Reducing regional disparity through WTO? -Endogenous formation of regions, labor market frictions and multiple equilibria

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May 22, 2006

Abstract

For more than a decade China's development has been driven by a rather small number of privileged regions. Many of these privileges facilitated international transactions and international integration. Introducing international market rules, attracting FDI, getting hold of international technologies, and learning by doing and by exporting to world markets has been a successful strategy for development in these regions. As a result, a strong regional disparity has developed. Introducing WTO rules to all of China is occasionally regarded as a tool for development for the currently less developed regions. In this theoretical paper we would like to contribute to this discussion by taking a closer look at the interdependencies of regional development and the endgenous formation of regions. In a neoclassical model of regional growth and development with imperfect labor markets (other than in NEG model) we will show four effects of regional development: 1. Regional development can indeed be driven by international integration via FDI, exports, and technological catching up. 2. This process of rapid regional growth in some regions will cause 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 (like WTO rules) some time later. 4. Finding an optimal tax rate that maximizes GDP limits government infrastructure investments and suggests the introduction of interregional transfers.

Keywords: catching-up, economic development, FDI, international trade, agglomeration, regional growth

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

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1 Regional disparity and three waves of international integration

Regional disparity is a well identified problem in China's development[1]. In a recent long term study Kanbur/Zhang (2005) suggest that regional disparity is driven by different factors in different historical periods. In the current period of increasing regional disparity, starting at the end of the 70s[2], international integration was identified as an important determinant of increasing inequality.

Since the beginning of the "Open Door Policy" at the end of the 70s three waves of international integration have been introduced to the Chinese economy.[3] The first wave was characterized by the introduction of Special Economic Zones (SEZ). All these SEZ were located in the coastal belt. The geographic advantages of the coast[4] and preferential policy[5] were used to reduce international transaction costs for exports and international investors.[6] Geographic advantages were not only given by low physical transport costs of the coast, but included cultural closeness to non mainland territories like Taiwan, Hong Kong, Macao etc. As a result, overseas Chines were attracted as international investors providing FDI. For the period 1978 to 1993 Chen/Fleisher (1996) found evidence of regional convergence conditional e.g. on coastal location and FDI. However, disparities between coastal areas and the hinterland seemed to increase.[7]

Since 1992 the experiment of trade and FDI facilitating deregulations has been extended to more locations. FDI and the ability of export[8] seem to be a major determinant of successful development in the coastal belt.[9] "Export and

[1] See e.g.Chen/Fleisher (1996), Jian/Sachs/Warner (1996), Chen/Feng (2000),Lee (2000), Wei (2000), Fujita/Hu (2001) Khan/Riskin (2001), Xiaojuan (2001), Wan (2001), Yao/Zhang (2001), Démurger (2000, 2001), Dayal-Gulati/Husain (2002), Golley (2002), Lu/Wang (2002), Yao/Zhang/Hanmer (2004). Besides the English laguage literature, there is a number of important Chinese language references that are not cited here.

[2] Kanbur/Zhang (2005) identified a structural break in their time series data in 1979.

[3] Tuan/Ng (2004) also identify three stages of integration policy. However, the definition in this paper is slightly different. While in Tuan/Ng (2004) adjusting for entering WTO was regarded as the third stage, in this paper wave 3 is defined as the ongoing broader liberalization as a conesquence of WTO accession.

[4] Bao et al. (2002) point out that geography which translates into international transaction costs is responsible for a significant part of the success story.

[5] See Demurger et. al. (2002), Geography, Economic Policy, and Regional Development in China.

[6] See Wei, X. (2000).

[7] See also Wen (2003) who found industrial clustering and high geograpic concentration of industries in several coastal regions. Cumulative causation in this process of industrial concentration is emphasized by Golley (2002).

[8] See e.g. Chen/Feng (2000) and Zhang/Song (2000).

[9] The effects of economic integration, particulary of FDI, on growth was studied in an number of papers. Technology spill over from FDI and imitation are an important impact of FDI. Cheung/Lin (2004) found that the spillover effect is strongest for minor innovations such as external design patents. Dayal-Gulati/Husain (2002) found that economic takeoff—or an acceleration in economic growth—is associated with inflows of foreign direct investment, possibly through technological transfer; and (ii) that takeoff is accompanied, at least in the short term, by widening income inequality. Mutually accelerating forces of FDI, exports and growth are identified by Liu/Burridge/Sinclair (2002). while Yao (2006) points out that both

FDI have been making the Chinese economy grow faster, while at the same time the highly uneven distribution of trade and FDI has caused the regional disparity to increase greatly." (Fujita/Hu (1999), p.31). The second wave of integration was still gradual and highly controlled, both in terms of instruments and affected locations. Again, the most important of the now privileged regions were located along the coast. This period of broader but still limited liberalization led to the tremendous success-story of the coastal belt in the 90s,[10] However, in this period economic disparity continued rising. [11]

With the adjustment to WTO accession the third wave of international integration had begun. Accession to the WTO required a change in economic rules in very many fields of regulations. Preferential policies have to be abolished. Hence, in contrast to the first and second wave, accession to the WTO does not systematically prefer certain locations. WTO accession will push convergence of economic rules across regions. Broad liberalization (throught WTO rules) as in the former less privileged regions, together with the "Go West Policy" is expected to trigger a broad wave of development in the former less privileged regions (see e.g. Xiaojuan (2001)).

Regional development is not an isolated phenomenon. Regions often have close links to neighboring regions and the growth process is highly interdependent. The discussion of mutual dependent regional growth and development basically focuses on two channels of interregional growth effects. First, a rapid growing and technological developing region is expected to have positive externalities on other regions close by. Backward and forward linkages in production may drive development in the neighborhood of an agglomerating centre. Brun/Combes/Renard (2002) and Fu, X. (2004) test for this idea and find limited linkages of this kind in China. Yao/Zhang (2002) however argue that these linkages depend on the distance. Second, regional growth is no isolated process. A growing and accumulating region will attract additional mobile resources, like mobile human capital. With a strong increase in interprovincial migration (Lin/Whan/Zao (2004), Section III), the reallocation process of human capital will widen the gap between the growth performance of regions.

In this theoretical paper we would like to contribute to the discussion above by taking a closer look at the interdependencies of regional development. We introduce a rather general stylized model of regional development and focus on this interregional allocation of factors of production As there is interregional migration of important resources like human capital the development of one region is closely linked to the development of neighboring regions. In a rather simple (basically neoclassical in contrast to NEG[12]) model of regional growth and development we include labor market frictions. Introducing labor

exports and FDI have a strong and positive effect on economic growth.

[10] Additional factors determining regional growth are broadly discussed in the literature. Chen/Feng (2000) identify human capital, education and the private sector as major contributors to high growth rates in these regions. Demurger (2001) focuses on infrastructure.

[11] Wang/Ge (2004) discover that the regional disparities between the east region and the rest of China are widening, while the regional disparity between the mid and the west is shrinking..

[12] New Economic Geography (NEG).

market frictions and uncertainty in the migration process, we obtain a multiple equilibrium solution. We will show five effects of mutually dependent regional development, agglomeration and disparity:

1. Regional development can indeed 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 the back of other regions, causing regional income disparity. 3. Under rather general conditions we find multiple equilibria solutions. With the existence of multiple equilibria the process of gradual and sequential introduction of international integration of different regions is highly path dependent. With path dependency of regional development there is no symmetry in economic development when all regions introduce identical conditions (like WTO rules) sequentially. Early development of the privileged regions and the resulting advantages cannot be compensated by simply giving identical conditions to backward regions later on. The history of the process of international integration matters. 4. Historical disadvantages can only be compensated by additional efforts of the government that go far beyond the mere introduction of identical conditions. If the reduction in regional disparity is a political goal, a big push in favor of the backward inland regions is needed in order to compensate historic disadvantages. A GDP maximizing optimal tax rate limits the ability of the government to promote growth. While some of the effects are in line with the findings in NEG growth models, the economic story and the mechanics in this model are neoclassic and hence rather different.

2 A four equation model of regional development

Ecfonomic Integration and NEG growth models: The effects of trade and economic *integration* have been discussed in a number of papers within the framework of New Regional Growth Theory. Eaton/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/Forslid (2000a) look at stabilizing or destabilizing effects of integration, while Baldwin/Forslid (2000b) introduce scale economies and imperfect competition into the R&D and financial inter-mediation sectors of a Romer-Grossman-Helpman endogenous growth model.

Baldwin/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/Ottaviano (2001) and Martin/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/Martin (2003) consider endogenous growth. Baldwin/Martin/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 agglomeration. Even if the connection between growth, migration and agglomeration seems very obvious, only few papers have appeared. Walz (1996), Puga (1999), Baldwin/Forslid (2000a), Black/Henderson (1999b), Fujita/Thisse (2002,Ch.11) and recently Kondo (2004) introduced this link. The basic framework of theses models again consists of 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.[13] 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 somewhat different. Within a neoclassical model, externalities are technical and information externalities in the imitation process. Market imperfection is located in the labor market. Non-separability of growth, urbanization and regional agglomeration have combined interactions. The main reason why firms are located in a certain region is because they have access and proximity to international technologies and a pool of human capital. In the discussion of this process Glaeser et al. (1992) point to the distinction between Jacobs (1969) and MAR (Marshall-Arrow-Romer) externalities. MAR externalities focus on knowledge spill-over processes between firms in 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 of 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, this section develops a basically 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, the focus is on the macro mechanics of development, rather than on concentrating on sophisticated micro foundations. This model will be stylized and simplified in such a way 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. Therefore, the advantage of this approach is that it models regional growth and agglomeration phenomena in a very clear and simple way. The disadvantage of this macro level "bird's-eye view" approach is obviously a less sophisticated way of looking at

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

micro processes. Mobile human capital can migrate according to expected wage arbitrage. Section 3 adds a second region to define a developing country where human capital is mobile between the regions. 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. Section 5 discusses implications in the context of China's WTO accession.

General model characteristics: The economy 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. In this stylized economy an international traded final good is produced with immobile land, regional human capital and international mobile real capital. All trading transactions are directed to world markets. Due to positive externalities, inflowing FDI induces imitation and hence productivity growth. The regional government can influence the economy by changing international transaction costs (transport costs as well as barriers to trade), and providing the public infrastructure required for imitation.

Final output: The final output sector uses land L_i international capital flowing into the region as FDI K_i and the number of employed skilled workers 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*[14]. Hence X_i is a production value function measured in international prices. With the concept of the *foreign exchange production function* the agregate 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 in 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.[15]. The production of the final good takes place under perfect competition and constant economies to scale and is described by a Cobb–Douglas technology

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

[14] See Findlay (1973, 1984).

[15] Another way to introduce international capital in domestic production of the final good at the micro level 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 micromodelling 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.

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).[16] 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 resources are taken as taxes from aggregate output. They are a politically determined fraction γ_i of GDP.

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[17] 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 and τ_i^{ex} are modeled as iceberg 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[18] 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 includ-

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

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

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

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

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

ing 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 (2), 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 that have to match with the profiles of vacant jobs offered by firms.

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 mechanism, which finally reduces to only one single simple labor market equation (3):

Human Capital: 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

$$N_i + U_i = H_i. \tag{3.1}$$

Labor market activities are described by *separation of jobs* and reemployment activities of firms, and *search activities* of workers. There is an outflow of recently separated jobs into the labor market and another outflow of the labor market into newly created jobs. The match between a worker's ability profile and the job requirements given by firms determines 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 permanently must be 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 between 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[19] and reduce the search and matching process of workers purely to a random process. Hence, the individual probability of finding a job (to have a match) p_i is described by a poissant distribution[20] and given by:

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

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

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

$$\theta_i = U_i / V_i \tag{3.5}$$

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

$$\lambda_i = \lambda(\theta_i, N_i) = \theta_i^{-\varepsilon_i} N_i^{-\mu_i} \quad 0 < \varepsilon_i, \mu_i < 1. \tag{3.6}$$

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. We assume that the labor market instantaneously adjusts. In 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:

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

[19] See again Diamond (1982), Howitt (1985), Mortensen (1989) or Pissarides (2000). For a recent survey see Rogerson/Shimer/Wright (2005).

[20] 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.

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[21]

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

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

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 regions to exactly fill the presently vacant jobs. If the search and matching process were perfect, the exact number of workers would be sufficient. Under non perfect matching conditions the equilibrium unemployment rate is

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

From 3.7 and 3.5 we can determine the expected rate of matches λ_i as a function of N_i jobs in the region[22]

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

Using (3.1) and (3.9) we can also determine the equilibrium employment ratio as the relation of the total number of skilled workers H_i to the number of employed skilled workers N_i, taking into account the rigidities of the search and matching process.[23]

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

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[24]

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

[21] See appendix 1a and 1b.
[22] See appendix 1c.
[23] See appendix 1d.
[24] See appendix 1e.

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:[25]

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 for positive spill-over from FDI to host regions 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. 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[26]. Later Nelson/Phelps (1966), Gries/Wigger (1993), Gries/Jungblut (1997) and Gries (2002) further developed these ideas in the context of catching-up economies. The catching-up hypothesis has been tested successfully and robustly by Benhabib/Spiegel (1994), de la Fuente (2002), and Engelbrecht (2003). Therefore, in this approach technological progress in a backward economy is modeled as a process of endogenous catching-up relative to an exogenous growth path of a technological leader.

Considering all three effects, the exogenous process is given by international innovation growth. The endogenous process of imitation and participation in the world wide technical progress is determined by dynamic externalities from FDI and from domestic government investments in the ability to imitate. 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 generated by externalities[27]

[25] There is a broad literature on international technology diffusion that suggested various channels. Eaton/Kortum (1999) discuss 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.

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

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

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

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 $\delta_G + \delta_K = \delta < 1$ and δ is small.

As described above, government expenditures are restricted by government tax income. We abstract from government borrowing or lending and interregional transfers. Hnece the government budget constraint is

$$G_i = \gamma_i X_i \tag{5}$$

The three equations (1), (2), and (4) capture the model of regional development for one region. Labor market friction (3) is needed for migration decisions only. 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)[28]

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

To simplify, this equation is rewritten as[29]

$$\begin{aligned} \dot{\omega}_i(t) &= \Psi_i \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t), \qquad \frac{d\dot{\omega}_i(t)}{d\omega(t)} < 0 && (6) \\ \text{with} \quad \Psi_i &:= \gamma^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta}. && (7) \end{aligned}$$

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

[28] See appendix 1f.

[29] 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 from $\dot{\omega}_i(t) = 0$[30]

$$\omega^* = \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \quad (8)$$

$$\frac{\partial \omega_i^*}{\partial N_i} = \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega^* N_i^{-1} > 0, \quad (9)$$

$$\frac{\partial \omega_i^*}{\partial \tau_i} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_K + \frac{\beta}{1-\beta}\delta \right] \tau_i^{-1} < 0 \quad (10)$$

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_K + \frac{\beta}{1-\beta}\delta \right] (1-\tau_i^{ex})^{-1} < 0 \quad (11)$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_G \gamma_i^{-1} - \left(\delta_K + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] \gtreqless 0 \quad (12)$$

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 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. Similarly, 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 in the success of a region.

Optimal level of government activity: The steady state reaction of ω_i^* resulting from a change in government expenditures is ambiguous and depends on the present state of government policy. With respect to the potential goal of maximizing the regions' steady state position we can determine an optimum tax rate[31] and hence an optimum value of government expenditures for technology related infrastructure

$$\max_{\gamma_i} \quad \omega^* \qquad \Rightarrow \gamma_i^* = \frac{\delta_G}{\left(\delta_K + \frac{\beta}{1-\beta}\delta + \delta_G \right)}.$$

Therefore, there is a range $\gamma_i < \gamma_i^*$ where an increase in γ positively affects ω_i^*. Beyond the optimal value γ_i^* (for $\gamma_i > \gamma_i^*$) an increasing tax rate and increasing

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

[31] In appendix 1g we show that the government can maximize the final development position of the economy and the speed of growth by choosing an optimal level of govenment expenditure for public infrastructure.

government expenditures reduce ω_i^*.

$$\frac{\partial \omega^*}{\partial \gamma_i} \begin{cases} > 0 & & \gamma_i < \gamma_i^* & \text{undertaxation} \\ = 0 & \text{for} & \gamma_i = \gamma_i^* & \text{GDP maximizing tax rate} \\ < 0 & & \gamma_i > \gamma_i^* & \text{overtaxation} \end{cases} \tag{13}$$

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 certain skills. Since the country's total endowment of human capital can migrate from one region to the other, human capital allocation can change over time:

$$H = H_1(t) + H_2(t). \tag{14}$$

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

$$\begin{aligned} \frac{dN_2}{dN_1} &= \frac{\left[1 + \left(1 + \frac{\mu_1}{(1-\varepsilon_1)}\right)\sigma N_1^{\left(\frac{\mu_1}{(1-\varepsilon_1)}\right)}\right] dH_2}{\left[1 + \left(1 + \frac{\mu_2}{(1-\varepsilon_2)}\right)\sigma N_2^{\left(\frac{\mu_2}{(1-\varepsilon_2)}\right)}\right] dH_1} = -a(N_1, N_2) < 0 \quad \text{in general} \\ \frac{dN_2}{dN_1} &= -1 < 0 \quad \text{for identical regions, that is } H_1 = H_2, \quad N_1 = N_2 \end{aligned} \tag{15}$$

This is an important condition which will be used many times in the analysis later on. 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 (8) 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[32]

[32] See Appendix 2a.

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \tag{16}$$

$$\frac{d\Omega^D}{dN_1} > 0, \quad \frac{d\Omega^D}{d\tau_1} < 0, \quad \frac{d\Omega^D}{d\tau_1^{ex}} < 0, \quad \text{and} \quad \frac{d\Omega^D}{d\gamma_1} < 0 \ \text{ for } \ \gamma_1 > \gamma_1^*.$$

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 (7)) and in particular on the allocation of H to the two regions. Depending on H the final development condition can be drawn as *final development curve* Ω^D in the $H_1 - \Omega$ 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 H_1 axis at 0 with an infinite positive slope. When N_1 increases the slope remains positive and eventually Ω^D becomes infinite, once H_1 approaches H. For symmetric and identical regions at $H_1 = H_2$ and $N_1 = N_2$ 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

$$\Omega(t) = \frac{\omega_1(t)}{\omega_2(t)} \implies \frac{\dot{\Omega}}{\Omega} = \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \tag{17}$$

$$\frac{\dot{\Omega}(t)}{\Omega(t)} = a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \ \text{ for } \Omega(t) > \Omega^D \tag{18}$$

For $a_1 > a_2$ the present position of the two regions Ω is above[33] the final development curve Ω^D in figure 1. From (17) can be seen that Ω decreases ($\frac{\dot{\Omega}}{\Omega} < 0$).[34]

$$\lim_{N_1\to 0}\Omega^D = 0, \quad \lim_{N_1\to o}\frac{d\Omega^D}{dN_1} = \infty, \lim_{N_1\to N}\Omega^D = \infty, \quad \lim_{N_1\to N}\frac{d\Omega^D}{dN_1} = \infty$$

$$\Omega^D_{|N_1=N_2} = 1, \quad \frac{d\Omega^D}{dN_1}_{|N_1=N_2} = 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}L_1^{-\frac{\alpha}{1-\beta}}N_1^{-1} > 0, \quad \text{for identical regions}$$

See appendix 2b.

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

[34] See appendix 2c.

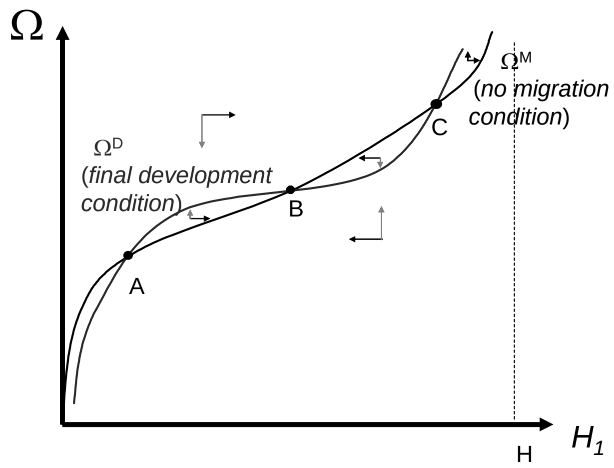

Figure 1: Steady State and Dynamics

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" has added portfolio and insurance effects. As micromodelling 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 wage income. As the probability of finding a job (probability of a match) was denoted p_i (see (3) and (3)) and the wage rate is w_{N_i}, expected wage earnings are $p_i w_{N_i}$[35]. As we assume perfect competition in the final goods market, factor prices (and wages alike) are determined by their marginal productivity[36]

$$w_{N_i} = \frac{1-\beta-\alpha}{1-\beta}\left(1-\gamma_i\right)\omega_i^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}}. \quad (19)$$

For simplicity we define expected income purely as expected wages and no income for the case of unemployment, we abstract from potential remittance

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

[36] See appendix 3a.

from a family support network. In this model unemployment stands for no income at all, neither in the formal 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

$$\dot{H}_1(t) = m(\frac{p_1 w_{N_1}}{P_2 w_{N_2}} - 1). \tag{20}$$

In no migration equilibrium $\dot{H}_1(t) = 0$. Therefore, no migration equilibrium is characterized by the expected wage no arbitrage condition

$$\frac{p_1 w_{N_1}}{p_2 w_{N_2}} = \frac{\lambda_1 e^{-\lambda_1} w_{N_1}}{\lambda_2 e^{-\lambda_2} w_{N_2}} = 1. \tag{21}$$

From condition (21) and the equilibrium expected matching rate (3.11) we can derive a curve describing all no-migration positions of relative technological upgrading Ω^M.[37]

$$\begin{aligned}
\Omega^M &= \frac{\omega_1}{\omega_2} \qquad (22)\\
&= \frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)} (1-\gamma_2)^{(1-\beta)} L_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha + \frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)} (1-\gamma_1)^{(1-\beta)} L_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha + \frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}}\\
\frac{d\Omega^M}{dN_1} &> 0 \qquad \text{for identical regions,} \qquad \frac{d\Omega^M}{dN_1} \lesseqgtr 0 \qquad \text{in general,}\\
\frac{d\Omega^M}{d\tau_1} &> 0, \qquad \frac{d\Omega^M}{d\tau_1^{ex}} > 0, \qquad \frac{d\Omega^M}{d\gamma_1} > 0.
\end{aligned}$$

We refer to this condition as the *no migration curve*. The *no migration curve*[38] 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 $[\lim_{N_1 \to N} \Omega^M = \infty]$[39]

Dynamic adjustment is shown in figure 1. If at a given endowment N_1 in region 1 relative productivity is presently smaller than required by the expected wage 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.

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

[38] For the reactions of the *no migration curve* see appendix 3c.

[39] 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.

Multiple Steady State Equilibria: For symmetric regions we find multiple equilibria under rather general conditions.[40] 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. The reasons 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 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 that the slope of the *final development curve* is smaller than the slope of the *no migration curve*. The corresponding condition is[41]

$$\frac{d\Omega^D}{dN_1} < \frac{d\Omega^M}{dN_1} \quad \text{that is} \quad \frac{\delta - \alpha}{(1-\beta-\delta)} < \frac{\mu}{(1-\varepsilon)}. \tag{23}$$

This stability condition is also a sufficient condition for the existence of multiple equilibria.[42] This stability condition holds if the parameter driving productivity growth δ and hence migration are relatively small compared to the parameters determining the productivity of the domestic immobile factor α. In other words, this condition for stability holds if the domestic immobile factor is sufficiently important in the production process.

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 instable adjustment. Region 1 will disappear in economic terms. With a symmetric mechanism the area to the right of A leads to a stable adjustment towards point B. Between point B and C a stable adjustment leads the two 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 a 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 Preferential policy and endogenous formation of agglomerations

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 act like non-tariff trade barriers. If a region reduces international

[40] See appendix 4a.
[41] See appendix 3d.
[42] See appendix 4b.

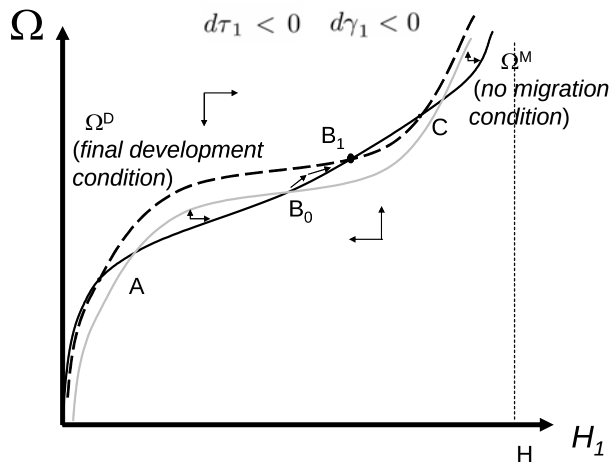

Figure 2: Endogenous Formation of Regions

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 shifts upward (see (16)). and the *no migration curve* Ω^M shifts downward (see (22))[43]. 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 decrease of the tax rate [$d\gamma_1 < 0$] in case of excessive taxation [$\gamma_1 > \gamma_1^*$]. 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. For a strong variation in parameters we may obtain a bifurcation and a process of complete divergence occures.

Population Size, Density and Agglomeration: For the system of two stationary conditions (16), (22),the resource constraint (14) and taking B (identical

[43] 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.

regions) as the starting point, we solve for the equilibrium reaction of human capital in region 1[44]

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

In region 1 population will grow, while region 2 faces a brain drain and shrinks. 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, since one region absorbs human capital from the other to feed agglomeration. Technological acceleration endogenously terminates when imitation becomes more difficult and a region approaches more sophisticated technologies. Further, immigration 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.

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.[45]

$$\frac{du_i}{dH_i} = \frac{1}{H_i}\left[\nu_i\left(N_i\right) + \frac{N_i}{H_i}\right] > 0 \tag{24}$$

The information problem in the search process includes the idea of information networks in more rural regions. The state of absolutely no employment and no income is more likely in agglomerating centers. 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

[44] See appendix 5.

[45]

$$\begin{aligned} u_i &= \frac{U_i}{H_i} = \frac{H_i - N_i}{H_i} \\ \frac{du_i}{dH_i} &= \frac{1}{H_i}\left[\left(1 - \frac{dN_i}{dH_i}\right) - \frac{H_i - N_i}{H_i}\right] \end{aligned}$$

result we find higher wages in the centers and lower wages in backward regions. The wage pattern is similar to that used in NEG models, however the economics are different. In this model higher wages in agglomeration compensates for a loss of security in the rural family network.

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 condition (15) for identical regions, GDP reactions in the two regions are

$$\begin{aligned}
\frac{dX_1^*}{d\tau_1} &= \overbrace{\frac{X_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{X_1^*}{\omega_1^*}\frac{d\omega_1^*}{dN_1}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\frac{X_1^*}{N_1}}^{\langle 3\rangle}\right)\frac{dN_1}{d\tau_1} < 0 \\
\frac{dX_2^*}{d\tau_1} &= -\left(\frac{X_2^*}{\omega_2^*}\frac{d\omega_2^*}{dN_2} + (1-\alpha-\beta)\frac{X_2^*}{N_2}\right)\frac{dN_1}{d\tau_1} > 0, \qquad (25) \\
& \text{For the tax rate } \gamma_1 \text{ we obtain} \qquad (26) \\
\frac{dX_1^*}{d\gamma_1} &< 0, \quad \frac{dX_2^*}{d\gamma_1} > \quad \text{for } \gamma_1 > \gamma_1^*
\end{aligned}$$

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

$$dX^* = dX_1^* + dX_2^* = \frac{X_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1} < 0. \qquad (27)$$

Adjusting for 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.

Price of Immobile Factors: While integrated labor markets lead to wage differentials among the two regions, factor prices for immobile land ρ_i[46] will be also affected non-symmetrically.

[46] See appendix 6.

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

$$\frac{d\rho_1}{d\tau_1} = \overset{(+)}{F_{L\omega}}\left(\overset{(-)}{\frac{d\omega_1^*}{d\tau_1}} + \overset{(+)}{\frac{d\omega_1^*}{dN_1}}\,\overset{(-)}{\frac{dN_1}{d\tau_1}}\right) + \overset{(+)}{F_{LN}}\,\overset{(-)}{\frac{dN_1}{d\tau_1}} < 0 \tag{28}$$

$$\frac{d\rho_2}{d\tau_1} = \overset{(+)}{F_{L\omega}}\left(\overset{(+)}{\frac{d\omega_2^*}{dN_2}}\,\overset{(-)}{\frac{dN_2}{dN_1}}\,\overset{(-)}{\frac{dN_1}{d\tau_1}}\right) + \overset{(+)}{F_{LN}}\,\overset{(-)}{\frac{dN_2}{dN_1}}\,\overset{(-)}{\frac{dN_1}{d\tau_1}} > 0 \tag{29}$$

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 and industrial specialization: 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*[47] the link to trade theory and endogenous determination of comparative advantages is straightforward. According to this concept the production function becomes a value 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 and the pattern of specialization according to neoclassical trade theory.

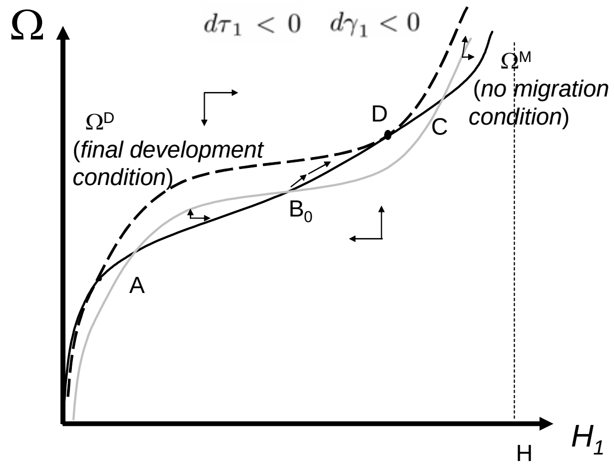

Figure 3: bifucation

5 Path dependence, transitory disadvantages and WTO accession

Path dependence: With the existence of a multiple equilibria solution and the identification of different international transaction cost as shift parameters of the final development curve 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.[48]. 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 dynamic properties With this bifurcation the stability of the equilibrium has disappeared. To the left of D we find a stable adjustment paths. To the right of D 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 (figure 4). Equilibrium D will disappear and the two regions will move on an unstable path. As soon as the interdependent regional development process passes D the economies move on an unstable path of divergence towards a

[47] See Findlay (1973, 1984).

[48] 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.

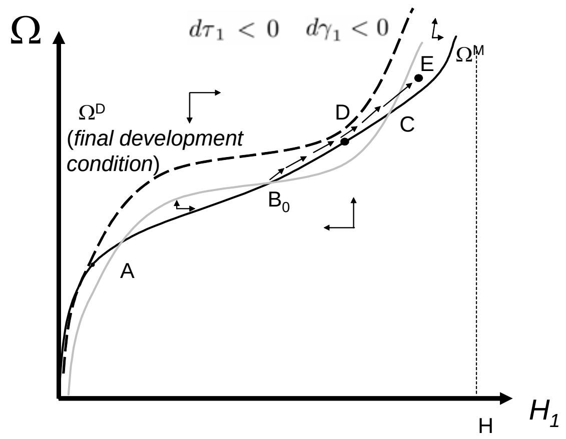

Figure 4: Instable agglomeration

general unstable locus. Once the economies are in E, 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 powerful.

Path dependence and WTO accession: What does this mean for China and the WTO accession? Preferential Policy has triggered a very successful development of the privileged regions.[49] Reducing international transaction costs and inviting FDI has initiated an unprecedented growth process[50] in some regions, but also has driven divergence in regional development.[51] To a large extent Preferential Policy was a policy of liberalization and gradual introduction of market rules.[52] WTO accession may have a comparable effect and cannot be limited to certain islands of the market economy. Therefore, WTO can be regarded as an instrument for market liberalization and for a convergence of economic rules across regions. The optimistic view is that a convergence of economic rules in terms of the degree of market liberalization may help to de-

[49] Mutually accelerating forces of FDI, exports and growth are identified by Liu/Burridge/Sinclair (2002). while Yao (2006) points out that both exports and FDI have a strong and positive effect on economic growth.

[50] See Zhang (1999).

[51] See again e.g. Fu (2004) or Fujita/Hu (2001).

[52] See Demurger et al. (2002).

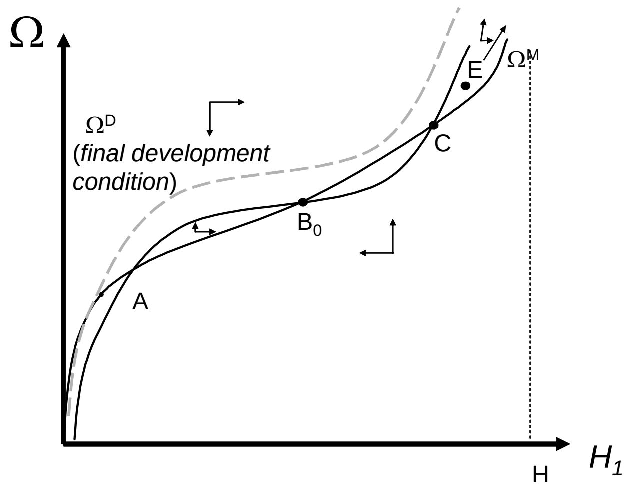

Figure 5: Path dependence and instable branch.

velop the previously less privileged regions and lead to a convergence of regional development. [53]

Our view is less optimistic. The problem of path dependence clearly suggests that advantages, even if they are transitory in nature, may have permanent effects. The time path matters. An early developing region absorbs resources from neighboring regions and positive externalities will further promote 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 cannot be compensated by just a convergence of economic rules. WTO may faciliate liberalization and convergence of economic rules[54], however liberalization 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 in the Western and North Western Regions.[55] 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. The "Go West" strategy can only be successful if these disadvantages can be overcompensated by a massive active push. The concentration of

[53] See e.g. Xiaojuan (2001).
[54] See Lingnan/Zhang (2003).
[55] See also Demurger et al. (2002).

relevant resources must reverse in favor of backward regions.

Government activities, taxation and interregional government transfers: The discussion above implies that a strong push in government infrastructure investments in the backward regions may be needed to reverse regional divergence. However, the model suggests that due to the growth effects of tax policy, government activities are limited. Since additional government investments must be financed by regional taxes and additional taxes have a negative effect on FDI inflows, there is an optimal tax rate and hence a optimal government investment level for growth (see (13)).

$$\frac{d\omega_i^*}{d\gamma_i}\begin{cases} > 0 & \gamma_i < \gamma_i^* & \text{undertaxation} \\ = 0 \quad \text{for} & \gamma_i = \gamma_i^* & \text{income maximizing tax rate} \\ < 0 & \gamma_i > \gamma_i^* & \text{overtaxation} \end{cases} .$$

For $\gamma_i < \gamma_i^*$ positive growth effects from additional infrastructure are stronger than negative effects on FDI and growth externalities from increasing taxes.

For $\gamma_i > \gamma_i^*$ general advantages from government investments become overcompensated by the negative effects from expenditure financing taxes. The binding government budget constraint restricts positive government activities. This problem becomes even more serious as poorer inland regions with a potential need for huge investments can afford only limited levels of government activities. An extraordinary investment push cannot be realized out of the regions' own resources.

Therefore, the budget constraint could be relaxed by interregional government transfers. The traditionally privileged regions could help finance these investments. An interregional transfer of resources to finance government infrastructure with high effects on productivity growth would be an organized spill over effect from the already successful regions to the still backward regions in the hinterland.

6 SUMMARY AND CONCLUSIONS

China's recent development has been driven by a rather small number of privileged regions. In these privileged regions international transactions and international integration were facilitated. Introducing international market rules, attracting FDI, obtaining international technologies, and learning by doing and by exporting to world markets has been a successful strategy for development in these regions. As a result, a strong regional disparity has developed. Introducing WTO rules to all of China is sometimes regarded as a tool for development for the currently less developed regions. In this theoretical paper we would like to contribute to the discussion of regional disparity and the potential effects generated by WTO accession.

We develop a rather simple (basically neoclassical in contrast to NEG) model of regional growth and development and include labor market frictions. Interregional migration and imitation of international technologies generates growth and agglomeration. With labor market frictions and uncertainty in the migration process we obtain a multiple equilibrium solution. While some of the effects are in line with the findings in NEG growth models, the economic mechanisms in this model are rather different. We would like to focus on four effects of mutually dependent regional development:

1. Regional development can indeed be driven by international integration via FDI, exports, and technological catching up. 2. Rapid regional growth and agglomeration in some regions will happen on the back of other regions, causing regional income disparity. 3. Under rather general conditions we find multiple equilibria solutions. With the existence of multiple equilibria the effects of a gradual and sequential introduction of international integration of different regions is highly path dependent. With path dependency of regional development there is no symmetry in economic development when all regions introduce identical conditions (like WTO rules) sequentially. The problem of path dependence suggests that advantages, even if they are transitory, may have permanent effects. 4. Historical disadvantages can only be compensated by additional efforts of the government which go far beyond simply introducing identical conditions. If the reduction in regional disparity is a political goal, a big push in favor of the backward inland regions is needed in order to overcompensate historic disadvantages. A GDP maximizing optimal tax rate limits the ability of the government to promote growth. Therefore, the budget constraint could be relaxed by interregional government transfers. The traditionally privileged regions could help finance these necessary investments to promote catching up of the yet underdeveloped regions.

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7 Extended Appendix

Appendix 1a: Equilibrium tightness:

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

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:

$$
\begin{aligned}
U_i &= \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)} \\
H_i &= N_i + \sigma N_i^{\left(1+\frac{\mu_i}{(1-\varepsilon_i)}\right)} \\
H_i &= N_i\left(1 + \sigma N_i^{\frac{\mu_i}{(1-\varepsilon_i)}}\right)
\end{aligned}
$$

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

Appendix 1e: determining the production level:

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

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:

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

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

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

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

To simplify, this equation is rewritten as

$$
\begin{aligned}
\dot{\omega}_i(t) &= \Psi_i\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega(t)^{\frac{\delta}{1-\beta}}-\omega(t) \qquad \text{see} \qquad (6)\\
\text{with}\quad \Psi_i &:= \gamma^{\delta_G}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)^{\delta_K+\frac{\beta}{1-\beta}\delta}. \qquad \text{see} \qquad (7)
\end{aligned}
$$

solve for the steady state position:

$$
\begin{aligned}
0 &= \dot{\omega}_i(t)\\
0 &= \Psi_i\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega^{\frac{\delta}{1-\beta}}-\omega\\
\omega &= \Psi_i\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega^{\frac{\delta}{1-\beta}}\\
\omega^{1-\frac{\delta}{1-\beta}} &= \Psi_i\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\\
\omega^{\frac{1-\beta-\delta}{1-\beta}} &= \Psi_i\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\\
\omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \text{see} \qquad (8)
\end{aligned}
$$

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

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

$$
\begin{aligned}
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-1} N_i^{\frac{-\alpha}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* N_i^{-\frac{1-\beta-\alpha}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* N_i^{\frac{-1+\beta+\alpha-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* N_i^{-\frac{1-\beta}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* N_i^{-1} > 0, \quad \text{see} \quad (9)
\end{aligned}
$$

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

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

$$
\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\Psi_i\tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{\delta+1-\beta-\delta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\omega^*\tau_i^{-1} < 0 \qquad \text{see} \qquad (10)
\end{aligned}
$$

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

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

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

$$
\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\Psi_i(1-\tau_i^{ex})^{-1} \\
&= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+1}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K + \frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1} \\
&= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+\frac{(1-\beta-\delta)}{(1-\beta-\delta)}}\left[L_i^{\frac{\alpha}{1-\beta}}N_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_K + \frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1} \\
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\left[\delta_K + \frac{\beta}{1-\beta}\delta\right]\omega_i^*(1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (11)
\end{aligned}
$$

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

$$
\begin{aligned}
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\Psi_i^{-1}\frac{\partial \Psi_i}{\partial \gamma_i} \\
\frac{d\Psi_i}{d\gamma_i} &= \delta_G\gamma_i^{\delta_G-1}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)^{\delta_K+\frac{\beta}{1-\beta}\delta} \\
&\quad -\left(\delta_K + \frac{\beta}{1-\beta}\delta\right)\gamma_i^{\delta_G}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)^{\delta_K+\frac{\beta}{1-\beta}\delta-1}\frac{(1-\tau_i^{ex})\beta}{\tau_i r_i} \\
&= \delta_G\gamma_i^{-1}\Psi_i - \left(\delta_K + \frac{\beta}{1-\beta}\delta\right)\Psi_i(1-\gamma_i)^{-1} \\
&= \Psi_i\left[\delta_G\gamma_i^{-1} - \left(\delta_K + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \\
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\left[\delta_G\gamma_i^{-1} - \left(\delta_K + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \quad see \quad (12)
\end{aligned}
$$

Appendix 1g: Optimal level of government activities:

$$\max_{\gamma_i} \quad \omega^* = \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_i^{\frac{\alpha}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \Psi_i := \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i} \right)^{\delta_K + \frac{\beta}{1-\beta}\delta}$$

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i} \\
\frac{d\Psi_i}{d\gamma_i} &= \Psi_i \left[\delta_G \gamma_i^{-1} - \left(\delta_K + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] = 0 \\
\delta_G &= \gamma_i \left(\delta_K + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \\
(1-\gamma_i)\,\delta_G &= \gamma_i \left(\delta_K + \frac{\beta}{1-\beta}\delta \right) \\
\delta_G - \gamma_i \delta_G &= \gamma_i \left(\delta_K + \frac{\beta}{1-\beta}\delta \right) \\
\delta_G &= \gamma_i \left(\delta_K + \frac{\beta}{1-\beta}\delta + \delta_G \right)
\end{aligned}$$

$$\gamma_i^* = \frac{\delta_G}{\left(\delta_K + \frac{\beta}{1-\beta}\delta + \delta_G \right)}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{\omega_i^*}{1-\delta} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i} \quad \text{with}$$

$$\frac{\partial \Psi_i}{\partial \gamma_i} \begin{cases} > 0 & \gamma_i < \gamma_i^* & \text{underinvestment, undertaxation} \\ = 0 \quad \text{for} & \gamma_i = \gamma_i^* & \text{growth maximizing tax rate} \\ < 0 & \gamma_i > \gamma_i^* & \text{overinvestment, overtaxation} \end{cases}$$

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

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \qquad \text{and} \qquad (15)$$

$$\begin{aligned}
d\Omega^D &= \frac{\omega_2^*}{(\omega_2^*)^2} \frac{\partial \omega_1}{\partial N_1} dN_1 - \frac{\omega_1^*}{(\omega_2^*)^2} \frac{\partial \omega_2}{\partial N_2} dN_2 = \frac{1}{(\omega_2^*)^2} (\omega_2^* \frac{\partial \omega_1}{\partial N_1} + \omega_1^* \frac{\partial \omega_2}{\partial N_2}) a dN_1 \\
\frac{d\Omega^D}{dN_1} &= \frac{1}{(\omega_2^*)^2} (\omega_2^* \frac{\partial \omega_1^*}{\partial N_1} + \omega_1^* \frac{\partial \omega_2^*}{\partial N_2} a) > 0 \quad \text{since} \quad \frac{\partial \omega_i^*}{\partial N_i} > 0.
\end{aligned}$$

properties of the curve:

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

$$
\begin{aligned}
\lim_{N_1\to N} \frac{d\Omega^D}{dN_1} &: \\
\text{since } \lim_{N_1\to N}\frac{\partial\omega_2^*}{\partial N_2} &= \lim_{N_1\to N}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_2^* N_2^{-1} = \infty \quad \text{and} \\
\lim_{N_1\to N} a(N_1,N_2) &= \frac{\left[1+\left(1+\frac{\mu_1}{(1-\varepsilon_1)}\right)\sigma N_1^{\left(\frac{\mu_1}{(1-\varepsilon_1)}\right)}\right]}{\left[1+\left(1+\frac{\mu_2}{(1-\varepsilon_2)}\right)\sigma N_2^{\left(\frac{\mu_2}{(1-\varepsilon_2)}\right)}\right]} = \infty \\
&\Longrightarrow \lim_{N_1\to N}\frac{d\Omega^D}{dN_1} = \infty
\end{aligned}
$$

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:

$$
\begin{aligned}
\frac{\dot{\Omega}}{\Omega} &= \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \\
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega_1^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega_2^{-\frac{1-\beta-\delta}{1-\beta}}
\end{aligned}
$$

$$
a_i(t) = \omega_i(t)/\omega_i^*
$$

$$
\begin{aligned}
\frac{\dot{\Omega}}{\Omega} &= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} [a_1\omega_1^*]^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} [a_2\omega_2^*]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \left[a_1 \Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{()1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \right]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&\quad -\Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \left[a_2 \Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \right]^{-\frac{1-\beta-\delta}{1-\beta}}
\end{aligned}
$$

$$
\begin{aligned}
&= \Psi_1 \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} a_1^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_1^{-1} \left[L_1^{\frac{\alpha}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{-\delta} \\
&\quad -\Psi_2 \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} a_2^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_2^{-1} \left[L_2^{\frac{\alpha}{1-\beta}} N_2^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{-\delta} \\
&= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} \\
\text{for } \Omega(t) &= \frac{a(t)_1}{a(t)_2}\Omega^D > \Omega^D \Longrightarrow a(t)_1 > a(t)_2 \\
&\Longrightarrow a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \Longrightarrow \frac{\dot{\Omega}(t)}{\Omega(t)} < 0 \quad \text{see} \quad (17)
\end{aligned}
$$

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

$$
\begin{aligned}
\frac{d\Omega^D}{d\tau_1} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{see} \quad (10) \\
\frac{d\Omega^D}{d\tau_1^{ex}} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{see} \quad (11)
\end{aligned}
$$

Appendix 2e: reaction of the final development curve Ω^D, $\frac{d\Omega^D}{d\gamma_1}$:

$$
\frac{d\Omega^D}{d\gamma_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\gamma_1} \begin{cases} > 0 & \gamma_i < \gamma_i^* \quad \text{undertaxation} \\ = 0 \quad \text{for} & \gamma_i = \gamma_i^* \quad \text{growth maximizing tax rate} \\ < 0 & \gamma_i > \gamma_i^* \quad \text{overtaxation} \end{cases}
$$

Appendix 3a: Determine wage rates:

$$
\begin{aligned}
\pi_i &= (1-\gamma_i)\,X_i - w_{N_i}N_i - \rho_i L_i \\
\text{with} \quad X_i &= \omega_i{}^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}
$$

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

Expected wage income is $Ey_i = p_i w_{N_i} + (1-p_i)\,0$

$$
p_i w_{N_i} = p_i \frac{1-\beta-\alpha}{1-\beta}\,(1-\gamma_i)\,\omega_i{}^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} N_i^{\frac{-\alpha}{1-\beta}} \quad \text{see} \qquad (19)
$$

Derive the *no migration curve* :

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

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

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

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

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

Slope of the *no migration curve* :

$$\Omega^M = \Omega^M(N_1, N_2) \quad \text{and} \quad (15)$$

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

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

$$
\begin{aligned}
\Omega^M &= \Omega^M(N_1, N_2) \quad \text{and} \quad (15) \\
\frac{\partial \Omega^M}{\partial N_1} &= C\frac{e^{-\left(N_2^{-\frac{\mu_2}{(1-\varepsilon_2)}}\right)(1-\beta)}}{e^{-\left(N_1^{-\frac{\mu_1}{(1-\varepsilon_1)}}\right)(1-\beta)}} \frac{N_1^{\alpha+\frac{(1-\beta)\mu_1}{(1-\varepsilon_1)}-1}}{N_2^{\alpha+\frac{(1-\beta)\mu_2}{(1-\varepsilon_2)}}} \left(\alpha + \frac{(1-\beta)\,\mu_1}{(1-\varepsilon_1)}\right) \\
&\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)}}\, 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} \\
&= 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 \quad \text{using also } (15) \\
&= 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:

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

$$C = 1, \qquad a=1 \qquad \text{for identical regions}$$

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

Appendix 3c: Reactions of the *no migration curve*:

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

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

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

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

$$\frac{d\Omega^D}{dN_1} < \frac{d\Omega^M}{dN_1}$$

$$4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}N^{-1} < \frac{4\left(\alpha+\frac{(1-\beta)\mu}{(1-\varepsilon)}\right)}{N}$$

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

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

Appendix 4a: Proposition: 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

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

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 f identical regions

Proposition: The stability condition

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

with $\epsilon < 1$ 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 5: 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 $\frac{dN_1}{d\tau_1}$

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

$$\frac{\partial\Omega^D}{\partial\tau_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0, \quad \frac{\partial\Omega^M}{\partial\tau_1} > 0$$

$$\begin{aligned}\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1} &> 0, \quad \text{since (23) holds} \\ &\text{and hence} \\ \frac{dN_1}{d\tau_1} &= \frac{\frac{\partial\Omega^D}{\partial\tau_1} - \frac{\partial\Omega^M}{\partial\tau_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}} < 0\end{aligned}$$

Reaction $\frac{dN_1}{d\gamma_1}$ (for $\gamma_i > \gamma_i^*$)

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

$$\frac{\partial\Omega^D}{\partial\gamma_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\gamma_1} < 0 \quad \text{for } \gamma_i > \gamma_i^*, \quad \frac{\partial\Omega^M}{\partial\tau_1} > 0$$

$$\begin{aligned}\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1} &> 0, \quad \text{since (23) holds} \\ &\text{and hence} \\ \frac{dN_1}{d\gamma_1} &= \frac{\frac{\partial\Omega^D}{\partial\gamma_1} - \frac{\partial\Omega^M}{\partial\gamma_1}}{\frac{\partial\Omega^M}{\partial N_1} - \frac{\partial\Omega^D}{\partial N_1}} < 0\end{aligned}$$

Appendix 6: Prices for the immobile land, ρ_i :

$$\begin{aligned}
X_i &= F(\omega_i, L_i, K_i, N_i) = \omega_i{}^{\frac{1}{1-\beta}} L_i^{\frac{\alpha}{1-\beta}} (\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i})_i^{\frac{\beta}{1-\beta}} N_i^{\frac{1-\beta-\alpha}{1-\beta}}. \\
\rho_1 &= F_L = \frac{\partial X_1}{\partial L_1} = \frac{\alpha}{1-\beta}(1-\gamma_1)\,\omega_1^{\frac{1}{1-\beta}} L_1^{\frac{\alpha}{1-\beta}-1} (\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1})_1^{\frac{\beta}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \\
&= \frac{\alpha}{1-\beta}(1-\gamma_1)\,\omega_1^{*\frac{1}{1-\beta}} L_1^{-\frac{1-\beta-\alpha}{1-\beta}} (\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1})_1^{\frac{\beta}{1-\beta}} N_1^{\frac{1-\beta-\alpha}{1-\beta}} \\
&= \frac{\alpha}{1-\beta}(1-\gamma_1)\,\omega_1^{*\frac{1}{1-\beta}} (\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1})_i^{\frac{\beta}{1-\beta}} \left[\frac{N_1}{L_1}\right]^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}$$