Discussion Paper No. 13-104

South-North Convergence from a New Perspective

Michael Hübler

ZEW

Zentrum für Europäische Wirtschaftsforschung GmbH

Centre for European Economic Research

Discussion Paper No. 13-104

South-North Convergence from a New Perspective

Michael Hübler

South-North Convergence from a New Perspective

Michael Hübler*

November 20, 2013

Abstract

This North-South model of Schumpeterian endogenous growth combines a market, productivity and knowledge effect. A set of various convergent and divergent growth paths is derived that is much richer than in the literature so far. South-North convergence based on North-South technology diffusion through intermediate goods trade is guaranteed if the knowledge effect dominates the productivity effect. Moreover, a larger Southern market expands the area of convergence and can prevent divergence. Not only a larger Southern market size, but also a higher Southern steady state growth rate benefit the North so that convergence is desirable for both, the South and the North.

JEL Classifications: F18, O11, O33, O41

Keywords: Schumpeter, endogenous growth, technology diffusion, convergence, poverty trap

*Corresponding author, email: michael-huebler@web.de, tel: +49-621-1235-340, fax: +49-621-1235-226, Centre for European Economic Research (ZEW), P.O. Box 103443, 68034 Mannheim, Germany; Leibniz University Hanover, Germany.

1 Introduction

One of the main topics in economics of growth is cross-country convergence versus divergence. On the one hand, in the ideal neoclassical case, countries converge to identical growth rates in the long-run steady state and under certain preconditions to identical per-capita income levels. For example, the Nelson and Phelps (1966) mechanism of technology diffusion yields convergence of the technology in practice towards the technology frontier until a certain relative distance to the technology frontier is reached. On the other hand, empirical evidence as summarized by Aghion and Howitt (2009), chapter 7, shows that only certain groups of countries converge to parallel growth paths (Barro and Sala-i-Martin 1992, Mankiw, Romer and Weil 1992, Evans 1996), whereas the richest and the poorest countries diverge (Maddison 2001, Mayer-Foulkes 2009). China is a prominent example for a country that manages well to catch up economically, wherein international technology diffusion plays an important role. Sub-Sahara African countries on the contrary do not make progress being stuck in a poverty trap.

Against this background, this paper improves on the Schumpeterian model of endogenous growth (drawing upon Aghion and Howitt 2009, chapters 4, 7, 15 and 16) by deriving various growth paths of North-South convergence and divergence that go beyond the scope of the literature so far. In the underlying model intermediate goods that embody advanced technologies are created in the North and can be utilized within the North or traded to the South. For the first time in the literature, convergence and divergence are modeled via the interaction of a market, a productivity and a knowledge effect.

The *market effect* (cf. Aghion and Howitt 2009, chapter 15) captures the expansion of the intermediate goods market with an increasing labor force (population) and productivity in both regions. It augments Northern and Southern growth in the same way. As a consequence, it does not directly influence convergence or divergence. As another consequence, catching up of the South is also beneficial for the North since it improves the productivity and therefore attractiveness of and revenues from the Southern market. This has important consequences, not highlighted in the literature so far: if the South is able to catch up in terms its technology level and hence economic development by growing more rapidly than the North, the North will achieve a higher growth rate as well, during the transition phase and in the long-run steady state. A larger Southern market indirectly fosters South-North convergence through the productivity effect.

The *productivity effect* (cf. Hübler 2011 in a model with exogenous growth), a crucial novel effect, captures the increase of technology diffusion and thus growth in the ratio of intermediate goods used in production in the South compared with the North. The intuition is that intermediate goods are not only vertically differentiated (via technological improvements for each variety over time), but also horizontally (distinct varieties with different characteristics). As a consequence, the South will receive half of the North's technological knowledge if only half of the intermediate goods are traded from North to South. The South-North ratio of intermediate goods is in turn proportional to the South-North ratio of technology levels and the South-North ratio of labor: intermediate goods trade is driven by international productivity differentials, and the marginal product of intermediate goods rises in the technology level and in the volume of labor input. Thus, a larger Southern labor force (market) improves technology diffusion to the South via intermediate goods trade. – Moreover, an exponential elasticity parameter governs the marginal impact of the productivity effect. The productivity effect can be detrimental and even catastrophic for the South: if the initial technology level of the South is low, the South can fall even further behind in terms of technologies. The resulting growth rate will even be lower. The economic reason is that due to the worsening marginal product of the intermediate goods input in the South, the Northern innovator and intermediate goods producer sells less and less intermediate goods to the South. The result is a downward spiral into a poverty trap in which the South falls further and further behind the North in terms of technologies and per capita income.

The *knowledge effect* (or Gerschenkron effect, cf. the seminal work by Nelson and Phelps 1966) works in the opposite direction: the further behind the South initially is in terms of its technology level, the higher will be its growth rate. The intuition is simple: the less one knows, the more and the faster one can learn. The related exponential elasticity parameter governs the marginal impact of the knowledge effect. It increases in the Southern absorptive capacity in reality. If the knowledge effect is strictly stronger than the productivity effect, the South will catch up to the North or fall further behind in terms of technologies, but only down to the point where its growth rate is equal to the Northern growth rate. Thereafter, South and North will grow at the same rate at a constant relative technology ratio in the steady state. A poverty trap does not emerge when the knowledge effect dominates the productivity effect. Nevertheless, the South-North technology gap can be substantial in the steady state if the Southern market is small and the marginal impact of the knowledge effect is small.

The paper makes the following contributions: it locates the paper within the related growth literature in section 2.

It is the first paper to set up a state-of-the-art Schumpeterian growth model that combines a market, a productivity and a knowledge effect. This straightforward decomposition of the channels of international technology diffusion as detailed in section 3 has been overlooked in the literature so far. It derives the distance-to-technology-frontier effect in a new and intuitive way. Hence, it improves on the theoretical foundations and the theoretical understanding of the channels of endogenous international technology diffusion. The model provides a useful mechanism for numerical large-scale growth models with technology spillovers. Such models gain more and more importance for studying long-term climate, development and trade issues. It provides a useful model for econometric studies on growth and convergence too.

It is the second contribution of the paper to derive convergent and divergent growth paths within this Schumpeterian model in a novel and straightforward way. These growth paths derived in section 4 match various empirical findings: (a) club convergence, that is convergence in growth rates and technological catching up of advanced economies, but divergence of laggard economies, (b) technology diffusion that may increase or decrease in the difference between the technology in practice and the technology frontier in various non-linear ways. The latter growth paths can much better describe the development of emerging economies like China with persistently high growth rates than the standard textbook model of convergence. The latter growth paths also fit much better to the diverse findings of the econometric literature: accordingly, productivity can increase or decrease in the distance to the technology frontier in various linear and non-linear forms (inverted U-shape, U-shape, logistic; for example Girma et al. 2001, Griffith et al. 2004, Benhabib and Spiegel 2005, Girma 2005, Girma and Görg 2007).

Based on these insights, the paper opts for a more distinct analysis of the barriers of technology diffusion to developing and emerging countries. The crucial barriers – that are different for each country – should be specifically addressed by policy measures. A one-fits-all approach, on the contrary, can fail if the productivity effect renders policy interaction that improves international technology transfer ineffective. This applies to poverty and development issues as well as to green growth and technology funding issues. Such policy implications are discussed in section 5.

2 Literature

This section reviews the related literature. On the one hand, growth theory based on the Gerschenkron (1962) effect, such as Nelson and Phelps (1966), suggests that growth increases in the existing difference between the technology in practice and the technology frontier. On the other hand, the econometric literature (OECD 2002, Saggi 2002, Keller 2004 and Hoekman and Javorcik 2006) about the effects of imports and FDI inflows on productivity and growth finds diverse results. The relation between the difference to the technology frontier and productivity gains can be increasing or decreasing in linear or non-linear forms (inverted U-shape, U-shape, logistic; Girma et al. 2001, Griffith et al. 2004, Benhabib and Spiegel 2005, Girma 2005, Girma and Görg 2007).

As a consequence of the diverse empirical facts on convergence and divergence, a variety of theoretical models has been developed that distinguishes cross-country convergence and divergence. In the category of exogenous growth models, the Solow-Swan model predicts convergence through capital accumulation, but only within groups of countries that have identical fundamental preconditions (savings rates, population growth rates and production functions). Different economic preconditions of countries result in convergence clubs with different steady state levels of per-capita income (club convergence or conditional convergence). Moreover, in the Solow-Swan model, a poverty trap can occur if the marginal product of capital (in efficiency units) increases in some stages and decreases in other stages during the process of capital accumulation (Barro and Sala-i-Martin 2004). This results in multiple steady states so that an economy can get trapped in a steady state with low capital and production levels (poverty trap).

The category of endogenous growth models encompasses various model types. The basic AK model does not produce cross-country convergence of growth rates. Basu and Weil (1998) link technical progress to capital accumulation based on a simplified learning-by-doing approach without R&D investments and endogenous growth. They study perfect international mobility of capital and technology and derive a situation where capital does not flow from North to South. More recently, Aghion and Howitt (2009, chapter 7) describe club convergence in a Schumpeterian model of endogenous growth by using an innovation cost function consisting of a linear and a quadratic term. Moreover, Aghion and Howitt (2009, chapter 11) describe a non-convergence trap equilibrium where a country fails to switch from an imitation- to an innovation-based strategy.

The literature that studies poverty traps in theoretical and empirical terms distinguishes critical thresholds, dysfunctional institutions and neighborhood effects as causes for poverty (Bowles, Durlauf and Hoff, 2006). This literature stream in general neglects international technology diffusion and trade in intermediate goods that embody advanced technologies, though. – Aspects that will be addressed in this paper.

Another literature stream examines the relation of trade and growth based on the Heckscher-Ohlin theory and demonstrates the possibility of convergent as well as divergent growth paths (Chen 1992, Mountford 1998, Atkeson and Kehoe 2000, Bajona and Kehoe 2010).

Recently, the issue of international technology diffusion and convergence in technology levels has become crucial in the context of global warming: achieving ambitious climate policy targets at acceptable costs requires the international diffusion of energy and carbon emissions saving technologies from industrialized to developing countries. Herein, international technology diffusion is closely related to international trade and foreign direct investment (FDI) as channels of technology transfer. Foreign direct investment and related imports of investment goods are supposed to be supported in order to save carbon emissions.

The interaction of international trade and FDI with endogenous growth and international technology diffusion has not yet been fully understood; in particular, the occurrence of international convergence and divergence and thus poverty traps. This paper deals with these open research aspects. It is related to the work by Grossman and Helpman (1991), chapters 9 and 11, Aghion and Howitt (2009), chapter 15, and Acemoglu et al. (2012) (for the latter also see Aghion and Howitt 2009, chapter 16, in a simplified version). Grossman and Helpman (1991) and Aghion and Howitt (2009) study international technology diffusion, in other words imitation, related to international trade in an endogenous growth context. Acemoglu et al. (forthcoming) show that a subsidy on clean innovation additional to a tax on dirty production is necessary for an efficient shift from dirty to clean production and that this policy intervention can be temporary under certain conditions.

3 Model

The following North-South model follows the Schumpeterian view of quality improvements as a driver of economic growth (based on Aghion and Howitt 2009, chapter 4 in combination with chapters 7, 15 and 16). In our model, technology does not spillover completely and immediately to the South but rather diffuses according to a distance-to-technology-frontier approach. Furthermore, a monopolist distributes intermediate goods across North and South depending on relative productivities and therefore on the current technology gap. These modifications will create new results.

3.1 Production

We assume two regions called North and South $r = \{n, s\}$ and a discrete series of time periods t. Aggregate production Y_{rt} is described by a Cobb-Douglas technology in each region:

$$Y_{rt} = (A_{rt}L_r)^{1-\alpha}x_{rt}^{\alpha} \tag{1}$$

This technology uses the inputs labor L_r, which is a certain fraction of the population of each region and constant over time, and intermediate goods x_{rt}, which is endogenous. $1-\alpha$ and $0 < \alpha < 1$ are the related exponents or income shares. A_{rt} reflects productivity of x_{rt} in each period. $A_{rt}L_r$ can be interpreted as the economies' effective labor supply or as its effective market size.

We assume, production of x_{rt} is the source of technical progress that raises A_{rt}. We further assume, only one monopolist located in the North is able to create intermediate goods that embody such advanced technologies. In the North, output Y_n can be transferred into intermediate goods in a 1:1 fashion by the monopolist. Thereafter, the intermediate goods can be perfectly traded across regions and used as a production input in both regions. Therefore, net income – available for consumption and for R&D expenditures in the North – generated by final production simply reads:

$$G_{nt} = Y_{nt} - X_t \tag{2}$$

$$G_{st} = Y_{st} \tag{3}$$

where $X_t = x_{nt} + x_{st}$. In each region a representative, risk neutral consumer draws utility from consumption C_{rt} in a linear fashion. Each consumer maximizes consumption expected over time (c.f. Aghion and Howitt 2009, chapter 4) without discounting the future so that the objective simply becomes: $\max C_{rt}$.

Selling x_{st} to the South, the Northern monopolist earns a revenue, as she or he does in the North. The monopolist chooses X_t in a profit maximizing way, where p_t is the price of X_t:

$$\max_{X_t} \Pi_{rt} = p_t X_t - X_t \tag{4}$$

In a perfectly competitive equilibrium of Y production, in each region input x_{rt} is demanded for production to such an extent that its price equals its marginal product:

$$p_t = \frac{\partial Y_{rt}}{\partial x_{rt}} = \alpha(A_{rt}L_r)^{1-\alpha}x_{rt}^{\alpha-1} \tag{5}$$

Solving for x_{rt} and summing up x_{rt} over regions yields in the symmetric case (with the same α for both regions):

$$X_t = (A_{nt}L_n + A_{st}L_s)\left(\frac{p_t}{\alpha}\right)^{\frac{1}{\alpha-1}} \tag{6}$$
$$\Leftrightarrow p_t = \alpha(A_{nt}L_n + A_{st}L_s)^{1-\alpha}X_t^{\alpha-1} \tag{7}$$

We calculate the optimal price and quantity of X_t by inserting into the profit equation and by maximizing profits. Inserting furthermore the price of X_t into the x_{rt} demand functions yields the optimal quantities; and inserting into the profit function yields the maximal profit of the monopolist:[1]

$$p_t^0 = \frac{1}{\alpha} \tag{8}$$
$$X_t^0 = (A_{nt}L_n + A_{st}L_s)\alpha^{\frac{2}{1-\alpha}} \tag{9}$$
$$x_{rt}^0 = A_{rt}L_r\alpha^{\frac{2}{1-\alpha}} \tag{10}$$
$$\Pi_{nt}^0 = \pi(A_{nt}L_n + A_{st}L_s) \tag{11}$$

where $\pi = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$.

Inserting x_{rt}^0 into the production function (1) yields:

$$Y_{rt}^0 = A_{rt}L_r\alpha^{\frac{2\alpha}{1-\alpha}} \tag{12}$$

Accordingly, in each region output is proportional to technology and labor (population). Now profits can be re-written as:

$$\Pi_{nt}^0 = \left(\frac{1}{\alpha} - 1\right)(Y_{nt}^0 + Y_{st}^0) \tag{13}$$

In the North, overall net income, denoted by C_{nt}^0 consists of G_{nt}^0, the value of Northern final production minus the value of intermediate inputs used in the North and in the South, plus Π_{nt}^0, the profit gained by supplying intermediate inputs within the North and to the South, minus R_{nt}^0, R&D expenditures by the X producer that will be detailed

[1] Optimality is indicated by 0.

in the following section. In the South, overall net income, C^0_{st}, consists of G^0_{nt} minus the profit repatriated to the North for receiving the intermediate input x^0_{st}, which is $\left(\frac{1}{\alpha}-1\right)Y^0_{st}$ according to (13):

$$
\begin{aligned}
C^0_{nt} &= \frac{1}{\alpha}Y^0_{nt} - x^0_{nt} - x^0_{st} - R^0_{nt} \qquad (14)\\
C^0_{st} &= \left(2-\frac{1}{\alpha}\right)Y^0_{st} \qquad (15)
\end{aligned}
$$

This implies, intermediate goods with the value $p_t x_{st} = \alpha^{\frac{1+\alpha}{1-\alpha}}$ are traded from North to South, while a revenue (in financial form or in form of final goods) with the same value expressed as $\alpha Y_{st} = \alpha^{\frac{1+\alpha}{1-\alpha}}$ is repatriated from South to North.[2]

3.2 Innovation

In each period, entrepreneurs attempt to become the monopolist by making a successful innovation. – Note that the producers of intermediate goods X are also the innovators who improve these intermediate goods. – A successful innovation creates a new variety of intermediate goods that is qualitatively superior to previous varieties. Therefore, given a successful innovation, the monopolist supplies the whole market for intermediate goods and earns a monopoly rent as described in the last section. In order to create an innovation, she needs to undertake research (R&D) that involves costs. An entrepreneur can decide upon how much to spend on research, denoted by R_{nt}. The more she spends on research, the higher the probability μ of a successful innovation:

$$\mu_t = \Phi\left(\frac{R_{nt}}{A_{nt}}\right) = \lambda\left[\frac{R_{nt}}{A_{nt}}\right]^{\sigma} \qquad (16)$$

The R&D function $\Phi(.)$ adopted from Aghion and Howitt implies that research costs increase in the existing technology level A_{nt}. This means, it becomes increasingly difficult to push the technology frontier forward, the more the frontier has already been pushed forward. As Aghion and Howitt, we assume $0 < \sigma < 1$, so that the marginal product of R&D expenditures is positive but decreasing.[3] At the same time, each technological step becomes larger over time in absolute terms. This implies that technical progress builds on the existing technological knowledge and that knowledge has public good character.

Additionally, we assume throughout the paper $A_{nt} \geq A_{st}$, that means the North is

[2] This can be verified by multiplying (8) with (10) and comparing the result to (12) multiplied by α for $r = s$ in each case.

[3] For example, it is more difficult to raise the speed of a microprocessor once in the speed has already come close to the technically possible limit a late stage of development than at an early stage.

the technology leader, and the South is the follower. For this reason, we assume that research costs are – at least at the margin – determined by the higher technology level A_{nt}. At the same time, as we know from the previous section, profits also increase in A_{nt} and in A_{st}. In particular, the entrepreneur solves the following maximization problem where profits Π_{nt}, as derived in the previous section, are inserted after maximization:[4]

$$\max_{R_{nt}} \Phi\left(\frac{R_{nt}}{A_{nt}}\right)\Pi^0_{nt} \quad - \quad R_{nt} \tag{17}$$

$$\Rightarrow \Phi'\left(\frac{R_{nt}}{A_{nt}}\right)\frac{\Pi^0_{nt}}{A_{nt}} \quad = \quad 1 \tag{18}$$

$$\Rightarrow \sigma\lambda\left(\frac{R_{nt}}{A_{nt}}\right)^{\sigma-1}\pi\left(L_n + \frac{A_{st}}{A_{nt}}L_s\right) \quad = \quad 1 \tag{19}$$

The latter equation is called the research arbitrage condition. Different to Aghion and Howitt, the $\frac{R_{nt}}{A_{nt}}$ ratio does not stay constant over time. It rather increases when the Southern technology level catches up to the Northern level so that $\frac{A_{st}}{A_{nt}}$ increases. While this happens, the Southern market becomes more attractive (more productive) which induces higher R&D efforts to deliver the Southern market with intermediate goods. Note that the monopolist cannot choose A_{nt}, but only R_{nt} given a certain A_{nt} at a certain point of time. Thus, A_{nt} and A_{st} are exogenous variables with respect to the monopolist's decision. In this respect, the monopolist is myopic. She does not anticipate the influence of today's research expenditures on future technology levels and thus on future research expenditures.

We gain the optimal R&D expenditure and the resulting probability of a successful innovation:

$$\frac{R^0_{nt}}{A_{nt}} \quad = \quad \left[\sigma\lambda\pi\left(L_n + \frac{A_{st}}{A_{nt}}L_s\right)\right]^{\frac{1}{1-\sigma}} \tag{20}$$

$$\Rightarrow \mu_t \quad = \quad \lambda^{\frac{1}{1-\sigma}}\left[\sigma\pi\left(L_n + \frac{A_{st}}{A_{nt}}L_s\right)\right]^{\frac{\sigma}{1-\sigma}} \tag{21}$$

4 Analysis

This section derives the Northern and the Southern growth rate and identifies convergent and divergent growth paths. The first subsection is strictly algebraic, whereas the second

[4]Different to an endogenous growth model with horizontal product differentiation, an innovation (a patent) holds only for a limited period of time in this model with vertical product differentiation through Schumpeterian creative destruction. Thus, profits are only gained within this period, not in form of a profit stream until infinity.

subsection parameterizes the model to illustrate the various possible growth paths.

4.1 Growth

We can see from equation (1) that per capita output $\frac{Y_{rt}}{L_r}$ is proportional to the technology A_{rt}. Therefore, output grows at the same rate as technology. In the following, we will therefore only derive technology growth rates. First, by the Law of Large Numbers, μ represents the expected log-run frequency of the appearance of successful innovations. Second, in case of a successful innovation, the newly developed technology A_t will replace the old technology A_{t-1}. The size of each step of technical progress is described by $\gamma = \frac{A_t}{A_{t-1}}$. In case of an innovation failure, which occurs with probability $1-\mu$, the old technology will be used further so that $A_t = A_{t-1}$. The regional technology growth rate is determined by successful innovations and reads:

$$g_{rt} \quad = \quad \mu_t(\gamma_{rt} - 1) \tag{22}$$

Aghion and Howitt (2009, chapter 7) and Acemoglu (2009, chapter 18) assume that $\gamma_{rt} - 1$ increases in the existing technology gap between the technology frontier and the technology in practice (Gerschenkron 1962 effect). We basically follow this idea but particularly set up a modified functional relationship derived from straightforward arguments that will provide new insights. We follow the view of Nelson and Phelps (1966) that the change in technology in a certain period is given by the existing North-South technology difference:

$$\Delta A_{st} \quad = \quad A_{nt} - A_{st} \tag{23}$$

$$\Leftrightarrow \frac{\Delta A_{st}}{A_{st}} \quad = \quad \frac{A_{nt}}{A_{st}} - 1 =: g'_{rt} \tag{24}$$

This formulation is straightforward by the following argumentation: in case of homogenous technology stocks A_{rt} and $A_{nt} > A_{st}$ and *perfect* technology diffusion between regions without time delay and without bounds, the technology gain ΔA_{st} is exactly equal to the inter-regional technology difference. However, there are bounds in reality so that $\Delta A_{st} < A_{nt} - A_{st}$ or $\Delta A_{st} = \epsilon(A_{nt} - A_{st})$, $0 < \epsilon < 1$.

We consider the following determinant of ϵ: as a *novel element*, we make the plausible assumption that the South receives the same amount of new technological knowledge as the North only if $x_{st} = x_{nt}$. This implies a certain *"horizontal"* heterogeneity of technologies within each *"vertical"* variety of technology in each period. If $x_{st} < x_{nt}$, only part of the "horizontal" varieties is transferred to the South and thus can be adopted: if each single variety has the same value, a lower value of the sum of all varieties x_{st} implies a smaller number of varieties. Thus, ϵ increases in $\frac{x_{st}}{x_{nt}}$ in a linear or in general in a non-linear way so that $\epsilon \sim \left(\frac{x_{st}}{x_{nt}}\right)^{\beta_X}$. A higher exponential elasticity parameter β_X results in a larger marginal impact of the relative Southern intermediate goods inflow on technical progress.

In the analog way, the technology gap may influence technology diffusion in a linear or non-linear way so that we consider $\left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A}$ as a more general functional form derived from equation (24). β_A can be assumed to increase in the absorptive capacity, determined by education, infrastructure, the legal system and so forth. The absorptive capacity determines in how far the inflow of knowledge embodied in intermediate goods can be exploited by the South. A higher exponential elasticity parameter β_A results in a larger marginal impact of the relative Southern intermediate goods inflow on technical progress.

The overall strength of technical progress in the South as in the North is governed by the constant Ψ which is determined by technological (engineering) constraints. There is one case in which solely the Ψ term determines technical progress: if a Southern region has become the technology leader, the distance to frontier term will become obsolete. Conversely, there is one case in which no technical progress occurs in the South at all: if the relative technology level of the South has dropped towards zero so that quasi no intermediate goods are allocated to this region.[5] Whereas the South can benefit from technology diffusion, the North can only benefit from innovation since the North determines the technology frontier.

Combining these mechanisms and collecting terms leads to the following steps of technical progress in case of a successful innovation in the North and the South:

$$\gamma_{nt} - 1 = \Psi \tag{25}$$

$$\gamma_{st} - 1 = \Psi \left(\frac{x_{st}}{x_{nt}}\right)^{\beta_X} \left[1 + \left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A}\right] \tag{26}$$

We now come to a *crucial step*. According to section 3.1, we can replace the South-North

[5] Intermediate goods also enter the Southern production function as a necessary input. Thus, production would cease if no intermediate goods were delivered because of a too low productivity. To prevent this effect, one may add a constant term to the intermediate goods input x_{st} in the production function. Such a constant term may represent any local substitutes for x_{st}. Without loss of generality, we leave this constant out in the calculations for the sake of mathematical simplicity.

ratio of intermediate inputs by the optimal South-North ratio of effective labor:

$$\frac{x_{st}^0}{x_{nt}^0} = \frac{A_{st}L_s}{A_{nt}L_n} \tag{27}$$

$$\Rightarrow \gamma_{st} - 1 = \Psi \left(\frac{A_{st}L_s}{A_{nt}L_n}\right)^{\beta_X} \left[1 + \left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A}\right] \tag{28}$$

Finally, after inserting the expression for μ_t derived in section 3.2, we arrive at the following growth rates in the North:

$$g_{nt} = \underbrace{\kappa\, L_n^{\frac{\sigma}{1-\sigma}} \left(1 + \frac{A_{st}}{A_{nt}}\frac{L_s}{L_n}\right)^{\frac{\sigma}{1-\sigma}} \Psi}_{market} \tag{29}$$

and in the South:

$$g_{st} = \underbrace{\kappa\, L_n^{\frac{\sigma}{1-\sigma}} \left(1 + \frac{A_{st}}{A_{nt}}\frac{L_s}{L_n}\right)^{\frac{\sigma}{1-\sigma}}}_{market} \Psi \underbrace{\left(\frac{A_{st}}{A_{nt}}\frac{L_s}{L_n}\right)^{\beta_X}}_{productivity} \left[1 + \underbrace{\left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A}}_{knowledge}\right] \tag{30}$$

where we write $\kappa = \lambda^{\frac{1}{1-\sigma}} (\sigma\pi)^{\frac{\sigma}{1-\sigma}}$ for simplicity. We can distinguish a market, a productivity and a knowledge effect of the technology ratio $\frac{A_{st}}{A_{nt}}$ as prescribed in the equations above.

4.2 Convergence

A steady state defined as a situation with equal growth rates satisfies the condition $g_{st} = g_{nt}$. South-North convergence requires $g_{st} > g_{nt}$. The related conditions can easily be derived with the help of (29) and (30). Convergence, leading to a the steady state with equal growth rates, thus requires:

$$\left(\frac{A_{nt}}{A_{st}}\frac{L_n}{L_s}\right)^{\beta_X} - 1 < \left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A} \tag{31}$$

Proposition 1. *The market effect affects both, South and North, simultaneously and can thus not guarantee convergence.*

Proof. The market effect as defined in Equations (29) and (30) cancels out with respect to convergence and divergence since it affects both regions in the same way. This is evident in Inequality (31). □

Proposition 2. *If the knowledge effect dominates the productivity effect, i.e. if $\beta_A > \beta_X$, there will exist an area of convergence. If not, there can be either convergence or* *divergence depending on the size of the Southern labor force (market).*

Proof. The condition for convergence will be fulfilled when the knowledge effect on the right hand side of Inequality (31) is stronger than the productivity effect on the left hand side. It is particularly relevant to examine the situation when the Southern technology level falls further and further behind the Northern one, i.e. $\lim_{A_{nt}\to 0}\left(\frac{A_{nt}}{A_{st}}\frac{L_n}{L_s}\right)^{\beta_X} - 1 < \lim_{A_{st}\to 0}\left(\frac{A_{nt}}{A_{st}} - 1\right)^{\beta_A}$ with all variables in the equation being positive and finite. This condition will asymptotically be fulfilled if $\beta_A > \beta_X$. Depending on the level of A_{st} and thus $\frac{A_{nt}}{A_{st}}$ for which the condition is fulfilled, the area of convergence will be larger or smaller. If, on the opposite $\beta_A < \beta_X$, there can be convergence or divergence depending on whether Inequality (31) holds for certain values of $\frac{A_{nt}}{A_{st}}$ or not. □

Proposition 3. *The larger the Southern labor force (market) relative to the Northern one, i.e. the higher the ratio* $\frac{L_s}{L_n}$ *, the larger will be the area of convergence and the South-North technology ratio in the long-run steady state.*

Proof. One can easily see that a larger L_s relative to L_n reduces the left hand side of Inequality (31) so that the condition is ceteris paribus more likely fulfilled for sufficiently high values of A_{st}. The area of convergence will hence become larger. And the likelihood of convergence in the absence of a dominant knowledge effect ($\beta_A < \beta_X$) will raise with respect to Proposition 2. □

4.3 Simulation

This section parameterizes the model in order to illustrate various South-North growth paths. As we will see, the simulation results corroborate Propositions 1, 2 and 3.

For simplicity, we normalize most parameter values to one: $\kappa = 1; L_n = 1; \sigma = 0.5 \Rightarrow \frac{\sigma}{1-\sigma} = 1; \Psi = 1$. A low market effect means $L_s = 0.5$ so that the Southern labor force size is half the Northern one. A high market effect implies $L_s = 1$ so that the Southern labor force has the same size as the Northern one. A low productivity effect is characterized by $\beta_X = 0.5$, a very low one by $\beta_X = 0.25$. In the same vein, a low knowledge effect is characterized by $\beta_A = 0.5$, a very low one by $\beta_A = 0.25$ and additionally a high one by $\beta_X = 1$. Figure 1 visualizes the simulation results for various parameter settings regarding the strength of the market, productivity and knowledge effect. In each subfigure, the horizontal axis depicts the South-North technology ratio which can take values between zero and one. The vertical axis depicts the corresponding growth rates of the North and the South. The growth values can be interpreted as annual percentage rates. The right axis represents the technology frontier given by the North where $\frac{A_{st}}{A_{nt}} = 1$.

The intersection of the growth paths of North and South will be a long-run steady state with equal growth rates and different technology levels if it is a stable situation. Full South-North convergence in growth rates as well as technology levels will be achieved if the Southern growth path is for all possible South-North technology ratios above the Northern path. On the opposite, full divergence irrespective of the initial South-North technology ratio will be the case if the Southern growth path is for all possible South-North technology ratios below the Northern path. The classical case of convergence occurs when the Southern growth rate is higher than the Northern one the left hand side of the intersection, and the Northern growth rate is higher than the Southern one on the right hand side. Divergence occurs in the opposite case. In this case, the intersection of the two growth paths is instable.

Figure 1 illustrates various constellations of parameter settings and hence relative magnitudes of the market, productivity and knowledge effect relative to each other. The left column always illustrates a constellation with a low Southern labor force, whereas the right column always illustrates a constellation with a high Southern labor force.

The classical case of convergence is illustrated in Figure 1 (a). The farther away the South is from the North in terms of its technology level, the higher will be its growth. This clearly results in South-North convergence until the intersection point with equal growth rates is reached – for this parameter setting at a South-North technology ratio of about 0.5. This case emerges because the knowledge effect is dominant so that Southern growth monotonously decreases in the South-North technology ratio. It is the classical Nelson-and-Phelps style textbook case. There is convergence, and there is a continuous decline in the growth rate during the catching up process too.

When the Southern market expressed as the size of its labor force expands, the intersection point will move to the right, and hence the convergence area will increase as spelled out by Proposition 3. In Figure 1 (b) the intersection point has moved that far to the right that it is beyond the right axis. This results in full convergence for all South-North technology ratios. The South will finally reach the same technology level as the North. Thereafter, the South will persistently growth with the same growth rate as the North because its labor force has the same the size as the Northern one. If the South has a larger labor force, its growth rate will be persistently higher than that of the North, e.g. over 4 percent per annum when the South has double the market size of the

North (not shown in the figure).[6] In this case, the South can apply the state-of-the-art technology to a larger labor force than the North and achieve higher growth. In both convergent cases, (a) and (b), the knowledge effect dominates the productivity effect as prescribed by Proposition 2.

In Figure 1 (c) the knowledge effect is still more pronounced than the productivity effect; yet both effects are weaker. As a consequence, the South's skyrocketing growth at low technology levels is mitigated. Moreover, the decline in its growth rate when coming closer to the technology frontier given by the North is mitigated too. The result is visible as a flat region with an almost constant growth rate at a relative technology ratio between 0.2 and 0.8. This constellation allows emerging economies to catch up without suffering a permanent significant decline in the growth rate. Notwithstanding, the Southern growth rate dilutes and reaches the Northern one at a certain South-North technology ratio, i.e. a certain proximity to the technology frontier given by the right axis denoting $\frac{A_{st}}{A_{nt}} = 1$. The intersection point is obviously much closer to the technology frontier than in (a) with a higher knowledge and productivity effect.

The characteristic effect of (c) is exacerbated in (d) due to a larger Southern labor force: now the Southern growth rate even rises during the catching up phase until full equality of technology levels is achieved on the right axis. This constellations reconciles the view that growth rises in the distance to the technology frontier (on the left hand side) because of a higher learning potential with the view that growth rises in the similarity of technology source and recipient (moving to the right hand side). Nonetheless, the Southern growth rate falls down to the Northern one when reaching equal technology levels because the Southern technology level gained solely via technology diffusion from the North cannot exceed the Northern one and hence creates the same growth effect in the South in case of equal market sizes. The graphs (a) to (d) relate to Propositions 1 and 2 which state that convergence is guaranteed when the knowledge effect exceeds the productivity effect independent of the market effect. They refer to Proposition 3 too, which affirms that a larger Southern labor force enlarges the area of convergence.

On the contrary, case (e) can be called tragic because the Northern growth path is an upward tangent to the Southern growth path. Hence, although there is a touching point, it is not stable: a minor shock shock can push the South down to the divergent path on the left. When the Southern labor force is even smaller, the Southern growth rate will completely lie below the Northern one, which is the case of full divergence (not

[6] This can easily be verified by inserting in Equations 29 and 30.

shown in the figure).

The opposite will happen when the Southern labor force becomes larger as visualized by Figure 1 (f): the intersection point has moved so far in the upper right direction that it lies beyond $\frac{A_{st}}{A_{nt}} = 1$. Hence, the larger labor force has remedied the divergence problem. The effect that Southern growth accelerates during the catching up phase is even more pronounced than in (d).

Figure 1 (g) depicts a more complex growth structure which contains a divergent intersection point in the middle and a convergent intersection point on the right. Now the occurrence of divergence or convergence depends upon the initial technology level: if the South starts in the divergent area left of the middle, it will fall further and further behind the North towards the left. If the South starts right of the middle, it will catch up until it reaches the right intersection point close to the technology frontier. This is the most illustrative case generated by this model. It highlights that a slightly modified stylized model of endogenous growth opens a much richer set of South-North growth constellations than the classical textbook case depicted in (a). This constellation will allow for the coexistence of convergent and divergent behavior of economies and thus club convergence when the model is applied to a set of heterogeneous economies.

The larger labor force assumed in (h) has moves the intersection point to the left and thus widened the area of convergence as declared by Proposition 3. Notwithstanding, a strong market effect does not guarantee convergence as spelled out by Proposition 1: a larger labor force (market) only enlarges the area of convergence. This means, when the Southern labor force exceeds the Northern one even more, the intersection point will shift further to the left, while a small area of divergence will still exist.

To conclude, in constellations (d), (f) and (h) with a high Southern labor force (market) growth is not continuously attenuated during catching up as in the classical textbook case. This fits to China's and India's development, both economies with huge labor forces (markets). In constellations (e), (g) and (h) economies with initially low technology levels diverge away from the technology frontier. This fits for example to Sub-Sahara African countries stuck in poverty.

It is obvious that a long-run steady state lying further at the right not only implies a higher Southern growth rate, but also a higher Northern one. Hence, convergence benefits both, South and North, not only in the level of economic activity, but also in the rate of persistent growth.

4.4 Interpretation

This section interprets the model behavior from a more general point of view.

In a more general context, Taylor (2009) emphasizes three preconditions for (environmental) crises: (1) failures in governance, (2) a system exhibiting a tipping point, and (3) economic (environmental) interactions with positive feedbacks.

The model analyzed above fulfills these criteria: (1) Many developing countries suffer from poor governance by political leaders and elites who pronounce their own success and wealth rather than national progress and wealth. As a consequence, education, infrastructure, the legal system, the economic conditions such as local taxes and other factors are insufficient for attracting foreign capital and spreading and absorbing foreign technologies, resulting in a low β_A in the model. Moreover, the initial technology levels of such countries are often low. Hence, they likely start in the area of divergence visualized in Figure 1 (e), (g) and (h). (2) In these graphs, the areas of convergence and divergence are separated by a tipping point. (3) A feedback mechanism will be generated if the productivity effect dominates so that a lower technology level in the South, i.e. a low A_{st} in the model, relative to the North reduces the input of intermediate goods in the South relative to the North and hence technology diffusion. This reduces the relative technology level increasingly. The resulting crisis is in our model a poverty trap in which the South falls further and further behind due to divergence so that the South-North technology ratio $\frac{A_{st}}{A_{nt}}$ approaches zero.

5 Conclusion

The endogenous growth model that we examined combines a (1) market, (2) productivity and (3) knowledge effect that determine the growth rate of a developing region, called the South. A higher growth rate in the South than in the industrialized region, called the North, implies convergence. The analysis shows that dominance of the productivity effect results in the possibility of divergence whereas dominance of the knowledge effect results in convergence. In the divergence case case, there can be a tipping point between convergence and divergence. This indicates that market forces may fail to create cross-country convergence and may leave countries in poverty traps as observed in reality. A larger Southern population and hence labor force and market expands the area of convergence and makes convergence more likely when the productivity effect dominates.

Supporting technology diffusion to the South is not only beneficial for the South, but also for the North because of the market effect. The market effect will raise the annual growth rate of the North and thus create substantial revenues over time if the mechanism of international technology diffusion via intermediate goods trade works. Therefore, it would be rational for the North to support and finance international technology diffusion. Southern economies that are stuck in poverty traps or that are near the tipping point between convergence and divergence require special and urgent attention. The reason is that the difference in terms of growth and wealth between the situation when the South is on a convergent path and when the South is on a divergent path for both, the North and the South, increases over time. It becomes more and more challenging to switch from a divergent to a convergent path because the South-North technology gap increases. As a consequence, less intermediate inputs and hence technologies diffuse to the South so that it becomes increasingly difficult to close the technology gap. Thus, it is rational to lift such countries onto convergent growth paths or to prevent them from falling to divergent paths as early as possible. This is in the interest of the industrialized countries since they will benefit from trading with successfully growing economies via the market effect.

In summary, the novel separation of the channels of endogenous technology diffusion in a (1) market, (2) productivity and (3) knowledge effect helps us understand through which channel technology diffusion fails in a specific economy. Accordingly, the analysis stresses the importance of enabling and fostering international technology diffusion through (1) the creation of sufficiently large competitive markets, (2) lifting the initial technology levels of countries at low technology levels and reducing market barriers that hinder international trade and thus technology transfer, and (3) the improvement of the absorptive capacity of developing countries so that the technological knowledge embodied in inflowing goods can be exploited. This threefold separation contradicts simple one-fits-all policies. For example, the improvement of the absorptive capacity might turn out to be ineffective because there is no sufficiently large prevailing technology level or the market is too small so that the productivity effect creates divergence. Or when convergence can be achieved given the absorptive capacity, an insufficient size and competitiveness of the Southern market can nonetheless tare down the pace of convergence. Thus, policy intervention should be aware of these interconnected forces. – Building on these insights, future research could take technological uncertainty into account.

6 References

Acemoglu, D. (2009). Introduction to Modern Economic Growth. Princeton University Press, Princeton, USA.

Aghion, P. and P. Howitt (2009). The Economics of Growth. The MIT Press, Cambridge, USA.

Acemoglu, D., P. Aghion, L. Burstyn and D. Hemous (2012). The Environment and Directed Technical Change. American Economic Review 102(1), 131-166.

Atkeson, A. and P.J. Kehoe (2000). Paths of Development for Early- and Late-Bloomers in a Dynamic Heckscher-Ohlin Model. Federal Reserve Bank of Minneapolis, Research Department Staff Report 256.

Bajona, C. and T.J. Kehoe (2010). Trade, growth, and convergence in a dynamic Heckscher-Ohlin model. Review of Economic Dynamics 13(3), 487-513.

Bowles, S., S.N. Durlauf and K. Hoff, editors (2006). Poverty Traps. Russel Sage Foundation, New York, Princeton University Press, Princeton and Oxford, USA.

Barro, R. and X. Sala-i-Martin (2004). Economic Growth. 2nd edition, The MIT Press, Cambridge, USA.

Basu, S. and D.N. Weil (1998). Appropriate Technology and Growth. The Quarterly Journal of Economics 113(4), 1025-1054.

Chen, Z. (1992). Long-Run Equilibria in a Dynamic Heckscher-Ohlin Model. The Canadian Journal of Economics 25(4), 923-943.

Evans, P. (1996). Using Cross-Country Variances to Evaluate Growth Theories. Journal of Economic Dynamics and Control 20, 1027-1049.

Gerschenkron, A. (1962). Economic Backwardness in Historical Perspective: A Book of Essays. Belknap Press of Harvard University Press, Cambridge, USA.

Girma, S., D. Greenaway and K. Wakelin (2001): Who benefits from Foreign Direct Investment in the UK? Scottish Journal of Political Economy 48, 119-133.

Girma, S. (2005). Absorptive capacity and productivity spillovers From FDI: a threshold regression analysis, Oxford Bulletin of Economics and Statistics 67(3), 281-306.

Girma, S. and H. Görg (2007). The role of the efficiency gap for spillovers from FDI: Evidence from quantile regressions. Open Economies Review 18(2), 215-232.

Griffith R., S. Redding and J. van Reenen (2004). Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries. The Review of Economics and Statistics 86(4), 883-895.

Grossman, G. and E. Helpman (1991). Innovation and Growth in the Global Economy. The MIT Press, Cambridge, Massachusetts, USA and London, England.

Hoekman, B., and B.S. Javorcik, eds. (2006). Global integration & technology transfer. The World Bank, Washington, DC, USA.

Hübler, M. (2011). Avoiding the Trap: The Dynamic Interaction of North-South Capital Mobility and Technology Diffusion. The Journal of International Trade and Economic Development 20(3), 401-427.

Keller, W. (2004). International Technology Diffusion. Journal of Economic Literature, American Economic Association 42(3), 752-782.

Maddison, A. (2001). The World Economy: A Millennial Perspective. Development Centre Studies, OECD, Paris.

Mayer-Foulkes, D. and P. Nunnenkamp (2009). Do Multinational Enterprises Contribute to Convergence or Divergence? A Disaggregated Analysis of US FDI. Review of Development Economics 13(2), 304-318.

Mankiw, N.G, P. Romer and D.N. Weil (1992). A Contribution to the Empirics of Economic Growth. Quarterly Journal of Economics 107, 407-437.

Mountford, A. (1998). Trade, convergence and overtaking. Journal of International Economics 46, 167-182.

Nelson, R. and E. Phelps (1966). Investment in Humans, Technological Diffusion, and Economic Growth. The American Economic Review, Papers and Proceedings 61, 69-75.

OECD (2002). Foreign Direct Investment for Development - Maximising Benefits, Minimising Costs. OECD Publications, Paris.

Saggi, K. (2002). Trade, Foreign Direct Investment, and International Technology Transfer: A Survey. World Bank Research Observer, Oxford University Press 17(2), 191-235.

Taylor, M.S. (2009). Environmental Crises: Past, Present and Future. Innis Lecture, Canadian Journal of Economics.

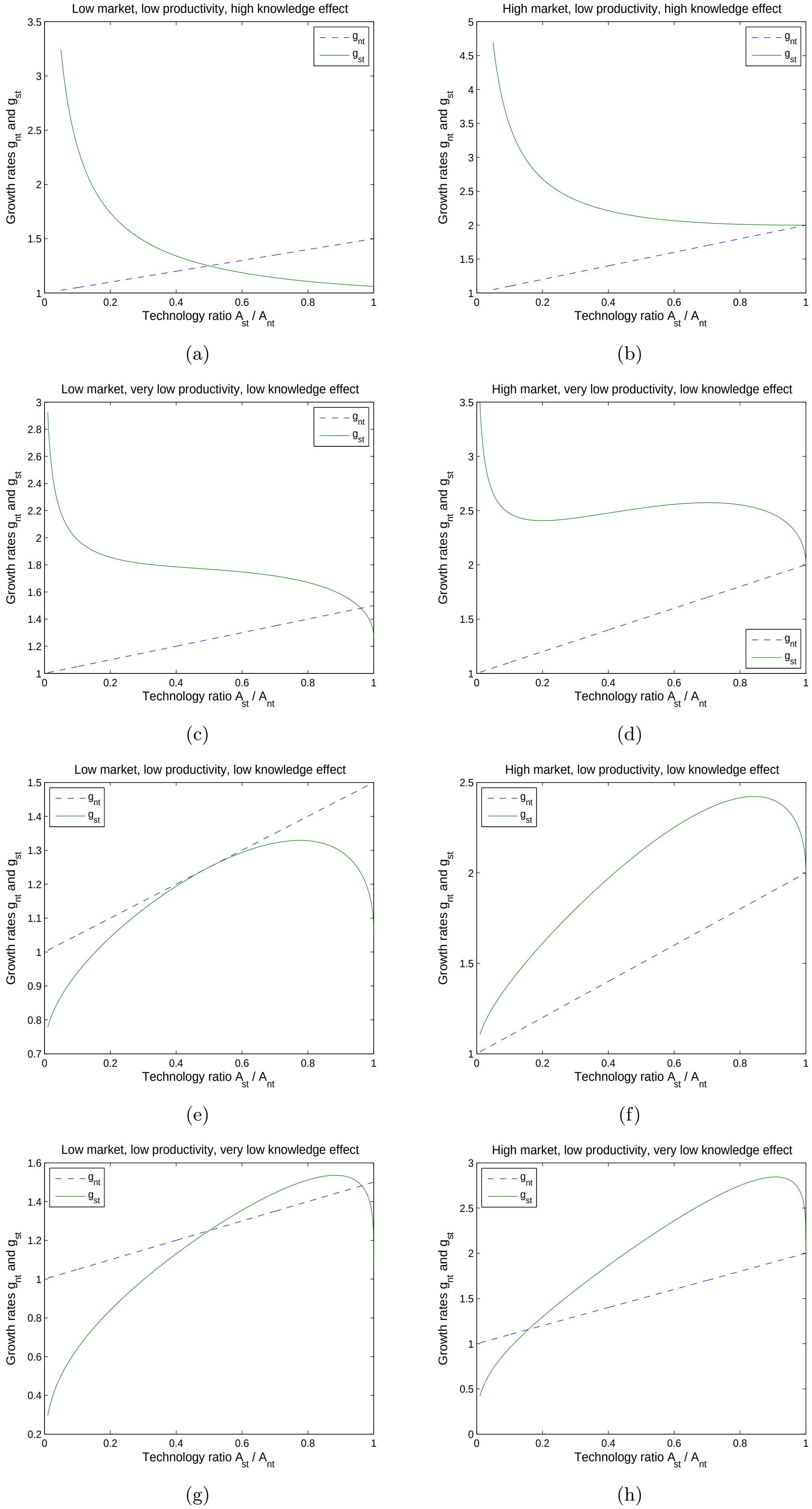

Figure 1: Simulation results for different parameter settings.