Climbing atop of Giants’ Shoulders: The Role of Migration in Endogenous Growth

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Abstract

I analyze the effect of endogenous migration and its spillovers on economic development in a 2-country, 3-sector endogenous growth framework. Particularly, three spillovers from migration are considered: remittances, technology diffusion, and re-migration after gaining knowledge abroad. Firms in the developing South initially accumulate physical and human capital to spur growth, while firms in the developed North conduct innovative R&D. Over time, the South accumulates enough human capital to make R&D profitable, thus becoming an innovator itself. Wage difference between the North and the South create an incentive for migration. Numerical analysis suggests that individual spillovers from migration do not affect Southern steady state and welfare levels, but do have idiosyncratic effects on the transition period from a physical capital accumulating economy to an innovating economy: spillovers from remittances and education abroad have the largest potential to speed up development, while technology diffusion slows down the transition process. Under the assumption of an immobile Southern workforce the transition from a capital accumulating economy to an innovative economy occurs fastest, however at the cost of forgone welfare in the innovative economy’s steady state.

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1 Introduction

Growth is driven by innovation. Many of the world’s innovations originate in developed countries with its specialized work force and equipment, while developing countries rely on imitative R&D or knowledge transfers for technical progress. According to Keller (2004), foreign sources of technology account for about 90 percent of domestic productivity growth in most developing countries. Migration plays a crucial role in the adaptive capacity of foreign technology in domestic production. On the one hand, migration drains a country of it’s human capital, which reduces the propensity to innovate or adopt new technology. On the other hand, migration creates several positive spillovers which can benefit development in the South: First, remittances account for the second largest international capital flow after foreign direct investments. These remittances free up scarce resources and allow individuals to invest in education or businesses. Second, diaspora networks promote innovation and technology adoption through research collaborations and information sharing within networks. Finally, re-migration of workers who have gained new knowledge abroad can foster productivity in the South. For example, in 2000, 113 out of 289 companies at the Hinschu Science-Based Industrial Park in Taiwan were started by U.S.-educated Taiwanese returning migrants (O’Neil, 2003).

Based on these stylized facts I develop a 2-country growth model with endogenous migration to determine the effects of these positive feedback channels on development and welfare in two structurally different countries: the developed North, and the developing South. Each economy consists of 3 sectors: a production sector, an education sector, and a research sector. While the North is fully developed, the South transitions through 3 stages of development that are separated by their major engine of growth: physical capital accumulation, human capital accumulation or innovation. The transition periods are determined endogenously, based on the household’s incentive to engage in either education or R&D. It is the goal of this paper to highlight the role of migration in the transition process of the developing South from accumulating capital to innovating, and to determine the impact of migration spillovers on steady state welfare levels.

Similar to Funke and Strulik (2000), the economy starts out stagnant in the neoclassical equilibrium (growth exclusively through physical capital accumulation). Due to an exogenous increase in the efficiency of human capital accumulation the representative household has an incentive to allocate some time to education. With increasing human capital, wages decrease, and the economy eventually reaches a state in which investment in R&D becomes lucrative, Thus, the economy has reached the final development stage of an innovator. A recent example of a country undergoing these stages of development is South Korea. South Korea has experienced rapid economic growth since the 1960s when South Korea’s GDP per capita was comparable to levels in African countries. In the 1960s, development strategies have focused on achieving sustained productivity growth by consistently investing in the education of their work force. Key to this shift was also the use of technologies obtained through foreign licensing and adapted for domestic production. In the 1980s, South Korea undertook efforts to increase domestic research and development through the establishment of the National Research and Development Program, while continuing to invest in higher education.

Traditional product cycle models provide a useful basis for studying endogenous growth in a tractable framework. Nevertheless, most of these models (Grossman and Helpman (1991), Segerstrom (1991), Davidson and Segerstrom (1998)) do not allow for the possibility of Southern development to an R&D based economy, or North-South migration: 2 features that are evident in the data. Exceptions include Barro and Sala-i Martin (1997) who construct a 2 country product variety model that combines elements of endogenous growth with the convergence implications of the neoclassical growth model. Their starting point is a scenario in which one country is intrinsically inferior to the other. By exogenously changing the initial conditions they analyze
a scenario in which the originally inferior country becomes superior and starts innovating after all product varieties have been copied. Glass (1999) develops a model of Southern firms using imitation as a stepping stone for innovation. In her model, imitation is necessary for the South to build sufficient knowledge to make innovation attractive. Absent the knowledge base from imitation, the expected reward to Southern innovation would not cover the innovation cost. While these models allow for Southern innovation and a switch in technological leadership, the foundation for these features are introduced exogenously. Santos and Postel-Vinay (2003) develop a dynamic 2-country overlapping generations model with migration. They show how migration can have a positively impact on developing countries through re-migration and knowledge sharing. Even though migration is endogenous, they assume that the developing country has no engine of growth on its own, while the developed country grows at an exogenous rate. In contrast, Lundborg and Segerstrom (2002) derive a two-country model in which growth is determined endogenously, but migration is determined exogenously through migration quotas.

By integrating the drawbacks of these different approaches into a single framework, this study contributes to the literature in two ways. First, this paper allows for the transformation form a physical capital accumulating economy to a R&D based economy. For many lagging economies, innovation may initially be prohibitively difficult due to their lower human capital and inferior equipment. By accumulating human capital the South creates the knowledge base needed to make innovation profitable, and improve upon existing technologies themselves. For example, until about 1970, Japan applied technologies invented elsewhere, but having caught up, it switched from copying to inventing ideas. Similar to Japan, South Korea, Taiwan, China, Indonesia and Thailand started their path to development from manufacturing economies to innovators in recent years. Korean firm Samsung was once an outsourcing partner for several Japanese firms. Today, Samsung belongs to the Top 3 Most Innovative Companies, according to the Boston Consulting Group. In addition, countries like China, South Korea, and Taiwan spend a similar percentage of their GDP on research and development than Germany, the United Kingdom, or the United States. In line with these stylized facts, I provide a set up in which the South starts from a position of inferiority relative to the North regarding innovative R&D. Over time, the accumulation of human capital makes innovation profitable and Southern firms switch to a R&D based economy.

The second contribution of the paper extends the traditional endogenous growth framework to permit for endogenous migration. While free mobility of final goods is a common assumption in those models, one of the few studies incorporating migration in such a framework is Lundborg and Segerstrom (2002). However, in their model, migration is determined exogenously. Today, many countries face a situation of potential mass migration with incentives for workers to migrate from low-wage to high-wage countries. In the United States, migrants make up 13% of total US population, with 3.3 million working in the R&D sector. The ignorance of migration in endogenous growth is a great drawback because migration has the potential to harm or benefit technological progress at home. One of the adverse effects of migration on the home country includes the often cited Brain Drain. By draining the home country of its human capital, the potential for adapting and imitating new technology significantly decreases. Despite the early believe that migration is unambiguously detrimental for the home country, more recent work has focused on potential positive effects of migration on the country of origin. These positive channels include, but are not limited to, remitting money back

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1. The before mentioned studies only provide a snapshot of the literature on 2-country endogenous growth models or endogenous migration. Other studies include Faini (1996) and Farmer and Lahiri (2005). Yet, none of these models provide a single framework to study the interactions of endogenous migration on growth and welfare in two structurally different countries.
2. According to an article from July 9th 1994 in The Economist
3. According to the World Economic Prospects from 2008, 75% of these migrant scientists and engineers are from developing countries.
home, facilitating the diffusion of technology through networks, and re-migration after gaining knowledge abroad (see Santos and Postel-Vinay (2003) or Docquier and Rapoport (2012)). The model presented in this paper incorporates all three positive feedback channels from migration - remittances, technology diffusion, and spillovers from education abroad - and analyzes their contribution to economic growth and welfare.

Therefore, I proceed as follows: First, I describe the general model under the assumption of a fully developed South with a mobile workforce, and spillovers from remittances, technology diffusion and education abroad. Subsequently, I discuss the adjustments necessary to incorporate the different stages of development (physical capital accumulation, human capital accumulation and R&D), and the different assumptions about labor mobility and the positive feedback channels associated with it (remittances, education abroad, and technology diffusion). Using numerical simulations with plausible parameter values I evaluate each of the model specifications and compare their results with respect to transition paths and steady state levels.

The model’s findings can be analyzed along two dimensions. First, the fastest transition from a physical capital accumulating economy to an innovating economy takes place in a model without labor migration (14 years) followed by model accounting for spillovers from remittances and education abroad (21 years), a model accounting for remittances only (32 years), and finally, a model accounting for positive feedback channels from remittances, education abroad and technology diffusion (39 years). This partial result gives support to the Brain Drain hypothesis: the loss of a country’s human capital harms its development potential. Positive feedback channels have limited success in offsetting these negative consequences. Allowing migrants to spend some time gaining education abroad shortens the time period significantly vis-a-vis the case where remittances are the only positive feedback channel: accumulating human capital abroad at the faster rate relative to the home country partially offsets the human capital loss from migration. The intuition behind the slowdown of the transition from accumulating physical capital to accumulating knowledge might be less obvious: as researchers have access to foreign knowledge to create new ideas their productivity increases. This drives up the wage rate in the R&D sector, which in turn delays the timing of profitable R&D.\footnote{Note that foreign technology is assumed to only affect the generation of new ideas, not the productivity of the final goods sector. This assumption can be relaxed in future work. Intuitively, the adoption of foreign technology in production reduces the incentive to engage in R&D even further.}

While migration seems to hurt the development process to an innovating economy, it bears the potential to benefit the economy in the long run. Welfare comparisons across models show that a household’s welfare in an economy with migration is almost 4 times higher relative to an economy without labor mobility. While positive feedback channels from migration have an effect on the timing of the transition from a capital accumulating economy to an innovating economy, they do not affect the steady state and welfare levels. Further, steady state consumption, and thus welfare, in an innovating economy is higher relative to the hypothetical steady state consumption in an economy stagnant in the stage of human capital accumulation. To sum up, restricting migration leads to a faster transition process to the final stage of development, at the cost of larger welfare levels in the long run.

2 The Model

The model describes two economies, the developed North and the developing South. Both countries produce a single traded good that can be consumed in both countries. In addition, capital is assumed to move freely across borders, and households have access to a perfect world bond market where they are able to borrow and lend at an endogenous interest rate. Finally, cross-sector labor movements with a country is costless, while cross-country labor migration is subject to a sunk cost.
There exists a social planner that maximizes the discounted sum of utilities of the two representative households in the North and South,

\[
max V = \int_{t=0}^{\infty} e^{-\rho t} [U_s(C_s) + U_n(C_n)] dt. \tag{1}
\]

In this equation, \(C_s\) and \(C_n\) represent consumption of the household in the South and North respectively, and \(\rho\) is the common rate of time preference. Further, the utility functions take the form

\[
U_s(C_s) = \frac{C_s^{1-\sigma}}{1-\sigma}, \quad U_n(C_n) = \frac{C_n^{1-\sigma}}{1-\sigma}.
\]

The social planner faces the following constraints, where time subscripts are omitted for notational convenience:

\[
\dot{N}_s = r_s N_s - Y_s + C_s + \Upsilon(m_a, m_z, m_n, H_s) + \Omega_s(I_s, K_s) - \text{Rem} \tag{2a}
\]

\[
\dot{N}_n = r_n N_n + Y_n - C_n - \Omega_n(I_n, K_n) - \text{Rem} \tag{2b}
\]

\[
K_s = I_s - \delta_{k,s} K_s \tag{2c}
\]

\[
K_n = I_n - \delta_{k,n} K_n \tag{2d}
\]

\[
\dot{H}_s = B_s(1 - u_s - x_s - m_z - m_a - m_n) H_s + B_n(m_n H_s)^{\nu_n} K_n^{1-\nu_n} - \delta_{h,s} H_s \tag{2e}
\]

\[
\dot{H}_n = B_n [(1 - u_n - x_n) H_n]^{\nu_n} K_n^{1-\nu_n} - \delta_{h,n} H_n \tag{2f}
\]

\[
\dot{A}_s = D_s (x_s H_s)^\phi_s (\mu A_s^{1-\phi_s} + (1 - \mu) A_n^{1-\phi_n}) \tag{2g}
\]

\[
\dot{A}_n = D_n [(x_n H_n)^{\phi_n} + (m_a H_s)^{\phi_n}] A_n^{1-\phi_n} \tag{2h}
\]

The variables and functional forms are defined in Table 1. Some of the variables call for further discussion: Migration costs, \(\Upsilon(.)\), are quadratic in migration shares \(m_z, m_a,\) and \(m_n,\) and capture sunk adjustment costs associated with cross-border movements such as intensity of border enforcement, and also includes the cost of searching for employment, adjustment to a new lifestyle and transportation expenditures. \(\Omega(.)\) is a convex adjustment cost homogenous of degree one associated with the accumulation of physical capital. The use of a quadratic function to specify adjustment costs has a long tradition in economics, dating back to Holt, Modigliani, and Muth (1960). Remittances, \(\text{Rem}\), can be interpreted as a migrant’s labor income abroad, net of migrant consumption. To make this explicit, it helps to break down the Southern budget constraint into income and expenditures of stayers and migrants:

\[
\begin{align*}
\dot{N}_s &= \begin{cases}
    r_s N_s + (1 - m_z - m_a - m_n) C_s - Y_s + \Upsilon(.) & \text{for Stayers} \\
    (m_z + m_a + m_n) C_s - w_y (m_z H_s) - w_A (m_a H_s) + \Upsilon(.) & \text{for Migrants}
\end{cases}
\end{align*}
\]

where \(w_y\) is the wage of migrants in the Northern production sector, \(w_A\) is the wage of migrants in the Northern R&D sector. Thus remittances are defined as \(\text{Rem} = w_y (m_z H_s) + w_A (m_a H_s) - (m_z + m_a + m_n) C_s\). With a perfect world bond market, borrowing in the South has to equal lending in the North, and vice versa, implying that \(N_s = N_n\) at all times. Thus, equation 2a is set up such that \(N_s\) defines the South’s debt, while equation 2b reflects the North’s assets. Human capital accumulation in the North requires both physical capital (libraries, laboratories, etc.) and human capital (faculty and students).\(^5\) Southern human capital

\(^5\)Typically, the literature displays a linear human capital accumulation function with human capital as the only input. In
accumulation consists of two parts: time spent on education at home, and time spent on abroad. The first part is a linear function of human capital only, as typically found in the literature (see e.g. Lucas (1988)). Time spent on education abroad accumulates human capital according to the Northern human capital accumulation function, and is therefore a function of human and physical capital. Finally, the accumulation of new ideas depends on the effort devoted to R&D, $x_i H_i$, and on the already existing stock of knowledge, $A_i$. This formulation was labeled by Jones (2005) as a “standing on the shoulders effect”: the discovery of ideas in the past increases the possibility of new discoveries. In addition to a country’s own existing stock of knowledge, I allow for technology diffusion from the North to the South. This is reflected by the term $(1 - \mu)A_i^{1-\phi^*}$. If $\mu = 1$, the Southern accumulation of new ideas relies exclusively on the stock of existing knowledge in the South, with $0 < \mu < 1$ Southern R&D uses Northern knowledge for the accumulation of Southern ideas.

### 3 Macroeconomic Equilibrium

As in Farmer and Lahiri (2005), a social planner maximizes a pseudo planning problem. This means, the social planner maximizes (3), subject to (2), while ignoring technology spillovers, as defined in 2g, and taking the interest rate as given. The Hamiltonian to the problem is as follows:

$$
\max \mathcal{H} = \int_0^\infty e^{\rho t} \left[ \frac{C_s^{1-\sigma_s}}{1-\sigma_s} + \frac{C_n^{1-\sigma_n}}{1-\sigma_n} \right] dt
+ q_s \left( r_s N_s + Y_s - C_s - \Omega_s(.) - \Omega(n(.) - \text{Rem} - \dot{N}_s) \right)
+ q_n \left( r_n N_n + Y_n - C_n - \Omega_n(.) - \text{Rem} - \dot{N}_n \right)
+ q_{ks} \left( I_s - \delta_s K_s - \dot{K}_s \right) + q_{kn} \left( I_n - \delta_n K_n - \dot{K}_n \right)
+ q_{hs} \left( B_s (1 - u_s - x_s - m_z - m_n - m_m) H_s + B_n (m_n H_s)^{\nu_n} K_n^{1-\nu_n} - \delta_{h,s} H_s + \dot{H}_s \right)
+ q_{hn} \left( B_n ([1 - u_n - x_n] H_n)^{\nu_n} K_n^{1-\nu_n} - \delta_{h,n} H_n + \dot{H}_n \right)
+ q_{as} \left( D_s (x_s H_s)^{\phi_s} \left[ \mu A_i^{1-\phi^*} + (1 - \mu) A_i^{1-\phi^*} \right] - \dot{A}_s \right)
+ q_{an} \left( D_n \left[ (x_n H_n)^{\phi_n} + (m_n H_s)^{\phi_n} \right] A_i^{1-\phi^*} - \dot{A}_n \right)
$$

The resulting optimality conditions associated with the Southern economy are:

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Footnote 6: In 2002, the OECD database reports capital expenditure for all levels of education (expenditure on assets that last longer than one year, including spending on construction, renovation, and expenditure on new or replacement equipment) of $79,321 million in the United States. In relation, capital expenditures in developing countries such as Mexico ($900 Mio), India ($850 Mio), Philippines ($80 Mio) or Indonesia ($230 Mio) are negligible.
The resulting optimality conditions associated with the Northern economy are:

\[ C_n \rightarrow C_n^{-\sigma n} = q_n \]  
\[ u_n \rightarrow q_{kn} v_n B_n \left[ (1-u_n-x_n)H_n \right] \phi n^{-1} K_n^{1-\nu n} H_n = q_o \frac{\partial Y_n}{\partial u_n} \]  
\[ x_n \rightarrow q_{kn} v_n B_n \left[ (1-u_n-x_n)H_n \right] \phi n^{-1} K_n^{1-\nu n} H_n = q_o \phi_n D_n(x_n H_n) \phi n^{-1} A_n^{1-\phi n} \]  
\[ I_n \rightarrow \frac{\dot{q}_n}{q_n} = \frac{\dot{q}_{kn}}{q_{kn}} = \rho - r_n \]  
\[ N_n \rightarrow \frac{\dot{q}_n}{q_n} = \rho - r_n \]  
\[ K_n \rightarrow \frac{\dot{q}_n}{q_n} = \rho + \delta_n - \frac{1}{Q_n} \left[ \left( \frac{q_n}{q_o} - 1 \right) \frac{\partial Rem}{\partial K_n} + \frac{\partial Y_n}{\partial K_n} - \frac{\partial Q_n - \partial H_n}{\partial K_n} \right] \]  
\[ A_n \rightarrow \frac{\dot{q}_n}{q_n} = \rho - (1-\phi_n) D_n \left[ (x_n H_n) \phi n + (m H_n) \phi n \right] A_n^{1-\phi_n} \]  
\[ H_n \rightarrow \frac{\dot{q}_n}{q_n} = \rho + \delta_n - v_n B_n \left[ (1-u_n-x_n) H_n \right] \phi n^{-1} K_n^{1-\nu n} \]

where \( q_i \) is the shadow value of household assets, \( q_{ki} \) and \( q_{ki} \) are the shadow values of physical and human capital, respectively, and \( q_{ai} \) is the shadow value associated with the generation of new ideas. In addition, the following transversality conditions must hold:

\[
\lim_{t \to \infty} q_t N_t = \lim_{t \to \infty} q_{kt} K_t = \lim_{t \to \infty} q_{nt} H_t = \lim_{t \to \infty} q_{at} A_t = 0
\]
3.1 Steady State

The steady state is characterized by a balanced growth path at which all variables grow at the same rate. First, note that the growth rate of consumption must equalize that of physical capital in order to have endogenous growth and not violate the transversality conditions. Second, in the steady state, the share of human capital devoted to production, human capital accumulation, the creation of new ideas, and migration has to be constant, otherwise the growth rate of human capital cannot be constant. Together, these two conditions imply that

\[ \frac{\dot{K}_i}{K_i} = \frac{\dot{C}_i}{C_i} = \frac{\dot{H}_i}{H_i} = \frac{\dot{A}_i}{A_i} = \frac{\dot{N}_i}{N_i} = \frac{\dot{I}_i}{I_i} = 0 \]  
\[ \frac{\dot{u}_i}{u_i} = \frac{\dot{x}_i}{x_i} = \frac{\dot{m}_a}{m_a} = \frac{\dot{m}_n}{m_n} = 0 \]

(5a)  

(5b)

The system can be solved by introducing the stationary variable \( x_i \equiv X_i \) for \( X_i \in \{ C_i, H_i, A_i, K_i, I_i \} \) and setting \( \frac{\dot{x}_i}{x_i} = 0 \) in accordance with a balanced growth path.\(^7\) Imposing these restrictions on the accumulation equations in (2), and the time derivatives of (3a) and (4a) yields:

\[ \frac{\dot{k}_i}{k_i} = \frac{\dot{c}_i}{c_i} = \frac{\dot{h}_i}{h_i} = \frac{\dot{a}_i}{a_i} = \frac{\dot{i}_i}{i_i} = 0 \]

(6)

where \( \frac{\dot{c}_i}{c_i} = -\frac{1}{\sigma_i} \frac{\dot{q}_i}{q_i} \). Moreover, taking the time derivative of (3c), (3d), (4c) and (4d), together with restriction (5) yields:

\[ \frac{\dot{q}_i}{q_i} = \frac{\dot{q}_{ai}}{q_{ai}} \]

(7)

\[ \frac{\dot{q}_i}{q_i} = \frac{\dot{q}_{ki}}{q_{ki}} \]

(8)

Equations (6) - (8) describe the dynamic equations of the system. In addition, taking time derivatives of (3b) and (4b) in combination with restriction (5) yields:

\[ \frac{\dot{q}_i}{q_i} = \frac{\dot{q}_{hi}}{q_{hi}} \]

From First Order Conditions (3h), (3k), (4e) and (4i), together with the assumption of a perfect world bond market we get:

\[ r_n = r_s \]

\[ \nu_n B_n [(1 - u_n - x_n) h_n]^{\nu_n - 1} k_n^{1-\nu_n - \delta_{hn}} = B_s - \delta_{hs} \]

(9)

Migration shares are determined by the payoffs in the North relative to the South. In order for restriction (5b) to hold, payoffs in the Northern sector, net of migration costs, have to be identical to the corresponding

\(^7\) The more common approach is a scaling by the capital stock, \( K \). However, in the case where labor is mobile across borders this approach is not suitable as it results in two different human-to-physical capital ratios for domestic labor and migrant labor, \( \frac{H}{K} \neq \frac{H}{K} \). The assumption of a perfect world bond market \( (N_s = N_n) \) provides a convenient solution to this problem.
Southern sectors. Thus we have

\[
\begin{align*}
\beta_n a_n^{1-\alpha_n-\beta_n} (m_z h_s) \phi_n^{\nu_n-1} k_n^{\alpha_n} - \frac{\chi}{2} m_z^2 h_s &= \beta_s a_s^{1-\alpha_s-\beta_s} (u_s h_s) \phi_s^{\nu_s-1} k_s^{\alpha_s} & (10a) \\
\phi_n D_n (m_a h_s) \phi_n^{1-\alpha_n-\beta_n} - \frac{\chi}{2} m_z^2 h_s &= \phi_s D_s (x_s h_s) \phi_s^{1-\alpha_s-\beta_s} [\mu a_n^{1-\phi_n} + (1-\mu) a_n^{1-\phi_n}] & (10b) \\
\nu_n B_n (m_n h_s) \nu_n^{1-\nu_n} k_n^{\alpha_n-1} - \frac{\chi}{2} m_z^2 h_s &= B_s & (10c)
\end{align*}
\]

Finally, efficient allocation of capital under free capital mobility implies that the marginal product of capital is equal in both countries:

\[
\frac{\partial Y_n}{\partial K_n} = \frac{\partial Y_s}{\partial K_s} & (11)
\]

Investments are determined by (3d) and 4(d): \( \frac{L}{K} (Q_i) = \frac{Q_i}{h_i} \). Therefore (6) - (11) describes a system of equations with 17 unknowns and 17 equations: \( c_i, k_i, a_i, h_i, Q_i, u_i, x_i, m_z, m_a, m_n \) with \( i \in \{n, s\} \)

### 3.2 Equilibrium Dynamics

The equilibrium dynamics for the two countries can be expressed in terms of the evolution of 9 state variables (12a - 12i) and 8 control variables (12j - 12q):

\[
\begin{align*}
\dot{k}_s &= i_s - \delta_s k_s - \frac{\dot{n}_s}{n_s} k_s & (12a) \\
\dot{k}_n &= i_n - \delta_n k_n - \frac{\dot{n}_n}{n_n} k_n & (12b) \\
\dot{n}_s &= B_s (1 - u_s - x_s - m_z - m_a - m_n) h_s + B_n (m_n h_s)^{\nu_n} k_n^{1-\nu_n} - \delta_h h_s - \frac{\dot{n}_s}{n_s} h_s & (12c) \\
\dot{n}_n &= B_n [(1 - u_n - x_n) h_n]^{\nu_n} k_n^{1-\nu_n} - \delta_h h_n + \frac{\dot{n}_n}{n_n} h_n & (12d) \\
\dot{a}_s &= D_s (x_s h_s) \phi_s \left[ \mu a_n^{1-\phi_s} + (1-\mu) a_n^{1-\phi_s} \right] - \frac{\dot{n}_s}{n_s} a_s & (12e) \\
\dot{a}_n &= D_n \left[ (x_n h_n)^{\nu_n} + (m_a h_s)^{\phi_n} \right] a_n^{1-\phi_n} - \frac{\dot{n}_n}{n_n} a_n & (12f) \\
\dot{m}_s &= \frac{m_s - \frac{\chi}{2} (m_a h_s)^{2} (m_z h_s) \phi_n^{\nu_n-1} k_n^{\alpha_n} - B_n (1-\nu_n) \nu_n (m_a h_s)^{\nu_n}}{\chi (m_a h_s)^{2} m_n K_n^{1-\nu_n} + \nu_n B_n (1-\nu_n) m_n h_s)^{\nu_n}} & (12g) \\
\dot{m}_a &= \frac{(1 - \alpha_s - \beta_s) \frac{\dot{a}_s}{a_s} + \alpha_n \frac{\dot{k}_n}{k_n} - (2 - \beta_s) \frac{\dot{h}_s}{h_s} - (1 - \beta_s) \frac{\dot{a}_s}{a_s}}{\chi (m_a h_s)^{2} m_a \phi_n^{\alpha_n} + (1 - \beta_s) K_n^{1-\nu_n} (m_a h_s)^{\beta_n}} \frac{\chi (m_z h_s)^{2} m_z a_n^{\alpha_n} + (1 - \beta_s) K_n^{\alpha_n} (m_a h_s)^{\beta_n}}{\chi (m_z h_s)^{2} m_a a_n^{\alpha_n} + (1 - \beta_s) K_n^{\alpha_n} (m_z h_s)^{\beta_n}} & (12h) \\
\dot{m}_a &= \frac{\chi (m_a h_s)^{2} m_a \phi_n^{\alpha_n} + (1 - \beta_s) K_n^{\alpha_n} (m_a h_s)^{\beta_n}}{\chi (m_z h_s)^{2} m_a a_n^{\alpha_n} + (1 - \beta_s) K_n^{\alpha_n} (m_z h_s)^{\beta_n}} \frac{(1 - \phi_s) \frac{\dot{a}_n}{a_n} + \frac{\dot{h}_s}{h_s} - \frac{\dot{a}_s}{a_s} - \mu \frac{\dot{h}_s}{h_s} h_s - \frac{\dot{a}_s}{a_s} \mu (1 - \mu) \frac{\dot{a}_s}{a_s}}{\mu (1 - \mu) \frac{\dot{a}_s}{a_s}} & (12i)
\end{align*}
\]
\[ \dot{c}_s = \left( \frac{(r_s - \rho)}{\sigma_s} \right) c_s \]  
\[ \dot{c}_n = \left( \frac{(r_n - \rho)}{\sigma_n} \right) - \frac{n_n}{n_n} c_n \]  
\[ \dot{Q}_n = (r_n + \delta h_n - B_s) Q_n \]  
\[ Q_n = (r_n + \delta h_n - \nu_n B_n \left[ (1 - u_n - x_n) h_n \right])^{\nu_n - 1} k_n^{1 - \nu_n} \]  
\[ \dot{u}_s = \frac{u_s}{1 - \beta_s} \left( (1 - \alpha_s - \beta_s) \frac{\dot{a}_s}{a_s} - (1 - \beta_s) \frac{\dot{h}_s}{h_s} + \alpha \frac{k_s}{h_s} \frac{\dot{q}_h}{q_h} + \frac{q_s}{q_s} \right) \]  
\[ \dot{u}_n = \frac{(1 - \alpha_n - \beta_n) \frac{\dot{a}_n}{a_n} + (\beta_n - \nu_n) \frac{\dot{h}_n}{h_n} - (1 - \alpha_n - \nu_n) \frac{\dot{k}_n}{k_n} + \frac{\dot{q}_a}{q_a} + \frac{q_n}{q_n} + (1 - \nu_n) \frac{k_n}{1 - u_n - x_n} \]  
\[ \dot{x}_s = \frac{x_s}{1 - \phi_s} \left( (1 - \phi_s) \frac{\mu a_n^x - 1 \frac{\dot{a}_s}{a_s}}{\alpha a_n^x} + (1 - \mu) \frac{a_n^x - 1 \frac{\dot{a}_n}{a_n}}{\alpha a_n^x} - (1 - \phi_s) \frac{h_s}{h_s} + \alpha \frac{\dot{k}_s}{k_s} + \frac{q_h}{q_h} + \frac{q_s}{q_s} \right) \]  
\[ \dot{x}_n = \frac{(1 - \phi_s) \frac{\dot{a}_n}{a_n} + (\phi_n - \nu_n) \frac{\dot{h}_n}{h_n} - (1 - \nu_n) \frac{\dot{k}_n}{k_n} + \frac{\dot{q}_a}{q_a} + \frac{q_n}{q_n} + (1 - \nu_n) \frac{u_n}{1 - u_n - x_n} \]  
\[ \frac{1 - \phi_n}{x_n} + \frac{1 - \alpha_n - \nu_n}{1 - u_n - x_n} \]

In general, this system is too complex to be solved analytically. Therefore, I proceed to analyze the model’s local dynamic properties through numerical calibration by linearizing the equilibrium dynamics around the steady state equilibrium described above.

4 Numerical Analysis and Discussion

4.1 Parameterization

Table 2 describes the parameterization of the model. The numerical simulation confirms the existence of a saddle point equilibrium with 9 stable (negative) eigenvalues corresponding to the 9 state variables of the dynamic system.

The intertemporal elasticity of substitution for consumption is given by \( \frac{1}{\sigma} \). Setting \( \sigma = 3 \) implies an elasticity of 0.33, consistent with evidence provided by Guvenen (2006). The rate of time preference, \( \rho \), is set at 0.06, and physical capital depreciation is 6\%, as standard in the literature. Human capital depreciation is slightly higher at 10\% and is in line with estimates by Mincer and Ofek (1982). Adjustment costs lie within the range specified by Auerbach and Kotlikoff (1987) and Ortigueira and Santos (1997), with slightly higher adjustment costs in the developed North, reflecting higher costs associated with installing higher quality equipment. The choice of migration cost is less obvious and the choice of \( \chi = 20 \) is chosen to obtain plausible steady state migration rates. The share of private capital in production, \( \alpha \), is set to 0.25 and 0.3 in developed and developing countries respectively. These values are slightly lower than typically found in the literature but fall within the plausible range specified by Bernanke and Gueraynak (2002). The share of human capital in R&D is set at 0.6 at and falls within the range of 0.4 and 0.9 estimated by Kortum (1993). Finally, the share of domestic technology in the South’s R&D sector is from Santacreu (2014), who estimates the fraction of productivity growth in emerging economies due to research performed in OECD countries is about 60\%.
4.2 Discussion of Development Stages

Before I proceed with the results, let’s restate the main objectives of this paper: First, it is the goal of this paper to describe the transition through several stages of economic development within a 2-country endogenous growth model where the decision to migrate is determined endogenously. While the North is assumed to be fully developed, the model starts out with the developing South being stagnant at the neoclassical equilibrium (Stage 1: capital accumulation as only source of growth). During this stage, the Southern technology level, $A_s$, as well as the Southern human capital, $H_s$, is set exogenously to 1. It is further assumed that in the absence of human capital accumulation and R&D at home, migrants also do not engage in these sectors abroad ($m_n = m_a = 0$). Equation (2) has to be adjusted accordingly by omitting 2e and 2g, which reduces the adjusted dynamic system to a system with 5 state variables ($K_s, m_s, K_n, A_n, H_n$) and 6 control variables. The derivation of the reduced system follows the steps described above. Due to an exogenous shock to the efficiency parameter in education, $B_s$, the South enters Stage 2, during which human capital accumulation, along side physical capital accumulation, is the engine of growth. During this stage, the Southern technology level is still set exogenously and Southern households do not engage in R&D at home or abroad ($m_a = x_s = 0$), however, human capital becomes endogenous and households start investing in education at home and abroad. By omitting 2e, the adjusted dynamic system becomes a system with 7 state variables ($K_s, H_s, m_n, m_a, K_n, A_n, H_n$) and 7 control variables. During this stage’s transition period to the steady state human capital becomes abundant enough for new inventions to be valuable, i.e. the wage rate for researchers is sufficiently low compared to the value of an innovation. At this point, the South enters the final stage of development in which economic growth is driven by innovations. This case is described in Section 2) and Section 3).

The second goal of the paper is to examine the effect of different spillovers from migration on the transition paths of economic development and steady state levels. In the first scenario, labor is assumed to be immobile. Consequently, no spillovers from migration are present, and the two countries are only connected through trading bonds and the free flow of physical capital. This is achieved by setting $m_z = m_a = m_n = 0$. In the second scenario, labor is mobile across borders at a sunk cost, but migrant workers are only allowed to join the Northern workforce, not accumulate human capital abroad ($m_n = 0$). Thus, the only spillovers from migration are in the form of remittances. Next I allow for human capital accumulation abroad. In this scenario, spillovers arise from remittances and education abroad, however, potential spillovers from R&D are not considered ($\mu = 1$). Finally, the model allows for migrant engagement in all three foreign sectors and accounts for spillovers from remittances, human capital accumulation abroad, and technology diffusion. This scenario describes the full model outlined in Section 3).

5 Results

This section presents adjustments paths for the calibrated economy, identifies the point of transition from one stage to the other, and compares steady state and welfare levels across different spillover assumptions. A comparison of the steady state equilibria can be found in Table 3, Table 4 shows welfare comparisons, and Figure 1 displays the adjustments paths for the Southern economy.\(^8\)

\(^8\)Since the focus of this paper is on the development stages of the developing South, I abstract from the presentation of Northern results. Northern transition paths and steady state levels are available from the author upon request.
5.1 Economy without Migration

I start by establishing a Benchmark case that shows transitions paths and steady state levels for the Southern economy with no cross-country labor mobility. As mentioned above, the economy starts out stagnant in the neoclassical equilibrium (capital accumulation as only source of growth). Thus the transition paths show the adjustment from this neoclassical equilibrium at $t = 0$ to the final stage of development where growth is driven by innovation. During this transition, human capital accumulation (Stage 2) serves as a description of development dynamics for about 14 years. During this time, the economy gradually invests more time into education and less into production (Figure 1 Panel 5). This temporarily lowers Southern GDP, until the increase in human capital makes up for the reduced time spent working in production (Figure 1 Panel 4 and 2). With increasing human capital, the wage rate decreases (not shown) making investments in R&D valuable. At this point, the economy enters stage 3 and starts innovating. The creation of the R&D sector instantly moves employment away from the employment share in production towards the R&D and educational sector (Figure 1 Panel 5 and 6). This leads to an instant increase in the level of human capital, and a gradual increase in the southern technology level. The increasing technology level raises GDP after a temporary drop due to the fall in time spent in production, and lowers the accumulation of human capital as less time is spent in education and more time in working in production and R&D.

Table 3 shows steady state values for each of the 3 stages. Note that the steady state values for Stage 2 (human capital accumulation as source of growth) are hypothetical in the sense that the economy did not converge to these values. This is because the economy transitioned to an innovative economy before the steady state in Stage 2 could be reached. If the economy would have been stagnant at stage 2, steady state consumption and time spent working in production would have been similar to stage 3. With the creation of the R&D sector, time was reallocated from education to innovation leading to an increase in the steady state technology level and a lower level of human capital.

Before I analyze the results from a model with cross-country labor mobility a general comments is in order. The development dynamics generated by the model predict a rather short transition period between Stage 1 and Stage 3, ranging from 14 years for the model without migration to a maximum of 39 years. This transition period appears rather short when compared with findings by Funke and Strulik (2000) who analyze stages of development in a closed economy and predict a duration of 90 years to move from capital accumulation to an innovative economy. However, there are examples in which economic development can take place within a few decades. In the 1960s, South Korea passed reforms and started investing heavily in education in order to build a highly educated workforce to boost economic growth. By the 1980s, South Korea undertook efforts creating domestic research and development through the establishment of the National Research and Development Program while continuing to invest in higher education. Thus, South Korea transformed from a pure manufacturing economy to research economy in only two decades. Today South Korea is listed as one of the most innovating nations worldwide.

5.2 Spillovers from Remittances

Allowing Southern households to work in the Northern production sector and remitting their income net of consumption back to the South increases the transition period from capital accumulation to R&D to 32 years. Note that remittances are the only spillovers from migration in this case. Migrants are not allowed to invest in education abroad or work in the R&D sector. Apart from the transition period, the dynamics

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9Recall that all variables are scaled by domestic bond holdings to make the variables stationary.
follow a similar trajectory compared to the no-migration case for the variables technology, human capital, consumption, GDP and domestic employment shares. Labor migration to the Northern production sector steadily rises from the neoclassical equilibrium to the R&D economy’s steady state, with a discrete jump at the time of the transition from Stage 2 to Stage 3. This jump is caused by a drop of the Southern wage rate relative to the North associated with the sudden increase in Southern human capital.

The steady state comparisons of the innovative economy can be made along two dimensions: relative to the benchmark case without migration, and relative to the hypothetical values of Stage 2. Relative to the benchmark case, R&D employment and technology levels are comparable. Migration primarily crowds out employment in the production sector which is now only one third of the benchmark case. Despite the decrease in domestic production employment, consumption of Southern households increases due to remittances sent back from migrating workers. Comparing steady state values of the innovative economy relative to Stage 2, the model displays higher consumption levels. Further, employment in the R&D sector at home and abroad, as well as migration to the Northern production sector takes place at the cost of time spent in domestic production. The creation of the R&D sector improves the technology level which substitutes for human capital in production. As a consequence, human capital increases relative to the neoclassical equilibrium, but falls short to the hypothetical steady state value of an economy that stagnates at human capital accumulation.

5.3 Human Capital Accumulation Abroad

Between 2004 and 2013, on average, almost 5% of migration to the United States was for educational purposes. Studies show that the majority of these migrants return to their home country within a couple of years of their graduation, taking their accumulated knowledge with them. Accounting for these spillovers from accumulating human capital abroad shortens the transition period from physical capital accumulation to R&D to 21 years. As households are able to receive education abroad, human capital raises faster relative to the previous case. This in turn reduces the wage rate at a faster pace, making innovations valuable at an earlier time. Apart from the timing of the switch from Stage 2 to Stage 3, the South follows a similar trajectory to the innovating economy’s steady state as before. Both, the innovative economy’s steady state and the hypothetical steady state from an economy stagnant at Stage 2 are comparable to the case without spillovers from education abroad.

5.4 Technology Spillovers

International scientific collaborations have increased tremendously over the years. For example, North America has doubled its collaboration with BRIC countries between 1998 and 2008 in terms of international co-authored articles and co-inventions as a percentage of total patents filed. Further, a study by Santacreu (2014) estimates that approximately 60% of emerging markets’ productivity growth is due to R&D undertaken in OECD countries. Even within the most innovative countries such as Germany and the U.S. foreign sources of R&D make up between 40-60 percent of productivity growth (Jovanovic, 1995). Therefore, I allow for technology diffusion as a final spillover from the North. The possibility of spillovers from the North increases the productivity of the R&D sector and therefore the wage rate R&D workers at any given point.

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10 Source: Yearbook of Immigration Statistics 2013: Percentage of migration to the US for educational reasons is the ratio of Academic students (F1) to total I-94 admissions

11 Source: OECD Science, Technology and Industry Scoreboard 2011. BRIC countries refer to the emerging economies Brazil, Russia, India and China.
in time relative to the case with technology diffusion. This postpones the timing of profitable innovation and increases the transition period from physical capital accumulation to R&D to 39 years. As before, final steady state values are not significantly affected by accounting for technology diffusion.

5.5 Welfare Comparison

As a final exercise I compare Southern welfare levels across different spillover assumptions, and Southern welfare levels relative to the North under the different assumptions. Cross-country comparisons imply that the South achieves approximately 50% of the Northern steady state welfare level. Moreover, Southern welfare relative to the North remains mostly unaffected by the assumptions about migration and spillovers from the North.

Cross-model comparisons imply that Southern welfare in a framework without migration is only about 25% relative to a specification allowing for migration. Accounting for different spillovers does not change welfare levels significantly. This renders two conclusions: First, migration has the potential to increase welfare in the developing South. This is an interesting property as migration from developing countries is usually viewed with caution due to its negative development impacts associated with a Brain Drain. While migration tends to delay the transition from physical capital accumulation to R&D, it also provides the potential for higher welfare levels in the long run. Second, migration spillovers in the form of gaining education abroad and technology diffusion do not significantly affect steady state and welfare levels. However, spillovers have the potential to significantly shorten the transition to an innovative economy.

6 Conclusion

I examine the role of migration on economic development and welfare levels in a 2-country, 3-sector endogenous growth framework, considering positive spillovers from migration in the form of remittances, technology diffusion and re-migration. The model is characterized by two structurally different countries, the developed North and the developing South. The North generates growth by conducting costly innovative research, while the South originally relies on physical capital accumulation. Over time, the South invests in human capital and makes the switch to an innovating economy.

This framework adds to the literature in two ways. First, it provides a set up in which the South starts from a position of inferiority relative to the North regarding innovative R&D. Over time, physical and human capital accumulation transform the South to an innovative economy. Second, I extend the typical product cycle models to permit for endogenous migration. The introduction of migration has two potential effects on the Southern economy. On the one hand, by draining the Home Country of its human capital, the development potential decreases. On the other hand, remittances, technology diffusion, and re-migration have the potential to offset the negative effect of a Brain Drain.

Numerical simulations indicate that migration slows down the transition process from a physical capital accumulating economy to an innovating economy. Allowing for positive spillovers from human capital accumulation abroad speeds up the transition vis-a-vis a case where remittances are the only spillovers and a case where the model allows additionally for technology diffusion. This result is in line with the Brain Drain hypothesis: the loss of a country’s human capital harms its development potential. While migration seems to hurt the development process to an innovating economy, it bears the potential to benefit the economy in the long run. Welfare comparisons across models show that a household’s welfare in an economy with migration is almost 4 times higher relative to an economy without labor mobility. Despite their effect on the
timing of the transition from a capital accumulating economy to an innovating economy, positive feedback channels from migration do not affect the steady state and welfare levels. Finally, a comparison between steady states of different development stages, rather than spillover assumptions, suggests that steady state consumption, and thus welfare, in an innovating economy is higher relative to the hypothetical steady state consumption in an economy stagnant at the stage of human capital accumulation. In conclusion, restricting migration leads to a faster transition process to the final stage of development, at the cost of forgone welfare levels in the long run.

As usual, some caveats apply. First, I have assumed that all consumers have identical preferences. For example, I have not allowed for any form of home bias, that is, Northern consumers preferring Northern goods, and vice versa. Second, there is perfect labor mobility between R&D and production sector. This assumption rules out the possibility that migration could affect wages idiosyncratically between sectors. Finally, the effect of diaspora on technology diffusion is difficult to quantify. However, there is some evidence that emigrating scientists and engineers boost the innovation of their native counterparts through research collaboration. For example, Agrawal et al. (2011), using patent data, find evidence of the influence of the diaspora in technology transfers to home countries. Due to these limitations, the simulation analysis is merely intended to qualitatively evaluate the potential role of migration in endogenous growth. Future research is needed to quantitatively pin down the overall effect of migration on development.
Appendix

Table 1: Variable Definition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_i$</td>
<td>Borrowing/ Lending</td>
<td>$m_n$</td>
<td>Migrant Share to education</td>
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<td>$K_i$</td>
<td>Physical Capital</td>
<td>$I_i$</td>
<td>Investment</td>
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<td>$H_i$</td>
<td>Human Capital</td>
<td>$B_i, D_i$</td>
<td>Efficiency parameter</td>
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<td>$m_a$</td>
<td>Migrant Share to R&amp;D</td>
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<td>Weight of domestic Technology in R&amp;D</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Borrowing Premium</td>
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</table>

Variable Definition Functional Form

| $Y_s$  | Southern Production             | $Y_s = A_{1 + \alpha s - \beta s} (u_{s} H_{s})^{\beta_s} K_{s}^{\alpha_s}$ |
| $Y_n$  | Northern Production             | $Y_n = A_{1 + \alpha n - \beta n} (u_{n} H_{n})^{\beta_n} (m_{z} H_{s})^{\beta_n} K_{n}^{\alpha_n}$ |
| $\Upsilon(.)$ | Migration Cost | $\Upsilon = \frac{1}{2} [m_{z} + m_{a} + m_{n} H_{s}]$ |
| $\Omega_{i}(I_s, K_s)$ | Capital Adjustment Cost | $\Omega_{i} = I_{i} \left(1 + \frac{h_{i} I_{i}}{K_{s}}\right)$ |
| $Rem$  | Remittances                     | $Rem = w_{y}(m_{z} H_{s}) + w_{A}(m_{z} H_{s}) - (m_{z} + m_{a} + m_{n}) C_{s}$ |
| $w_y$  | Migrant wage in production      | $w_{y} = \beta_{n} A_{1 + \alpha n - \beta n} (m_{z} H_{s})^{\beta_n - 1} K_{s}^{\alpha_n}$ |
| $w_a$  | Migrant wage in R&D             | $w_{a} = \phi_{n} D_{n}(m_{z} H_{s})^{\phi_n - 1} A_{1 + \phi_n}$ |

Table 2: Parameterization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value (North, South)</th>
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<tbody>
<tr>
<td>$\sigma$</td>
<td>Intertemporal elasticity of substitution</td>
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<td>$\rho$</td>
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<td>$\delta_k$</td>
<td>Depreciation rate for physical capital</td>
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<tr>
<td>$h$</td>
<td>Adjustment cost for investment</td>
<td>15, 10</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Labor migration cost</td>
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<td>$\alpha$</td>
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<tr>
<td>$\beta$</td>
<td>Share of human capital in production</td>
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<td>$B$</td>
<td>Efficiency parameter in education</td>
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<td>$\delta_h$</td>
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<td>$\nu$</td>
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<td>$\phi$</td>
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<tr>
<td>$\mu$</td>
<td>Share of domestic technology in domestic R&amp;D</td>
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### Table 3: Steady State Equilibria

<table>
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<tr>
<th></th>
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<td>-</td>
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### Table 4: Welfare Comparison

#### Panel A: Welfare Comparison across Models

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<th>Technology Diffusion</th>
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#### Panel B: Welfare Comparison North vs. South

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Figure 1: Adjustment Paths South
References


