Center for International Economics

Working Paper Series

No. 2008-11

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August 2008

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Business Administration & Economics
University of Paderborn

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July 5, 2008

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 mutually 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 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 per capita income Theil index) to the disparity of selected income determining factors (indicated by the contribution to every other Theil index of the determinants). We examine the determinants of income and inequality for 28 Chinese provinces over the period 1991-2004 and apply a fixed 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, foreign and domestic capital and 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 decisions 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 indicated 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 an inverted U-curve relation between these variables. A couple of papers (Paukert 1973, Ahluwalia 1976, Carter and Chenery 1976) supported 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 an 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, those 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 $T = \frac{1}{n}\sum_{i=1}^{n}(\frac{x_i}{\overline{x}}\ln\frac{x_i}{\overline{x}})$,where x_i is the GDP per capita of

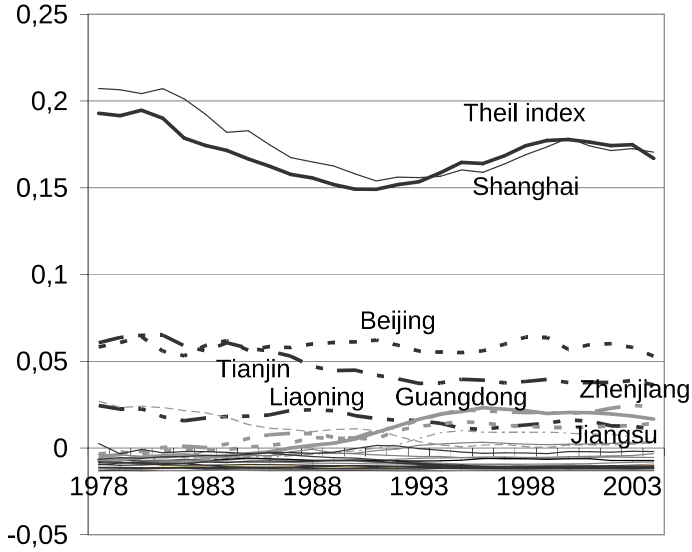

Figure 1: Chinas' Theil index and the provincial contribution

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 divided 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.

In a next step, we analyse the inequality contribution of China's eastern,

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

central and western region[2]. Therefore, we decomposed the Theil index, where we account for the weighted average of inequality within the three regions, plus inequality between those regions.[3]

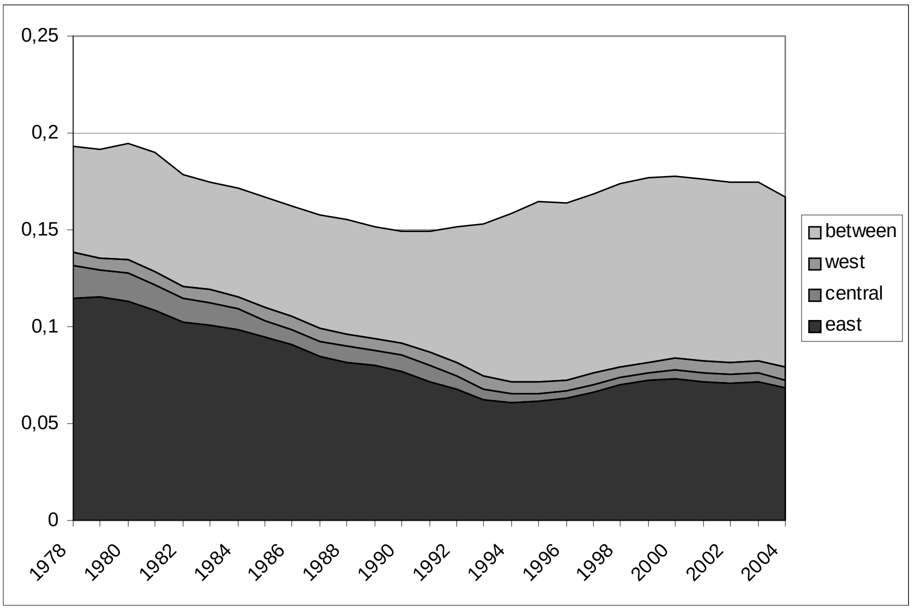

Figure 2: Decomposition of China's Theil index

Figure 2 presents the decomposition of the regional Theil index. The developing of the decomposed index shows a similar view. The three regions do not contribute to the countries inequality in the same degree. The inequality *within* the western region and the central region has only a slight impact. In particular, the inequality *within* the eastern region and *between* the three regions drives the Theil index.

Although we could not identify a falling trend to 1990, the rise in inequality since 1990 is concurrent with the Theil index. Again, it becomes apparent that the inequality is mainly caused by the rich eastern provinces, in particular by the *within* effect of the eastern provinces.

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

[2]The provinces Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Guangxi are referred as eastern provinces, Shanxi, Jilin, Heilongjiang, Anhui, Jiagxi, Henan, Hubei, Hunan and Inner Mongolia belong to the central region and Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang are the western provinces.

[3]The decomposed Theil index is defined as $T = \sum_{k=1}^{m} s_k T_k + \sum_{k=1}^{m} s_k \ln \frac{\overline{x_k}}{\overline{x}}$,
where the country is devided in m regions and s_k is the income share of region k, T_k is the Theil index for that region, and $\overline{x_k}$ is the average income in region k.

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 model of development 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 itself. 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 income 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

In case of a developing region, international spill-over and externalities through FDI and trade, and infrastructure are relevant determinants of growth and development.[4] Taking these externalities and international spill-over as the starting point, 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 is taken from Gries/Redlin (2008) and will be stylized and simplified in such a way that a province can be modeled with three equations.

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

Final output: Final output of a 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. Domestic capital and international capital are supposed to be different. Like in a *Lewis Economy,* labor is not a growth restricting factor, and 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 final product markets into world markets, the per capita production of the final good y_i can be defined as Findlay's *foreign exchange production function*[5]. y_i is a production value function measured in international prices. Each value of output indicates a full specialization in the industry characterized by the corresponding factor intensity. Inflowing international capital $\mathcal{F}_i$ is fully depreciated during the period of influx. Production of the final product takes place under constant economies of scale and perfect competition, and is described by

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

In (1) A_i measures the level of technology in province i, and ω_i is the province's relative technological position compared to the technology leader A which increases at a given rate n. The domestic output is used for domestic consumption, exports, and government expenditures which is the fraction γ_i of GDP.

FDI inflow and exports: Optimal capital inflows are determined by the firms' optimal factor demand. Due to the small economy assumption, capital costs for international capital are determined by an exogenous world market interest factor r[6] and an ad valorem factor for international transaction costs τ_i which is specific for each proivince. τ_i^{ex} is a transaction cost parameter for exports. τ_i and τ_i^{ex} are modeled as iceberg costs on exports. Returns on international capital investments in a province will be fully repatriated, exports $\mathcal{E}x_i$ 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 $\mathcal{E}x_i^{\mathcal{F}}(1-\tau_i^{ex}) = \tau_i r \mathcal{F}_i$. Solving the firms' optimization problem[7] we obtain the required influx of foreign capital

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

and as a fraction φ_i of GDP

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

[5] See Findlay (1973, 1984).

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

[7] 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.

To simplify, 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 imports of the province. Imports for consumption purposes are determined by a standard household decision problem[8].

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

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). Including optimal capital inflows in the production function leads to the production level

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

As we do not want to consider scale effects from technological leaders, production is now normalized for the international technology level.[9] Therefore, 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 acquires technologies by imitating foreign designs from international technology leaders. International knowledge spill-over and positive technological externalities from the influx of FDI are included at a macro level of modeling. In order to make spill-over from FDI effective for the host province, technology and firm-relevant public infrastructure must exist. 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 improve the technology by imitating foreign designs. However, the process becomes increasingly difficult as the technology gap narrows.

The endogenous process of imitation and participation in worldwide technical progress is determined by pure externalities from FDI or trade indicated by exports and from domestic government investments in the ability to imitate and improve productivity.[10] Externalities in the imitation process generate tem-

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

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

For the solution see appendix 1b.

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

[10] 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 1a..

porary dynamic scale economies. We focus on the technical externalities from factors of production and the resulting transitory dynamic scale economies,[11]

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

The externalities from FDI $F(t)$ or exports $Ex(t)$, and government infrastructure $G(t)$ 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 we abstract from government borrowing or lending and interprovincial transfers government expenditures are restricted by tax income. Therefore, 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.[12] 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.[13]

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

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 $\dot{\omega}_i(t) = 0$[14] we

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

[12] See appendix 1f.

[13] 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.

[14] 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.

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.

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 real capital).

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

The mobility of domestic factors from one province into the other 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. The relative steady state position for the two provinces for a given endowment is[15]

[15] See Appendix 3a.

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

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

This condition is referred to as the *final development condition.* The final development condition identifies the relative technological position of a 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 (3)).

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

$$\Omega(t) = \frac{A_1(t)}{A_2(t)} \implies \frac{\dot\Omega}{\Omega} = \frac{\dot\omega_1}{\omega_1} - \frac{\dot\omega_2}{\omega_2} \quad (13)$$

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

For $a_1 > a_2$ the present position of the two provinces Ω is above[16] the final development curve Ω^D in figure 3. As we can see from (13) Ω decreases ($\frac{\dot\Omega}{\Omega} < 0$).[17]

Regional factor mobility: 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 productivity[18]

$$\lim_{K_1\to 0}\Omega^D = 0, \quad \lim_{K_1\to o}\frac{d\Omega^D}{dK_1} = \infty, \quad \lim_{K_1\to K}\Omega^D = \infty, \quad \lim_{K_1\to N}\frac{d\Omega^D}{dK_1} = \infty$$

$$\Omega^D_{|K_1=K_2} = 1, \quad \frac{d\Omega^D}{dK_1}_{|K_1=K_2} = 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}H_1^{-\frac{\alpha}{1-\beta}}K_1^{-1} > 0, \quad \text{for identical regions}$$

See appendix 3b.

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

[17] See appendix 3c.

[18] See appendix 4a.

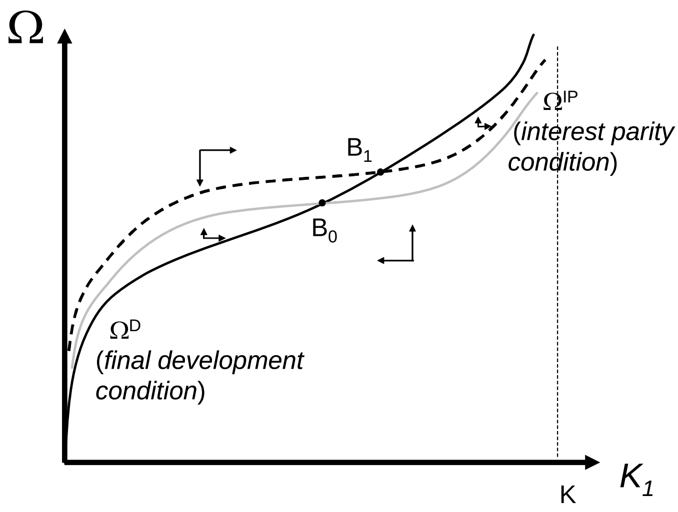

Figure 3: Steady state and dynamics

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

The arbitrage process is not perfect, adjustment takes time. Gradual adjustment to interest parity translates into an imperfect arbitrage function

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

In *a* 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}.[19]

[19] For the derivative $\frac{d\Omega^M}{dK_1}$ see Appendix 4a.

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

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

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

We refer to this condition as the *interest parity curve*. The *interest parity curve*[20] is also drawn in figure 3. 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 [$\lim_{K_1 \to K} \Omega^{IP} = \infty$][21]

Dynamic adjustment is shown in figure 3. 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 3.

Steady State: When both provinces are identical[22] 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 3 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[23]

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

[20] For the reactions of the *no migration curve* see appendix 4c.

[21] The properties of the no-migration curve is given by $\lim_{K_1 \to 0} \Omega^M = 0, \lim_{K_1 \to 0} \frac{d\Omega^M}{dK_1} = \infty, \lim_{K_1 \to K} \Omega^M = \infty, \lim_{K_1 \to N} \frac{d\Omega^M}{dK_1} = \infty$. See also appendix 4.

[22] Identical regions are defined as all parameters and factor endowments (including $K_1 = K_2$) being identical.

[23] See appendix 4d.

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 transaction costs 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 3 shifts upward (see (12)) and the *interest parity curve* Ω^{IP} shifts downward (see (17))[24]. 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 process.

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 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 determine all other reactions, we start by analyzing the shift of domestic capital in province 1[25]

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

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 an interest gap between the provinces opens. As domestic capital moves between the two provinces, domestic capital migrates to the high-productivity, high-interest province. Inflowing capital 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

[24] 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.

[25] See appendix 5.

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 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

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

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

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

For identical provinces

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

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 activ policy itself. 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 to identify 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 income divergence because it is diverging itself. In other words, we would like to identify the determinants of disparity directly.

The Table in figure 4 gives an overview of the most frequently used disparity measures and the properties of each measure.[26] This table shows that 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 sorts of questions related to 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 since it has an appropriate distance concept and all required properties, we choose the Theil index as an appropriate instrument for the empirical analysis. More precise, we can determine each province's Theil-contribution to income disparity. All these provincial contributions add up to the overall measure of provincial income disparity. Moreover, we will explain the Theil-contribution of income

[26] For more details see Cowell (2005).

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 4: Properties of different measures of disparity, source: Cowell (1995).

disparity by the Theil-contribution of the disparity determining variables like capital, human capital etc...

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

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.

Further, 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 particularly 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.

Therefore, we choose an estimation approach where 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 (see (23)).

5 Panel data analysis of provincial disparity

For the empirical study 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}.[27] 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 tests 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.

In order to analyze the determinants of inequality within China, it is necessary to use provincial data to consider the provinces' heterogeneity. Our data set covers the period 1991-2004[28] and includes 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. Due to missing values the provinces Tibet and Hainan are excluded. Constructing our data set, we have used new income data reported by Hsueh and Li (1999) as well as various (some?) sources of Chinese official statistics provided by the National Bureau of Statistics (NBS). These are the

[27] In our case a LM-test for the presence of individual effects rejects the hypothesis that $\mu_i = 0$ so we start we include an individual effect.

[28] 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.

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 province's 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 (20) 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 $TH\_C_{i,t}$, $TH\_HC_{i,t}$, $TH\_T_{i,t}$, $TH\_FDI_{i,t}$, $TH\_GOV1_{i,t}$, $TH\_GOV2_{i,t}$ and $TH\_HIGHWAY_{i,t}$ are the corresponding contributions to 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 country's Theil index. 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 by using the standard perpetual inventory approach. It is accumulated according to

$$K_{t+1} = I_t + (1-\delta)K_t \tag{26}$$

where K_t and 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 from the Chinese Statistical Yearbooks. Like Miyamoto and Liu (2005) we assume that the depreciation rate δ is 5 percent for all provinces. As weight 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. 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. In order to calculate the real capital stock we use a new investment deflator provided by Hsueh and Li (1999) for the period 1978-1995 and combine it 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. Enrolment in higher education as log of the share in the total population is the proxy for human capital. We obtained the data from the China Compendium of Statistics 1949-2004.

Theil Index Contribution of Trade: $TH\_T_{i,t}$: We use the log of trade calculated as the sum of imports and exports in GDP as a measure for economic integration. The data is taken from the China Compendium of Statistics 1949-2004. We again compute the Theil index contribution $TH\_T_{i,t}$ for each province.

Theil Index Contribution of FDI: $TH\_FDI_{i,t}$: The second variable measuring the economic integration is foreign direct investment measured as the log of FDI in GDP taken from the China Compendium of Statistics 1949-2004. 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.[29]

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***	(0.006)
$TH\_GOV1_{i,t}$	-0.003	(0.002)
$TH\_GOV2_{i,t}$	-0.028*	(0.016)
$TH\_HIGHWAY_{i,t}$	0.053***	(0.021)
$CONS$	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

[29] To avoid the problem of possible endogeneity of the explanatory variables we also run a system GMM estimation. The coefficient values are similar and confirm the FE results. Merely the signification of human capital rise to a 5% level and those of trade and GOV2 to a 1% level, FDI is not significant.

We tested for the presence of multicolinearity calculating variance inflation factors (VIFs). VIF values in excess of 10 often indicate a multicolinearity problem. The VIF values for the independant variables ranged from 1.5 to 7.8 with a mean VIF of 3.5, this indicates that there is no serious multicolinearity problem.

The Breusch Pagan/ Cook-Weisberg test for heteroscedasticity rejects the hypothesis of constant variance, so we use robust standard errors.

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. Expenditure in culture, education, science and public wealth are smaller and distributed more evenly. The provinces which are responsible for the income inequality enter with a negative contribution to the expenditure inequality. Both coefficients have 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 an accentuated impact on FDI inequality. Furthermore, in contrast to the income and trade inequality FDI inequality shows a decreasing development.

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 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 fixed 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, 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

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:

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

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

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:

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

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

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

To simplify, this equation is rewritten as

$$\begin{aligned}
\dot{\omega}_i(t) &= \Psi_i \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad \text{see} \qquad (4) \\
\text{with} \quad \Psi_i &: = \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}}. \qquad \text{see} \qquad (6)
\end{aligned}$$

solve for the steady state position:

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

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

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

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

$$\begin{aligned}
\omega_i^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \\
\frac{\partial \omega_i^*}{\partial K_i} &= \frac{\delta(1-\beta)}{1-\beta-\delta} \frac{1-\beta-\alpha}{1-\beta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} K_i^{\frac{1-\beta-\alpha}{1-\beta}-1} H_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* K_i^{-\frac{1-\beta-\alpha}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* K_i^{-1} > 0, \quad \text{see} \quad (7)
\end{aligned}$$

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

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

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

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

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

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

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

$$\begin{aligned}\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i (1-\tau_i^{ex})^{-1} \\ &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)} + \frac{(1-\beta-\delta)}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] (1-\tau_i^{ex})^{-1} \\ \frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \omega_i^* (1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (9)\end{aligned}$$

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

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

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

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

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:

$$\begin{aligned}
\lim_{K_1 \to 0}\Omega^D &= 0, \lim_{K_1 \to K}\Omega^D = \infty \\
\lim_{K_1 \to o}\frac{d\Omega^D}{dK_1} &: \\
\frac{d\Omega^D}{dK_1} &= \frac{1}{(\omega_2^*)^2}\left[\omega_2^*\frac{\partial \omega_1^*}{\partial K_1} + \omega_1^*\frac{\partial \omega_2^*}{\partial K_2}a\right] \\
&= \frac{1}{\omega_2^*}\left[\frac{\partial \omega_1^*}{\partial K_1} + \Omega^D\frac{\partial \omega_2^*}{\partial K_2}a\right] \\
\text{since } \lim_{K_1 \to o}\frac{\partial \omega_1^*}{\partial K_1} &= \lim_{K_1 \to o}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_1^* K_1^{-1} = \infty \\
&\implies \lim_{K_1 \to o}\frac{d\Omega^D}{dK_1} = \infty
\end{aligned}$$

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

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

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

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

Appendix 3b: Slope of the final development curve Ω^D, identical provinces: $\omega_1^* = \omega_2^*$

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

Appendix 3c: Dynamic adjustment:

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

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

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

$$
\begin{aligned}
&= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} \\
\text{for } \Omega(t) &= \frac{a(t)_1}{a(t)_2}\Omega^D > \Omega^D \Longrightarrow a(t)_1 > a(t)_2 \\
&\Longrightarrow a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \Longrightarrow \frac{\dot{\Omega}(t)}{\Omega(t)} < 0 \quad \text{see} \quad (13)
\end{aligned}
$$

Appendix 3d: Reaction of the final development curve Ω^D, $\frac{d\Omega^D}{d\tau_1}$, $\frac{d\Omega^D}{d\tau_1^{ex}}$:

$$
\begin{aligned}
\frac{d\Omega^D}{d\tau_1} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{see} \quad (8) \\
\frac{d\Omega^D}{d\tau_1^{ex}} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{see} \quad (9)
\end{aligned}
$$

Appendix 4a: Determine domestic interest rate:

$$
\begin{aligned}
\pi_i &= (1-\gamma_i)\, y_i - i_i K_i - \rho_i H_i \\
\text{with } \; y_i &= A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}
$$

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

Derive the *interest parity curve*:

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

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

Slope of the *interest parity curve* :

$$\begin{aligned}
\Omega^{IP} &= \Omega^{IP}(K_1, K_2) \quad \text{and (11)} \\
\Omega^{IP} &= \frac{\omega_1}{\omega_2} = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_1^{\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_2^{\alpha}} \\
\Omega^{IP} &= C\frac{K_1^{\alpha}}{K_2^{\alpha}} = C K_1^{\alpha} K_2^{-\alpha} \quad \text{.with} \quad C = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}
\end{aligned}$$

$$\begin{aligned}
d\Omega^{IP} &= \alpha C \frac{K_1^{\alpha-1}}{K_2^{\alpha}} dK_1 - \alpha C \frac{K_1^{\alpha} K_2^{\alpha-1}}{[K_2^{\alpha}]^2} dK_2 = \alpha C \left[\frac{K_1^{\alpha-1}}{K_2^{\alpha}} dK_1 - \frac{K_1^{\alpha} K_2^{-1}}{K_2^{\alpha}} dK_2\right] \\
&= \alpha C \frac{K_1^{\alpha}}{K_2^{\alpha}} \left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0
\end{aligned}$$

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 4b: Slope of the *interest parity curve,* identical provinces:

$$\begin{aligned}
&= \alpha C \frac{K_1^{\alpha}}{K_2^{\alpha}} \left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0 \\
C &= 1, \qquad \text{for identical provinces} \\
\frac{d\Omega^{IP}}{dK_1} &= \alpha C \left[\frac{2}{K} + \frac{2}{K}\right] = \frac{4\alpha}{K} > 0
\end{aligned}$$

Appendix 4c: Reactions of the *interest parity curve*:

$$\begin{aligned}
\Omega^{IP} &= \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_1^{\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_2^{\alpha}}, \\
\text{with} \quad C &= \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}, \quad \text{and} \quad B = \frac{K_1^{\alpha}}{K_2^{\alpha}} \\
\frac{d\Omega^{IP}}{d\tau_1} &= B\frac{\partial C}{\partial \tau_1} > 0, \frac{d\Omega^{IP}}{d\tau_1^{ex}} = B\frac{\partial C}{\partial \tau_1^{ex}} > 0, \frac{d\Omega^{IP}}{d\tau_1} = B\frac{\partial C}{\partial \gamma_1} > 0
\end{aligned}$$

Appendix 4d: Relative slope of the *final development position* and the *interest parity condition* for identical provinces:

$$\begin{aligned}\frac{d\Omega^D}{dK_1} &< \frac{d\Omega^{IP}}{dK_1}\\ 4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}K^{-1} &< \frac{4\alpha}{K}\\ \delta-\delta\beta &< \alpha-\alpha\beta\\ \delta &< \alpha\end{aligned}$$

Appendix 5: Equilibrium reaction of local capital allocation. As we start from point B_0 in fig 3 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 $\gamma_i>\gamma_i^*$)

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

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

$$\begin{aligned}\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1} &> 0,\quad \text{since (19) holds}\\ &\text{and hence}\\ \frac{dK_1}{d\gamma_1} &= \frac{\frac{\partial\Omega^D}{\partial\gamma_1}-\frac{\partial\Omega^{IP}}{\partial\gamma_1}}{\frac{\partial\Omega^{IP}}{\partial K_1}-\frac{\partial\Omega^D}{\partial K_1}}<0\end{aligned}$$

9 Annotaion

The annotations are an extended appendix. They are attached for the convenience of the referee to easily check the mathematical discussion.

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

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

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

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

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

Annotation 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

$$\begin{aligned}
\dot{\omega}_i(t) &= \Psi_i \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad \text{see} \qquad (4) \\
\text{with} \quad \Psi_i &:= \gamma_i^{\delta_G} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}}. \qquad \text{see} \qquad (6)
\end{aligned}$$

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 $\frac{\partial \omega_i^*}{\partial K_i}$:

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

$$
\begin{aligned}
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-1} K_i^{\frac{-\alpha}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* K_i^{-\frac{1-\beta-\alpha}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* K_i^{\frac{-1+\beta+\alpha-\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* K_i^{-\frac{1-\beta}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_i^* K_i^{-1} > 0, \quad \text{see} \quad (7)
\end{aligned}
$$

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

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

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

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

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

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

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i (1-\tau_i^{ex})^{-1} \\
&= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}+1} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] (1-\tau_i^{ex})^{-1} \\
&= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}+\frac{(1-\beta-\delta)}{(1-\beta-\delta)}} \left[H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] (1-\tau_i^{ex})^{-1} \\
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \omega_i^* (1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (9)
\end{aligned}$$

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

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i} \\
\frac{d\Psi_i}{d\gamma_i} &= \delta_G \gamma_i^{\delta_G - 1} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \\
&\quad - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right) \gamma_i^{\delta_G} \varepsilon_i^{\delta_{Ex}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})\beta}{\tau_i r} \\
&= \delta_G \gamma_i^{-1} \Psi_i - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right) \Psi_i (1-\gamma_i)^{-1} \\
&= \Psi_i \left[\delta_G \gamma_i^{-1} - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \\
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[\delta_G \gamma_i^{-1} - \left(\delta_F + \frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \quad \textit{see} \quad (10)
\end{aligned}$$

Annotation 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:

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

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

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

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

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

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

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

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

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

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

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

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

$\omega_1^* = \omega_2^*$

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

Annotation 3c: Dynamic adjustment:

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

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

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

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

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

$$\frac{d\Omega^D}{d\tau_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{see} \quad (8)$$
$$\frac{d\Omega^D}{d\tau_1^{ex}} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{see} \quad (9)$$

Annotation 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*:

$$i_1 = i_2$$
$$\frac{1-\beta-\alpha}{1-\beta}(1-\gamma_1)\, A_1{}^{\frac{1}{1-\beta}} H_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\,\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}}$$
$$= \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_2)\, A_2{}^{\frac{1}{1-\beta}} H_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\,\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}}$$
$$\frac{A_1{}^{\frac{1}{1-\beta}}}{A_2{}^{\frac{1}{1-\beta}}} = \frac{p_2\,(1-\gamma_2)\, H_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}}}{p_1\,(1-\gamma_1)\, H_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}}}$$
$$\Omega^{IP} = \frac{A_1}{A_2} = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_2^{-\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_1^{-\alpha}}$$

Slope of the *interest parity curve* :

$$\Omega^{IP} = \Omega^{IP}(K_1, K_2) \quad \text{and} \quad (11)$$

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

$$\Omega^{IP} = C\frac{K_1^{\alpha}}{K_2^{\alpha}} = CK_1^{\alpha}K_2^{-\alpha} \quad .\text{with} \quad C = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}$$

$$\begin{aligned} d\Omega^{IP} &= \alpha C\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \alpha C\frac{K_1^{\alpha}K_2^{\alpha-1}}{[K_2^{\alpha}]^2}dK_2 = \alpha C\left[\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \frac{K_1^{\alpha}K_2^{-1}}{K_2^{\alpha}}dK_2\right] \\ &= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0 \end{aligned}$$

properties of the curve:

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

Annotation 4b: Slope of the *interest parity curve,* identical provinces:

$$\begin{aligned} &= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0 \\ C &= 1, \qquad \text{for identical provinces} \\ \frac{d\Omega^{IP}}{dK_1} &= \alpha C\left[\frac{2}{K} + \frac{2}{K}\right] = \frac{4\alpha}{K} > 0 \end{aligned}$$

Annotation 4c: Reactions of the *interest parity curve*:

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

$$\text{with} \quad C = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}, \quad \text{and} \quad B = \frac{K_1^{\alpha}}{K_2^{\alpha}}$$

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

Annotation 4d: Relative slope of the *final development position* and the *interest parity condition* for identical provinces:

$$\begin{aligned}
\frac{d\Omega^D}{dK_1} &< \frac{d\Omega^{IP}}{dK_1} \\
4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}K^{-1} &< \frac{4\alpha}{K} \\
\delta(1-\beta-\alpha) &< \alpha\,(1-\beta-\delta)
\end{aligned}$$

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

Annotation 5: Equilibrium reaction of local capital allocation. As we start from point B_0 in fig 3 we have identical provinces in the starting position:

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

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

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

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

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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