technology leader which increases at a given rate n. In this production function the technology stock is normalized for the level of the technological leader. Hence the relative technological position ω_i, rather than the absolute position of domestic technology A_i, enters the production function.

In New Economic Geography models the existence of scale economies and imperfect competition is crucial. "... the constant returns-perfect competition paradigm is unable to cope with emergence of large economic agglomerations. Increasing returns in production activities are needed if we want to explain economic agglomerations without appealing to the attributes of physical geography." Fujita/Thisse (2002 p.7).[4] The simple model introduced here allows for agglomerations without increasing returns to scale in production.

The domestic product is used for government expenditures, domestic consumption and exports. Total capital costs for international capital r_i are earned by exports. Government expenditures G_i are defined as investments in technology-relevant public spending. These investments are taken from aggregate output. They are a politically determined fraction γ_i of GDP.[5]

[2] See Findlay (1973, 1984).

[3] Another way to introduce international capital in domestic production for the final good in a more micro-related way is the introduction of intermediate goods. $X_i = L_i^{\alpha} H_i^{1-\alpha-\beta} \int_0^A x(i)^{\beta} di$. If an intermediate good $x(i)$ is produced with κ units of capital the production function converts to $X = L_i^{\alpha} H_i^{1-\alpha-\beta} K_i^{\beta}$. In facts, for different parts of this model more sophisticated micro-modelling could be done. However, to keep things as straight as possible, I will always choose the most simple way of modelling to make the point.

[4] See also Krugman (1995 ch. 1).

[5] Government spending is financed by taxation of the immobile factor.

FDI inflow and exports: Optimal capital inflow is derived from the firms' optimal factor demand. Due to the small country assumption, capital cost in a region are determined by the exogenous world market interest factor r[6] and an ad valorem factor for region specific international transaction costs τ_i. τ_i may include a risk premium related to the specific region. Since we also look at trade policies we introduce τ_i^{ex} as an transaction cost parameter for exports. τ_i^{ex}may be an export tariff or the equivalent of bureaucratic transaction costs. τ_i^{ex} is modeled as ice berg cost on exports. As we assume that returns on international capital investments in a region K_i will be fully repatriated, exports Ex must earn international interest rates and all international transaction costs. On the firm level $Ex_i(1-\tau_i^{ex}) = \tau_i r K_i$. Solving the firms' optimization problem[7] we obtain the optimal influx of foreign capital

$$K_i = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} X_i. \tag{2}$$

To keep things simple, international borrowing or lending beyond FDI is excluded. Since international capital costs have to be paid by exports we can determine the export value necessary to cover international capital costs including all transaction costs

$$Ex_i = \frac{\tau_i r_i}{(1-\tau_i^{ex})} K_i, \qquad \frac{Ex_i}{X_i} = (1-\gamma_i)\beta.$$

Whereas, the export share of GDP is simply determined by the elasticity of production of foreign capital β and the tax rate γ_i (2).

Land, labor market frictions and unemployment: While the production function (1) and the choice of optimal input of foreign capital, as well as introducing business land L_i as a fixed and given factor is neoclassical standard, the labor market is assumed not to be perfect. Unemployment (open or hidden) is a widely observed phenomenon in developing countries. Therefore, in this stylized model of a developing region we would like to include a simple labor market unemployment model. While in many models of development unemployment is modeled using a version of the 'Todaro model' we suggest a very simple matching approach. We choose the matching approach as this approach can address the problem of changing job characteristics driven by structural change and the development of a modern sector. The matching model also allows for an easy integration of heterogenous labor. Workers have ability profiles which have to match with the profiles of vacant jobs offered by firms.

[6] The interest factor is one + interest rate.

[7] The firm has to determine optimal factor inputs by maximizing profits.

$$\begin{aligned}\pi_i &= (1-\gamma_i)F(L_i,K_i,N_i) - Ex_i - wN_i - \rho L_i \\ &= (1-\gamma_i)F(L_i,K_i,N_i) - \frac{\tau_i r}{1-\tau_i^{ex}}K_i - wN_i - \rho L_i\end{aligned}$$

Since all capital services have to be payed in terms of exports full capital cost include several components like government taxes on output γ_i or transaction costs for exports.

In order to keep the model as simple as possible we simplify the rather sophisticated modelling of the matching approach as introduced by Diamond (1982), Howitt (1985), Mortensen (1989) or Pissarides (2000) to a simple search and matching mechanic, which finally reduces to only one simple single labor market equation:

Human Capital (h.c.): The aggregate endowment of human capital is defined by the number of skilled workers H_i in a region. At any point in time these workers are either employed N_i, or unemployed U_i and searching for a job

$$N_i + U_i = H_i, \quad i = 1, 2. \tag{3.1}$$

Labor market activities are described by *separation of jobs* and reemployment activities of firms, and *search activities* of workers. There is a flow out of recently separated jobs into the labor market and another flow out of the labor market into newly created jobs. The fit of a worker's ability profile and the job requirements given by firms determine the success of this labor market matching process.

Separation of Jobs: Firms determine an optimal level of factor input N_i. Because of permanent restructuring of production job specifications must be permanently adjusted. Hence a certain number of jobs will be separated and adjusted to new requirements. Job separation can be described by a random process with an expected rate of separation σ. Hence, the expected number of vacancies offered to the market is

$$V_i = \sigma N_i. \tag{3.2}$$

Search for jobs and matching: Workers in a region try to find a job. In order to fill a vacancy there must be a match of a worker's ability profile and job requirements defined by the firm. The number of successful job matches, M_i, is determined by search activities of the yet unemployed labor U_i. In many matching models search activities are investments and hence part of optimal firm decisions. In order to keep the model as simple as possible we abstract from economically determined search decisions of firms[8] and reduce the search and matching process of workers to a pure random process. Hence, the individual probability of finding a job (to have a match) p_i is described by a poissant distribution[9] and given by

$$p_i = \frac{M_i}{U_i} \tag{3.3}$$

$$p_i = \lambda_i e^{-\lambda_i} \quad i = 1, 2. \tag{3.4}$$

[8] See again Diamond (1982), Howitt (1985), Mortensen (1989) or Pissarides (2000).

[9] In many matching models the matching process is covered by a linear homogeneous matching function. There is empirical evidence that the assumption of a linear homogeneous matching function is reasonable (See Pissarides (2000, p35) and the references therein, and Petrongolo/Pissarides (2001)). Nevertheless, Diamond (1982), Howitt (1985), and Mortensen (1989) allow for increasing returns and obtain more interesting results including multiple equilibria and coordination failures. Referring to the purpose of this paper we try to keep things simple and cover the idea of a labor market matching process by a pure random process.

Further, we assume, that the expected rate of matching is negatively related to the tightness θ_i (presently unemployed workers to vacancies) of the labor market

$$\theta_i = U_i/V_i \tag{3.6}$$

and the size of the information set relevant for the search process. The size of the informaiton set is indicated by the number of jobs N_i. Therefore, in this simplifying model, the matching process is driven by technical parameters of the search process, rather than economic decisions

$$\lambda_i = \lambda\left(\theta_i, N_i\right) = \theta_i^{-\varepsilon_i} N_i^{-\mu_i} \quad 0 < \varepsilon_i, \mu_i < 1. \tag{3.5}$$

Labor market equilibrium: The labor market flow process is defined by a simultaneous inflow of workers into the market and an outflow of labor out of the market. The inflow into the labor market is fed by separations of jobs leading to vacancies. Outflow out of the labor market is driven by job matches, i.e. an unemployed person can fill one of the recently separated and now vacant jobs. In the instantaneous labor market equilibrium, on average all vacancies are filled. The expected number of vacancies ($V_i = \sigma_i N_i$) equals the expected number of matches λU_i

$$\lambda U_i = V_i. \tag{3.7}$$

The equilibrium rate of labor market tightness θ_i and the level of unemployment U_i in the region can now be determined as a function of total jobs available in the region, N_i[10]

$$\theta_i = N_i^{\frac{\mu_i}{(1-\varepsilon_i)}}, \tag{3.8}$$

$$U_i = \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)}. \tag{3.9}$$

The economic reasoning of an equilibrium tightness and unemployment is rather simple. Due to frictions in the search and matching process more workers have to be in a region to exactly fill the presently vacant jobs. If search and matching processes were perfect, the exact number of workers would be sufficient. Under non perfect matching conditions the equilibrium unemployment rate is

$$\begin{aligned} u_i &= \frac{U_i}{H_i} = \frac{U_i}{U_i + N_i} = \frac{\sigma N_i^{\frac{\mu_i}{(1-\varepsilon_i)}}}{\sigma N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} + 1} \\ \frac{du_i}{dN_i} &= \frac{\mu_i}{(1-\varepsilon_i)} \frac{\sigma N_i^{\frac{\mu_i}{(1-\varepsilon_i)}-1}}{H_i} \left[1 - u_i\right] > 0. \end{aligned} \tag{3.10}$$

From 3.7 and 3.6 we can determine the expected rate of matches λ_i as a function of N_i jobs in the region[11]

$$\lambda_i = N_i^{-\frac{\mu_i}{(1-\varepsilon_i)}}. \tag{3.11}$$

[10] See appendix 1a and 1b.

[11] See appendix 1c.

Using 3.1 and 3.9 we can also determine the labor market equilibrium relation between the number of workers H_i in the region and the number of jobs N_i which could potentially be filled, taking into account the rigidities of the search and matching process.[12]

$$N_i = N_i(H_i), \quad \frac{dN_i}{dH_i} = \left[1 + \left(1 + \frac{\mu_i}{(1-\varepsilon_i)}\right)\sigma N_i^{\left(\frac{\mu_i}{(1-\varepsilon_i)}\right)}\right]^{-1} = \nu_i(N_i) > 0. \quad (3)$$

In other words, immigration of one additional skilled worker (unit of human capital) leads to an increase of the resource base of the region that allows for ν_i more jobs that can be filled under the present matching conditions.

Determining the production level: Including optimal capital imports in the production function leads to the production level[13]

$$X_i = \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)_i^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}.$$

Technology and imitation: The developing region does not create new knowledge, but acquires technologies by decoding and imitating foreign designs from international technology leaders. In the present model growth through technological imitation and agglomeration is driven by three components:[14]

1) International knowledge spill-over and hence positive technological externalities from the influx of FDI: Access to international technologies is due to international integration into the world economy. The local economy obtains international technologies by an information channel that implicitly and explicitly opens with trade and FDI. Trade and FDI define the channel of transmission of international knowledge to the local economy. In a partial equilibrium model for multinational firms some of these channels were modelled by Markusen/Venables (1999). Here the macro result of this externality is used in the simplest possible way.

2) Technology and firm relevant public infra structure: Martin (1999) analyzed the effects of public policies and infra structure to the growth performance of a regional economy. In order to make FDI effective for the host region suitable local conditions in terms of local infrastructure must be available. This externality from a public good combines with the spill-over from FDI.

3) The technology gap $(1-\omega)$ between the developing region and world leaders in technologies: As the focus is on underdeveloped regions the case of innovations in this backward region is excluded. The imitation process is affected by the technology gap between the backward region and the industrialized world.

[12] See appendix 1d.

[13] See appendix 1e.

[14] There is a broad literature on international technology diffusion with various channels suggested. Eaton/Kortum (1999) disucss trade as a channel of diffusion in a multi-country setting. See also Coe/Helpman (1995) who link the direction of technology diffusion to exports. Keller (1998) however has some doubts about the link between trade and diffusion.

If the domestic stock of technology is low (ω is small), it is relatively easy to increase it by adopting foreign designs. However, the process becomes increasingly difficult as the technology gap narrows. This idea draws back to the well-known Veblen-Gerschenkron Hypothesis[15]. Later Nelson/Phelps (1966), Gries/Wigger (1993), Gries/Jungblut (1997) and Gries (2002) further developed these ideas in the context of catching-up economies. Even if the catching-up hypothesis was tested successfully and robustly by Benhabib/Spiegel (1994), de la Fuente (2002), and Engelbrecht (2003), it is amazing that catching-up as a process of relative technology upgrading compared to a technology leader has rarely been modeled in growth and development theory. Even more, technological progress can easily be modeled as a process of endogenous catching-up where the exogenous process is driven by international innovation growth.

Considering all three effects the relative increase of domestic technologies by imitation activities and hence the speed of closing the gap to the technology leader (rate of convergence) is described by a simple relative growth mechanics[16]

$$\dot{\omega}_i(t) = G(t)_i^{\delta_G} K(t)_i^{\delta_K} - \omega(t), \tag{4}$$

where G_i denotes government outlays in technology-relevant public infrastructure, and t denotes time. The externalities from FDI and government infrastructure are assumed to have a rather limited effect on imitation such that $\delta_G + \delta_K = \delta < 1$ is small.

The three equations (1), (2), and (4) capture the model of regional development. The solution to (1), (2), and (4) is a differential equation determining the growth of the relative stock of technology available to the region (catching-up in technology)[17]

$$\dot{\omega}_i(t) = \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t).$$

To simplify, this equation is rewritten as[18]

$$\begin{aligned} \dot{\omega}_i(t) &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t), \qquad \frac{d\dot{\omega}_i(t)}{d\omega(t)} < 0 \qquad (5) \\ \text{with} \quad \Psi_i &:= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta}. \qquad (6) \end{aligned}$$

For each endowment we can determine the steady state position ω_i^* of the

[15] See Veblen (1915) and Gerschenkron (1962).

[16] For the dynamic catching-up-spill-over equation we assume that G and K are sufficiently large for positive upgrading.

[17] See appendix 1f.

[18] The dynamic catching-up-spill-over equation contains a scaling problem if G and K are taken as absolute values. As ω is defined relative to the leading technology G and K can be also regarded relative to an external nomeraire. As the region is assumed to remain backward, the values of Ψ, L and N are assumed to be sufficiently small. See appendix 1a for the derivatives.

region[19] from $\dot{\omega}_i(t) = 0$[20]

$$\begin{aligned}
\omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} && (7) \\
\frac{\partial \omega_i^*}{\partial N_i} &= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega^* N_i^{-1} > 0, && (8) \\
\frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_K + \frac{\beta}{1-\beta}\delta \right] \tau_i^{-1} < 0 && (9) \\
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_K + \frac{\beta}{1-\beta}\delta \right] (1-\tau_i^{ex})^{-1} < 0 && (10) \\
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[(\gamma_i^{\delta_G})^{-1} - \left[\delta_K + \frac{\beta}{1-\beta}\delta \right] (1-\gamma_i)^{-1} \right] > 0. && (11)
\end{aligned}$$

The essential determinants of the speed of convergence and the final relative convergence position are the endowment of human capital N_i, technology relevant government expenditure indicated by γ_i, and international (and domestic) transaction costs connected to FDI, τ_i and connected to exports, τ_i^{ex}.

The economic story is rather simple. Reducing τ_i will reduce costs of international capital and increase the input of international capital. With more FDI or government investments into the region, spill-over and positive externalities will accelerate imitations and technology convergence and in turn improve the final relative technology position of the region. Similar, with a larger endowment of human capital or land, capital productivity will increase such that additional FDI speeds up imitation and the final position of the region improves.

As will be shown later, not only rather obvious determinants like $N_i, \tau_i, \tau_i^{ex}, \gamma_i$ are important. Technology parameters related to industry characteristics like β or the spill-over characteristics of a certain industry like δ_K may play an important role for the success of a region.

3 Two regions and multiple equilibria

To analyze interregional migration and agglomeration we need to look at two regions $i = 1, 2$ in a country. Both regions have a local immobile factor (land) and a mobile factor, human capital, i.e. workers with some skills. Since the country's total endowment of human capital. H can migrate from one region to the other, human capital allocation can change over time:

$$H = H_1(t) + H_2(t). \tag{12}$$

[19] We assume that the contribution of FDI to production β as well as externality effect from FDI on the technology δ are suficiently small. This also reflects the already mentioned assumtion of a rather limited spill-over effect of FDI to the relative catching up process.

[20] The reaction $\frac{\partial \omega_i^*}{\partial \gamma_i}$ suggests, that there is an optimal tax rate, that can maximize final development position. Here we always assume that the net effect of taxes is positive via infra structure effects.

Migration from one region into the other region is a shift of resources. Even if we consider unemployment due to frictions in the labor market matching process migration leads to a change in access to human capital in the regions. Migration is an inter-regional transformation of available resources depending on labor market conditions in each region. Immigration of one skilled person will lead to an increase of human capital actually available for ν_i additional jobs (see (3)). Hence, inter-regional migration of human capital translates into an inter-regional rate of transformation of jobs from one region into another by

$$\begin{aligned}
\frac{dN_2}{dN_1} &= \frac{\left[1+\left(1+\frac{\mu_1}{(1-\varepsilon_1)}\right)\sigma N_1^{\left(\frac{\mu_1}{(1-\varepsilon_1)}\right)}\right]dH_2}{\left[1+\left(1+\frac{\mu_2}{(1-\varepsilon_2)}\right)\sigma N_2^{\left(\frac{\mu_2}{(1-\varepsilon_2)}\right)}\right]dH_1} = -a(N_1,N_2)<0 \quad \text{in general} \\
\frac{dN_2}{dN_1} &= -1<0 \quad \text{for perfectly symmetric regions.} \qquad (13)
\end{aligned}$$

As there is an interaction between the development position of a region and the allocation of human capital, two conditions, the *final development condition* and the labor market equilibrium condition (*no migration condition*), have to be considered.

Relative Regional Development: From equation (7) we know that ω_i^* is the steady state position of each region. Then, the relative steady state position for the two regions for a given endowment is given as[21]

$$\begin{aligned}
\Omega^D &= \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_1^{\frac{\alpha}{1-\beta}}N_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_2^{\frac{\alpha}{1-\beta}}N_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \qquad (14) \\
\frac{d\Omega^D}{dN_1} &> 0, \quad \frac{d\Omega^D}{d\tau_1}<0, \quad \frac{d\Omega^D}{d\tau_1^{ex}}<0, \quad \frac{d\Omega^D}{d\gamma_1}>0.
\end{aligned}$$

This condition is referred to as the *final development condition.* The final development condition identifies the relative technological position of a region compared to the other region in steady state. In general, this relative final position depends on all parameters of Ψ_i (see (6)) and in particular on the allocation of

[21] See Appendix 2a.

$$\begin{aligned}
\lim_{N_1\to 0}\Omega^D &= 0, \quad \lim_{N_1\to o}\frac{d\Omega^D}{dN_1}=\infty, \lim_{N_1\to N}\Omega^D=\infty, \quad \lim_{N_1\to N}\frac{d\Omega^D}{dN_1}=\infty \\
\Omega^D_{|N_1=N_2} &= 1, \quad \frac{d\Omega^D}{dN_1}_{|N_1=N_2} = 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}L_1^{-\frac{\alpha}{1-\beta}}N_1^{-1}>0, \quad \text{for symmetric regions}
\end{aligned}$$

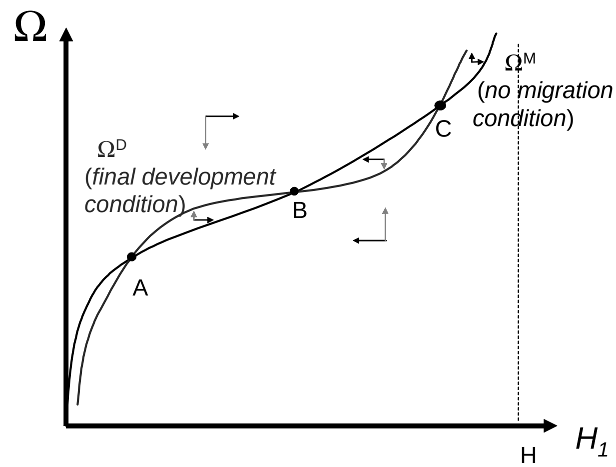

Figure 1: Steady State and Dynamics

N to the two regions. Depending on N the final development condition can be drawn as *final development curve* Ω^D in the $N_1 - \Omega$ diagram (1). If the stock of human capital in one region falls to zero economic activity in this region would relatively shrink to zero. In Figure 1 the Ω^D curve intersects the N_1 axis at 0 with an infinite positive slope. When N_1 increases the slope remains positive and eventually Ω^D becomes infinite, once N_1 approaches N. For symmetric regions at $N_1 = N_2$ the curve takes the level of $\Omega^D = 1$ and has a slope of $2\frac{\delta(1-\beta)}{1-\beta-\delta}N_i^{-1} > 0$.

Dynamic adjustment can be directly derived from the equation of motion for each single region. Denoting a_i as the distance of the region's present position relative to the steady state position $(a_i = \omega_i(t)/\omega_i^*)$ the dynamics are given by

$$\Omega(t) = \frac{\omega_1(t)}{\omega_2(t)} \implies \frac{\dot{\Omega}}{\Omega} = \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \tag{15}$$

$$\frac{\dot{\Omega}(t)}{\Omega(t)} = a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \quad \text{for } \Omega(t) > \Omega^D \tag{16}$$

For $a_1 > a_2$ the present position of the two regions Ω is above[22] the final development curve Ω^D in figure 1. From (15) can be seen that Ω decreases $(\frac{\dot{\Omega}}{\Omega} < 0)$.[23]

[22] $\Omega = \frac{\omega_1(t)}{\omega_2(t)} = \frac{a_1\omega_1^*}{a_2\omega_2^*} = \frac{a_1}{a_2}\Omega^D$

[23] See appendix 2c.

Regional Migration and Labor Market: The central mechanism of endogenous formation of regions is the endogenous allocation of mobile human capital to the two regions. The theory of migration offers a rich spectrum of models to understand migration decisions. Mobile human capital migrates as long as one region is a more attractive location than another. How attractive a location is will be determined by many factors like local income opportunities and positive or negative externalities including congestion costs. Recently, "New Economic Migration" adds portfolio and insurance effects. As micro-modelling of migration is an additional field of literature, rather sophisticated theories of migration were developed. However, to keep things as straight as possible, we suggest a rather simple rule of migration: Human capital migrates to the region with the highest expected income. As the probability to find a job (probability of a match) was denoted p_i (see (3.3) and (3.4)) and the wage rate is w_{N_i} the expected wage earnings are $p_i w_{N_i}$[24]. As we assume perfect competition in the final goods market, factor prices (and wages alike) are determined by their marginal productivity

$$w_{N_i} = \frac{1-\beta-\alpha}{1-\beta}\left(1-\gamma_i\right)\omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}}. \quad (17)$$

For simplicity we define expected income purely as expected wages and no income for the case of unemployment, we abstract from potential earnings in the informal sector, or remittance from a family support network. In this model unemployment stands for no income at all, neither in the formal sector nor in the informal sector. As the migration process is not perfect adjustment takes time. The simple rule of migration can be translated into a migration function

$$\dot{H}_1(t) = m(\frac{p_1 w_1}{P_2 w_2} - 1). \quad (18)$$

In steady state no migration takes place ($\dot{H}_1(t) = 0$). Therefore, the steady state is characterized by the expected income no arbitrage condition

$$\frac{p_1 w_1}{p_2 w_2} = \frac{\lambda_1 e^{-\lambda_1} w_1}{\lambda_2 e^{-\lambda_2} w_2} = 1. \quad (19)$$

From condition (19) and the equilibrium expected matching rate (3.11) we can derive a curve describing all no-migration steady state positions.[25]

[24] From the perspective of the individual person expected wage income in a region i is given by wages times the probability to find a job in this region. $Ey_i = p_i w_i + (1-p_i)0 = p_i w_i$

[25] For the derivative $\frac{d\Omega^M}{dN_1}$ see Appendix 3a.

$$
\begin{aligned}
\Omega^M &= \frac{\omega_1}{\omega_2} \qquad (20)\\
&= \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}\,(1-\gamma_2)\,L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}\,(1-\gamma_1)\,L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}\\
\frac{d\Omega^M}{dN_1} &> 0 \qquad \text{for identical regions} \qquad \frac{d\Omega^M}{dN_1} \lesseqgtr 0 \qquad \text{in general,}\\
\frac{d\Omega^M}{d\tau_1} &> 0, \quad \frac{d\Omega^M}{d\tau_1^{ex}} > 0, \quad \frac{d\Omega^M}{d\gamma_1} < 0
\end{aligned}
$$

We refer to this condition as the *no migration condition.* The *no migration condition* is also drawn in figure 1. Ω^M intersects the origin with an infinite positive slope. With increasing N_1 the slope starts positive, may become negative and eventually turns positive such that Ω^M becomes infinite when N_1 approaches N [$\lim_{N_1 \to N} \Omega^M = \infty$].[26]

Dynamic adjustment is shown in figrure 1. If at a given endowment N_1 in region 1 relative productivity is presently smaller than required by the expected income no arbitrage condition, human capital will emigrate from region 1 and N_1 decreases. Therefore, at any point below the Ω^M curve human capital will emigrate from region 1. This process is indicated by the horizontal arrows in figure 1.

Multiple Steady State Equilibria: For symmetric regions the two curves [Ω^D curve, Ω^M curve] must have an uneven number of intersections and hence an uneven number of long term steady state positions.[27] The reason for multiple equilibria in this basically neoclassical model are job uncertainty and labor market frictions. While in figure 1 we consider a simple but already interesting case of three intersections, more equilibria can easily occur. At point B in figure 1 the two regions are identical since $N_1 = N_2$. In figure 1 we look at the two curves for the stable case such that the slope of the *final development curve* is smaller than the slope of the *no migration curve.* The corresponding condition is[28]

$$
\frac{d\Omega^D}{dN_1} < \frac{d\Omega^M}{dN_1} \quad \text{that is} \quad \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} < \left(\alpha + \frac{(1-\beta)\,\mu}{(1-\varepsilon)}\right). \qquad (21)
$$

This condition holds if the parameters driving productivity growth and hence migration are relatively small compared to the parameters determining the productivity of the domestic immobile factor. In other words, this condition for

[26] The properties of the no migration curve is given by $\lim_{N_1 \to 0} \Omega^M = 0, \lim_{N_1 \to 0} \frac{d\Omega^M}{dN_1} = \infty, \lim_{N_1 \to N} \Omega^M = \infty, \lim_{N_1 \to N} \frac{d\Omega^M}{dN_1} = \infty$. See also appendix 3a.

[27] See appendix 4a.

[28] See appendix 3c.

stability holds if the domestic immobile factor is sufficiently important in the production process. This stability condition is also a sufficient condition for the existence of multiple equilibria.[29]

Further, as can be seen from the arrows drawn in figure 1, we have one stable and two unstable equilibria. At any point to the left of point A human capital will decrease in region 1 and increase in region 2. Since this process will not stop endogenously, it is an unstable adjustment. Region 1 will disappear. With a symmetric mechanism the area to the right of A leads to a stable adjustment towards point B. Between points B and C a stable adjustment leads regions towards point B. To the right of C the process again becomes unstable, but this time in favor of region 1.

With multiple equilibria we have variety of potential results. There may be a number of inner solutions as well as corner solutions. With any stable inner solution we identify a process of conditional convergence. A corner solution will lead to potential regional divergence.

4 Endogenous formation of regions

For two regions the effects of preferential policy can be analyzed. We are interested in the effects of an non-symmetrical decrease in international transaction and information costs in one region. Many local conditions including bureaucratic policies have the effect of non-tariff trade barriers. If a region reduces international transaction and information costs, it may be able to generate a decisive advantage over other regions. A non-symmetrical reduction of international transactions cost via preferential policy can be translated into the model by $d\tau_1 < 0$ or $d\tau_1^{ex} < 0$. As result the *final development curve* Ω^D in figure 2[30] shifts upward (see (14)) and the *no migration curve* Ω^M shifts downward (see (20)). Starting from the original equilibrium point B_0 the two regions will move towards the new equilibrium point B_1. The change in international transaction costs will trigger two mutually dependent reactions: First, a change in the relative technological development of the two regions, and second, a migration process towards the faster growing region. As immigration of human capital and faster growth of technologies are mutually favorable, an agglomerating process is initiated. A similar effect could be initiated by a change in public infrastructure investments $[d\gamma_1 > 0]$. The existence of a number of stable inner solutions allows for conditional convergence of regions. Starting from B_0 we find a stable regional adjustment processes, as long as the change in the policy parameters is not strong enough to lead to a bifurcation.

Population Size, Density and Agglomeration: For the system of two stationary conditions (14), (20) and the resource constraint (12) we solve for

[29] See appendix 4b.

[30] In this figure Ω^D shifts upwards and Ω^M shifts downwards. In order to keep the figure simple, we draw the relative shift of the two curves instead of shifting both curves at the same time.

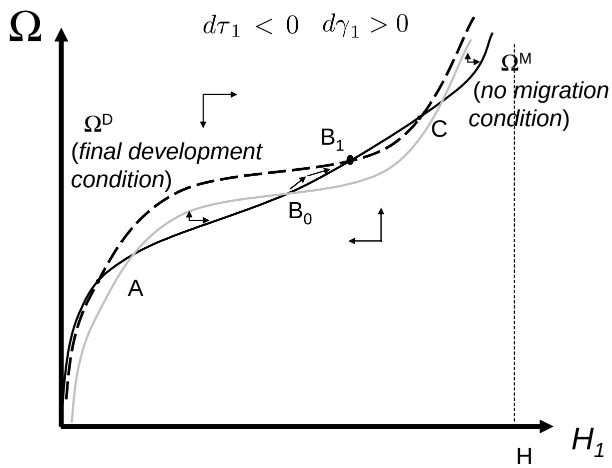

Figure 2: Endogenous Formation of Regions

the equilibrium reaction of human capital in region 1[31]

$$\frac{dN_1}{d\tau_1} < 0, \quad \frac{dN_1}{d\gamma_1} > 0, \quad \frac{dN_1}{d\tau_1^{ex}} < 0.$$

In region 1 population grows, while region 2 faces brain drain and shrinkes. Decreasing international transaction costs and better access to international technologies in region 1 will increase technology growth and trigger agglomeration advantages for this region. Faster imitation increases productivity growth and a wage gap between the regions opens. As human capital is mobile between the two regions, human capital migrates to the high productivity, high wage region. Immigration and the resulting additional technological growth will both drive a process of acceleration and agglomeration. In this process the success of one region is driven at the expense of the other region, since one region absorbs human capital from the other region to feed agglomeration. Technological acceleration endogenously terminates when imitation becomes more difficult and a region approaches more sophisticated technologies. Further, immigrating to the agglomerating region will eventually drive down wage growth by decreasing marginal productivity. At the same time emigrating human capital will drive up marginal productivity in the less favored region. Eventually all incentives for additional migration and labor market adjustment between the two regions will vanish. A new equilibrium allocation of mobile human capital occurs.

[31] See appendix 5.

Total GDP: A second question to look at is income in both regions as well as total income development of the country. As we adjust the domestic technology level for the level of the technology leader (A) we obtain for the relative GDP position of region i

$$X_i^* = \omega_i^* L_i^\alpha K_i^\beta N_i^{1-\alpha-\beta}.$$

Using the resource constraint (12), income reactions in the two regions are

$$\frac{dX_1^*}{d\tau_1} = \overbrace{\frac{X_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{d\omega_1^*}{dN_1}\frac{X_1^*}{\omega_1^*}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\frac{X_1^*}{N_1}}^{\langle 3\rangle}\right)\frac{dN_1}{d\tau_1} < 0 \qquad (22)$$

$$\frac{dX_2^*}{d\tau_1} = -\left(\frac{d\omega_2^*}{dN_2}\frac{X_2^*}{\omega_2^*} + (1-\alpha-\beta)\frac{X_2^*}{N_2}\right)\frac{dN_1}{d\tau_1} > 0. \qquad (23)$$

For γ_1 we obtain

$$\frac{dX_1^*}{d\gamma_1} > 0, \quad \frac{dX_2^*}{d\gamma_1} < 0 \qquad (24)$$

Income is driven by three channels: a direct improvement of technology $\langle 1\rangle$ and two effects from interregional migration $\langle 2\rangle$ and $\langle 3\rangle$. Immigration of human capital drives up technological abilities and increases factor endowments and production capacity in the region. Both effects from migration are mutually reinforcing. They are positive in one region and negative in the other. The total income effect is

$$dX^* = dX_1^* + dX_2^* = \frac{X_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1} < 0. \qquad (25)$$

Adjusting for a mutually symmetric compensating migration effects in both regions we are left with the original positive technology shock in region 1. When access to international technologies improves at least in one region, imitation accelerates the attainment of a better steady state position. On average, the country is better off.

Unemployment of human capital: In the context of this model unemployment means no income neither in a formal nor in an informal sector. Hence an increasing unemployment rate with increasing urbanization and agglomeration of a region has a clear interpretation.[32]

$$\frac{du_i}{dH_i} = \frac{1}{H_i}\left[\nu_i(N_i) + \frac{N_i}{H_i}\right] > 0 \qquad (26)$$

[32] $$u_i = \frac{U_i}{H_i} = \frac{H_i - N_i}{H_i}, \quad \frac{du_i}{dH_i} = \frac{1}{H_i}\left[\left(1 - \frac{dN_i}{dH_i}\right) - \frac{H_i - N_i}{H_i}\right]$$

The information problem in the search process includes the idea of information networks in more rural regions. The state of completely no employment and no income is more likely in anonymous urban centers that in rural regions, where at least employment in the informal sector can be realized more easily. Hence, the migration arbitrage condition will imply an unemployment and wage differential for the two regions. With increasing unemployment rates in agglomerating centers, a higher wage for human capital has to compensate for the additional risk of survival. As a result we find higher wages in the center and lower wages in the backward regions. The wage pattern is similar than in NEG models, however the economics is different. In this model higher wages in an agglomeration compensate for a loss of security in the rural family network.

Price of Immobile Factors: While integrated labor markets lead to wage differentials among the two regions, factor prices for immobile land ρ_i[33] will be also affected in a non symmetrical way.

$$\rho_i = F_L = \frac{\partial X_i}{\partial L_i} = \frac{\alpha\left(1-\gamma_i\right)}{1-\beta}\left(\omega_i^*\right)^{\frac{1}{1-\beta}}\left(\frac{\left(1-\tau_i^{ex}\right)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}}\left[\frac{N_i}{L_i}\right]^{\frac{1-\beta-\alpha}{1-\beta}} \qquad i=1,2$$

$$\frac{d\rho_1}{d\tau_1} = \overset{(+)}{F_{L\omega}}\left(\overset{(-)}{\frac{d\omega_1^*}{d\tau_1}} + \overset{(+)}{\frac{d\omega_1^*}{dN_1}}\overset{(-)}{\frac{dN_1}{d\tau_1}}\right) + \overset{(+)}{F_{LN}}\overset{(-)}{\frac{dN_1}{d\tau_1}} < 0 \tag{27}$$

$$\frac{d\rho_2}{d\tau_1} = \overset{(+)}{F_{L\omega}}\left(\overset{(+)}{\frac{d\omega_2^*}{dN_2}}\overset{(-)}{\frac{dN_2}{dN_1}}\overset{(-)}{\frac{dN_1}{d\tau_1}}\right) + \overset{(+)}{F_{LN}}\overset{(-)}{\frac{dN_2}{dN_1}}\overset{(-)}{\frac{dN_1}{d\tau_1}} > 0. \tag{28}$$

Prices for land ρ_i will increase in the agglomerating region and relatively decrease in the other region. As intuitively expected, land becomes less abundant and more expensive in the agglomerating region. In the less favored regions where human capital has emigrated and the population density has decreased land prices decline correspondingly.

Change in Comparative advantages: The model determines the relative final technological position of a region. Hence, technologically driven Riccardian comparative advantages are directly affected by the technological development of the region. However, comparative advantages through Heckscher-Ohlin trade are also endogenously determined. If the production function for the final good is identified as Findlay's *foreign exchange productions function*[34] the link to trade theory and endogenous determination of comparative advantages is straightforward. According to this concept the production function becomes a value

[33] See appendix 6.
[34] See Findlay (1973, 1984).

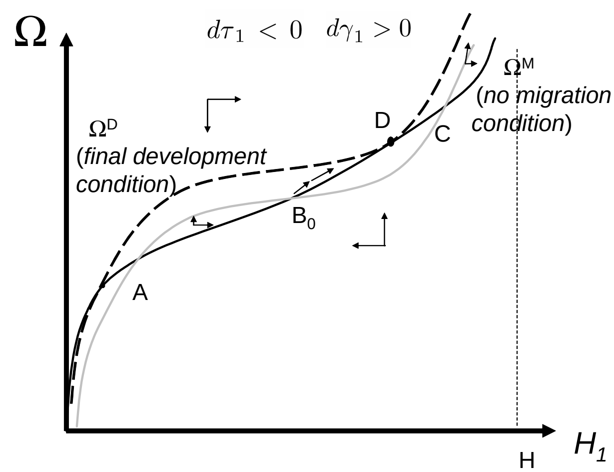

Figure 3: Bifurcation

function in international prices. For a given vector of world market prices and a continuum of goods, each location fully specializes in the production of one good. Factor abundance determines the factor intensity in production. Factor intensities identify the particular industry and specialization of the region. A location with an abundance of human capital will specialize in a human capital intensive industry. Hence, the inflow of human capital and the endogenous termination of immigration will also determine the H-O position of the region and international comparative advantages. Therefore, the process of endogenous formation of regions determines not only the size and agglomeration of the region, but also comparative advantages according to neoclassic trade theory.

5 Path dependence and transitory disadvantages

With the existence of a multiple equilibria solution and the identification of international transaction cost as shift parameter we can illustrate path dependence of mutual dependent regional developments. As already shown in the previous section preferential policy in region 1 has shifted the final development curve upward and the no migration curve downward.[35] In figure 3 preferential policy in region 1 reduces international transactions costs strong enough to shift the Ω^D-curve sufficiently upward to obtain a bifurcation. In point D the two equilibria B and C transform into one new equilibrium D with a change in

[35] In this figure Ω^D shifts upwards and Ω^M shifts downwards (see (14) ans (20)).. In order to keep the figure simple, we draw the relative shift of the two curves instead of shifting both curves at the same time.

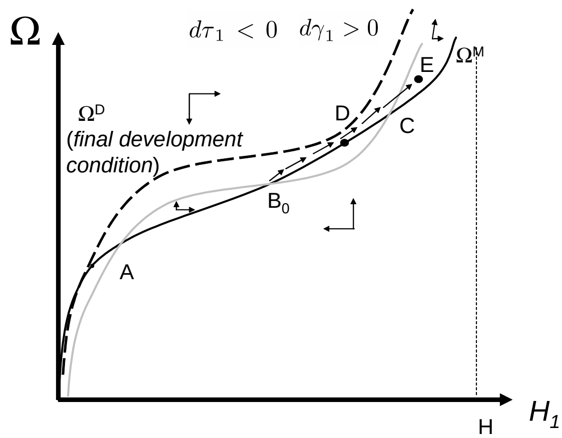

Figure 4: Instable agglomeration

dynamic properties With this bifurcation the stability of the equilibrium has disappeared. To the left of D we find a number of stable adjustment paths. To the right of D all dynamic paths will end in the corner solution. The process of interdependent regional development is unstable. Region 1 will agglomerate and absorb all resources. Region two will desert in economic terms.

If preferential policy was sufficiently strong, we have another bifurcation. Equilibrium D will disappear and the two regions will move on an unstable path. As soon as the interdependent regional development process is passing D (figure 4) the economies are moving on an unstable path of divergence towards a general unstable locus. Once the economies are in E (figure 4), even the reestablishment of original relative conditions (see figure 5) will not turn the direction of the process. The unstable time path continues and the ability to reverse the process becomes more difficult, the longer the economies stay on this divergence path. As a result transitory historical conditions have permanent effects on the long term position. The longer the process of divergence the more difficult the reversal of the process. The instruments needed to return to the stable path of conditional convergence must be very strong and powerful.

The problem of path dependence clearly suggests, that advantages even if they are transitory in nature, may have long term permanent effects. The time path matters. An early developing region absorbs resources from neighboring regions and positive externalities will further push the development and advantages of this region. The link between the regions is the competition for relevant resources, namely human capital. The shift in resource allocation, a brain drain in one region and additional human capital in the other region, drives agglomeration, deglomeration and hence divergence. Reallocation has led to an additional permanent disadvantage. This disadvantage in relative resource allocation can-

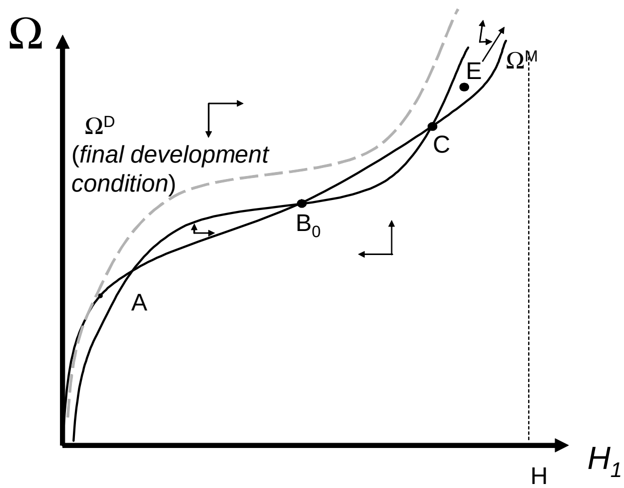

Figure 5: Path dependence and instable branch.

not be compensated by just a convergence of economic rules. The convergence of economic rules is a necessary but not a sufficient condition for a reversal of the process. Therefore, a political strategy for convergence must overcompensate geographic, and institutional disadvantages of regions.[36] The process of reallocation of human capital has reinforced resource divergence, and hence path dependence of regional development. Development of backward regions must take this additional disadvantage into account. A development strategy of rural regions can only be successful, if these disadvantages can be overcompensated by a massive active push. The concentration of relevant resources must reverse in favor of backward regions.

6 SUMMARY AND CONCLUSIONS

The insights of graphical economics provides a much better understand of development and underdevelopment in the world. Empirically, agglomerations and concentration are not a phenomenon of developed countries only. The concentration of high proportions of economic activities in just a few centers is a recurrent pattern in developing countries, too.

In this paper a stylized macro-model of regional growth without scale effects, but with catching-up growth and migration and labor market frictions is introduced. In two less developed regions the interaction between migration and agglomeration, FDI, international technology spill-over and productivity

[36] See also Demurger et al. (2002).

growth drives the endogenous formation of regions. We identify the determinants of regional success as well as endogenous population size and density. Access to international markets through low international transaction costs and FDI play a crucial role for regional development and comparative advantages of endogenously formed regions. Due to labor market frictions we obtain a multiple equilibria solution and path-dependence of the development process. A decrease in international transaction costs in only one region of an LDC leads to the formation of different regions with ultimately different per capita incomes or even divergence. It was shown that two processes would drive the development in each region. Firstly, for a given resource endowment, technology imitation determines the relative regional development. Secondly, migration between regions endogenously determines the resource endowments of each region. This mutually dependent process terminates once the no migration equilibrium is reached. The no migration equilibrium endogenously determines population size and density as well as per capita income and comparative advantages in a region. There will be agglomeration in the region with easy access to international markets, while the less favored region will realize a relative drop in income and technological capability.

7 Appendix

Appendix: 1a: Equilibrium tightness:

$$\begin{aligned}
\lambda U_i &= V_i \\
\lambda &= \frac{V_i}{U_i} = \frac{1}{\theta_i} \\
\lambda(\theta_i, N_i) &= \frac{1}{\theta_i} \quad \text{if} \quad \lambda(N_i, \theta_i) = \theta_i^{-\varepsilon_i} N_i^{-\mu_i} \\
\theta_i^{-\varepsilon_i} N_i^{-\mu_i} &= \frac{1}{\theta_i} \\
\theta_i^{1-\varepsilon_i} &= N_i^{\mu_i} \\
\theta_i &= N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} \qquad \text{see} \qquad 3.8
\end{aligned}$$

Appendix 1b: Equilibrium unemployment:

$$\begin{aligned}
\theta_i &= U_i / \sigma N_i \\
N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} &= U_i / \sigma N_i \\
U_i &= \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)} \qquad \text{see} \qquad 3.9
\end{aligned}$$

Appendix 1c: expected rate of matches:

$$\begin{aligned}
\lambda_i &= \lambda(\theta_i, H_i) = \theta_i^{-\varepsilon_i} N_i^{-\mu_i} \\
\theta_i &= N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} \\
\lambda_i &= \left(N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} \right)^{-\varepsilon_i} N_i^{-\mu_i} \\
&= N_i^{-\frac{\varepsilon_i \mu_i}{(1-\varepsilon_i)} - \mu_i} = N_i^{-\frac{\varepsilon_i \mu_i}{(1-\varepsilon_i)} - \frac{\mu_i (1-\varepsilon_i)}{(1-\varepsilon_i)}} \\
\lambda_i &= N_i^{-\frac{\varepsilon_i \mu_i}{(1-\varepsilon_i)} - \frac{\mu_i - \mu_i \varepsilon_i}{(1-\varepsilon_i)}} = N_i^{-\frac{\mu_i}{(1-\varepsilon_i)}} \qquad \text{see} \qquad 3.11
\end{aligned}$$

Appendix 1d: Labor market equilibrium employment-ratio:

$$\begin{aligned}
U_i &= \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)} \\
H_i &= N_i + \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)} \\
H_i &= N_i \left(1 + \sigma N_i^{\frac{\mu_i}{(1-\varepsilon_i)}} \right) \\
dH_i &= dN_i + \left(1 + \frac{\mu_i}{(1-\varepsilon_i)} \right) \sigma N_i^{\left(\frac{\mu_i}{(1-\varepsilon_i)}\right)} dN_i \\
dH_i &= \left[1 + \left(1 + \frac{\mu_i}{(1-\varepsilon_i)} \right) \sigma N_i^{\left(\frac{\mu_i}{(1-\varepsilon_i)}\right)} \right] dN_i \\
\frac{dN_i}{dH_i} &= \left[1 + \left(1 + \frac{\mu_i}{(1-\varepsilon_i)} \right) \sigma N_i^{\left(\frac{\mu_i}{(1-\varepsilon_i)}\right)} \right]^{-1} > 0 \\
N_i &= N_i(H_i) \quad \text{with} \quad \nu_i = \frac{dN_i}{dH_i} > 0 \qquad 3
\end{aligned}$$

Appendix 1e: determining the production level:

$$\begin{aligned}
X_i &= \omega_i L_i^{\alpha} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} X_i \right)^{\beta} H_i^{1-\alpha-\beta} \\
X_i^{1-\beta} &= \omega_i L_i^{\alpha} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\beta} H_i^{1-\alpha-\beta} \\
X_i &= \omega_i{}^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} (\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}^{\frac{\beta}{1-\beta}} H_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}$$

Appendix 1f: Steady state determination and reactions of ω_i^* when N_i, τ_i, τ_i^{ex} and γ are changing:

Solve for $\dot{\omega}$ by plugging in

$$\begin{aligned}
\dot{\omega}_i(t) &= G(t)_i^{\delta_G} K(t)_i^{\delta_K} - \omega(t), \\
\dot{\omega}_i(t) &= (\gamma X(t)_i)^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} X(t)_i \right)^{\delta_K} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K} X(t)_i^{\delta_G+\delta_K} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K} X(t)_i^{\delta} - \omega(t)
\end{aligned}$$

$$X_i = \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K} \\
&\quad \left[\omega(t)_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} (\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i})^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K} \\
&\quad \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}\delta} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t)
\end{aligned}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t). \\
\frac{d\dot{\omega}_i(t)}{d\omega(t)} &= \frac{\delta}{1-\beta} \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta-1+\beta}{1-\beta}} - 1 < 0 \\
&\quad \text{as } L_i \text{ and } N_i \text{ are assumed to be sufficient small}
\end{aligned}$$

To simplify, this equation is rewritten as

$$\dot{\omega}_i(t) = \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad (5)$$

$$\text{with} \quad \Psi_i := \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta} \qquad (6)$$

solve for the steady state position:

$$\begin{aligned}
0 &= \dot{\omega}_i(t) \\
0 &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega^{\frac{\delta}{1-\beta}} - \omega \\
\omega &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega^{\frac{\delta}{1-\beta}} \\
\omega^{1-\frac{\delta}{1-\beta}} &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \\
\omega^{\frac{1-\beta-\delta}{1-\beta}} &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \\
\omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad (7)
\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial N_i}$:

$$\begin{aligned}
\omega_i^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \\
\frac{\partial \omega_i^*}{\partial N_i} &= \frac{\delta(1-\beta)}{1-\beta-\delta} \frac{1-\beta-\alpha}{1-\beta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} N_i^{\frac{1-\beta-\alpha}{1-\beta}-1} L_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta\,(1-\beta-\alpha)}{1-\beta-\delta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} N_i^{\frac{-\alpha}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} N_i^{\frac{-\alpha}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}}
\end{aligned}$$

$$\begin{aligned}
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{-1} N_i^{\frac{-\alpha}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* N_i^{-\frac{1-\beta-\alpha}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* N_i^{\frac{-1+\beta+\alpha-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* N_i^{-\frac{1-\beta}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* N_i^{-1} > 0
\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i}$:

$$\frac{\partial \omega_i^*}{\partial \tau_i} = \frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i}$$

$$\begin{aligned} \frac{\partial \Psi_i}{\partial \tau_i} &= -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \tau_i^{-1} \\ &= -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta} \tau_i^{-1} = -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i \tau_i^{-1} \end{aligned}$$

$$\begin{aligned} \frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i \tau_i^{-1} \\ &= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i^{\frac{\delta+1-\beta-\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\ &= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\ &= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\ &= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \omega^* \tau_i^{-1} < 0 \end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i^{ex}}$:

$$\begin{aligned} \frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= \frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i^{ex}} \\ \omega_i^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \end{aligned}$$

$$\begin{aligned} \frac{\partial \Psi_i}{\partial \tau_i^{ex}} &= -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta - 1} \frac{\beta}{\tau_i r_i} \\ &= -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \\ &= -\left[\delta_K + \frac{\beta}{1-\beta}\delta\right] \Psi_i (1-\tau_i^{ex})^{-1} \end{aligned}$$

$$\frac{\partial\omega_i^*}{\partial\tau_i^{ex}} = -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K+\frac{\beta}{1-\beta}\delta\right]\Psi_i(1-\tau_i^{ex})^{-1}$$

$$= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+1}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K+\frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1}$$

$$= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+\frac{(1-\beta-\delta)}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K+\frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1}$$

$$\frac{\partial\omega_i^*}{\partial\tau_i^{ex}} = -\frac{(1-\beta)}{(1-\beta-\delta)}\left[\delta_K+\frac{\beta}{1-\beta}\delta\right]\omega_i^*\,(1-\tau_i^{ex})^{-1}$$

Steady state reactions $\frac{\partial\omega_i^*}{\partial\gamma_i}$:

$$\frac{\partial\omega_i^*}{\partial\gamma_i} = \frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\frac{\partial\Psi_i}{\partial\tau_i}$$

$$\frac{d\Psi_i}{d\gamma_i} = \left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\delta_K+\frac{\beta}{1-\beta}\delta} = \Psi_i\left(\gamma^{\delta_G}\right)^{-1}$$

$$\frac{\partial\omega_i^*}{\partial\gamma_i} = \frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta+1-\beta-\delta}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left(\gamma^{\delta_G}\right)^{-1}$$

$$= \frac{(1-\beta)}{(1-\beta-\delta)}\frac{\omega^*}{\gamma^{\delta_G}} > 0$$

Appendix 2a: Slope of the final development curve Ω^D :

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_1^{\frac{\alpha}{1-\beta}}N_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_2^{\frac{\alpha}{1-\beta}}N_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \qquad and \qquad N = N_1+N_2$$

$$d\Omega^D = \frac{\omega_2^*}{(\omega_2^*)^2}\frac{\partial\omega_1}{\partial N_1}dN_1 - \frac{\omega_1^*}{(\omega_2^*)^2}\frac{\partial\omega_2}{\partial N_2}dN_2 = \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1}{\partial N_1}+\omega_1^*\frac{\partial\omega_2}{\partial N_2})dN_1$$

$$\frac{d\Omega^D}{dN_1} = \frac{1}{(\omega_2^*)^2}\left(\omega_2^*\frac{\partial\omega_1^*}{\partial N_1}+\omega_1^*\frac{\partial\omega_2^*}{\partial N_2}\right) > 0 \quad \text{since} \quad \frac{\partial\omega_i^*}{\partial N_i} > 0.$$

properties of the curve:

$$\begin{aligned}
\lim_{N_1\to 0}\Omega^D &= 0, \lim_{N_1\to N}\Omega^D = \infty \\
\frac{d\Omega^D}{dN_1} &= \frac{1}{(\omega_2^*)^2}\left(\omega_2^*\frac{\partial\omega_1^*}{\partial N_1} + \omega_1^*\frac{\partial\omega_2^*}{\partial N_2}\right) \\
&= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial N_1} + \frac{\omega_1^*}{\omega_2^*}\frac{\partial\omega_2^*}{\partial N_2}\right] \\
&= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial N_1} + \Omega^D\frac{\partial\omega_2^*}{\partial N_2}\right] \\
\text{since } \lim_{N_1\to o}\frac{\partial\omega_1^*}{\partial N_1} &= \lim_{N_1\to o}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_1^* N_1^{-1} = \infty \Longrightarrow \lim_{N_1\to o}\frac{d\Omega^D}{dN_1} = \infty
\end{aligned}$$

$$\begin{aligned}
\lim_{N_1\to N}\Omega^D &= \infty \\
\frac{d\Omega^D}{dN_1} &= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial N_1} + \frac{\omega_1^*}{\omega_2^*}\frac{\partial\omega_2^*}{\partial N_2}\right] \\
&= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial N_1} + \Omega^D\frac{\partial\omega_2^*}{\partial N_2}\right] \\
\text{since } \lim_{N_1\to N}\frac{\partial\omega_2^*}{\partial N_2} &= \lim_{N_1\to N}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_2^* N_2^{-1} = \infty \Longrightarrow \lim_{N_1\to N}\frac{d\Omega^D}{dN_1} = \infty
\end{aligned}$$

Appendix 2b: Slope of the final development curve Ω^D, identical regions: $\omega_1^* = \omega_2^*$

$$\begin{aligned}
\frac{d\Omega^D}{dN_1} &= \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1^*}{\partial N_1} + \omega_1^*\frac{\partial\omega_2^*}{\partial N_2}) \\
&= \frac{1}{\omega_i^*}\left(\frac{\partial\omega_1^*}{\partial N_1} + \frac{\partial\omega_2^*}{\partial N_2}\right) = \frac{2}{(\omega_i^*)}\frac{\partial\omega_i^*}{\partial N_i} \\
&= \frac{2}{\omega_i^*}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega^* N_i^{-1} \\
&= 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}N_i^{-1} > 0 \qquad \text{for identical regions.}
\end{aligned}$$

Appendix 2c: Dynamic adjustment:

$$
\begin{aligned}
\frac{\dot{\Omega}}{\Omega} &= \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \\
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega_1^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega_2^{-\frac{1-\beta-\delta}{1-\beta}} \\
a_i(t) &= \omega_i(t)/\omega_i^* \\
\frac{\dot{\Omega}}{\Omega} &= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} [a_1 \omega_1^*]^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} [a_2 \omega_2^*]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \left[a_1 \Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \right]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&\quad - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \left[a_2 \Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \right]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} a_1^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_1^{-1} \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{-\delta} \\
&\quad - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} a_2^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_2^{-1} \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{-\delta} \\
&= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} \\
\text{for} \;\; \Omega(t) &= \frac{a(t)_1}{a(t)_2} \Omega^D > \Omega^D \Longrightarrow a(t)_1 > a(t)_2 \\
\Longrightarrow & \;\; a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \Longrightarrow \frac{\dot{\Omega}(t)}{\Omega(t)} < 0
\end{aligned}
$$

Appendix 2d: reaction of the final development curve Ω^D, $\frac{d\Omega^D}{d\tau_1}$, $\frac{d\Omega^D}{d\tau_1^{ex}}$:

$$
\begin{aligned}
\frac{d\Omega^D}{d\tau_1} &= \frac{1}{\omega_2^*} \frac{\partial \omega_1^*}{\partial \tau_1} < 0 \\
\frac{d\Omega^D}{d\tau_1^{ex}} &= \frac{1}{\omega_2^*} \frac{\partial \omega_1^*}{\partial \tau_1^{ex}} < 0
\end{aligned}
$$

Appendix 2e: reaction of the final development curve Ω^D, $\frac{d\Omega^D}{d\tau_1}$:

$$
\frac{d\Omega^D}{d\gamma_1} = \frac{1}{\omega_2^*} \frac{\partial \omega_1^*}{\partial \gamma_1} > 0
$$

Appendix 3a:
Determine wage rates:

$$X_i = \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$\begin{aligned} w_{N_i} &= \frac{1-\beta-\alpha}{1-\beta} \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha-1+\beta}{1-\beta}} \\ &= \frac{1-\beta-\alpha}{1-\beta} \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}} \end{aligned}$$

$$p_i w_{N_i} = p_i \frac{1-\beta-\alpha}{1-\beta} \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}}$$

Derive the *no migration curve* :

$$\begin{aligned} p_1 w_{N_1} &= p_2 w_{N2} \\ & \quad p_1 \frac{1-\beta-\alpha}{1-\beta} \omega_1^{\frac{1}{1-\beta}} L_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1} \right)^{\frac{\beta}{1-\beta}} N_1^{\frac{-\alpha}{1-\beta}} \\ &= p_2 \frac{1-\beta-\alpha}{1-\beta} \omega_2^{\frac{1}{1-\beta}} L_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2} \right)^{\frac{\beta}{1-\beta}} N_2^{\frac{-\alpha}{1-\beta}} \\ \frac{\omega_1^{\frac{1}{1-\beta}}}{\omega_2^{\frac{1}{1-\beta}}} &= \frac{p_2 L_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2} \right)^{\frac{\beta}{1-\beta}} N_2^{\frac{-\alpha}{1-\beta}}}{p_1 L_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1} \right)^{\frac{\beta}{1-\beta}} N_1^{\frac{-\alpha}{1-\beta}}} \\ \frac{\omega_1}{\omega_2} &= \frac{p_2^{1-\beta} L_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2} \right)^{\beta} N_2^{-\alpha}}{p_1^{1-\beta} L_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1} \right)^{\beta} N_1^{-\alpha}} \end{aligned}$$

$$\begin{aligned} \Omega^M &= \frac{\omega_1}{\omega_2} = \frac{\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}} e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}} \right)} \right)^{1-\beta} L_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2} \right)^{\beta} N_2^{-\alpha}}{\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}} e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}} \right)} \right)^{1-\beta} L_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1} \right)^{\beta} N_1^{-\alpha}} \\ &= \frac{N_2^{-\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}} e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}} \right)(1-\beta)} L_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2} \right)^{\beta} N_2^{-\alpha}}{N_1^{-\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}} e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}} \right)(1-\beta)} L_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1} \right)^{\beta} N_1^{-\alpha}} \end{aligned}$$

$$= \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_2^{-\alpha-\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_1^{-\alpha-\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}$$

$$= \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}$$

Slope of the *no migration curve* :

$$\Omega^M = \Omega^M(N_1, N_2) \quad \text{and} \quad (13)$$

$$\Omega^M = \frac{\omega_1}{\omega_2} = \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}$$

$$= \frac{L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}} \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}},$$

$$= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}} \quad \text{with} \quad C = \frac{L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}$$

$$\Omega^M = \Omega^M(N_1, N_2) \quad \text{and} \quad (13)$$

$$\frac{\partial \Omega^M}{\partial N_1} = C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}-1}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}\left(\alpha + \frac{(1-\beta)\,\mu_1}{(1-\varepsilon_1)}\right)$$

$$-C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}} e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{\left[e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}\right]^2}$$

$$
\begin{aligned}
&= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}N_1^{-1}\left(\alpha+\frac{(1-\beta)\,\mu_1}{(1-\varepsilon_1)}\right)-C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}} \\
\frac{\partial\Omega^M}{\partial N_2} &= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}} \\
&\quad -C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{\left[e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}\right]^2}e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}-1}\left(\alpha+\frac{(1-\beta)\,\mu_2}{(1-\varepsilon_2)}\right) \\
&= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}-C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}N_2^{-1}\left(\alpha+\frac{(1-\beta)\,\mu_2}{(1-\varepsilon_2)}\right) \\
\frac{d\Omega^M}{dN_1} &= \frac{\partial\Omega^M}{\partial N_1}-\frac{\partial\Omega^M}{\partial N_2}a \\
&= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)}N_1^{\alpha+\beta+\frac{\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon)}}\right)}N_2^{\alpha+\beta+\frac{\mu_2}{(1-\varepsilon_2)}}}\left[\frac{\left(\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}\right)}{N_1}+a\frac{\left(\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}\right)}{N_2}-1-a\right]\begin{matrix}>\\=\\<\end{matrix}0
\end{aligned}
$$

properties of the curve:

$$
\lim_{N_1\to 0}\Omega^M=0,\ \lim_{N_1\to 0}\frac{d\Omega^M}{dN_1}=\infty,\ \lim_{N_1\to N}\Omega^M=\infty,\ \lim_{N_1\to N}\frac{d\Omega^M}{dN_1}=\infty.
$$

Appendix 3b: Slope of the *no migration curve,* identical regions:

$$\frac{d\Omega^M}{dN_1} = C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)} N_1^{\alpha+\beta+\frac{\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon)}}\right)} N_2^{\alpha+\beta+\frac{\mu_2}{(1-\varepsilon_2)}}} \left[\frac{\left(\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}\right)}{N_1} + a\frac{\left(\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}\right)}{N_2} - 1 - a\right] \gtreqless 0$$

$$C = 1, \quad a = 1 \quad \text{for perfectly symmetric regions}$$

$$\frac{d\Omega^M}{dN_1} = \frac{4\left(\alpha+\frac{(1-\beta)\mu}{(1-\varepsilon)}\right)}{N} > 0$$

Appendix 3c: Relative slope of the *final development position* and the *no migration condition* for identical regions:

$$\begin{aligned}
\frac{d\Omega^D}{dN_1} &< \frac{d\Omega^M}{dN_1} \\
4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}N^{-1} &< \frac{4\left(\alpha+\frac{(1-\beta)\mu}{(1-\varepsilon)}\right)}{N} \\
\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} &< \left(\alpha+\frac{(1-\beta)\,\mu}{(1-\varepsilon)}\right) \\
\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} &< \left(\alpha+\frac{(1-\beta)\,\mu}{(1-\varepsilon)}\right)
\end{aligned}$$

Appendix 4a:

Proposition 1: For a feasible set of parameters The curves

$$\Omega^D = \frac{\Psi_1^{\frac{1-\beta}{1-\beta-\delta}}(L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}})^{\frac{\delta(1-\beta)}{1-\beta-\delta}}}{\Psi_2^{\frac{1-\beta}{1-\beta-\delta}}(L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}})^{\frac{\delta(1-\beta)}{1-\beta-\delta}}}$$

and

$$\Omega^M = \frac{N_2^{-\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}-\alpha} e^{-(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}})^{1-\beta}} L_2^{\alpha}(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2})^{\beta}}{N_1^{-\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}-\alpha} e^{-(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}})^{1-\beta}} L_1^{\alpha}(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1})^{\beta}}$$

have, more than one point of intersection, where $N_1 = N_1(H_1)$ and $N_2 = N_2(H_2)$ are functions of $H_1$and H_2 , with $H_1 + H_2 = H$, and $N(H) = N_1(H_1) + N_2(H_2)$.

Proof: <u>Existence of one solution:</u> If we set $\Omega^D = \Omega^M$, we obtain

$$\frac{N_1^{\frac{1-\beta-\alpha}{1-\beta}*\frac{\delta(1-\beta)}{1-\beta-\delta}-\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}-\alpha} e^{-(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}})^{1-\beta}}}{N_2^{\frac{1-\beta-\alpha}{1-\beta}*\frac{\delta(1-\beta)}{1-\beta-\delta}-\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}-\alpha} e^{-(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}})^{1-\beta}}} = k,$$

where k is a constant. Under symmetry assumptions let k be 1.Furthermore we choose A_1, A_2, B_1 and B_2 so that the following equation holds:

$$\frac{N_1^{A_1}}{N_2^{A_2}} * \frac{e^{-(N_1^{B_1})^{1-\beta}}}{e^{-(N_2^{B_2})^{1-\beta}}} = 1.$$

$A_1$and B_1 depend on H_1 and $A_2$and B_2 depend on H_2 . Taking the logarithm on both sides of the equation, we obtain

$$(N_2^{B_2})^{1-\beta} - (N_1^{B_1})^{1-\beta} + A_2 \ln(N_2) - A_1 \ln(N_1) = 0,$$

where ln denotes the natural logarithm. Assuming, that $A_1 = A_2 < 0$ and $B_1 = B_2 < 0$ we obtain that

$$f(N_1) = (N_2^{B_2})^{1-\beta} - (N_1^{B_1})^{1-\beta} + A_2 ln(N_2) - A_1 ln(N_1)$$

tends to $+\infty$ or $-\infty$ for $N_1 \to 0$ respectively $N_1 \to N$. Besides we have: $f(\frac{N}{2}) = 0$. Therefore, we have found one solution.

Proof: Existence of at least two solutions:
Now we compute $f(\frac{N}{4})$:

$$\begin{aligned}
f(\frac{N}{4}) &= ((3\frac{N}{4})^{B_1})^{1-\beta} - ((\frac{N}{4})^{B_1})^{1-\beta} + A_1(\ln(\frac{3N}{4}) - \ln(\frac{N}{4})) \\
&= (\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)} - 1) + A_1(\ln(3) + \ln(N) - \ln(4) - \ln(N) + \ln(4)) \\
&= (\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)} - 1) + A_1 \ln(3)
\end{aligned}$$

A sufficient condition for a second intersection is $f(\frac{N}{4}) < 0$. This holds iff

$$\begin{aligned}
\frac{(\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)} - 1)}{\ln(3)} &< -A_1 \quad \text{or} \\
-\frac{(\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)} - 1)}{\ln(3)} &> A_1.
\end{aligned}$$

If we choose A_1appropriately the last condition is fulfilled. We can choose the parameter so that $f(\frac{N}{4})$ is negative. As f is positive near 0, there is another zero in the interval $(0, \frac{N}{4})$ because of the intermediate value theorem and that is why another point of intersection of the two curves exists.
q.e.d.

Appendix 4b: Multiple Equilibria for stable symmetric equilibrium:

Proposition: The stability condition

$$(\alpha + \frac{(1-\beta)\mu}{1-\varepsilon}) > \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}$$

with $\varepsilon < 1$ is a sufficient condition for multiple equilibria.

Proof: A sufficient condition for multiple equilibria is

$$-\frac{(\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)}-1)}{\ln(3)} > A_1$$

with $B_1 = -\frac{\mu}{1-\epsilon}$. As $B_1 < 0$ holds, the term $3^{B_1(1-\beta)} - 1 < 0$ and as $(\frac{N}{4})^{B_1(1-\beta)} > 0$ the term $-\frac{(\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)}-1)}{\ln(3)} > 0$.
A_1 is given by $A_1 = \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} - \frac{(1-\beta)\mu}{1-\varepsilon} - \alpha$. As we have $(\alpha + \frac{(1-\beta)\mu}{1-\varepsilon}) > \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}$, the number A_1 is negative and the condition $-\frac{(\frac{N}{4})^{B_1(1-\beta)}(3^{B_1(1-\beta)}-1)}{\ln(3)} > A_1$ holds.
q.e.d.

Appendix 5b: Reaction of final development curve:

$$\Omega^M = C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}, \qquad with \qquad C = \frac{L_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{L_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}$$

$$\frac{d\Omega^M}{d\tau_1} = \frac{dC}{d\tau_1} > 0, \frac{d\Omega^M}{d\tau_1^{ex}} = \frac{dC}{d\tau_1^{ex}} > 0, \frac{d\Omega^M}{d\tau_1} = \frac{dC}{d\gamma_1} > 0$$

Appendix 5b: Equilibrium reaction of human capital allocation. As we start from point B_0 in fig 2 we have identical regions in the starting position:

Reaction $\frac{dN_1}{d\tau_1}$:

$$\frac{\partial\Omega^M}{\partial N_1}dN_1 = \frac{\partial\Omega^D}{\partial N_1}dN_1 + \frac{\partial\Omega^D}{\partial\tau_1}d\tau_1$$

$$\frac{dN_1}{d\tau_1} = \frac{\frac{\partial\Omega^D}{\partial\tau_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}}$$

$$\frac{\partial\Omega^D}{\partial\tau_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1}$$

$$\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1} > 0, \quad \text{since (21) holds}$$

and hence

$$\frac{dN_1}{d\tau_1} = \frac{\frac{\partial\Omega^D}{\partial\tau_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}} > 0$$

Reaction $\frac{dN_1}{d\gamma_1}$:

$$\begin{aligned}
\frac{\partial\Omega^M}{\partial N_1}dN_1 &= \frac{\partial\Omega^D}{\partial N_1}dN_1 + \frac{\partial\Omega^D}{\partial\tau_1}d\gamma_1 \\
\frac{dN_1}{d\gamma_1} &= \frac{\frac{\partial\Omega^D}{\partial\gamma_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}}
\end{aligned}$$

$$\frac{\partial\Omega^D}{\partial\gamma_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\gamma_1}$$

$$\begin{aligned}
\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1} &> 0, \quad \text{since (21) holds} \\
& \text{and hence} \\
\frac{dN_1}{d\gamma_1} &= \frac{\frac{\partial\Omega^D}{\partial\gamma_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}} > 0
\end{aligned}$$

Appendix 6: Prices for the immobile land, ρ_i :

$$\begin{aligned}
X_i &= F(\omega_i, L_i, K_i, N_i) = \omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}. \\
\rho_1 &= F_L = \frac{\partial X_1}{\partial L_1} = \frac{\alpha}{1-\beta}\omega_1^{*\frac{1}{1-\beta}} L_1^{\frac{\alpha}{1-\beta}-1} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \\
&= \frac{\alpha}{1-\beta}\omega_1^{*\frac{1}{1-\beta}} L_1^{-\frac{1-\beta-\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \\
&= \frac{\alpha}{1-\beta}\omega_1^{*\frac{1}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} \left[\frac{N_1}{L_1}\right]^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}$$

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