China's provincial disparities and the determinants of provincial inequality

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Abstract

The paper explains the growth – inequality nexus for China's provinces. The theoretical model of provincial development consists of two regions and studies the interactions of a mutual depending development process. Due to positive externalities, incoming trade and FDI induce imitation and hence productivity growth. The regional government can influence the economy by changing international transaction costs and providing the public infrastructure. Due to mobile domestic capital disparity effects are reinforced. The implications of the theoretical model are tested. As the cntral intention of the paper is to explain provincial disparity we directly relate income disparity (indicated by the contribution to the income Theil index) to the disparity of selected income determining factors (indicated by the contribution to each other Theil index). We examine the determinants of income and inequality for 28 Chinese provinces over the period 1991-2004 and apply random effects panel estimation. Our analysis is based on revised GDP and investment data from Hsueh and Li (1999) and various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS). The results confirm the theoretical framework and suggest a direct linkage between the factors that determine regional income and regional disparity. More specific it is apparent that trade, and foreign and domestic capital as well as government expenditure have an impact on the provincial inequality. Moreover it is the success of the coastal regions and hence potentially geography with the low international transaction costs that drives the provincial inequality of China.

JEL Classification: J24, O14, O18, O33, O40, R55

Keywords: regional development, FDI, international integration, China

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1 Introduction

Since the implementation of economic reforms and opening up to the world market China experienced a continuously high rate of annual growth. The unprecedented boom in foreign direct investment (FDI), and the sustained increase in trade were of impressive dimensions. This positive economic development induced an enormous improvement in the standard of living for China and had an important impact on the global economy regarding the effect of foreign investment decision and international trade. However, a different aspect of this economic success story was a rising inequality within the country and lasting poverty in rural areas. Numerous studies on this topic reflect the importance of this problem. Analyzing the economic development of the coast, the interior and the rural and urban provinces Kanbur and Zhang (2005), Huang, Kuo and Kao (2003), Li and Zhao (1999) and Wan (1998) find statistical evidence for rising inequality brought about by increasing provincial disparities.

What are the sources of the rising provincial disparity? In the 1950s already Kuznets assumed a relationship between average income and inequality and found evidence for a inverted U-curve relation between these variables. A couple of papers (Paukert 1973, Ahluwalia 1976, Carter and Chenery 1976) varified this inverted U-hypothesis across countries at different development levels, however recent studies using other econometric methods and longer data periods find evidence against the Kuznets hypothesis. For example, Deininger and Squire (1996) find no evidence of the Kuznets curve in 90 percent of the cases and argue that there is no clear relationship between income growth and inequality. This results are consistent with the findings of several authors including Dollar and Kraay (2005), Chen and Ravallion (1997), and Easterly (1999).The results of Ravillion (2003) are also different than the Kuznets curve. He identifies a positive relationship between income growth and absolute disparities between the "rich" and the "poor". Beside income a couple of other factors are assumed to have impact on disparity. A number of recent papers have found evidence that openness is associated with higher inequality. Barro (1999) and Spilimbergo et. al. (1999) find that trade is significantly positively associated with inequality and Lundberg and Squire (2000) find that an increase from zero to one in the Sachs-Warner openness index is associated with a significant 9.5 point increase in the Gini index. Concerning the government activities and human capital the results of Fan et. al. (2002) show that government's production-enhancing investments, such as agricultural research and development, irrigation, expenditure on education and infrastructure contributed not only to agricultural production growth, but also to reduction of rural poverty and provincial inequality. To conclude, this results make clear that inequality is a complex phenomenon and has many sources and factors of influence.

To get a general impression of disparity in China and the provincial contribution to this inequality we calculate the *Theil index*[1] and focus on the composition

[1] The Theil index is defined as $T = \frac{1}{n}\sum_{i=1}^{n}(\frac{x_i}{\bar{x}}\ln\frac{x_i}{\bar{x}})$,where x_i is the GDP per capita of

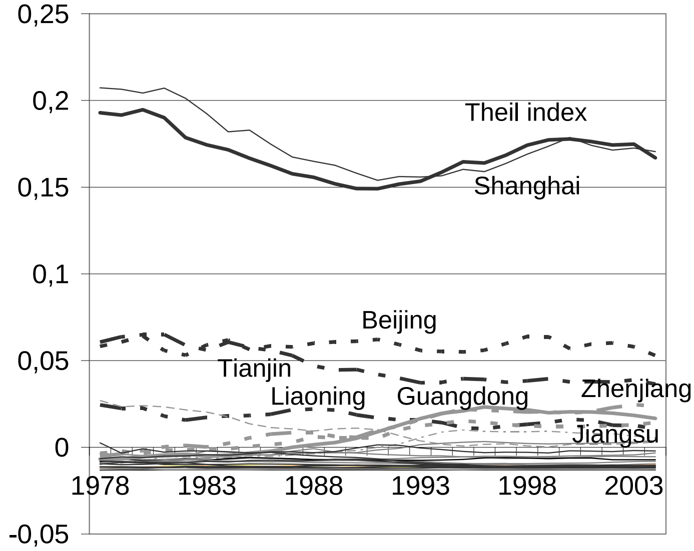

Figure 1: Chinas' Theil index and the provincial contribution

of this index.

As a first step we show the development of the total Theil index and the contributions of the most important provinces for disparity. Figure 1 presents the results for the postreform period from 1978 to 2004. Starting with a value of 0.19 in 1978 the Theil index fell below a value of 0.15 in 1990. Since this point the situation turned, the inequality increased consistently and reached the value of 0.17 in 2004. Hence, the postreform period can be devided into two subperiodes: 1) the period from 1978 to 1990 where inequality decreased, and 2) the period since 1990 where inequality increased. Furthermore the overall Theil index is fragmented by the provinces' contributions.

The composition reveals that the provinces do not contribute to the country's inequality to the same degree. In figure 1 we present only the six provinces with the highest contribution to the Theil index, all other provinces have a contribution lower than 0.02 or even negative. Especially the eastern provinces, in particular the contribution of Shanghai inflates the Theil index to a high degree, the central and western provinces show only a minor impact on the degree of the index. This indicates that the inter-provincial inequality in China is driven mainly by a few rich provinces.

Therefore, the major goal of this paper is to explain provincial disparity in

province i, $\overline{x}$ is the mean income, and n is the number of provinces. The contribution of each province i is defined as $T_i = \frac{1}{n}(\frac{x_i}{\overline{x}} \ln \frac{x_i}{\overline{x}})$.

China. The focus is not the income and growth process itself, but the process leading to disparity is the phenomenon to understand. As theoretical approach we introduce a two region growth model in which a change in international transaction costs will trigger disparity accelerating growth with two mutually dependent processes. First, additional trade or FDI, and positive externalities in one province will accelerate relative technological growth in this province. Second, there is arbitrage of domestic capital towards the faster growing province. As an inflow of domestic capital and faster imitation and growth of technologies are mutually favorable, an agglomerating process is initiated. International and inter-regional factormobility reinforces the disparity. They are positive in one province and negative in the other. Local policies do not only effect the province of policy activity. Factor mobility, international and interprovincial, will clearly have additional effects on all provinces and on provincial disparity. Generally, disparities in provincial income are caused by disparities in the income the determining factors.

While in the standard income and growth regression only the existence of a slope between the dependent and independent variable is important, explaining disparity requires an additional information. As disparity measured in distances is the target, the distance from the mean must be included in the measurement concept. The Theil concept considers this requirement. Therefore, if we apply the theoretical model above to standard income and growth regression analysis, we can identify income and growth determining factors. However, we do not know to what extend each of these factors is responsible for disparity. Therefore, we relate income disparity (indicated by the contribution to the income Theil index) to the disparity of selected income determining factors (indicated by the contribution to each other Theil index). The empirical part identifies the determinants of inequality for 28 Chinese provinces over the period 1991-2004. We apply a random effects panel estimation. Our analysis is based on revised GDP and investment data from Hsueh and Li (1999) and various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS).

2 A 3-equation model of provincial development

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.[2] While the idea of New Economic Geography basically works through increasing returns to scale, monopolistic competition, market size and pecuniary externalities, the idea in this paper is slightly different. Within a neoclassical model, we introduce technical and information externalities in the imitation process. The main reason why firms are located in a certain province 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

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

knowledge spill-over processes between firms in the same industries. Taking these ideas of externalities and international spill-over as the point of departure, we develop a basically neoclassical model of growth for a single backward province. Externalities will lead to temporary dynamic scale economies and drive the technical imitation process. The dynamics of the model are driven not by accumulation but by technological catching up and imitation. The model will be stylized and simplified in such a way that a province can be modeled with three equations.

Final output: The final output sector of province i uses human capital H_i international capital flowing into the province as FDI $\mathcal{F}_i$ and domestic real capital K_i to produce a homogeneous final good. Hence, in this model the most important factors of production that might eventually drive the growth process are three different types of capital. We especially assume that domestic capital and international capital are different. The fundamental difference and the continued high degree of capital control segregates the market for domestic and international capital. Workers are assumed to be allocated to any production process at a subsistence level of income from a pool of surplus labor. Like in a *Lewis Economy,* labor is not a growth restricting factor. The Lewis turning point has not yet been reached. Hence, H_i, K_i and $\mathcal{F}_i$ can be regarded as the respective capital per unit labor. Based on the small economy assumption and the integration of provincial goods markets into world markets, the per capita production of the final good y_i can be regarded as Findlay's *foreign exchange production function*[3]. Hence y_i is a production value function measured in international prices. With the concept of the *foreign exchange production function* the aggregate production value function stands for a continuum of industries characterized by different factor intensities valuated in given international prices. Each level of output value indicates a full specialization in the industry characterized by the corresponding factor intensity. A change in output value and hence factor intensity indicates a switch in specialization pattern towards another industry. Inflowing international capital F_i is fully depreciated during the period of influx. Production of the final good takes place under perfect competition and constant economies of scale and is described by

$$\begin{aligned} y_i &= A_i H_i^{\alpha} \mathcal{F}_i^{\beta} K_i^{1-\alpha-\beta}, \\ \textit{with} \quad A_i &= \omega_i / A \end{aligned} \tag{1}$$

where A_i indicates the provincial level of technology and ω_i is the province's relative technological position compared to the technology leader A which increases at a given rate n. As we will see later, domestic technology will be driven by ω_i. The domestic product is used for government expenditures which is the fraction γ_i of output, domestic consumption and exports.

[3]See Findlay (1973, 1984).

FDI inflow and exports: Optimal capital inflow is derived from the firms' optimal factor demand. Due to the small country assumption, capital costs in a province for international capital $\mathcal{F}_i$ are determined by the exogenous world market interest factor r[4] and an ad valorem factor for province specific international transaction costs τ_i. τ_i may include a risk premium related to the specific province. Since we are also looking at trade policies we introduce τ_i^{ex} as a 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 costs on exports. As we assume that returns on international capital investments in a province $\mathcal{F}_i$ will be fully repatriated, exports $\mathcal{E}x$ must earn international interest rates and all international transaction costs. On the firm or provincial level each province needs to export a corresponding value to pay for international capital costs connected to the province's FDI $\mathcal{E}x_i^F(1-\tau_i^{ex}) = \tau_i r \mathcal{F}_i$. Solving the firms' optimization problem[5] we obtain the optimal influx of foreign capital

$$\mathcal{F}_i = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y_i \qquad (2)$$

and as a fraction φ_i of GDP

$$\varphi_i = \frac{\mathcal{F}_i}{y_i} = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}.$$

To keep things simple, international borrowing or lending beyond FDI is excluded. We also assume that foreign exchange reserves are not transferred between provinces. Therefore, international capital costs have to be paid by provincial exports. Additional exports are required, to finance international imports of the province which are determine by a household decision problem. Solving the household's decision problem[6] we determine how many additional exports are required, to pay for the optimal import level of a province.

$$\frac{\mathcal{E}_i}{y_i} = \varepsilon_i = (1-\lambda)\left[1-(1-\tau_i^{ex})\beta\right](1-\gamma_i)$$

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).

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

[5] The firm has to determine optimal factor inputs by maximizing profits. Since all capital services have to be paid in terms of exports, the full capital costs include several components like government taxes on output γ_i or transaction costs for exports.

[6] The households decision prob lem is described as:

$$\begin{aligned} \max &: \quad U = C^{\lambda}\,\mathrm{Im}^{1-\lambda}, \\ s.t. &: \quad 0 = y(1-\gamma_i) - \tau_i r \mathcal{F}_i - C_i - p_i(1-\tau_i^{ex})\,\mathrm{Im}_i \end{aligned}$$

For the solution see appendix xxx.

Determining the production level: Including optimal capital inflows in the production function leads to the production level [7]

$$Y_i = {\omega_i}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} (\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r})_i^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}, \qquad Y_i = \frac{y_i}{A^{\frac{1}{1-\beta}}}$$

As we do not want to consider scale effects from technological leaders, production is now normalized for the international technology level. Hence, production is determined by provincial factor endowments and the relative technology position of the province compared to the technological leader ω_i.

Technology and imitation: The developing province 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:[8]

1) International knowledge spill-over and positive technological externalities from the influx of FDI were modelled by Markusen/Venables (1999). Here the effects of these externalities are included at a macro level of modeling.

2) In order to make spill-over from FDI effective for the host province, technology and firm-relevant public infrastructure must exist.[9]

3) As the focus lies on underdeveloped provinces the case of innovations in this backward province is excluded. The imitation process is affected by the technology gap $(1-\omega)$ between the backward province and the industrialized world. If the domestic stock of technology is low (ω is small), it is relatively easy to increase the technology position by adopting foreign designs. However, the process becomes increasingly difficult as the technology gap narrows.[10] 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 technology leader.

While the exogenous process is driven by international innovation growth, the endogenous process of imitation and participation in worldwide technical progress is determined by pure externalities from FDI $\mathcal{F}(t)$ or trade indicated by exports $\mathcal{E}x_i$ and from domestic government investments $G(t)$ in the ability

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[7] $Y_i = y_i A^{-\frac{1}{1-\beta}}$. see also appendix 1e.

[8] There is a broad literature on international technology diffusion that has 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.

[9] E.g. Martin (1999) has analyzed the effects of public policies and infrastructure to the growth performance of a regional economy.

[10] This idea draws back to the well-known Veblen-Gerschenkron hypothesis (Veblen (1915) and Gerschenkron (1962)). 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).

to imitate and improve productivity.[11] These externalities and the resulting relative increase in domestic technologies by imitation are the elements that allow us to depart from neoclassics. Externalities in the imitation process generate temporary dynamic scale economies. As scale economies are the driving element in the models introduced by the *New Economic Geography* (NEG), there is a link to NEG even if the market structure is not monopolistic competition. While pure size and pecuniary externalities are permanently positive in NEG models in this approach we focus on the underlying factors of technical externalities from factors of production and the resulting transitory dynamic scale economies,[12]

$$\dot{\omega}_i(t) = G(t)_i^{\delta_G} F(t)_i^{\delta_F} Ex(t)_i^{\delta_{Ex}} - \omega(t). \tag{3}$$

The externalities from FDI and government infrastructure are assumed to have a rather limited effect on imitation such that $\delta_G + \delta_F + \delta_{Ex} = \delta < 1$ and δ is small.

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

$$G_i = \gamma_i Y_i, \qquad Ex_i = \varepsilon_i y_i$$

The three equations (1), (2), and (3) capture the model of provincial development for one province. The solution to (1), (2), and (3) is a differential equation determining the growth of the relative stock of technology available to the province (catching-up in technology) during the period of transition to the steady state.[13] In this period we observe additional technological catching up with the steady state productivity growth. As this acceleration process is driven by additional factors flowing into the province, the economy can realize temporary dynamic scale economies during this catching up and adjustment period. While $\dot{\omega}_i(t)$ is positive during transition, it converges to zero when approaching the steady state path. Equation (4) suggests a decreasing speed of growth with a rising income level as a result of increasing difficulties in the imitation process.[14]

$$\dot{\omega}_i(t) = \gamma_i^{\delta_G} \varphi_i^{\left(\delta_F + \frac{\beta}{1-\beta}\right)} \varepsilon_i^{\delta_G} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t), \quad \text{with} \quad \frac{d\dot{\omega}_i(t)}{d\omega(t)} < 0. \tag{4}$$

[11] As we would like to exclude pure scale effects from technical progress of the technical leader $F(t)_i$ and $G(t)_i$ and Ex_i are normalized values transformed by an international technology index factor $A(t)^{\frac{1}{1-\beta}}$, and A is growing at a given constant rate n. See also appendix 1e..

[12] For the dynamic catching-up-spill-over equation we assume that G and $\mathcal{F}$ and Ex are sufficiently large for positive upgrading.

[13] See appendix 1f.

[14] The dynamic catching-up-spill-over equation contains a scaling problem if H and K are taken as absolute values. As the region is assumed to remain backward, the values of γ, φ, H and K are assumed to be sufficiently small. See appendix 2 for the derivatives.

Not only the speed of technological catching up $\dot{\omega}_i(t)$ is determined by the factor endowments K_i, H_i and the fractions γ_i and φ_i. For each endowment we can determine the steady state position ω_i^* of the province. For $\dot{\omega}_i(t) = 0$[15] we obtain

$$\omega^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} \varphi_i^{\frac{\delta_F (1-\beta)+\delta\beta}{(1-\beta-\delta)}} \varepsilon_i^{\delta_G} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tag{5}$$

$$\text{with} \quad \Psi_i := \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}}. \tag{6}$$

$$\frac{\partial \omega_i^*}{\partial K_i} = \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega^* K_i^{-1} > 0, \quad \frac{\partial \omega_i^*}{\partial H_i} = \frac{\delta\alpha}{1-\beta-\delta} \omega^* H_i^{-1} > 0, \tag{7}$$

$$\frac{\partial \omega_i^*}{\partial \tau_i} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_F + \frac{\beta}{1-\beta}\delta \right] \tau_i^{-1} < 0 \qquad \textit{FDI effect} \tag{8}$$

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_F + \frac{\beta}{1-\beta}\delta \right] (1-\tau_i^{ex})^{-1} < 0 \quad \textit{trade effect} \tag{9}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_G \gamma_i^{-1} - \left(\delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] \gtreqless 0 \tag{10}$$

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

The economic story is rather simple. Reducing τ_i will reduce the costs of international capital and increase the input of international capital. As more FDI or government investments enter the province, spill-over and positive externalities will accelerate imitation and technology convergence and in turn improve the final relative technology position of the province. Similarly, with a larger endowment of domestic real capital, international capital productivity will increase such that additional FDI speeds up imitation and the final position of the province improves.

3 Two provinces and provincial equilibrium

To analyze interprovincial factor mobility and the effects on provincial disparity we need to look at two provinces $i = 1, 2$ in a country. Both provinces have a local immobile factor (human capital) and a mobile factor (domestic capital). Since the country's total endowment of domestic capital can move from one province to the other, domestic capital allocation can change over time:

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

$$K = K_1(t) + K_2(t), \qquad \frac{dK_2}{dK_1} = -1 < 0. \tag{11}$$

The mobility of domestic factors from one province into the other province represents a shift of resources.

As there is an interaction between the development position of a province and the allocation of domestic capital, two conditions, the *final development condition* and the equilibrium condition for the domestic capital market (*interest parity condition*), have to be considered.

Relative Regional Development: From equation (5) we know that ω_i^* is the steady state position of each province. Then, the relative steady state position for the two provinces for a given endowment is[16]

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \left(\frac{A_1}{A_2}\right)^* = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \tag{12}$$

$$\frac{d\Omega^D}{dK_1} > 0, \quad \frac{d\Omega^D}{d\tau_1} < 0, \quad \frac{d\Omega^D}{d\tau_1^{ex}} < 0, \quad \text{and} \quad \frac{d\Omega^D}{d\gamma_1} < 0 \quad \text{for} \quad \gamma_1 > \gamma_1^*.$$

This condition is referred to as the *final development condition.* The final development condition identifies the relative technological position of a province compared to the other province in steady state. In general, this relative final position depends on all parameters of φ_i (see (6)) and in particular on the allocation of the mobile factor K to the two provinces. Depending on K the final development condition can be drawn as *final development curve* Ω^D in the $K_1 - \Omega$ diagram (figure (2)). If the stock of capital in one province falls to zero economic activity in this province would relatively shrink to zero. In figure 2 the Ω^D curve intersects the K_1 axis at 0 with an infinite positive slope. When K_1 increases the slope remains positive and eventually Ω^D becomes infinite once K_1 approaches K. For symmetric and identical provinces at $H_1 = H_2$ and $K_1 = K_2$ the curve takes the level of $\Omega^D = 1$ and has a slope of $2\frac{\delta(1-\beta)}{1-\beta-\delta}K_i^{-1} > 0$.

Dynamic adjustment can be directly derived from the equation of motion for each single province. Denoting a_i as the distance of the province's present

[16] See Appendix 2a.

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

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

See appendix 2b.

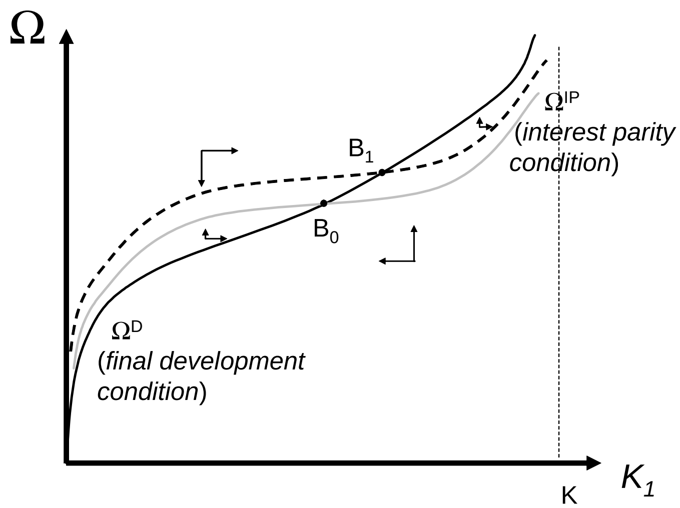

Figure 2: Steady state and dynamics

position relative to the steady state position $(a_i = \omega_i(t)/\omega_i^*)$ the dynamics are given by

$$\begin{aligned} \Omega(t) &= \frac{A_1(t)}{A_2(t)} \implies \frac{\dot{\Omega}}{\Omega} = \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \\ \frac{\dot{\Omega}(t)}{\Omega(t)} &= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \quad \text{for } \Omega(t) > \Omega^D \end{aligned} \tag{13}$$

For $a_1 > a_2$ the present position of the two provinces Ω is above[17] the final development curve Ω^D in figure 2. From (13) can be seen that Ω decreases $(\frac{\dot{\Omega}}{\Omega} < 0)$.[18]

Regional factor mobility: The central mechanism of endogenous determination of provincial disparity is the endogenous allocation of the mobile factors to the two provinces. In this model domestic capital is the only mobile factor between provinces.

As we assume perfect competition in the final goods market, domestic interest rates i_i for domestic capital in each province i is determined by marginal

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

[18] See appendix 2c.

productivity[19]

$$i_i = \frac{1-\beta-\alpha}{1-\beta} \left(1-\gamma_i\right) A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r_i} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}}. \quad (14)$$

As the arbitrage process is not perfect, adjustment takes time. The simple rule for a gradual adjustment to interest parity can be translated into an imperfect arbitrage function

$$\dot{K}_1(t) = m(\frac{i_1}{i_2} - 1). \quad (15)$$

In no-arbitrage equilibrium $\dot{K}_1(t) = 0$. Therefore, the potential *interest parity* equilibrium is characterized by the *interest parity*-condition

$$\frac{i_1}{i_2} = 1. \quad (16)$$

From condition (16) we can derive a curve describing all *interest parity* positions of relative technological upgrading Ω^{IP}.[20]

$$\Omega^{IP} = \frac{\omega_1}{\omega_2} = \frac{A_1}{A_2} = \frac{\left(1-\gamma_2\right)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_2^{-\alpha}}{\left(1-\gamma_1\right)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_1^{-\alpha}} \quad (17)$$

$$\frac{d\Omega^{IP}}{dK_1} > 0 \quad \text{for identical provinces}, \quad \frac{d\Omega^{IP}}{dK_1} \lesseqgtr 0 \quad \text{in general},$$

$$\frac{d\Omega^{IP}}{d\tau_1} > 0, \quad \frac{d\Omega^{IP}}{d\tau_1^{ex}} > 0, \quad \frac{d\Omega^{IP}}{d\gamma_1} > 0.$$

We refer to this condition as the *interest parity curve*. The *interest parity curve*[21] is also drawn in figure 2. Ω^{IP} intersects the origin with an infinite positive slope. With increasing K_1 the slope starts positively, may become negative and eventually turns positive such that Ω^{IP} becomes infinite when K_1 approaches K $[\lim_{K_1 \to K} \Omega^{IP} = \infty]$[22]

Dynamic adjustment is shown in figure 1. If at a given endowment K_1 in province 1 relative productivity is presently smaller than required by the *interest parity*-condition, domestic capital will move from province 1 and K_1 decreases. Therefore, at any point below the Ω^{IP} curve domestic capital will flow out of province 1. This process is indicated by the horizontal arrows in figure 2.

[19] See appendix 3a.

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

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

[22] 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.

Steady State: When both provinces are identical[23] there must be at least one equilibrium.

Using the implicit function theorem we obtain an equilibrium for the steady state of the relative technology position $\Omega^*_{ij} = \omega^*_1/\omega^*_1$

$$\Omega^*_{ij} = \Omega^*_{ij}\left(\frac{H_i}{H_j}, \frac{K_i}{K_j}, ...\right) \tag{18}$$

At point B in figure 2 the two provinces are identical since $K_1 = K_2$ and we consider a stable case. For stability the slope of the *final development curve* must be smaller than the slope of the *interest parity curve*. The corresponding condition is[24]

$$\frac{d\Omega^D}{dK_1} < \frac{d\Omega^{IP}}{dK_1} \quad \text{that is if} \quad \delta < \alpha. \tag{19}$$

4 Endogenous Provincial Disparity

Preferential Policies and International Integration: For two provinces the effects of preferential policy for provincial disparity can be analyzed. We are interested in the effects of an non-symmetrical decrease in international transaction and information costs in one province. Many local conditions including bureaucratic policies act like non-tariff trade barriers. If a province reduces international transaction and information costs, it may be able to generate a decisive advantage over other provinces. 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 (12)) and the *interest parity curve* Ω^{IP} shifts downward (see (17))[25]. Starting from the original equilibrium point B_0 the two provinces will move towards the new equilibrium point B_1. The existence of a number of stable inner solutions allows for conditional convergence of provinces. Starting from B_0 we find a stable provincial adjustment processes.

The economic process is quite simple to describe. The change in international transaction costs will trigger accelerating growth with two mutually dependent processes. First, additional trade or FDI, and positive externalities in one province will accelerate relative technological growth in this province. Second, there is arbitrage of domestic capital towards the faster growing province. As an inflow of domestic capital and faster imitation and growth of technologies

[23] Identical regions are defined as all parameters and factor endowments (including $H_1 = H_2$) being identical.

[24] See appendix 3d.

[25] In this figure Ω^D shifts upwards and Ω^{IP} 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.

are mutually favorable, an agglomerating process is initiated. The internationally more integrated province with more inflows of FDI and exports will strongly improve its relative steady state position.

Factor Mobility, Agglomeration and Disparity: Since arbitrage and agglomeration determines all other reactions we start by analyzing the shift of domestic capital and potential jobs available in province 1[26]

$$\frac{dK_1}{d\tau_1} < 0, \quad \frac{dK_1}{d\tau_1^{ex}} < 0.$$

In province 1 the access to domestic capital will grow, while province 2 faces a reduction and shrinks. Decreasing international transaction costs and better access to international technologies in province 1 will increase technology growth and trigger agglomeration advantages for this province. Faster imitation increases productivity growth and a interest gap between the provinces opens. As domestic capital is moves between the two provinces, domestic capital migrates to the high-productivity, high-interest province. Immigration and the resulting additional technological growth will both drive a process of acceleration and agglomeration. In this process the success of one province is driven at the expense of the other, since one province absorbs domestic capital from the other to feed agglomeration. Technological acceleration endogenously terminates when imitation becomes more difficult and a province obtains more sophisticated technologies. Further, factor mobility to the agglomerating province will eventually drive down interest rates by decreasing marginal productivity. At the same time emigrating domestic capital will drive up marginal productivity in the less favored province. Eventually, interest adjustment combined with the adjustment in unemployment (see below) will equalize arbitrage incentives between the two provinces.

Analyzing the determinants of disparity: The major focus of the paper is to analyze income disparity between provinces. As a result of the model we can determine relative provincial income of a province i compared to a reference province j ($\Delta_{ij}^{y} = \frac{y_i}{y_j}$). This relative provincial income could be a first indicator of bilateral provincial disparity. With the theoretical model we can explain this income relation by relative differences in policies and relative differences in factor abundance

$$\begin{aligned}
\Delta_{ij}^{y} &= \frac{y_i}{y_j} = \Omega_{ij}^{*}\left(\frac{H_i}{H_j}, \frac{K_i}{K_j}, ...\right)\left(\frac{H_i}{H_j}\right)^{\alpha}\left(\frac{\mathcal{F}_i}{\mathcal{F}_j}\right)^{\beta}\left(\frac{K_i}{K_j}\right)^{1-\alpha-\beta} \qquad (20) \\
\log\frac{y_i}{y_j} &= \log\Omega_{ij}^{*}\left(\right) + \alpha\log\frac{H_i}{H_j} + \beta\log\frac{\mathcal{F}_i}{\mathcal{F}_j} + (1-\alpha-\beta)\log\frac{K_i}{K_j}
\end{aligned}$$

[26]See appendix 5.

Further, using comparative statics we obtain the effects of policy differentials on mobile factors and relative income. As an example for a policy we analyze the relative income reaction when international transaction costs are reduced $\frac{dy_1^*}{d\tau_1}$. Using condition (11) for identical provinces, the reaction of the disparity relation between the two provinces Δ_{ij}^y is

$$\begin{aligned}
d\log\Delta_{ij} &= d\log y_i^* - d\log y_j^* = \frac{1}{y_1^*}\frac{dy_1^*}{d\tau_1} - \frac{1}{y_2^*}\frac{dy_2^*}{d\tau_1} \\
\frac{dy_1^*}{d\tau_1} &= \overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{dK_1}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\frac{y_1^*}{K_1}}^{\langle 3\rangle}\right)\frac{dK_1}{d\tau_1} < 0 \\
\frac{dy_2^*}{d\tau_1} &= -\left(\overbrace{\frac{y_2^*}{\omega_2^*}\frac{d\omega_2^*}{dK_2}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\,\frac{y_2^*}{K_2}}^{\langle 3\rangle}\right)\frac{dK_1}{d\tau_1} > 0, \qquad (21)
\end{aligned}$$

For identical provinces

$$d\ln\Delta_{ij}^y = \frac{1}{y_1^*}\overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{K_1}{y_1^*}\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{dK_1}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)}^{\langle 3\rangle}\right) d\ln\Delta_{ij}^K \qquad (22)$$

Income differentials between provinces are driven by three channels: a direct improvement in technology ⟨1⟩ and two effects from interprovincial arbitrage ⟨2⟩ and ⟨3⟩. Factor mobility of domestic capital drives up technological abilities ⟨2⟩ and increases factor endowments and production capacity in the province ⟨3⟩. Both factor mobility effects are mutually reinforcing. They are positive in one province and negative in the other. Local policies do not only effect the province of policy activity. Factor mobility, international and interprovincial, will clearly have additional effects on all provinces and on provincial disparity. Effects of policies are not limited to the policy making province. These disparity effects are in the focus of the empirical study.

Up to this point we are still close to the standard income and growth analysis. The only difference is that in this approach we add the provincial interactions caused by provincial factor mobility. Factor mobility can be a substantial additional disparity driving factor. Therefore, in contrast to the standard growth regression it is not only interesting, what are the growth driving factors, we would also like to know, if the growth driving factors are determining disparity because they are diverging themselves. Which growth driving factor contributes to divergence or convergence of income because it is diverging or converging itself.

The standard growth model could be directly translated into the bilateral disparity indicating income relation Δ_{ij}^{y}. However, in no construction of a disparity measure the bilateral relation of income in province i to income in a reference province j or there log is used Even if the reference observation j were chosen as the mean income $\frac{y_i}{\bar{y}}$ there is no standard disparity index using the pure relation $\frac{y_i}{\bar{y}}$ as an appropriate component for construction. For various reasons all measures define a certain weighting scheme or transformations for $\frac{y_i}{\bar{y}}$ to obtain the appropriate component a province provides to the overall index. The Table in figure 3 gives an overview of the most frequently used disparity measures and the properties of each measure. This table shows that disparity

Measure	Definition	decompos.	transfer	scale	interval
Variance	$V = \frac{1}{n}\sum[y_i - \bar{y}]^2$	yes	strong	no	$0, \bar{y}^2[n-1]$
Coeff. of Var.	$c = V^{1/2}/\bar{y}$	yes	weak	yes	$0, [n-1]^{1/2}$
Gen. entrophy	$E = \frac{1}{\theta^2-\theta}\left[\frac{1}{n}\sum \frac{y_i}{\bar{y}}^{\theta} - 1\right]$	yes	strong	yes	$0, \infty$
entrophy : Theil	$T = \sum \frac{y_i}{n\bar{y}} \log \frac{y_i}{\bar{y}}$	yes	strong	yes	$0, \log n$
Atkinson	$A = 1 - \left[\frac{1}{n}\sum \frac{y_i}{\bar{y}}^{1-\varepsilon}\right]^{\frac{1}{(1-\varepsilon)}}$	yes	weak	yes	$0, -n^{-\varepsilon/(1-\varepsilon)}$
Dalton		yes	weak	no	$0, \frac{1-n^{1-\varepsilon}}{1-n\bar{y}^{1-\varepsilon}}$
Herfindal	$H = \frac{1}{n}[c^2+1]$	yes	strong	no	$0, \frac{1}{n}$
Gini	$G = \frac{1}{2n^2\bar{y}}\sum\sum\lvert y_i - y_j\rvert$	no	weak	yes	$0, \frac{n-1}{n}$
rel. mean dev	$M = \frac{1}{n}\sum\left\lvert \frac{y_i}{\bar{y}} - 1\right\rvert$	no	just fails	yes	$0, 2[1-\frac{1}{n}]$
Log variance	$v = \frac{1}{n}\sum\left[\log \frac{y_i}{\bar{y}}\right]^2$	no	fails	yes	$0, \infty$
variance of log	$v_1 = \frac{1}{n}\sum\left[\log \frac{y_i}{y^*}\right]^2$	no	fails	yes	$0, \infty$
Range	$R = y_{\max} - y_{\min}$				$0, \bar{n}\bar{y}$
	$y^* = e^{\left[\frac{1}{n}\sum \log y_i\right]}$				

Figure 3: Properties of different measures of disparity

measures are expected to have an appropriate *distance concept* related to the problem and certain properties like the *weak transfer principal*, *scale independence*, or well *defined interval.* As the different measures emphasize different aspects of disparity they are not equally suitable for all sort of questions related with disparity.

In this paper we would like to explain provincial income disparity (measured by an appropriate disparity index) by the disparity of income determining factors. Since the Theil index is decomposable into the different contributions of each province to the country wide Theil index of provincial disparity, and the

Theil index has an appropriate distance concept as well as all required properties, we choose the Theil index as an appropriate instrument. More precise, we can determine each provinces Theil-contribution to disparity, and all these contribution add up to the overall disparity measure. Moreover we can try to explain the Theil-contribution of income disparity by the Theil-contribution of the disparity determining variables like capital, human capital etc...

$$\begin{aligned} TH_i^y &= \frac{1}{n}\frac{y_i}{\bar{y}}\log\frac{y_i}{\bar{y}}, \quad TH_i^K = \frac{1}{n}\frac{K_i}{\bar{K}}\log\frac{K_i}{\bar{K}}, ... \\ TH_i^y &= \alpha + \beta_1 TH_i^K + \beta_2 TH_i^{HC} ... \end{aligned} \tag{23}$$

While in the standard income and growth regression only the existence of a slope between the dependent and independent variable is important, explaining disparity requires an additional information. As disparity measured in distances is the target, the distance from the mean must be included in the measurement concept. The Theil concept considers this requirement with the help of an appropriate weighting scheme. Therefore, if we apply the theoretical model above to standard income and growth regression analysis, we can identify income and growth determining factors. However, we do not know to what extend each of these factors is responsible for disparity. Even if a factor is highly income determining, it does not necessarily drive disparity if the differences in this factor are small among the regions. This is particular obvious in case of panel data. If a determining factor is equally abundant in two provinces, and growing at the same rate, it may clearly contribute to income growth but not to disparity.

As a result we choose an estimation approach were the Theil-index-contribution of income in each province is determined by the Theil-index contribution of each explanatory variable of income derived from the theoretical model above.

5 Panel data analysis of provincial disparity

In this paper we suggest a panel data analysis. More specifically, our point of departure is a simple individual effects model of the form

$$Y_{i,t} = \alpha + \beta X'_{i,t} + u_{i,t} \tag{24}$$

where $Y_{i,t}$ is the dependent variable and $X'_{i,t}$ is a set of explanatory variables. This method allows for an inclusion of individual effects for each province. Hence $u_{it} = \mu_i + \varepsilon_{it}$ denotes the disturbance term that is composed of the individual effect μ_i and stochastic white noise disturbance ε_{it}. Depending on the assumption that μ_i and the explanatory variables $X'_{i,t}$ are uncorrelated the random effects estimator should be used, whereas if the specific effects μ_i and $X'_{i,t}$ are correlated the fixed effects estimator may be appropriate. The Hausman specification test is a test of whether the fixed or random effects model should be used. It test the null hypothesis that the fixed effects model and the random effects model estimators do not differ substantially. If this hypothesis is accepted, the random effects estimator is consistent and more efficient and should be favoured over the fixed effects estimator. If it is rejected, there is a correlation between μ_i and $X'_{i,t}$ so that the random effects model is inconsistent and the fixed effects model is the appropriate choice.

To analyze the determinants of inequality within China it is necessary to use provincial data to take the provinces' heterogeneity into account. Our data set covers the period 1991-2004[27] and contains annual data for 28 Chinese provinces, autonomous provinces, and municipalities. These are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Shanxi, Jilin, Heilongjiang, Anhui, Jiagxi, Henan, Hubei, Hunan, Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The provinces Tibet and Hainan are excluded because of missing values. In constructing our data set, we have used new income data reported by Hsueh and Li (1999) and various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS). They are the China Statistical Yearbook (CSY) from 1996-2004 and the China Compendium of Statistics 1949-2004. In the following the variables are accurately described.

The basic goal is to explain provincial disparity in China. Moreover, Disparities in provincial income are caused by disparities in income determining factors. In this context inequality is measured by the Theil index, and the dependant variable is defined as the provincial contribution to the country's inequality. To account for the distribution of the explanatory variables we calculate the corresponding Theil indices for all inequality factors and compute analogically the provincial contribution to those indices. Hence we try to explain a provinces contribution to income inequality with the help of the share of inequality of other factors. Our estimation equation is directly derived from the theoretical model presented above. The general equation of motion for the above model translates into the estimation equations (**??**) with the following specification

$$\begin{aligned} TH\_GDP_{i,t} &= \alpha + \beta_1 TH\_C_{i,t} + \beta_2 TH\_HC_{i,t} + \beta_3 TH\_T_{i,t} \\ &\quad + \beta_4 TH\_FDI_{i,t} + \beta_5 TH\_GOV1_{i,t} + \beta_6 TH\_GOV2_{i,t} \\ &\quad + \beta_7 TH\_HIGHWAY_{i,t} + \mu_i + \varepsilon_{i,t} \end{aligned} \tag{25}$$

where $TH\_GDP_{i,t}$ denotes the contribution of province i to the country's income inequality and $TH\_HC_{i,t}$, $TH\_T_{i,t}$, $TH\_FDI_{i,t}$, $TH\_GOV1_{i,t}$, $TH\_GOV2_{i,t}$ and $TH\_HIGHWAY_{i,t}$ are the corresponding contributions to

[27] The choice of the period makes sense for two reasons. First, the early 1990s saw the latest wave of international integration policy in China. Also in the early 1990s the Chinese government started to prepare for WTO accession and a further opening up of the economy. Second, we want to focus on the period where China's inequality increased, as can be seen in the development of the Gini cefficient and the Theil index this period started in 1991. Third, with respect to some important indicators some provinces would have had to be excluded if the time period had been expanded to earlier years.

inequality in physical capital, human capital, trade, foreign direct investment, government expenditure and infrastructure measured by highways.

The notation of the estimation equation translates as follows:

Theil Index Contribution of Income: $TH\_GDP_{i,t}$ $TH\_GDP_{i,t}$ denotes the contribution of province i to the countries Theil index[28]. The provincial income used for the calculation is obtained from Hsueh and Li (1999) covering the period 1991-1995 and from various issues of the Statistical Yearbook of China for 1996-2004. GDP per capita expressed in current prices (yuan) has been deflated with 1995 as the base year.

Theil Index Contribution of Capital: $TH\_K_{i,t}$ $TH\_K_{i,t}$ denotes the corresponding Theil index of the real capital stock per capita. The real physical capital stock for all provinces is estimated using the standard perpetual inventory approach. It is accumulated according to

$$\mathcal{K}_{t+1} = I_t + (1 - \delta)\mathcal{K}_t \tag{26}$$

where $\mathcal{K}_t$ and $\mathcal{K}_{t+1}$ is the capital stock of year t and $t+1$, I_t denotes investment, and δ the depreciation rate. The investment series used is gross fixed capital formation and is taken at current prices, it is taken from Hsueh and Li (1999) and the Chinese Statistical Yearbooks. We assume that the depreciation rate δ is 5 percent for all provinces as in Miyamoto and Liu (2005). For the initial capital stocks for each province we use the average ratio of provincial GDP to national GDP for each province over the period 1952-1977 as the weight. Following Wang and Yao (2003) we assume their estimate of 26609.67 billion yuan as the initial real capital stock for 1977 at the national level. By multiplying this initial capital stock with the provincial weights we derive the initial capital stock for each province. To calculate the real capital stock we use a new investment deflator provided by Hsueh and Li (1999) for the period 1978-1995 combined with the price index for fixed asset investment for the period 1996-2004.

Theil Index Contribution of Human capital: $TH\_HC_{i,t}:$ $TH\_HC_{i,t}$ is the Theil Index contribution of human capital. Enrollment in higher education as log of the share in the total population is the proxy for human capital H_i. We obtained the data from the China Compendium of Statistics 1949-2004.

Theil Index Contribution of Trade: $TH\_T_{i,t}:$ The second variable measuring the economic integration is trade. It is the log of the sum of imports and export in GDP taken from the China Compendium of Statistics 1949-2004. We again compute the Theil index contribution $TH\_T_{i,t}$ for each province.

[28] See formula (**??**).

Theil Index Contribution of FDI: $TH\_FDI_{i,t}$: We use the log of foreign direct investment in GDP as a measure for economic integration. Because FDI data is available only in yuan we transform the data into US dollars using the national exchange rate for each year reported by the National Bureau of Statistics. $TH\_FDI_{i,t}$ denotes the Theil index share of this variable.

Theil Index Contribution of Government Expenditure: $TH\_GOV1_{i,t}$**,** $TH\_GOV2_{i,t}$: Two variables can indicate the effect of government expenditure on income inequality. The first is the Theil contribution of the share of local government general expenditure in administration ($TH\_GOV1_{i,t}$) and the second is the corresponding contribution of the ratio of local government general expenditure in culture, education, science and public health to GDP ($TH\_GOV2_{i,t}$). Again, the source of the data is the China Compendium of Statistics 1949-2004.

Theil Index Contribution of Highway: $TH\_HIGHWAY_{i,t}$: We use the Theil index contribution of the highway length per squared kilometer ($TH\_HIGHWAY_{i,t}$) as a proxy for the inequality in infrastructure. We obtain the data for the highway length and the area in square kilometers from the China Compendium of Statistics 1949-2004.

6 Estimation results

The results of the estimates are summarized in table 1. It shows the results for the fixed effects estimator for the period 1991-2004. We use the Hausman test for the appropriate choice between random and fixed effects. With a p-value of 0.00 the test rejects the hypothesis that the random and fixed effects estimators do not differ substantially, so there is a correlation between μ_i and $X'_{i,t}$ and the random effects model is inconsistent hence the fixed effects model is the appropriate choice.

Table 1 Fixed Effects Estimation (1991-2004)

Dependant variable: $TH\_GDP_{i,t}$		
	Coeff.	Std. Err.
$TH\_K_{i,t}$	0.302***	(0.034)
$TH\_HC_{i,t}$	-0.015	(0.012)
$TH\_T_{i,t}$	0.020***	(0.010)
$TH\_FDI_{i,t}$	-0.020**	(0.120)
$TH\_GOV1_{i,t}$	-0.003	(0.014)
$TH\_GOV2_{i,t}$	-0.028*	(0.147)
$TH\_HIGHWAY_{i,t}$	0.053***	(0.123)
$CONS$	0.003***	(0.000)
R^2	0.594	
Hausman test: chi2(7)=42.97 Prob>chi2=0.00		

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

Looking at table 1, most explanatory variables enter with the sign predicted from the model, except human capital. Hence, the major findings of the estimates suggest that both mean income but also the typical growth determinants tend to have a positive impact on inequality. Furthermore, it is the success of the eastern provinces that to a high degree drives the inequality:

1. *Domestic sources of Inequality:*

   - Controlling for other explanatory variables the coefficient for the inequality contribution of physical capital is highly significant and has the strongest positive effect on inequality. This result indicates that inequality in China is not only a phenomenon caused by foreign firms investing in selected provinces of the country. The growth process has strong and important domestic components. Such as in the case of income inequality physical capital inequality shows the same progress and is also driven by few coastal provinces namely Shanghai, Beijing and Tinajin.
   - The same provinces account for a high fraction of the inequality in Human Capital. However in contrast to the income inequality human capital inequality is continuously decreasing over the period 1991-2004. The coefficient shows no significant impact on the dependant variable.
   - The contributions of the inequality variables of government expenditure show a contrary picture. Here inequality is driven by completely other provinces than income inequality. The inequality in expenditure in administration is mainly driven by the provinces Quinghai and Gouizhou, this of expenditure in culture, education, science and

public wealth has a lower extent and is distributed more evenly. The provinces which are responsible for the income inequality enter with a negative contribution to the expenditure inequality. Both coefficients has a negative impact on the dependant variable, however only the effect of the second variable is significant.

2. *Openness and Inequality*

   - The coefficient of the inequality contribution of trade is significant and has a positive effect on income inequality. This result supports the findings of Barro (1999) and Spilimbergo et. al. (1999) that suggest that trade is significantly positively associated with inequality.
   - Openness inequality measured by the inequality contribution of FDI is also significant but shows a contrary effect on income inequality. In comparison to the trade variable this might be due to the more even distribution of the Theil index to the provinces, so that driving provinces of income inequality have not accentuated impact on FDI inequality. On the other hand. Furthermore, in opposition to the income and trade inequality FDI inequality shows a decreasing developing.

3. *Infrastructure and Inequality*

   - Infrastructure inequality measured by the Theil index contribution of highway length per squared kilometers is highly significant and shows a strong effect on income inequality, so that a high share in infrastructure inequality leads to a high share in income inequality.

7 Summary and conclusion

The paper explains the growth – inequality nexus for China's provinces. The theoretical model of provincial development consists of two regions and studies the interactions of a mutual depending development process. Due to positive externalities, incoming trade and FDI induce imitation and hence productivity growth. The regional government can influence the economy by changing international transaction costs and providing the public infrastructure. Due to mobile domestic capital disparity effects are reinforced. The implications of the theoretical model are tested. As the central intention of the paper is to explain provincial disparity we directly relate income disparity (indicated by the contribution to the income Theil index) to the disparity of selected income determining factors (indicated by the contribution to each other Theil index). We examine the determinants of income and inequality for 28 Chinese provinces over the period 1991-2004 and apply random effects panel estimation. Our analysis is based on revised GDP and investment data from Hsueh and Li (1999) and various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS). The results confirm the theoretical framework and suggest a direct linkage between the factors that determine regional income and regional disparity. More specific it is apparent that trade, and foreign and domestic capital as well as government expenditure have an impact on the provincial inequality. Moreover it is the success of the coastal regions and hence potentially geography with the low international transaction costs that drives the provincial inequality of China.

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8 Appendix as extended Annotation

These annotation include all detailed steps of calculation for the convenience of the referee.

Appendix 1a: determining the aggregate production level of the province:

$$\begin{aligned}
y_i &= A_i H_i^{\alpha}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}y_i\right)^{\beta} K_i^{1-\alpha-\beta} \\
y_i^{1-\beta} &= A_i H_i^{\alpha}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\beta} K_i^{1-\alpha-\beta} \\
y_i &= A_i{}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \\
Y_i &= \frac{y_i}{A^{\frac{1}{1-\beta}}} \quad \text{hence} \quad Y_i = \omega_i{}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}$$

Appendix 1b: Determining export values by a household decision and international capital costs:

$$\begin{aligned}
\max &: \; U = C^{\lambda}\,\mathrm{Im}^{1-\lambda}, \\
s.t. &: \; 0 = y\,(1-\gamma_i) - \tau_i r \mathcal{F}_i - C_i - p_i(1-\tau_i^{ex})\,\mathrm{Im}_i \\
0 &= y\,(1-\gamma_i) - \tau_i r\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}y_i - C_i - p_i(1-\tau_i^{ex})\,\mathrm{Im}_i \\
0 &= [1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)\,y_i - C_i - p_i(1-\tau_i^{ex})\,\mathrm{Im}_i
\end{aligned}$$

$$\begin{aligned}
FOC &: \\
\frac{dU_i}{dC_i} &= \lambda C_i^{\lambda-1}\,\mathrm{Im}_i^{1-\lambda} = 1, \qquad \frac{dU_i}{d\,\mathrm{Im}_i} = (1-\lambda)\,C_i^{\lambda}\,\mathrm{Im}_i^{-\lambda} = p_i(1-\tau_i^{ex}) \\
\frac{\frac{dU_i}{d\,\mathrm{Im}_i}}{\frac{dU_i}{dC_i}} &= \frac{(1-\lambda)\,C_i^{\lambda}\,\mathrm{Im}_i^{-\lambda}}{\lambda C_i^{\lambda-1}\,\mathrm{Im}_i^{1-\lambda}} = p(1-\tau_i^{ex}) \\
C_i - \lambda C_i &= \lambda p(1-\tau_i^{ex})\,\mathrm{Im}_i \\
C_i - \lambda C_i &= \lambda\,[[1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)\,y_i - C_i] \\
[1-\beta]\,(1-\gamma_i)\,y_i - C_i &= (1-\lambda)\,[1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)\,y_i \\
\frac{\mathcal{E}x_i}{y_i} &= \varepsilon_i = (1-\lambda)\,[1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)
\end{aligned}$$

Appendix 2: Steady state determination and reactions of ω_i^* when H_i, K_i, τ_i, τ_i^{ex} and γ are changing:

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

$$\begin{aligned}
\dot{\omega}_i(t) &= (G(t)_i)^{\delta_G} (F(t)_i)^{\delta_F} (Ex(t)_i)^{\delta_{Ex}} - \omega(t), \\
\dot{\omega}_i(t) &= A^{\frac{\delta}{1-\beta}} \left(A^{-\frac{1}{1-\beta}} \gamma y(t)_i\right)^{\delta_G} \left(A^{-\frac{1}{1-\beta}} \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y(t)_i\right)^{\delta_F} \left(A^{-\frac{1}{1-\beta}} \varepsilon_i y(t)_i\right)_i^{\delta_{Ex}} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F} \varepsilon_i^{\delta_{Ex}} A^{-\frac{\delta_G+\delta_F+\delta_{Ex}}{1-\beta}} y(t)_i^{\delta_G+\delta_F} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F} \varepsilon_i^{\delta_{Ex}} A^{-\frac{\delta}{1-\beta}} y(t)_i^{\delta} - \omega(t)
\end{aligned}$$

$$y_i = A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F} \varepsilon_i^{\delta_{Ex}} \\
&\quad \left[\omega(t)_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} - \omega(t) \\
\dot{\omega}_i(t) &= \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F} \varepsilon_i^{\delta_{Ex}} \\
&\quad \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}\delta} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t)
\end{aligned}$$

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

To simplify, this equation is rewritten as

$$\dot{\omega}_i(t) = \Psi_i \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad \text{see} \qquad (4)$$

$$\text{with} \quad \Psi_i \quad : \quad = \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}}. \qquad \text{see} \qquad (6)$$

solve for the steady state position:

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

$$
\begin{aligned}
\Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} &= \left[\gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}} \right]^{\frac{(1-\beta)}{(1-\beta-\delta)}} \\
&= \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} \varepsilon_i^{\delta_{Ex} \frac{(1-\beta)}{(1-\beta-\delta)}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\left(\delta_F + \frac{\beta}{1-\beta}\delta\right)\frac{(1-\beta)}{(1-\beta-\delta)}} \\
&= \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F \frac{(1-\beta)}{(1-\beta-\delta)} + \frac{\beta}{1-\beta}\delta \frac{(1-\beta)}{(1-\beta-\delta)}} \varepsilon_i^{\delta_{Ex} \frac{(1-\beta)}{(1-\beta-\delta)}} \\
&= \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} (\varphi_i)^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}} \varepsilon_i^{\delta_{Ex} \frac{(1-\beta)}{(1-\beta-\delta)}}
\end{aligned}
$$

$$
\omega_i^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} (\varphi_i)^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}} \varepsilon_i^{\delta_{Ex} \frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \text{see} \qquad (5)
$$

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

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

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

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

$$
\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i} &= \frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i} \\
\frac{\partial \Psi_i}{\partial \tau_i} &= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\gamma^{\delta_G}\varepsilon_i^{\delta_{Ex}} \left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1} \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r}\tau_i^{-1} \\
&= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\gamma^{\delta_G}\varepsilon_i^{\delta_{Ex}} \left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta} \tau_i^{-1} = -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\Psi_i\tau_i^{-1}
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\Psi_i\tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{\delta+1-\beta-\delta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\omega^*\tau_i^{-1} < 0 \qquad \text{see} \qquad (8)
\end{aligned}
$$

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

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

$$\frac{\partial \Psi_i}{\partial \tau_i^{ex}} = -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\gamma^{\delta_G}\varepsilon_i^{\delta_{Ex}}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1}\frac{\beta}{\tau_i r}$$

$$= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\gamma^{\delta_G}\varepsilon_i^{\delta_{Ex}}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1}\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}$$

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

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

$$= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+1}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_F + \frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1}$$

$$= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}+\frac{(1-\beta-\delta)}{(1-\beta-\delta)}}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_F + \frac{\beta}{1-\beta}\delta\right](1-\tau_i^{ex})^{-1}$$

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = -\frac{(1-\beta)}{(1-\beta-\delta)}\left[\delta_F + \frac{\beta}{1-\beta}\delta\right]\omega_i^*(1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (9)$$

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

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\Psi_i^{-1}\frac{\partial \Psi_i}{\partial \gamma_i}$$

$$\frac{d\Psi_i}{d\gamma_i} = \delta_G\gamma_i^{\delta_G-1}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta}$$

$$-\left(\delta_F + \frac{\beta}{1-\beta}\delta\right)\gamma_i^{\delta_G}\varepsilon_i^{\delta_{Ex}}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1}\frac{(1-\tau_i^{ex})\beta}{\tau_i r}$$

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

$$= \Psi_i\left[\delta_G\gamma_i^{-1} - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right]$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\left[\delta_G\gamma_i^{-1} - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \quad see \quad (10)$$

Appendix 3a: Slope of the final development curve Ω^D :

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[H_1^{\frac{\alpha}{1-\beta}}K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[H_2^{\frac{\alpha}{1-\beta}}K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \quad \text{and} \quad (11)$$

$$d\Omega^D = \frac{\omega_2^*}{(\omega_2^*)^2}\frac{\partial\omega_1}{\partial K_1}dK_1 - \frac{\omega_1^*}{(\omega_2^*)^2}\frac{\partial\omega_2}{\partial K_2}dK_2 = \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1}{\partial K_1} + \omega_1^*\frac{\partial\omega_2}{\partial K_2})adK_1$$

$$\frac{d\Omega^D}{dK_1} = \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1^*}{\partial K_1} + \omega_1^*\frac{\partial\omega_2^*}{\partial K_2}a) > 0 \quad \text{since} \quad \frac{\partial\omega_i^*}{\partial K_i} > 0.$$

Properties of the curve:

$$\lim_{K_1\to 0}\Omega^D = 0, \lim_{K_1\to K}\Omega^D = \infty$$

$$\lim_{K_1\to o}\frac{d\Omega^D}{dK_1} :$$

$$\frac{d\Omega^D}{dK_1} = \frac{1}{(\omega_2^*)^2}\left[\omega_2^*\frac{\partial\omega_1^*}{\partial K_1} + \omega_1^*\frac{\partial\omega_2^*}{\partial K_2}a\right]$$

$$= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial K_1} + \frac{\omega_1^*}{\omega_2^*}\frac{\partial\omega_2^*}{\partial K_2}a\right]$$

$$= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial K_1} + \Omega^D\frac{\partial\omega_2^*}{\partial K_2}a\right]$$

$$\text{since } \lim_{K_1\to o}\frac{\partial\omega_1^*}{\partial K_1} = \lim_{K_1\to o}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_1^*K_1^{-1} = \infty$$

$$\Longrightarrow \lim_{K_1\to o}\frac{d\Omega^D}{dK_1} = \infty$$

$$\lim_{K_1\to K}\frac{d\Omega^D}{dK_1} :$$

$$\text{since } \lim_{K_1\to K}\frac{\partial\omega_2^*}{\partial K_2} = \lim_{K_1\to K}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_2^*K_2^{-1} = \infty \quad \text{and}$$

$$\lim_{K_1\to K}a(K_1,K_2) = \frac{\left[1+\left(1+\frac{\mu_1}{(1-\varepsilon_1)}\right)\sigma K_1^{\left(\frac{\mu_1}{(1-\varepsilon_1)}\right)}\right]}{\left[1+\left(1+\frac{\mu_2}{(1-\varepsilon_2)}\right)\sigma K_2^{\left(\frac{\mu_2}{(1-\varepsilon_2)}\right)}\right]} = \infty$$

$$\Longrightarrow \lim_{K_1\to K}\frac{d\Omega^D}{dK_1} = \infty$$

Appendix 3b: Slope of the final development curve Ω^D, identical provinces:

$\omega_1^* = \omega_2^*$

$$\begin{aligned}
\frac{d\Omega^D}{dK_1} &= \frac{1}{(\omega_2^*)^2}(\omega_2^* \frac{\partial \omega_1^*}{\partial K_1} + \omega_1^* \frac{\partial \omega_2^*}{\partial K_2}) \\
&= \frac{1}{\omega_i^*}\left(\frac{\partial \omega_1^*}{\partial K_1} + \frac{\partial \omega_2^*}{\partial K_2}\right) = \frac{2}{(\omega_i^*)}\frac{\partial \omega_i^*}{\partial K_i} \\
&= \frac{2}{\omega_i^*}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega^* K_i^{-1} \\
&= 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}K_i^{-1} > 0 \qquad \text{for} \quad \text{identical} \quad \text{provinces}
\end{aligned}$$

Appendix 3c: Dynamic adjustment:

$$\begin{aligned}
\frac{\dot{\Omega}}{\Omega} &= \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \\
&= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega_1^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega_2^{-\frac{1-\beta-\delta}{1-\beta}}
\end{aligned}$$

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

$$\begin{aligned}
\frac{\dot{\Omega}}{\Omega} &= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} [a_1\omega_1^*]^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} [a_2\omega_2^*]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \left[a_1 \Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\right]^{-\frac{1-\beta-\delta}{1-\beta}} \\
&\quad -\Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \left[a_2 \Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\right]^{-\frac{1-\beta-\delta}{1-\beta}}
\end{aligned}$$

$$\begin{aligned}
&= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} a_1^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_1^{-1} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-\delta} \\
&\quad -\Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} a_2^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_2^{-1} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-\delta} \\
&= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} \\
\text{for} \quad \Omega(t) &= \frac{a(t)_1}{a(t)_2}\Omega^D > \Omega^D \Longrightarrow a(t)_1 > a(t)_2 \\
\Longrightarrow &\quad a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \Longrightarrow \frac{\dot{\Omega}(t)}{\Omega(t)} < 0 \quad \text{see} \quad (13)
\end{aligned}$$

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

$$\frac{d\Omega^D}{d\tau_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{see} \quad (8)$$

$$\frac{d\Omega^D}{d\tau_1^{ex}} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{see} \quad (9)$$

Appendix 4a: Determine domestic interest rate:

$$\pi_i = (1-\gamma_i)\, y_i - i_i K_i - \rho_i H_i$$

$$\text{with} \quad y_i = A_i{}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$i_i = \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_i)\, A_i{}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha-1+\beta}{1-\beta}}$$

$$i_i = \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_i)\, A_i{}^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}}$$

Derive the *interest parity curve*:

$$\begin{aligned} i_1 &= i_2 \\ &\frac{1-\beta-\alpha}{1-\beta}(1-\gamma_1)\, A_1{}^{\frac{1}{1-\beta}} H_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\,\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}} \\ &= \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_2)\, A_2{}^{\frac{1}{1-\beta}} H_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\,\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}} \end{aligned}$$

$$\frac{A_1{}^{\frac{1}{1-\beta}}}{A_2{}^{\frac{1}{1-\beta}}} = \frac{p_2\,(1-\gamma_2)\, H_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}}}{p_1\,(1-\gamma_1)\, H_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}}}$$

$$\Omega^{IP} = \frac{A_1}{A_2} = \frac{(1-\gamma_2)^{1-\beta}\, H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_2^{-\alpha}}{(1-\gamma_1)^{1-\beta}\, H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_1^{-\alpha}}$$

Slope of the *no-migration curve* :

$$
\begin{aligned}
\Omega^{IP} &= \Omega^{IP}(N_1, N_2) \quad \text{and} \quad (\textbf{??}) \\
\Omega^{IP} &= \frac{\omega_1}{\omega_2} = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha}} \\
\Omega^{IP} &= C\frac{K_1^{\alpha}}{K_2^{\alpha}} = CK_1^{\alpha}K_2^{-\alpha} \quad .\text{with} \quad C = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{IP} &= \Omega^{IP}(K_1, K_2) \quad \text{and} \quad (\textbf{??}) \\
d\Omega^{IP} &= \alpha C\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \alpha C\frac{K_1^{\alpha}K_2^{\alpha-1}}{[K_2^{\alpha}]^2}dK_2 = \alpha C\left[\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \frac{K_1^{\alpha}K_2^{-1}}{K_2^{\alpha}}dK_2\right] \\
&= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0
\end{aligned}
$$

properties of the curve:

$$
\lim_{K_1\to 0}\Omega^{IP} = 0, \lim_{K_1\to 0}\frac{d\Omega^{IP}}{dK_1} = \infty, \lim_{K_1\to K}\Omega^{IP} = \infty, \lim_{K_1\to K}\frac{d\Omega^{IP}}{dK_1} = \infty.
$$

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

$$
\begin{aligned}
&= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0 \\
C &= 1, \qquad \text{for identical provinces} \\
\frac{d\Omega^{IP}}{dN_1} &= \alpha C\left[\frac{2}{K} + \frac{2}{K}\right] = \frac{4\alpha}{K} > 0
\end{aligned}
$$

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

$$
\begin{aligned}
\Omega^{IP} &= \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} N_1^{\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} N_2^{\alpha}}, \\
\text{with} \qquad C &= \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}, \quad \text{and} \quad B = \frac{N_1^{\alpha}}{N_2^{\alpha}} \\
\frac{d\Omega^{IP}}{d\tau_1} &= B\frac{\partial C}{\partial \tau_1} > 0, \frac{d\Omega^{IP}}{d\tau_1^{ex}} = B\frac{\partial C}{\partial \tau_1^{ex}} > 0, \frac{d\Omega^{IP}}{d\tau_1} = B\frac{\partial C}{\partial \gamma_1} > 0
\end{aligned}
$$

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

$$\begin{aligned}
\frac{d\Omega^D}{dN_1} &< \frac{d\Omega^{IP}}{dN_1} \\
4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}N^{-1} &< \frac{4\alpha}{N} \\
\delta(1-\beta-\alpha) &< \alpha\,(1-\beta-\delta)
\end{aligned}$$

$$\begin{aligned}
\delta-\delta\beta-\delta\alpha &< \alpha-\alpha\beta-\alpha\delta \\
\delta-\delta\beta &< \alpha-\alpha\beta \\
\delta\,(1-\beta) &< \alpha\,(1-\beta) \\
\delta &< \alpha
\end{aligned}$$

Appendix 5: Equilibrium reaction of local capital allocation. As we start from point B_0 in fig **??** we have identical provinces in the starting position:

Reaction $\frac{dK_1}{d\tau_1}$

$$\begin{aligned}
\frac{\partial\Omega^{IP}}{\partial K_1}dK_1+\frac{\partial\Omega^{IP}}{\partial\tau_1}d\tau_1 &= \frac{\partial\Omega^{D}}{\partial K_1}dK_1+\frac{\partial\Omega^{D}}{\partial\tau_1}d\tau_1 \\
\frac{dK_1}{d\tau_1} &= \frac{\frac{\partial\Omega^D}{\partial\tau_1}-\frac{\partial\Omega^{IP}}{\partial\tau_1}}{\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1}}
\end{aligned}$$

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

$$\begin{aligned}
\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1} &> 0,\quad \text{since (19) holds} \\
&\text{and hence} \\
\frac{dK_1}{d\tau_1} &= \frac{\frac{\partial\Omega^D}{\partial\tau_1}-\frac{\partial\Omega^{IP}}{\partial\tau_1}}{\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1}}<0
\end{aligned}$$

Reaction $\frac{dK_1}{d\gamma_1}$ (for $\gamma_i>\gamma_i^*$)

$$\begin{aligned}
\frac{\partial\Omega^{IP}}{\partial K_1}dK_1+\frac{\partial\Omega^{IP}}{\partial\gamma_1}d\gamma_1 &= \frac{\partial\Omega^{D}}{\partial K_1}dK_1+\frac{\partial\Omega^{D}}{\partial\tau_1}d\gamma_1 \\
\frac{dK_1}{d\gamma_1} &= \frac{\frac{\partial\Omega^D}{\partial\gamma_1}-\frac{\partial\Omega^{IP}}{\partial\gamma_1}}{\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1}}
\end{aligned}$$

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

$$\frac{\partial\Omega^{IP}}{\partial K_1} - \frac{\partial\Omega^{D}}{\partial K_1} > 0, \quad \text{since (19) holds}$$

and hence

$$\frac{dK_1}{d\gamma_1} = \frac{\frac{\partial\Omega^{D}}{\partial\gamma_1} - \frac{\partial\Omega^{IP}}{\partial\gamma_1}}{\frac{\partial\Omega^{IP}}{\partial K_1} - \frac{\partial\Omega^{D}}{\partial K_1}} < 0$$

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