Trade in human capital

Abdulaziz B. Shifa
IIES, Stockholm University *
Institute for International Economic Studies
Stockholm University, Sweden

May 31, 2012

Abstract

This paper models human capital investment through formal education as a globally traded service and analyzes the implication for catch-up. Historically, the global market for education, particularly tertiary education in the fields of advanced science and technology, played an important role in the diffusion of advanced knowledge across countries. For example, Korea, Japan and Taiwan have successfully used the global tertiary education market as a conduit for technology transfer. A globalized tertiary education market is likely to be more relevant for the diffusion of advanced knowledge on science and technology as production activities become increasingly knowledge-intensive. However, existing models of endogenous economic growth have not yet incorporated the implication of an increasingly globalized education market for cross-country income differences and catch-up. This paper thus develops a model of economic growth with a global market for human capital. In the model, individuals have the opportunity to invest in high-quality education. The market for teachers, who may vary in quality, is assumed to be globalized. Then, I analyze the circumstances that influence the flow of high-quality human capital to economies with a low level of human capital. Three effects are identified: the scarcity effect, the opportunity cost effect and the externality effect. Whether human capital flows to economies with a lower level of human capital depends on whether the scarcity and opportunity cost effects dominate the externality effect. I also analyze the impact of major economic reforms that boost productivity (such as China’s reform in the early 1980s) on the flow of human capital. The analysis shows that the impact of such reforms can show substantial variations depending on the initial conditions. I argue that the insights from the model regarding the initial conditions are particularly relevant for understanding the success of economic reforms in inducing the catching-up process.

*I thank Philippe Aghion, John Hassler, Paul Klein, Per Krusell, Conny Olovsson, Jakob Svensson and participants in the macro study group at IIES, Development Workshop group at Gothenburg University and SUDWEC 2012 conference for helpful feedbacks. Contact email: abdulaziz.shifa@iies.su.se
1 Introduction

Economic growth over the past centuries has mainly been driven by technological improvements (see, e.g., Solow 1956; Hall and Jones 1999; Mankiw et al. 1992; Acemoglu and Zilibotti 2001). Thus, a number of models have been developed to analyze cross-country income differences induced by technological differences. The models typically endogenize the process of technological innovation and/or diffusion in a unified framework where both economic growth and technological innovation/diffusion evolve jointly (see, e.g., Romer 1990; Lucas 1988; Rodriguez-Clare 2007; Eaton and Kortum 2001).

One of the institutional platforms through which advanced technological knowledge diffuses across countries is higher education (e.g., universities). For example, higher training institutions played a crucial role when Japan embarked on importing technologies from the West in the late 19th century (after the Meiji restoration in 1868). This was done by employing individuals who had been trained in the West. Japan’s first engineering college, the Imperial College of Engineering, was founded in 1873 exclusively by British engineers to train Japanese students (Mazzoleni 2008). A large number of Japanese were also sent abroad to study in Western universities. The successful catch-up of Korea and Taiwan was also complemented by skill transfer through foreign-trained professors in science and technology. The Korea Advanced Institute of Science and Technology (KAIST), which primarily focused on supplying skilled workers needed to advance the Korean industrial sector, mainly employed foreign-trained professors as a means of transferring knowledge to domestic students. A 1988 study by Hsieh (1989) shows that at the two leading universities in Taiwan, National Tsing Hua University and National Taiwan University, 84% and 74% of the faculty received their degrees abroad, respectively.

Despite the potentially important implications of a globalized higher educa-
tion market for technological progress and income, there has surprisingly been no model of economic growth that incorporates those implications for cross-country income dynamics. Hence, this paper analyzes the implication of a globalized market for higher education for the dynamics of knowledge transfer and per capita income across countries.

This is an interesting exercise for two reasons. First, by now, there is a large theoretical work and empirical evidence that human capital is one of the crucial factors determining technological progress and income per capita. More recently, the role of higher education as an important determinant of aggregate income has been increasingly emphasized both by policy makers and researchers alike. Acemoglu and Zilibotti (2001) show that, due to biases in technological progress toward the high-skilled sectors, differences in skill levels account for a significant portion of cross-country income differences. Using a generalized framework for productivity accounting, Jones (2011) finds that differences across economies in the acquisition of advanced knowledge by skilled workers play a substantial role in explaining cross-country income differences. In the policy arena too, multilateral development organizations such as the World Bank increasingly put more focus on tertiary education as a tool for transferring advanced technologies to developing countries.¹

Second, the market for higher education is highly globalized and is increasingly becoming more so (Knight 2002). The labor market for university mentors is one of the most globalized labor markets. The implications of this competition constitute both a challenge and an opportunity for countries. The competition presents a challenge because a particular country may not manage to come out as a “winner” to attract high-quality mentors in the face of a globally competitive market (or even encounter “brain drain”), and remain trapped in a low

human capital equilibrium. On the other hand, a globalized market for mentors provides an opportunity for a diverse pool of mentors across the world, and facilitates a faster technology transfer that would otherwise not have been possible with a market constrained by the local supply of mentors.

What are the circumstances under which countries take advantage of the global market to transfer knowledge and narrow income differences? What conditions lead to a failure to “catch-up” and persistent differences in cross-country incomes? What role can public policy toward the education sector (and other relevant sectors) play to promote welfare?

I build on the Lucas (1988) model to examine those questions in a general equilibrium model of the world economy. This is done in two steps in a dynamic model.

First, I assume that in each country, there are two sectors: the goods sector and the human capital sector. In the goods sector, skilled and unskilled individuals produce goods. Wages depend on productivity.

In the human capital sector, mentors train students. Skilled individuals work as mentors in the human capital sector. Students pay wages (tuition fee) to the mentors. Thus, the acquisition of human capital involves an investment of time by the two agents: the mentors and the students. And the quality of human capital acquired by a student depends on, among other factors, the quality of the student’s mentors.

Second, I assume that mentors are mobile across countries, while other workers are immobile. This assumption is motivated by the highly globalized market for mentors in the real world. Hence, the wage for mentors, which may vary according to their quality, is determined by an internationally competitive market for mentors. Students face the trade-off between acquiring higher quality human capital and a higher cost of education (as the cost of education increases
with an increase in the quality of mentors).

The model is then used to analyze the steady-state equilibrium outcomes of human capital and per capita income. I analyze the circumstances under which incomes across countries persistently diverge (or converge).

One of the equilibrium outcomes is clusters of countries that feature a large and persistent gap in human capital (and hence per capita income). The gaps tend to converge among countries that are sufficiently close to each other whereas the gaps tend to persist among countries that have larger differences in the initial level of human capital. This equilibrium features a segregated market for mentors. Mentors with a relatively higher level of skill work in richer economies while low-skilled mentors work in poorer economies. The differences in per capita income are driven by differences in the quality of human capital (rather than by the differences in the quantity; i.e., the number of school attendants). The extent of complementarity among skills plays a key role in determining whether the initial gaps perpetuate.

The model is also used to analyze policies that affect the incentive to acquire human capital. The ultimate source of the incentive for acquiring human capital is its role in boosting productivity in the goods sector. Thus, I analyze the effect of policy changes (such as trade reforms, market liberalization, property right regime, etc.) on steady state per capita income. This is done by analyzing the impact of an exogenous shift in total factor productivity (TFP). Interestingly, depending on the initial conditions, an equal level of improvements in TFP may have a substantially different level of effect on income. This is due to the extent to which countries find it optimal to embark on a rapid transfer of human capital from leading economies. Thus, the model shades light on the circumstances under which economic reforms succeed in technology transfer and income catch-up.
This paper is related to the large literature on human capital and growth (see, e.g., Ljungqvist 1993; Bils and Klenow 2000; Hendricks 2002). The models typically assume a closed market for human capital. I relax this assumption and allow for the transfer of skills across borders through a globalized market for human capital. Another strand of the recent literature exclusively focuses on a one-way flow of skilled labor from relatively poorer countries to relatively richer ones (see, e.g., Beine et al. 2001; Beine et al. 2008; Gibson and McKenzie 2011). The model in this paper extends further by allowing for a two-way flow of skills in a general equilibrium model of the world economy. Traditionally, the trade literature focused on trade in goods and services (Krugman 1980; Eaton and Kortum 2002; Grossman and Rossi-Hansberg 2008). In the line of Damsgaard and Krusell (2010), this paper models human capital as a tradeable item in the global economy.

2 Environment of the model

2.1 Demography, preference and endowment

Assume that there are two countries, labeled $a$ and $b$. Each country is populated by individuals who live for two periods. Time is discrete. Half of the population are young and the other half are old. The population size of each age group in each country is normalized to mass 1. Thus, each country has a population size of mass 2. Let $x_{i,j}$ denote an individual $j \in [0,1]$ that is born in period $\tau \in \mathbb{N}$ and a citizen of country $i \in \{a, b\}$. The utility of individual $x_{i,j}$ is a function of consumptions during the two periods – as young (in period $\tau$) and as old (in period $\tau + 1$). Let $c(x_{i,j})$ and $C(x_{i,j})$ denote the consumption of individual

\[c^{2}\text{The assumption of two countries is for simplicity. Otherwise, it can easily be relaxed and is of no importance for the results.}\]
while young and old, respectively. We consider the log utility function:

\[ U(x) = \mathbb{E} \log c(x_{i,\tau,j}) + \beta \log C(x_{i,\tau,j}) \]

where \( \beta \in (0, 1) \) is the time discount factor.

In each period, agents have one unit of time. Young individuals are born with zero human capital. While young, an individual decides between working and studying. If she studies, she will acquire a positive amount of human capital for the next period (when she becomes old). Let the human capital of individual \( x_{i,\tau,j} \) be denoted by \( h_{i,\tau,j} \geq 0 \). Country \( i \)'s total stock of human capital in period \( t \), denoted by \( \bar{h}_{i,t} \), is thus given by

\[ \bar{h}_{i,t} = \int_{j=0}^{1} h_{i,t-1,j} dj \]

We have \( t - 1 \) on the right-hand-side of the above expression (the subscript in \( h_{i,t-1,j} \)) because, at any point in time, it is only the old that have a positive amount of human capital.

Finally, let the distribution of human capital in country \( i \) and period \( t \) be given by \( \Gamma_{i,t}(\sigma) \), a probability measure on \( (\Omega_{i,t}, \mathcal{F}_{i,t}) \) where

\[ \Omega_{i,t} = \{ h : \exists j \in [0, 1] \text{ s.t. } h = h_{i,t-1,j} \} \]

and \( \mathcal{F}_{i,t} \) is the associated Borel \( \sigma \)-algebra.

### 2.2 Sectors

The economy in each country has two sectors – the goods sector and the human capital sector. In the goods sector, output is a function of unskilled labor and human capital. In addition, the total stock of human capital in the economy may
have a positive externality on the productivity of the goods sector. The positive externality of aggregate human capital on productivity is also emphasized in previous studies. The externalities may arise due to complementarity among skills (where skilled individuals are more productive when complemented by other skilled individuals) and/or creating conducive conditions for technology adoption (see, e.g., Lucas 1988; Bils and Klenow 2000; Jones 2011; Acemoglu and Angrist 2000). A skilled individual with human capital $h$ and employing $l$ unit of unskilled labor thus produces

$$y(h,l,h_i) = A_i h^\alpha_1 l^\alpha_2 h_i^{\alpha_3}, \quad \alpha_1 + \alpha_2 + \alpha_3 = 1, A_i > 0$$  \hspace{1cm} (1)

$A_i$ denotes total factor productivity. It can vary across countries depending on factors such as institutional quality. $\alpha_3$ captures the externality effect of the total stock of human capital in the economy.

In the human capital sector, skilled individuals mentor the young to acquire human capital. The amount of human capital that a young individual acquires depends positively on the quality of her mentor – high-quality mentors produce high-quality graduates. Suppose that individual $x_{i,\tau,j}$ decides to invest in human capital while young (in period $\tau$). Let the human capital of her mentor be denoted by $H_{i,\tau,j}$. The human capital of individual $x_{i,\tau,j}$ is given by the following function:

$$h_{i,\tau,j} = \eta (H_{i,\tau,j})^{1-\kappa} (\bar{h}_{i,\tau})^\kappa, \quad \eta > 0, \kappa \in [0,1]$$  \hspace{1cm} (2)

where $\kappa$ measures the externality of aggregate human capital on the productivity of the human capital sector. In the absence of such an externality, $\kappa = 0$. The teacher-to-student ratio is given by the parameter $\theta$. We realistically assume that the teacher-to-student ratio is less than 1, i.e., $\theta \in (0,1)$. We also allow
for the possibility that the human capital acquired by some of the individuals may become outdated after a generation. This is achieved by assuming that with probability \( \psi \in (0, 1) \), a skilled individual can work both in the goods and the human capital sector, and with probability \( \psi - 1 \), a skilled worker can only work in the goods sector. Thus, a fraction \( \psi \in (0, 1) \) of the skilled individuals cannot work as mentors, i.e., their skills become obsolete upon their death.

### 2.3 The individual’s decision problem

In every period, each young individual chooses whether to work or study. If she chooses to work while young, she becomes an unskilled worker both while young and old.

Acquiring human capital is an endeavour that requires an investment of time both by the student and the mentor. Thus, if the young individual chooses to study, she gives up her current wage from working as an unskilled worker. Moreover, she incurs a tuition fee to pay for the salary of her mentor. Let the tuition fee for acquiring \( h \) level of human capital in period \( t \) be given by the function \( \zeta_t(h) \). The tuition fees vary depending on the quality of the mentors. The human capital acquired by the young individual is determined according equation (2).

For the purpose of simplifying the exposition, let us drop the country indices for a while. For individual \( x_{\tau,j} \), the maximization problem is as follows

\[
\max_{c_{\tau,j}, C_{\tau,j}, q_{\tau,j}(s_{\tau,j}), h_{\tau,j}} U(c_{\tau,j}, C_{\tau,j}(s_{\tau,j})) = \mathbb{E}_r \log c_{\tau,j} + \beta \log C_{\tau,j}(s_{\tau,j})
\]

\( s.t. \)
\[ m_{\tau,j} - c_{\tau,j} - \mathcal{I}(h_{\tau,j}) \zeta_r(h_{\tau,j}) \geq \sum_{s_{\tau,j}} p_{\tau,j}(s_{\tau,j}) q_{\tau,j}(s_{\tau,j}) \]  \hspace{1cm} (3)

\[ M_{\tau,j}(s_{\tau,j}) + q_{\tau,j}(s_{\tau,j}) \geq C_{\tau,j}(s_{\tau,j}), \quad \forall s_{\tau,j} \]  \hspace{1cm} (4)

\[ m_{\tau,j} = [1 - \mathcal{I}(h_{\tau,j})] w_{\tau}^n \]  \hspace{1cm} (5)

\[ M_{\tau,j}(s_{\tau,j}) = [1 - \mathcal{I}(h_{\tau,j})] w_{\tau+1}^n + \mathcal{I}(h_{\tau,j}) Z_{\tau,j}(s_{\tau,j}) \]  \hspace{1cm} (6)

\[ Z_{\tau,j}(s_{\tau,j}) = \max \{ s_{\tau,j} w_{\tau+1}(h_{\tau,j}), \pi_{\tau+1}(h_{\tau,j}) \} \]  \hspace{1cm} (7)

\[ \pi_{\tau+1}(h) = \max \left\{ Ah_{\tau+1}^{\alpha_1} l_{\tau+1}^{\alpha_2} \right\} - w_{\tau+1} l_{\tau+1} \]  \hspace{1cm} (8)

\(w_{\tau}^n\) is the wage rate for one unit of unskilled labor in period \(\tau\). The period \(t\) wage rate for mentors with human capital \(h\) is denoted by \(w_t^r(h)\). \(s_{\tau,j} \in \{0, 1\}\) is a state variable indicating whether the individual can work as mentor in period \(\tau + 1\). \(s_{\tau,j}\) equals zero if the individual cannot become a mentor (i.e., if her skill becomes obsolete for the next generation). \(p_{\tau,j}(s_{\tau,j})\) is the period \(\tau\) price of the asset that pays 1 one unit of good in period \(\tau + 1\) and in state \(s_{\tau,j}\). \(q_{\tau,j}(s_{\tau,j})\) is the quantity of assets purchased by the individual. \(\mathcal{I}(h_{\tau,j})\) is an indicator function that takes the value of 1 if the individual decides to acquire human capital (i.e., \(h_{\tau,j} > 0\)). Otherwise, \(\mathcal{I}(h_{\tau,j})\) equals 0. \(m_{\tau,j}\) is the income in period \(\tau\). \(M_{\tau,j}(s_{\tau,j})\) is the income in period \(\tau + 1\) and state \(s_{\tau,j}\).

Total expenditure in period \(\tau\) consists of the expenditures on current consumption \(c\) and, should the individual decide to invest in human capital, the tuition fee \(\zeta_r(h_{\tau,j})\). Equation (3) states that the total value of assets acquired in period \(\tau\) cannot exceed the period \(\tau\) income net of total expenditure in period \(\tau\) (which equals \(c_{\tau,j} + \mathcal{I}(h_{\tau,j}) \zeta_r(h_{\tau,j})\)). Equation (4) imposes the condition that consumption in period \(\tau + 1\) cannot exceed the individual’s income and wealth. Equations (5) – (8) describe the relationship between income and human capital. According to equation (5), period \(\tau\) income equals the unskilled wage rate if the individual decides to work (i.e., \(\mathcal{I}(0) = 0\)). Instead, if the individual...
decides to acquire human capital, \( m_{\tau,j} = 0 \) (since \( I(h_{\tau,j}) = 1 \) when \( h_{\tau,j} > 0 \)).

If the individual does not acquire human capital, \( M_{\tau,j}(s_{\tau,j}) = M_{\tau,j} = w^{\tau+1}_{\tau+1} \), i.e., the wage rate for the unskilled worker (equation (6)). \( Z_{\tau,j}(s_{\tau,j}) \) is the period \( \tau + 1 \) income if the individual acquires human capital. If \( s_{\tau,j} = 1 \), the individual chooses between working in the human capital sector as a mentor (while earning the wage rate \( w^{\tau+1}_{\tau+1}(h_{\tau,j}) \)) and working in the goods sector as a skilled worker (equation (7)). The income for skilled workers in the goods sector equals the residual of output after paying the wage for unskilled workers (equation (8)).

Taking the first-order condition for the maximization problem in equation (8), the amount of unskilled labor demanded by a skilled individual with human capital \( h \) who is engaged in the goods sector is given by:

\[
l_t(h) = \left( \frac{\alpha_2 Ah^{\alpha_3} h_t^{\alpha_3}}{w_t} \right)^{-\frac{1}{\alpha_2}} \tag{9}\]

The demand for unskilled labor is decreasing in its price \( (w_t) \) and increasing in the marginal product of unskilled labor \( \alpha_2 Ah^{\alpha_3} h_t^{\alpha_3} \) (which, in turn, is increasing in total factor productivity \( A \) and aggregate human capital \( h_t \)).

The first-order conditions for consumption and assets choices are:

\[
\frac{\beta^\psi}{C_{\tau,j}(1)} = p_{\tau,j}(1) \frac{1}{c_{\tau,j}} \tag{10}
\]

\[
\frac{\beta (1 - \psi)}{C_{\tau,j}(0)} = p_{\tau,j}(0) \frac{1}{c_{\tau,j}} \tag{11}
\]

The right-hand sides of the above two equations capture the utility cost of owning one more unit of assets. The left-hand-sides are the weighted utility benefits of owning one more unit of the assets, the weights being the likelihood of the states. Thus, the utility cost of owning one more unit of the assets should equal the expected utility gain from the ownership.
3 Equilibrium in a closed market for human capital

Let us first take the equilibrium in a simpler case – a stationary equilibrium in the closed economy where cross-border trade of human capital does not occur.

Denote the occupation of a skilled individual \( x_{r,j} \) by \( \mu_{r,j} \in \{0, 1\} \). \( \mu_{r,j} = 1 \) if \( x_{r,j} \) is a mentor; otherwise, \( \mu_{r,j} = 0 \). Total output in the economy \( Y_t \) is thus given by

\[
Y_t = \int (1 - \mu_{j,t-1}) A h_{j,t-1}^{\alpha_1} (l_t (h_{j,t-1}))^{\alpha_2} \bar{h}_t^{\alpha_3} dj
\]

Moreover, let \( \Omega^c_{i,t} \subseteq \Omega_{i,t} \) denote the subset of skilled individuals who engage in teaching. Define \( \Gamma^c_{i,t} (\sigma) \) as a probability measure on \( (\Omega^c_{i,t}, \mathcal{F}^c_{i,t}) \) where \( \mathcal{F}^c_{i,t} \) is the associated Borel \( \sigma \)-algebra. The equilibrium of this economy is defined as follows.

**Definition 1** By equilibrium, we mean allocations \( \{c^*_t, h^*_t, (C^*_t, q^*_t) (s_{t,j})\}_{\forall t,j} \), occupation \( \{\mu^*_t\}_{\forall t,j} \), demand function for unskilled labor \( \{l_t (h)\}_{\forall t} \) and prices \( \{q^*_t (s_{t,j}), w^*_t, w^*_t, \zeta^*_t (h)\}_{\forall t,j} \) such that, given the prices,

1. \( \{c^*_t, h^*_t, (C^*_t, q^*_t) (s_{t,j}), \mu^*_t\}_{\forall t,j} \) solve the maximization problem for individual \( x_{t,j} \).

2. the demand for unskilled workers equals the supply of unskilled labor.

\[
\int l_t (h^*_{t-1,j}) \mu^*_{t-1,j} dj = \Gamma_{t+1} (0) + \Gamma_t (0)
\]

3. the demand for mentors equals the supply of mentors.

\[
\frac{\Gamma_{t+1} (\sigma)}{1 - \Gamma (\{0\})} = \Gamma^c_t (g^{-1} (\sigma; \bar{h}_t))
\]
4. the goods market clears

\[ \int [c_{t,j}^* + C_{t-1,j}^*] \, dj = Y_t \]

The stationary equilibrium is defined as follows.

**Definition 2** Stationary equilibrium is an equilibrium where

\[ \Gamma_t^*(\sigma) = \frac{\theta \Gamma_t(\sigma)}{1 - \Gamma_t(\{0\})} \] (12)

The interpretation of the above definition is that a constant fraction \( \theta \) of the skilled individuals from each level of skill engage in teaching.

**Lemma 3** If equation (12) is satisfied with \( \kappa > 0 \), \( \Omega_{t,t} \) converges to a singleton. Moreover, if \( \kappa = 0 \), \( \Omega_{t,t} \) is a singleton for the stationary equilibrium.

**Proof.** See the Appendix. ■

Given that the distribution is singleton for \( \kappa = 0 \), and that the distribution converges to a singleton if the stationary equilibrium condition (12) is satisfied when \( \kappa > 0 \), I focus on the stationary equilibrium with a singleton distribution. The following proposition states such an equilibrium.

**Proposition 4** The economy has a stationary equilibrium with singleton \( \Gamma_t(\sigma) \) given by

\[ \Gamma_t(\sigma) = \begin{cases} 
\phi \in (0,1) & \text{if } \sigma = \{h_{t-1,j}^*\} = \{h_{t-1}^*\} \text{ for } \{h_{t-1}^*\} \in \Omega_t \text{ and } h \neq 0 \\
1 - \phi & \text{if } \sigma = \{0\} \\
0 & \text{otherwise}
\end{cases} \]
where

\[ \phi = \frac{(1 - \alpha_2) (g_{\pi} \rho - \theta) 2}{(1 - \theta) (1 + g_{w} \rho) \alpha_2 + (1 - \alpha_2) (g_{\pi} \rho - \theta) 2} \]  \tag{13} \\
\[ R = \frac{1 2g_{\pi} (1 - \alpha_2) + g_{w} \alpha_2 (1 - \theta)}{\beta \alpha_2 (1 - \theta) - 2\theta (1 - \alpha_2)} \]

\[ p (0) = \psi \frac{1}{R} \]
\[ p (1) = (1 - \psi) \frac{1}{R} \]
\[ g_{w} = g_{\pi} = g_{h}^{\alpha_1 + \alpha_3} \]
\[ g_{h} = \eta \phi^{\kappa} \] \tag{14}

**Proof.** See the Appendix. \( \blacksquare \)

As in Lucas (1988), growth is driven by the accumulation of human capital. The growth rate of human capital is given by \( g_{h} \). The growth rates of income for skilled and unskilled labor are determined by the growth rate of human capital amplified by the economy’s dependence on human capital (i.e., \( \alpha_1 + \alpha_3 \)). Since \( \Gamma_t (\sigma) \) is a singleton, in each period, all old skilled individual have the same level of human capital, i.e., \( h_{t-1, j}^* = h_{t-1}^* \). Moreover, note also that \( \phi \) is independent of the quality of human capital in the economy. The total stock of human capital in the country is given by

\[ \bar{h}_t = \phi h_{t-1}^* \]

The total stock is a product of the quantity of human capital (\( \phi \)) and the quality \( (h_{t-1}^*) \). If we further assume that

\[ \eta = \left( \frac{(1 - \alpha_2) (\rho - \theta) 2}{(1 - \theta) (1 + \rho) \alpha_2 + (1 - \alpha_2) (\rho - \theta) 2} \right)^{\kappa-1} \] \tag{15}

then \( g_{w} = g_{\pi} = g_{h} = 1 \) (follows from equation (14)). This condition gives us a stationary equilibrium with a constant level of income.
4 Equilibrium in an open market for human capital

Now we introduce a global market for human capital by assuming an international market for mentors. We assume that mentors are mobile across borders as long as there is a demand for them at the ongoing international wage rate. This assumption is motivated by the fact that the market for university professors is one of the highly globalized labor markets in the actual world. The focus again is once more on the stationary equilibrium where the distribution functions for each country, $\Gamma_{i,t}(\sigma)$ and $\Gamma_{i,t}(\sigma)$, are singletons and satisfy condition (12).

4.1 Transfer of human capital across borders – a simple illustration

One interesting question is whether a country with a low-quality human capital finds it optimal to import high-quality human capital in equilibrium. For the purpose of analyzing this question, assume that both countries are in a stationary equilibrium prior to opening up. Assume further that, upon opening up, country $a$ has a higher human capital than country $b$, i.e., $\bar{h}_{a,t} > \bar{h}_{b,t}$. Since $\phi$ is independent of the level of human capital (see equation (13)), the number of skilled individuals is the same in both countries. It is only the quality of their skills that differs.

Country $b$ can improve the quality of its human capital by importing high-quality mentors from $a$, and increase its stock of human capital and income. This is possible because the quality of human capital acquired by the students, according to (2), is increasing in the quality of mentors. However, for that to happen, individuals in $b$ should be willing to pay at least as much tuition fees as the tuition paid by individuals in $a$. Otherwise, high-quality human capital
does not flow from $a$ to $b$. Figure 1 illustrates this point. The two panels in the figure illustrate the two scenarios – a case where $b$ imports human capital and where it does not.

*Figure 1 here*

On the horizontal axis, we have the number/quantity of high-quality mentors, $Q(h_a)$. The international wage rate for high-quality mentors, $\bar{w}^e(h_a)$, is on the vertical axis. The curve $SS_a$ is the supply curve of high-quality mentors in the global market. These mentors are supplied by country $a$. The curves $DD_a$ and $DD_b$, respectively, describe the demand for high-quality mentors by country $a$ and country $b$. $\bar{w}^e$ is the wage rate where country $a$’s demand for high-quality mentors equals the global supply of high-quality mentors. If the international wage rate of high-quality mentors is above $\bar{W}^e$, country $b$’s demand for high-quality mentors is zero. If the world market clears at a wage rate greater than $\bar{W}^e$, none of the high-quality mentor will be employed in country $b$. Thus, whenever $\bar{w}^e \geq \bar{W}^e$, there will be no flow of high-quality mentors to country $b$. All high-quality mentors remain in country $a$. This is the case in *Panel A*. On the other hand, in *Panel B*, $\bar{w}^e < \bar{W}^e$. In this case, the world market for high-quality mentor does not clear if all of the high-quality mentors are employed in country $a$. Thus, there is a flow of human capital to country $b$, i.e., some of the high-quality mentors teach in country $b$.

### 4.2 When does human capital flow?

What factors lead to the scenario where country $b$ imports high-quality mentors, increase its stock of human capital and catch-up? The fact that country $b$ has a lower level of initial human capital has three major effects on its demand for high-quality human capital: (1) the scarcity effect, (2) the opportunity-cost effect, and (3) the productivity effect.
Human capital is a scarce resource in country $b$. All else equal, this leads to a higher return to acquiring a higher level of human capital. From equations (9) and (8), the income of a skilled individual working in the goods sector is given by

$$
\pi_t (h) = (1 - \alpha_2) h^{\frac{\alpha_1}{1-\alpha_2}} h^{\frac{\alpha_3}{1-\alpha_2}} \left( \frac{\alpha_2}{w_t} \right)^{\frac{\alpha_2}{1-\alpha_2}}
$$

Thus, $\pi_t (h)$ is decreasing in the wage rate for unskilled labor, $w_t$, which is lower in the low human capital economy.

The cost of acquiring human capital includes the tuition fee, $\zeta_r (h_{r,j})$, and the opportunity cost of time spent at school (equation (3)). The forgone income from attending school is the wage rate for unskilled labor, which is lower in the low-human capital economy. The low total cost of acquiring human capital in country $b$ thus creates more demand for human capital.

According to the production functions in the goods and human capital sectors (equations (1) and (2)), productivity could be lower in the low human capital economy if either/both of $\kappa$ and $\alpha_3$ are positive. This productivity effect of aggregate human capital reduces the demand for acquiring human capital in country $b$. Thus, human capital flows from country $a$ to $b$ if the first two effects (the scarcity and the opportunity-cost effects) dominate the productivity effect. The productivity effect is more likely to dominate when: (i) the externality of aggregate human capital is higher (i.e., the values of $\kappa$ and/or $\alpha_3$ are larger), (ii) for positive values of $\kappa$ and/or $\alpha_3$, country $b$’s relative level of initial human capital is lower, (iii) total factor productivity of country $b$, $A_b$, is lower, and (iv) the education technology is less efficient (i.e., $\theta$ is higher).

Figure 2 illustrates the effects of the above four factors with a numerical example. The horizontal axis measures the relative human capital of country $b$ to that of country $a$, $h_b/h_a$. By assumption, this ratio is less than one (country $b$ is assumed to have a lower level of initial human capital). On the vertical
axis, we have the ratio of \( \bar{W}^e(h_a) \) to \( \bar{w}^e(h_a) \). \( \bar{W}^e(h_a) \) is the maximum wage at which individuals in country \( b \) ever demand to import a positive quantity of high-quality mentors. If the international wage rate for mentors is beyond \( \bar{W}^e(h_a) \), country \( b \) does not import high-quality mentors (see the discussion in Section 4.1). \( \bar{w}^e(h_a) \) is the wage rate at which the quantity of high-quality mentors demanded by country \( a \) equals the world supply of high-quality mentors. Thus, whenever the ratio \( \bar{W}^e(h_a) / \bar{w}^e(h_a) \) is less than one (i.e. when \( \bar{W}^e(h_a) < \bar{w}^e(h_a) \)), the productivity effect dominates and country \( b \) does not import high-quality mentors.

**Figure 2 here**

In all of the panels in the figure (Panel A-D), the ratio \( \bar{W}^e(h_a) / \bar{w}^e(h_a) \) is more likely to be less than one the lower is country \( b \)'s relative human capital. Panel (A) shows that the higher is the externality of aggregate human capital in the goods sector (as captured by increases in \( \alpha_3 \)), the more likely it is that \( \bar{W}^e(h_a) / \bar{w}^e(h_a) \) is less than one. Panel (B) shows that the externality of aggregate human capital on the human capital sector has a similar effect. Finally, \( \bar{W}^e(h_a) / \bar{w}^e(h_a) \) tends to be higher when the education technology improves (i.e., when \( \theta \) is lower) and the total factor productivity increases (Panel (C) and Panel (D)).

### 4.3 TFP shocks, human capital import and income

How does access to trade in human capital influence an economy’s response to a permanent TFP shock? Such TFP shocks could be interpreted as (and the interpretation I favor for the purpose of this discussion), major policy reforms that substantially alter the economic environment. Examples of such reforms abound: Sweden’s reform in the mid-19th century, China’s reform in the late 1970s and early 1980s, Japan’s reform in the late 19th century, and Taiwan’s and
South Korea’s pro-market reforms after WWII (as opposed to, say, communist North Korea). As we will see below, access to human capital trade can have a substantial implication for TFP shocks.

In general, positive TFP shocks increase output in a straightforward way as the shocks increase productivity (see the production function in equation (1)). However, not all economies respond to TFP shocks to the same extent. We can observe different responses depending on the model parameters and the initial conditions. These responses depend on how the TFP shocks affect the incentives to import human capital. Despite the variations in the responses, a systematic pattern emerges corresponding to three types of initial conditions: “low”, “intermediate” and “high” level of initial human capital. It is the economy with an intermediate level of human capital that responds most to TFP shocks. This is the case because, as compared to the low and high human capital economy, TFP shocks induce a higher shift in demand for importing human capital in the economy with an intermediate level of human capital. Remember that the incentive to import human capital consists of three effects: the scarcity effect, the opportunity cost effect and the productivity effect. In the low-human-capital economy, TFP shocks fail to induce a demand to import human capital since the productivity effect dominates. In the high-human-capital economy, on the other hand, the scarcity and opportunity cost effects are not large enough due to the relative abundance of human capital. Thus, it is the economy with an intermediate level of human capital that responds most to TFP shocks.

Figures 3 illustrates the above three patterns with a numerical example. We consider that country $b$ is the “follower” in knowledge (i.e., has lower level of human capital). On the horizontal axis, we have the TFP of country $b$ relative to $a$, $A_b/A_a$. The vertical axis is $b$’s relative output. The figure shows the response of output to TFP increases for three scenarios of $b$’s initial level of
human capital – high, intermediate and low levels of initial human capital. The uppermost curve plots the scenario where $b$’s initial level of human capital is relatively high – about 83% of $a$’s human capital. The middle and lower curves plot the scenarios for intermediate and low level of human capital for country $b$ – 33% and 4% of $a$’s human capital, respectively.

*Figure 3 here*

All of the three curves have positive slopes as the increase in the TFP shifts the production function in (1). However, note that the intermediate human capital economy shows what could be considered as a dramatic output response to TFP changes (after the TFP level at point $C_1$). This is due to the fact that the TFP improvements induce a much larger incentive to import human capital. Figure 4 shows this effect of TFP improvements on human capital import. We see that it is the intermediate human capital economy that shows a substantial improvement in the quantity of its human capital stock in response to TFP increases. Point $C_2$ in Figure 4 corresponds to point $C_1$ in Figure 3.

*Figure 4 here*

The prediction of the model that economies with a moderate level of human capital respond most to policy reforms appears to be consistent with anecdotal observations. Over the past decades, many non-resource economies, including Japan, Taiwan and Korea, managed to narrow their income gaps with leading economies (such as the U.S.) through rapid economic growth. Other emerging economies such as China and Turkey also seem to be on the same path. The experiences of these economies, as they go along the income ladder, typically consist of, among other things, two major events – a one-time shift in policy
regime and a gradual shift to high-tech products. After the Meiji restoration in the late 19th century, Japan carried out many reforms to encourage the private sector. After the WWII, South Korea and Taiwan (as opposed to, e.g., North Korea and China) also followed a policy regime that created a relatively more conducive environment for businesses. These policy shifts, as discussed in Section 1, are followed by a rapid import of technological knowledge where graduates of foreign universities played a crucial role in training students at domestic universities. A number of scholars have emphasized the “right” initial conditions for the success of these countries. Among those conditions are a fairly moderate level of human capital at the time of the reforms. For example, Mazzoleni (2008) emphasizes that the relatively moderate level of human capital in Japan at the start of the reform (in the late 19th century) created the basis for its capacity to absorb imported technologies.

5 Concluding remarks

Higher education institutions play a crucial role in the transfer of human capital across countries. Historical evidences over the past two centuries abound. German and other European scientists played an important role in the early phase of US universities. An examination of the more recent economic histories of countries that experienced a successful catch-up shows that higher learning institutions played a crucial role in the transfer of technology from leading economies. Moreover, in recent times, the higher education market is becoming increasingly globalized, providing a potential platform for the “late-comers” to import knowledge. However, whether the countries can use this platform to narrow the income gap is far from obvious. At least in a pure market equilibrium, the analysis of the model in this paper shows that the initial conditions matter. Economies that start out with a very low level of human capital may thus lack
the “critical” level of human capital needed to absorb advanced knowledge imported from the global higher education market. Moreover, although economic reforms that improve the business environment increase productivity, they may not always result in rapid catch-up unless they are met with the “right” initial conditions. Hence policies that aim to achieve catch-up through economic reforms should take those conditions into account.

This paper is part of an ongoing research project. A number of questions still remain open. Although the predictions of the model appear to be consistent with a number of anecdotal evidences, statistical tests are warranted to verify their systematic validity, an endeavour I am still working on.

References


Damsgaard, E. F. and P. Krusell (2010, September). The world distribution


A Proof of Proposition

Since a positive fraction of skilled workers engage in the human capital and the goods sector (by the definition of stationary equilibrium), skilled individuals must earn the same amount from working in either of the sectors (otherwise, they will not be indifferent). Hence, \( w_t^e = \pi_t \). For notational simplicity, we ignore \( h_t \) (as we are considering the case where \( \Omega_t \) is a singlton, \( h_t \) is the same for all skilled individuals in period \( t \)).

To avoid profit from pure arbitrage of the mentors, the equilibrium tuition fee should satisfy

\[
\zeta_t = \theta w_t^e
\]

The young should be indifferent between investing on human capital or not:

\[
w_t^n + \frac{w_{t+1}^n}{R_{t+1}} = \frac{w_{t+1}^e}{R_{t+1}} - \theta\zeta_t = \frac{w_{t+1}^e}{R_{t+1}} - \theta w_t^e
\]

\[
= \frac{\pi_{t+1}}{R_{t+1}} - \theta\zeta_t = \frac{\pi_{t+1}}{R_{t+1}} - \theta\pi_t
\]

where \( R \) is the risk-free interest rate.

Let us conjecture that the growth rates of \( \pi \) and \( w \) in the stationary equilibrium are constant, and denote them by \( g_\pi \) and \( g_w \), respectively. Let us also conjecture that the risk-free interest rate is constant over time. Then, from (17), we have

\[
w_t^n \left(1 + \frac{g_w}{R}\right) = \pi_t \left(\frac{g_\pi}{R} - \theta\right)
\]

\[
= (1 - \alpha_2) A \frac{1}{\alpha_2} h_t^{\alpha_1/\alpha_2} (\phi h_t) \frac{\alpha_2}{\alpha_1} \left(\frac{\alpha_2}{w_t^e}\right)^{\alpha_2/\alpha_1} \left(\frac{g_\pi}{R} - \theta\right)
\]

The total quantity of unskilled workers equals \( 2(1 - \phi) \). The total quantity of skilled individuals equals \( \phi \), and \( (1 - \theta) \) of them engage in the goods sector.

25
So market clearing for unskilled labor implies

\[ \phi (1 - \theta) \left( \frac{\alpha_2 Ah_t^{\alpha_1} \bar{\bar{\eta}}^{\alpha_3}}{w_t^n} \right)^{\frac{1}{1 - \alpha_2}} = 2 (1 - \phi) \]

Re-arranging this equation,

\[ w_t^n = \left( \frac{\phi (1 - \theta) (\alpha_2 Ah_t^{\alpha_1} \bar{\bar{\eta}}^{\alpha_3})^{\frac{1}{1 - \alpha_2}}}{2 (1 - \phi)} \right)^{1 - \alpha_2} \]  

(19)

Insert (19) into (18) to get

\[ \phi (\alpha_2 (1 - \theta))^{\frac{1}{1 - \alpha_2}} \left( 1 + \frac{g_w}{R} \right) = (1 - \alpha_2) \alpha_2 \frac{\bar{\bar{\eta}}^{\alpha_3}}{1 - \alpha_2} \left( \frac{g_w}{R} - \theta \right) \]

The no-arbitrage condition in the asset market implies

\[ p (1) = (1 - \psi) \frac{1}{R} \]
\[ p (0) = \psi \frac{1}{R} \]

Given this asset prices, the first-order conditions (10) and (11) imply that consumption in both states are the same, i.e., \( c_{r,j} (0) = c_{r,j} (1) = c_{r,j} \) and \( C_{r,j} (0) = C_{r,j} (1) = C_{r,j} \). The euler equations then become

\[ \frac{C_{r,j}}{c_{r,j}} = \beta R \]  

(20)

The market clearing condition for asset and goods markets imply

\[ c_{t,j} + \phi \zeta_t = (1 - \phi) w_t^n \]  

(21)

\[ C_{r-1,j} = (1 - \phi) w_t^n + \phi \pi_t \]  

(22)
Combining (19), (16), (20), (21) and (22), we get

\[ R = \frac{1}{\beta} \frac{2g_\pi (1 - \alpha_2) + g_w \alpha_2 (1 - \theta)}{\alpha_2 (1 - \theta) - 2\theta (1 - \alpha_2)} \]
B  Proof of Lemma

Let the $R_t$ denote the interest on the risk-free asset. We have the no-arbitrage condition. Then, the growth rate for each type of human capital is

$$\frac{\dot{h}}{h} = \eta \left( \frac{\dot{h}}{h} \right)^\kappa,$$

$$\frac{\dot{h}'}{h'} = \eta \left( \frac{\dot{h}'}{h'} \right)^\kappa.$$

Since $(\dot{h}/h')^\kappa < (\dot{h}/h)^\kappa$, $\dot{h}'/h' < \dot{h}/h$. Hence, if $\kappa > 0$, $\Omega_T$ converges to a singleton as $T \to \infty$.

When $\kappa = 0$, the stationary equilibrium should have a unique $h$. Note that an agent should be indifferent between choice of level of human capital: for any two human capital levels $h', h > 0$, with $h' \neq h$, we should have

$$\frac{\pi (h') g_{\pi}}{R} - \theta \pi (h') = \frac{\pi (h) (1 + \gamma_{\pi})}{R} - \theta \pi (h)$$

$$\pi (h') \left( \frac{g_{\pi}}{R} - \theta \right) = \pi (h) \left( \frac{g_{\pi}}{R} - \theta \right)$$

(23)

However, since $\pi (h') > \pi (h)$ for any $h' > h$, this is a contradiction.
C Figures

Figure 1: Demand for and supply of high-quality mentors in the world market
Figure 2: Transfer of human capital, production technology and initial conditions

Panel (A)  Panel (B)

Panel (C)  Panel (D)
Figure 3: TFP increase and output
Figure 4: TFP increase and human capital