Catching-up and Falling-behind in Economic Development: A Human Capital Approach

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Abstract
This paper proposes an endogenous growth model where human capital is the engine of growth and can be transferred across countries via costly foreign education. Importing advanced knowledge by students abroad can improve a developing country’s chance of catching up with a developed host country. An excessively wide difference in knowledge level between the two countries, however, can hamper the chance of catching-up because few students can afford foreign education. Taking these two counteracting forces into account, our model predicts that the relationship between income growth in a developing country and income gap will assume the form of an inverted-U schedule. The model also produces an endogenous threshold level of income gap which separates catching-up and falling-behind. We test the model’s propositions and estimate the threshold using international panel data, which lends support to our theory.

Key words: Catch-up; Convergence; Divergence; Human capital; Foreign education

JEL Classification Code: O40, I20

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I. Introduction

Transfer of knowledge or diffusion of technology has long been considered one of the key driving forces behind convergence in income across countries. Recognizing the importance of knowledge or technology in modern economic growth, economists have advocated the advantage of backwardness in knowledge for latecomers. According to Easterlin (1981), “the worldwide spread of modern economic growth has depended chiefly on the diffusion of a body of knowledge concerning new production techniques.” Abramovitz (1986) points out that the surge of productivity growth in industrialized countries after World War II was due to a large backlog of unexploited technology. Baumol (1986) cites spillovers of innovation and investment as the primary explanation for the convergence in income within industrialized nations. International trade has been considered by many researchers as a key channel for knowledge transfer or technological diffusion from developed to developing countries. Export or import of high-quality and sophisticated goods can help developing countries utilize a large learning potential from those goods and advance the skills of workers (see Grossman and Helpman, 1991; Stokey, 1991; Lucas, 1993; Quah, 1997; Ben-David and Loewy, 1998).

Since World War II, the world has witnessed a fast process of integration in various dimensions. The annual worldwide trade volume from 1970 to 2000 has increased by 5.8 times. The ratio of international tourists to world population has risen from 0.064 in 1980 to 0.115 in 2000. Over the period 1950-1990, the number of students abroad worldwide at tertiary-level institutions increased at the average annual rate of 6.3 percent, while the growth rate of student enrollment worldwide in tertiary schools was 5.9 percent during the same period. \(^1\) Communication technology such as the Internet has rapidly advanced as well. However, cross-

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\(^1\) Trade data are from *World Economic Outlook* (IMF, 2001). Data on the number of international tourists are from *World Development Indicators* (World Bank, 2002). Data on students abroad are from *Statistical Yearbook* (UNESCO, various years).
country data do not show any uniform catch-up pattern in per capita income across countries. Table I illustrates this point with several inequality measures of the worldwide distribution of the average per capita income over the period 1960-2000. On the one hand, the ratio of per capita income at the 90th percentile to that at the 75th percentile shows a trend of convergence in income to some extent. On the other hand, income disparity between richer and poorer countries has been steadily widening throughout this period: the Gini coefficient has increased from 0.4699 in 1960 to 0.5108 in 2000, while the ratio of per capita income at the 90th percentile to that at the 10th percentile has risen from 10.74 to 25.29 during the same period. On average, the poorest countries with per capita income below the 10th percentile in 1960 managed to grow only at 1.85 percent annually over the period 1960-2000, while the worldwide growth rate during the same period was 2.05 percent.

Why are some developing countries unable to take advantage of their backwardness and catch up with developed countries, especially during the time when countries are getting more interconnected through trade in goods and in people? Explanations for this question offered in the literature are generally based on the notion that each country has a distinct capacity for, or barrier to absorbing advanced knowledge. For example, Nelson and Phelps (1966) and Easterlin (1981) argue that the lack of formal education in the population is an obstacle to diffusion of advanced knowledge. Abramovitz (1986) stresses “social capability” identified with technical competence and political, industrial, and financial institutions. Benhabib and Spiegel (1994) and Griffith et al. (2004) find evidence that workers’ skills, acquired by domestic education or R&D, are an important determinant of a country’s absorptive capacity.

Earlier theoretical models have attempted to explain both convergence and divergence in income across countries by following the idea of the barrier to knowledge transfer. A common
underlying assumption in these models is that advanced knowledge is freely diffused to other (developing) countries without the cost of knowledge transfer and, hence, has an externality or spillover effect on followers, which promotes income convergence among countries. Income divergence is accounted for in these models by assuming specific exogenous forces that limit this spillover effect. Azariadis and Drazen (1990) and Tamura (1996) assume that a developing country cannot benefit from the knowledge of advanced countries until its knowledge reaches an exogenous threshold value. Parente and Prescott (1994) hypothesize that the externality of advanced knowledge is limited by an exogenous barrier to knowledge transfer in developing countries. In Basu and Weil (1998), a follower country can use a leading country’s technology only if the follower has a sufficiently high level of development with specific degree of capital intensity. The R&D-based growth models of Acemoglu et al. (2002) and Howitt and Mayer-Foulkes (2002) assume that a failure to switch from the “imitation” stage of development to the “innovation” stage due to either inappropriate institutions or a lack of required skill level prevents convergence to advanced countries.

This paper attempts to address the question of why some developing countries are catching up with advanced countries while others aren’t, by identifying a threshold of catching-up and falling-behind that is determined endogenously in the model. We present an endogenous growth model with human capital as the engine of growth that departs from the previous literature in one important aspect: advanced knowledge is acquired by developing countries through the specific channel of foreign education, and is thus not freely transferred to developing countries. In our model, researchers who create new knowledge are motivated by the prospect of obtaining revenues from selling (or teaching) their product to students since researchers have temporary property rights to their knowledge owing to specialization in research field or legal
protection. Developing countries import knowledge from advanced countries by financing students to study abroad who end up contributing to the accumulation of human capital in their home countries. On the one hand, it is beneficial for a developing country to send students to the most advanced country, because more advanced knowledge acquired by students abroad speeds up human capital accumulation. On the other hand, sending students to a host country with excessively advanced knowledge may not promote the chances for a developing country to catch up, because tuition cost in the host country will be very high and few students will be able to afford foreign education. Taking these two counteracting forces into account, we predict that income growth in the home country of students abroad has an inverted-U shaped relationship with the income gap between the home country and a host country. In addition, our model endogenously produces a threshold level of income gap which separates catching-up and falling-behind: the home country will catch up with the host country, if the initial income gap between the two countries is narrower than the threshold. Otherwise, the home country will fall behind the host country even while advanced knowledge is being transferred to the home country.

This paper generalizes the theoretical formulation in endogenous growth models like Lucas (1988), Becker et al. (1990), and Galor and Weil (2000), which do not consider human capital transfer across countries, and extends the analysis in Kim (1998), which studies the growth effect of international knowledge transfer, but does not investigate theoretically and empirically the threshold of income gap for convergence. This paper also goes beyond Kim (1998) by employing more extensive empirical analysis using international panel data.

This paper is organized as follows. Section II presents a theoretical model of knowledge import by students abroad and examines the growth effect of foreign education and the possibility of convergence (catching-up) and divergence (falling-behind) in developing countries.
Section III describes the empirical methodology and tests the implications from section II against international panel data. The threshold level of income gap is also estimated in section III. Section IV contains concluding remarks with some policy implications.

II. Theoretical Model of Knowledge Import

1. The Optimization Problem

Consider an overlapping-generations model where each generation with constant population $L$ consists of homogeneous individuals who live for two periods. Each agent is endowed with one unit of time in the first period that is devoted entirely to working with leisure ignored in utility. In the second period, everyone retires.

Before the first period, each agent acquires human capital from teachers of the previous generation and chooses between two types of occupations: a worker who produces goods or a researcher who creates new knowledge and teaches it to students. We assume that due to specialization in research, each researcher has temporary ownership of new knowledge she creates, but loses the property right in the next period because researchers in the next generation can teach the knowledge after learning it. Note that this assumption is not required for our model’s implications and we only have to assume that at least some part of output from new research endeavor is transformed to revenues for researchers and that knowledge eventually becomes part of the public domain.\[2\]

It is assumed that researchers acquire the highest level of societal knowledge available in that period, $H_t$, while workers get either $H_t$ or $H_{t-1}$. Those who want $H_{t-1}$ will be able to

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2 The assumption that new knowledge is perfectly inappropriable in such growth models as Romer (1990) and Grossman and Helpman (1991) may be proper for disembodied knowledge such as blueprints. However, it is hard to imagine that embodied knowledge is perfectly inappropriable. Each researcher specializes in some specific fields and has to forego income and time to acquire new knowledge others create. An economist may have to devote a significant effort to understand a newly developed theory in biochemistry and preparing to teach it to students.
obtain it for free because knowledge up to that level already belongs in the public domain. Those who want knowledge higher than $H_{t-1}$ must pay, because researchers can appropriate newly created knowledge.

The budget constraints for a representative worker in generation $t$ for the first and the second period are

(1) \[
    c_i^t(h_i) + b^t(h_i) \leq w_i(h_i) - s_i(h_i),
\]

\[
    c_{i+1}^t(h_i) \leq (1 + r_{i+1})b^t(h_i),
\]

where $c_i^t$ and $c_{i+1}^t$ denote the consumptions in the first and the second period, respectively, $s_i$ is the tuition when he wants to obtain $H_i$, $b^t$ denotes savings, $r_{i+1}$ is the interest rate, and $h_i$ is the knowledge or human capital level of individual $i$, which is either $H_i$ or $H_{i-1}$. With the assumption that consumption goods are produced by human capital with linear technology, the wage rate is set as $w_i(h) = mh$ ($m>0$).

A researcher borrows in the first period to pay for consumption and tuition, and collects research revenue in the next period. Her budget constraints in both periods are

(2) \[
    c_i^t(h_i) + b^t(h_i) \leq -s_i(h_i)
\]

\[
    c_{i+1}^t(h_i) \leq (1 + r_{i+1})b^t(h_i) + \Pi_i,
\]

where $\Pi_i$ denotes research revenue that will be defined later in this section, and $h_i = H_i$ for researchers. A representative agent maximizes the utility function:

\[
    \max_{c} \log c_i^t(h_i) + \beta \log c_{i+1}^t(h_i),
\]

subject to the budget constraints and $c^t = (c_i^t, c_{i+1}^t) \geq 0$, given $w_i$, $r_{i+1}$, $s_i$.

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3 Our model’s main implications can be derived under more general functional forms of utility such as that with constant intertemporal elasticity of substitution.
As in Becker and Murphy (1992), we assume that a large number of specialized research fields are combined to create societal knowledge. A continuum of research fields, indexed by $\omega \in [0,1]$, are equally difficult in undertaking, and the research output in each field is produced by the same production function. Each field is occupied by one researcher, and each researcher, being homogeneous, conducts research in an equal set of fields. The accumulation of societal knowledge is based on the following Leontief production function:

\begin{equation}
H_{t+1} - H_t = \min_{\text{fields}}\{H_{t+1}(\omega) - H_t(\omega)\} = \min_{\text{fields}} z_t(\omega)e_t(\omega),
\end{equation}

where $H_t$ is the level of societal knowledge in period $t$, and $H_t(\omega)$ is the knowledge level in research field $\omega$ in period $t$. New knowledge in research field $\omega$ is produced by time devoted in research, $z_t(\omega)$, and a researcher’s productivity for each unit of time, $e_t(\omega)$.

We denote the equal set of fields each researcher specializes in as $\Omega_t$, which should be equal the inverse of the number of researchers in generation $t$, $L_r$. The productivity of a researcher depends on her knowledge level and the degree of specialization:

\begin{equation}
e_t(\omega) = \varepsilon H_t \Omega_t^{-\gamma}, \quad \varepsilon > 0.
\end{equation}

The gain (or loss) from specialization is captured in this function by the term $\Omega_t^{-\gamma}$. When $\gamma > 0$, specialization in a smaller set of fields by each researcher raises productivity. On the other hand, when $\gamma < 0$, an increase in specialization lowers research productivity, possibly due to rising coordination cost. Since each field is equally difficult, each researcher allocates her research time uniformly for her specialized fields. Therefore,

\begin{equation}
z_t(\omega) = u_t \Omega_t^{-1},
\end{equation}

where $u_t (\in [0,1])$ denotes the total time spent in research. We assume henceforth that $\gamma > -1$, because more researchers would slow down human capital accumulation if $\gamma \leq -1$. 
A researcher uses her time endowment for teaching as well as for research. Let $k_{r,1}$ denote the maximum number of students whom a researcher can teach, which is proportional to the time spent in teaching, $(1-u_t)$:

$$k_{r,1} = \kappa (1-u_t)^{\zeta} \quad \kappa > 0, \quad \zeta > 0.$$  

Since all agents are homogeneous and each researcher has exclusive ownership of the knowledge she creates for one period, the wage differentials between the more educated with $H_t$ and the less educated with $H_{t-1}$ will be paid to teachers. Research revenue is, therefore, the product of the number of students and each researcher’s share of the wage differentials:

$$\Pi_t = \max_{u_t} k_{r,1} \Omega_t \left[w_{r,1}(H_{t+1}) - w_{r,1}(H_t)\right] = \max_{u_t} \kappa (1-u_t)^{\zeta} m u_t H_t \Omega_t^{-\gamma}.$$  

The research revenue maximization problem yields

$$u_t = u = 1/(1 + \zeta).$$

The present value of income net of tuition cost should be the same regardless of whether it is for a researcher, or for a worker. Therefore,

$$\Pi_t - (1 + r_{t,1}) \left[w_t(H_t) - w_t(H_{t-1})\right] = (1 + r_{t,1})w_t(H_{t-1}).$$

From the utility maximization problem for a representative agent and equation (8), the optimal consumption levels in both periods are

$$c'_t = \frac{1}{1+\beta} w_t(H_{t-1}) \quad \text{and} \quad c'_{t-1} = \frac{\beta (1+r_{t,1})}{1+\beta} w_t(H_{t-1}).$$

2. Equilibrium Outcomes

The equilibrium conditions consist of equations (3)–(5) and (7)–(10), along with the following market-clearing conditions.

$$L c'_t + L c'_{t-1} = m H_t \rho_t L_{pt} + m H_{t-1} (1-\rho_t) L_{pt} \quad \text{(Goods market),}$$
(12) \[ L_{pt}\left[w_t(H_{t-1}) - c_t^r\right] + L_{rt}\left[-w_t(H_t) + w_t(H_{t-1}) - c_t^r\right] = 0 \] (Credit market),

(13) \[ L = L_{pt} + L_{rt} \] (Labor market),

(14) \[ \rho_{t+1}L_{pt+1} + L_{rt+1} = \kappa(1 - u_t)^\zeta L_{rt} \] (Education market),

where \( L_{pt} \) is the total number of workers in generation \( t \) and \( \rho_t \) is the fraction of more-educated workers in \( L_{pt} \). Using equations (7)–(9) and the equality \( \Omega_t = 1/L_{rt} \), we get

(15) \[ \left(1 + r_{t+1}\right) = \kappa\varepsilon\zeta\left(1 + \zeta\right)^{-1-\zeta} L_{rt}^\gamma. \]

From equations (3)–(5), (10), and the credit and the labor market clearing conditions,

(16) \[ L_{rt} = \frac{\beta L}{1 + \beta} \cdot \frac{H_{t-1}}{H_t}. \]

Then the law of motion for \( H \) becomes

(17) \[ H_{t+1} - H_t = \alpha u H_t L_{rt}^{1+\gamma} = \alpha u H_t \left(\frac{\beta L}{1 + \beta}\right)^{(1+\gamma)} \left(\frac{H_t}{H_{t-1}}\right)^{-1-\gamma}. \]

The equilibrium dynamics and the conditions for stability and uniqueness of a steady state are described in Appendix A.

3. Foreign Education

Students in a developing country have two options in the location of education: studying at home or abroad in a developed country whose societal knowledge \( H_t^A \) is higher than that of the developing country and growing at a constant rate, \( g^A.4 \) When studying abroad, students pay tuition to teachers as well as other expenses such as transportation cost. For simplicity foreign students are assumed to obtain the highest level of knowledge in the host country and return

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4 We can generalize our model with multiple destinations for foreign education, which will not change our theoretical implications. See Kim (1998) for the empirical analysis of what factors affect the number of students abroad as well as their destinations.
home to take research jobs.\footnote{See section IV for discussion on non-returning students.} Being homogeneous, all researchers should have the same choice on the location of education.\footnote{If we allow for the heterogeneity among researchers, for example, in financing costs of foreign education, largely due to social status or implicit capital market segmentation, a fraction of researchers may prefer domestic education while others may opt for foreign education. The result of our model is qualitatively the same with or without this generalization.} In our model the knowledge acquired by foreign-educated researchers cannot be simply turned into productive knowledge for home country. Rather, the acquired knowledge needs additional local investment in both its adaptation and transmission through teaching.\footnote{Evenson and Westphal (1995) and Howitt and Mayer-Foulkes (2002) raise the same point in R&D endeavor. Howitt and Mayer-Foulkes write “a country cannot keep up with the frontier merely by copying technologies developed in leading countries, because technological knowledge is often tacit and circumstantially sensitive. Therefore countries that avoided stagnation without performing leading edge R&D must have made significant technology investments to learn, modify, adapt and implement technologies that were originally developed elsewhere.”}

Assuming other expenses of foreign education are proportional to the knowledge level in the host country, $H_i^A$, the total cost for foreign education is

$$\left[w_i^A(H_i^A) - w_i^A(H_{i-1}^A)\right] + \Phi H_i^A = m^A(H_i^A - H_{i-1}^A) + \Phi H_i^A = m^A g^A H_{i-1}^A + \Phi H_i^A,$$

where the first term in the bracket is tuition cost and $\Phi H_i^A$ denotes other expenses.\footnote{Alternatively, foreign tuition cost can be assumed to be proportional to the difference between $w_i(H_i^A)$ and $w_i(H_{i-1}^A)$. This modification will not change the main implications of our model in the following propositions.} The optimal time allocation between research and teaching that maximizes the research revenue for a foreign-educated researcher can be shown identical to that for a domestically educated researcher. The research revenue for a foreign-educated research is thus

$$\Pi_i^f = \kappa(1-u)^\zeta \Omega_i^f \left[w_{t+1}(H_{t+1}) - w_{t+1}(H_t)\right] = \kappa(1-u)^\zeta m^A u H_i^A \left(\Omega_i^f\right)^\zeta,$$

where the research effort $u$ is $1/(1+\zeta)$, $\Omega_i^f$ denotes the set of fields in which each foreign-educated researcher specializes, and should be equal to the reciprocal of the number of foreign-educated researchers, $L_{rt}^f$. The research revenue net of cost for a foreign-educated researcher in the second period is
\[ \Pi_t' = (1 + r_{i,t}) \left( m^A g^A + \Phi (1 + g^A) \right) H_{t-1} = (1 + r_{i,t}) m H_{t-1}, \]

where the equality comes from the no-arbitrage condition between workers and foreign-educated researchers. The number of foreign-educated researchers is determined from the loan market clearing condition:

\[ L_t' = \frac{\beta L}{1 + \beta} \frac{m H_{t-1}}{m H_{t-1} + (m^A g^A + \Phi (1 + g^A) ) H_{t-1}}. \]

Denote the ratio of per capita income in the developed country to that in the developing country as \( q_t \left( = m^A H_{t-1} / m H_t \right) \). Researchers choose foreign education if and only if the net research revenue from foreign education is larger than that from domestic education. Foreign education is preferred to domestic education if and only if

\[ 1 - \frac{H_t}{H_{t-1}} \left( \frac{m}{m^A} \right)^{(1/(1+r))} q_t^{(1/(1+r))} + \frac{H_t}{H_{t-1}} \frac{g^A + \Phi (1 + g^A) / m^A}{g^A + 1} q_t < 0. \]

The following proposition studies the effect of the income gap, \( q_t \), on the growth rate of per capita income in the developing country which imports knowledge through foreign education.

**Proposition 1** Let \( g_t \) denote the growth rate of per capita income, \( m H_t \). The growth effect of the income gap, \( \partial g_t / \partial q_t \), is positive if \( q_t < \frac{H_{t-1}}{H_t} \frac{g^A + 1}{g^A + \Phi (1 + g^A) / m^A} r^{-1} \), and it is negative, otherwise.

**Proof** See Appendix B.

This proposition indicates that, as long as \( \gamma > 0 \), the income growth rate, \( g_t \), and the income gap, \( q_t \), are more likely to be positively related when \( q_t \) is small, but negatively related when \( q_t \) is large. Intuitively, income gap can have two opposing effects on the growth rate in the developing country if there is productivity gain in research specialization, i.e. \( \gamma > 0 \). On the one
hand, a bigger gap reduces the number of foreign-educated researchers, due to higher tuition for foreign education. This makes the income gap adversely affect the growth rate. On the other hand, with the number of foreign-educated researchers given, a bigger gap raises the growth rate, because researchers learn more advanced knowledge and become more productive in creating new knowledge. Proposition 1 shows that the former effect can be dominant when the income gap is large, but the latter effect can be stronger when the gap is small. If \( \gamma < 0 \) (i.e. specialization lowers research productivity due to high coordination cost), both effects work in the same direction so that a bigger gap unambiguously raises the growth rate.

**Proposition 2** Faster income growth in the developed country or higher non-tuition expenses of foreign education lowers the income growth rate in the developing country.\(^9\)

A decrease in the developed country’s growth rate lowers tuition cost, raises the number of foreign-educated researchers, and raises the growth rate in the developing country. A reduction in non-tuition expenses will have the similar effect.

4. Catching-up or Falling-behind

Can the transfer of knowledge via foreign education help a developing country catch up in income with a developed country? When the developing country imports advanced knowledge, its human capital accumulation follows the law of motion:

\[
H_{t+1} - H_t = \alpha u H_t^A \left( \frac{\beta L}{1 + \beta} \cdot \frac{m H_{t-1}}{m H_{t-1} + (m H_{t-1}^A + \Phi (1 + g^A)) H_{t-1}^A} \right)^{1+\gamma}.
\]

Dividing both sides of this equation by \( H_t^A \), and using \( H_t^A = (1 + g^A) H_{t-1}^A \), we have

\[
(1 + g^A) h_{t+1} - h_t = \alpha u \left( \frac{\beta L}{1 + \beta} \right)^{1+\gamma} \frac{m}{m^A} \left( \frac{h_{t-1}}{h_{t-1} + (g^A + \Phi (1 + g^A)/m^A)} \right)^{1+\gamma},
\]

\(^9\) The proof for this proposition is straightforward and will be provided by the author upon request.
where $h_i \left(= mH_i/m^4H_i^4\right)$ denotes the income ratio which is the inverse of income gap, $q_i$. The following two propositions deal with the steady states of the model.

**Proposition 3** Consider the case when $\gamma > 0$. In this case, there exists a locally stable steady state where $h_i = 0$. If $\Gamma_2 \gamma^\gamma (1 + \gamma)^{1+\gamma} < \Gamma_1$ where $\Gamma_1 \equiv g^4 + \Phi(1+g^4)/m^4$, and $\Gamma_2 \equiv \epsilon u \left[(\beta L/(1+\beta))^{1+\gamma} m/(m^4g^4)\right]$, the steady state at $h_i = 0$ is unique. If $\Gamma_2 \gamma^\gamma (1 + \gamma)^{1+\gamma} = \Gamma_1$, there is one additional steady state that is locally unstable. If $\Gamma_2 \gamma^\gamma (1 + \gamma)^{1+\gamma} > \Gamma_1$, two more steady states exist besides that with $h_i = 0$ where the steady state with the smaller steady state value of $h$, $h^*$, is locally unstable while the steady state with the higher value of $h$, $h^{**}$, is locally stable.

**Proof** See Appendix C.

Although importing more advanced knowledge may help a developing country grow faster, this proposition points out that the developing country can still fall behind the developed country from which knowledge is imported if the knowledge level in the developing country is initially too low, relative to that in the developed country. On the other hand, a developing country can catch up with the developed country if the developing country is not far behind. In other words, proposition 3 indicates that there is a threshold in the income ratio that separates catching-up and falling-behind, which is the value $h^*$ defined in this proposition.\(^{10}\) This threshold is more likely to materialize when foreign education is relatively cheaper (i.e. lower value of $\Gamma_1$), or domestic research is more productive (i.e. higher value of $\Gamma_2$) so that the condition $\Gamma_2 \gamma^\gamma (1 + \gamma)^{1+\gamma} \geq \Gamma_1$ is satisfied, because the developing country can then afford more foreign-educated researchers or human capital can accumulate faster with higher productivity of researchers. When $\gamma \leq 0$, we can show that there exist two stable steady states and thus no threshold level of the income ratio.

\(^{10}\) Evidently, the threshold is meaningful only when $h^*$ is less than 1.
Based on numerical simulations of the model, Figure I shows simulated trajectories of the income ratio $h$ over time for two different cases with different initial values of $h$ (see the note in the figure for parameter values used in the simulations). Starting with the initial income ratio that is low enough, the developing country falls over time behind the developed country that exports knowledge (see the curve titled “Divergence”). Note that the developing country eventually abandons foreign education in this case, and switches to domestic education in the 25th period. The developing country that starts with the initial income ratio high enough catches up with the developed country (see the curve titled “Convergence”).

What factors determine the threshold of catch-up and falling-behind? The following proposition addresses this question.

**Proposition 4** The threshold level $h^*$ gets higher when non-tuition cost of foreign education or the growth rate in host country rises: $\partial h^*/\partial \Phi > 0$ and $\partial h^*/\partial g_A > 0$.

**Proof** See Appendix D.

Proposition 4 shows that the threshold level is higher so that catching-up is harder (i) when non-tuition cost of foreign education is higher, or (ii) when the income growth rate is higher in the developed country so that tuition cost is higher.

### III. Empirical Findings

In this section, we test our theoretical implications against international panel data. We measure the number of foreign-educated researchers in our theory by the flow of students abroad who study in foreign institutions of higher education. Data on the annual bilateral flows of students who study abroad at the tertiary level are taken from *Statistics of Students Abroad*, published by the UNESCO. The data that are available in 92 countries for three years (1969, 78,
and 85) indicate that the size of students abroad is substantial. In 1985, for example, there was on average one student who studied abroad for every 4 students at the domestic tertiary level in our sample countries. Note that this size of students abroad may be of more importance than appears since the ratio of graduate students to undergraduates in foreign education is much higher than in domestic tertiary education.\footnote{For evidence, see \textit{Open Doors}, various years, Institute of International Education.}

We measure the income gap, $q_i$, by the ratio of per capita GDP in home country $i$ to the average per capita GDP in all host countries where country $i$ sent students (GAP):

$$\text{GAP}_i = \frac{\sum_{j=1}^{J_i} n_{ijt} \left( \frac{I_{jt}}{I_{kt}} \right)}{\sum_{j=1}^{J_i} n_{ijt}} \quad (t = 1969, 78, \text{ or } 85),$$

where $n_{ijt}$ is the number of students abroad in year $t$ from home country $i$ to host country $j$, $I_{kt}$ is real per capita GDP in year $t$ for country $k$, $J_i$ denotes the number of host countries where home country $i$ sent its students. As a measure for the income growth rate in host country, $g^d$, we use

$$\text{HOSTGTH}_i = \frac{\sum_{j=1}^{J_i} n_{ijt} g_{jt}}{\sum_{j=1}^{J_i} n_{ijt}},$$

where $g_{jt}$ is the average per capita GDP growth rate over the period from year $t$ to $(t+7)$ for host country $j$. We use a 7-year interval in creating this and other variables, because 7 years is the shorter year gap of the two: 9 (1969-1978) and 7 (1978-1985).

To control for the cost of foreign education, our explanatory variables include the average distance between home country and all host countries (DIST),\footnote{Distance is shown in Redding and Schott (2003) to be an important factor for economic development.} trade openness in host countries over the period from year $t$ to $(t+7)$ (HOSTOPEN), dummy variables for whether the same language is used in both home country and host countries (LANG), for whether the two countries
have the same religion (RELI), and for whether either country was once a colony of the other country (COLONY).

Additional explanatory variables included in our analysis are: average schooling years in the population (SCHYR), the GDP share of domestic investment (INV), the population growth rate (POPGTH), and several policy variables such as the GDP share of government spending (GOV), the openness measure in home country (OPEN), and the inflation rate (INFLA). Definitions, data sources and summary statistics for all variables are reported in Table II.

1. Growth Regression

Our basic specification is a linear model with country-specific fixed-effects:

\[ GTH_{it} = \alpha_0 + \alpha_1 GAP_{it} + \alpha_2 GAP_{it}^2 + \beta X_{it} + \omega_{it}, \]

where the dependent variable is the average growth rate of real per capita GDP in a student-sending country over a 7-year lead period, \( \alpha_0 \) is a vector of country-specific dummy variables, and \( X_{it} \) is a vector of regressors. The error term \( \omega_{it} \) is a white noise to be distributed i.i.d. with zero mean. As part of our sensitivity analysis, this paper uses various types of regression specifications, including a model with country-specific random effects and a two-stage least squares regression with fixed effects.

Table III shows our findings from the growth regression analysis. As a benchmark case, model 1 includes only those regressors that are identified as explanatory variables in earlier studies (for example, see Barro and Lee, 2003). In model 2, we add two key regressors of our interest to the benchmark model: income gap and income gap squared. To control for variations in physical capital level, we include in this model as an additional regressor the ratio of the weighted average of the GDP shares of domestic investment in host countries to that in home country (INVGAP). In model 3, the regressors include the number of students abroad as a ratio
to population and the income gap variable to directly estimate the growth effect of students abroad. Note that we exclude the income gap squared in this model per our human capital production function.

Instead of fixed effects, we employ alternative specifications with random effects and with no country-specific effect in model 4 and 5, respectively. Model 6 includes additional regressors that are related to the cost of foreign education. Since the fixed-effects specification captures only within-country variations in our regressors, we also try a specification that captures only between-country variations in the regressors in model 7 by using the income growth rate as the dependent variable and other regressors with all variables averaged over the entire data period.

To account for the endogeneity of both INV and POPGTH in our regressions where they enter as the averages over the sample period, we employ a 2SLS estimation procedure. In models 8 and 9, we re-estimate models 6 and 7 via 2SLS, treating INV and POPGTH as endogenous. We expect INV and POPGTH to be endogenous in income growth regressions, because various factors will simultaneously influence the decisions on human capital investment, physical capital investment and the quantity of children. Instrumental variables used in the first-stage regressions to derive the estimated values of INV and POPGTH (in addition to the included exogenous variables) are one-period lagged values of INV and POPGTH.

The results in all the models of Table III indicate that the income growth rate in home country has an inverted-U shaped relationship with the income gap variable. This finding is consistent with our prediction in proposition 1 when \( \gamma > 0 \) and lends support to the case that research specialization improves research productivity. A larger gap can help speeding up knowledge accumulation in home country. On the other hand, if the gap is too big, the import of

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13 There is now a long list of papers in the growth literature that recognize the endogeneity of human capital and physical capital investment, and fertility. For example, see Becker et al. (1990) and Galor and Weil (2000).
more advanced knowledge can slow down the accumulation because of higher costs and fewer foreign-educated researchers. This relationship is statistically significant in all specifications, including fixed-, random-effects models, and 2SLS models. The growth effect of students abroad is shown in model 3 to be significantly positive. Controlling for the number of students abroad, the result in this model shows that the income gap variable still has a significantly positive effect on income growth.

The ratio of the GDP shares of domestic investment, INVGAP, generally shows an insignificant effect on host country’s income growth. As a proxy for the initial income level or the development stage, SCHYR has an adverse effect on income growth whenever the effect is significant. Higher investment rate in home country leads to faster physical capital accumulation and, thus, faster income growth, which is confirmed in Table III by the coefficient associated with INV. Based on the quantity-quality tradeoff theory of children, we expect high fertility, or fast population growth will have an adverse effect on human capital accumulation and, therefore, income growth. The result in Table III is generally consistent with this story. The GDP share of government spending GOV shows a significantly adverse effect on growth, possibly due to a negative effect of taxation, which is also shown in earlier studies in the growth literature. Home country’s trade openness is argued to have a positive effect on growth, and the coefficient associated with OPEN is shown in Table III to have a positive, but marginally significant effect. The effect of INFLA is insignificant in this table.

We expect that higher transportation cost due to longer distance from home country to

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14 The results in Table III indicate that the growth rate reaches its maximum point in this inverted-U shaped curve when GAP is about 15.
15 See Kim (1998) for more evidence of the effect of students abroad on economic growth in their home country.
16 We use the initial human capital level in stead of initial per capita income due to a “regression fallacy bias” noted by Friedman (1992): countries with higher than expected per-capita income at an initial period are likely to regress towards the means in later years, exerting a downward bias. We mitigate the potential bias by using average schooling years to account for the development stage.
host country will result in fewer foreign-educated researchers and slower knowledge accumulation at home. The coefficient associated with DIST shows an expected effect, albeit marginally significant only in models 6 and 8. If language and religion similarities are considered as non-pecuniary cost factors in foreign education, they are predicted to have positive effects on growth (see Proposition 2). The predicted effect of language similarity is confirmed in models 6 and 8 where the effects are significant. But religion similarity shows no significant effect. The result in Table III indicates that income growth in home country is slower when more students are sent to the country that the home country used to a colony of, given the number of students constant. This may be because selecting as the destination for foreign education the country that the home country used to a colony of is generally motivated by political consideration, not by economical one. Economic openness in host country can influence the cost of foreign education and, thus, student exchange. Variable HOSTOPEN is shown in Table III to have a positive effect on growth in the home country. Table III shows no significant effect of host country’s growth rate on home country’s growth rate.

2. Threshold Estimation

In Table IV, we estimate the threshold level of the income ratio $h$ that separates convergence (catching-up) and divergence (falling-behind). A country is categorized as a divergence case if its per capita income growth rate is lower than the average per capita income growth rate in host countries where the country sent students. Using this binomial variable as the dependent variable, we estimate the following univariate logit model with random effects:

$$y_{it} = 1 \quad \text{if} \quad \pi GAP_{it} + \lambda' X_{it} + \varepsilon_{it} > 0,$$

$$y_{it} = 0 \quad \text{if} \quad \pi GAP_{it} + \lambda' X_{it} + \varepsilon_{it} \leq 0,$$
where \( y_n \) is the binary variable for divergence (falling-behind), \( \pi \) and \( \lambda \) are coefficient parameters, and \( \varepsilon_n \) is an error term which includes country-specific random effects component. The threshold level of the income ratio \( h \) can be estimated by \(-\frac{\pi}{\lambda} \bar{X}\) where \( \bar{X} \) is a vector of the sample medians of the regressors. To check the sensitivity of the result to our model specification, we alternatively estimate a probit model with random effects (model 2).

Model 1 is the simplest specification where \( X_n \) includes only the constant term and INVGAP. The estimated threshold value of the income ratio \( h \) is 0.2064 in this model. According to this estimation, about 59 percent of observations in our data have the income ratio below the threshold. The threshold values are predicted in other models to be quite close to that in model 1, ranging from 0.16 to 0.22.

Models 3 and 4 include additional regressors that may affect the threshold level. According to Proposition 4, higher cost of foreign education raises the threshold level because a home country can afford to send fewer students. However, most of the variables related to foreign education cost are not significant in these models. Not surprisingly, the coefficient associated with each regressor in model 3 or 4 has the opposite sign to the corresponding coefficient for the same variable in Table III since a factor that exerts a positive effect on growth will lower the probability of divergence.

IV. Concluding Remarks

Why are some developing countries unable to take advantage of their backwardness in knowledge and catch up with developed countries in a world where countries are getting more interconnected through trade in goods and people? This paper was motivated by the observed income divergence across some countries along with income convergence among other countries.
Unlike earlier models that explained this phenomenon with the idea of an exogenous barrier to absorbing advanced knowledge or with the conception of imitation-innovation switch, this paper offers a model within a human-capital-based growth framework that endogenously produces a threshold level of income gap which separates convergence (catching-up) and divergence (falling-behind). Importing more advanced knowledge improves a developing country’s chance of catching up with a developed country. However, an excessively wide knowledge level difference between the two countries can keep the developing country from catching up, because few students will be able to afford education abroad. These two counteracting forces give rise to an endogenous threshold level of income. Furthermore, our model predicts that the relation between income gap and income growth in home country will assume the form of an inverted-U schedule.

Another important contribution of our model is that it provides an explicit mechanism for knowledge transfer across borders and analyzes its effect on economic growth unlike the earlier models that assume an inexplicit process of externality in knowledge transfer.

Our empirical results find the inverted-U shaped relationship between income growth and income gap, which is consistent with the theoretical prediction. This paper also provides an estimate of the income gap threshold: a developing country whose per capita income is less than about 20 percent of the host country’s income is likely to fall behind. It should be noted, however, that the threshold can vary for different developing countries because it depends upon such factors as transportation cost.

While the empirical results generally support the implications of our theoretical model, we have left a number of issues unaddressed. First, our theory does not consider non-returning students or the brain drain problem. The existence of non-returning students, however, would
reinforce the adverse effect of income gap on convergence. If foreign students tend to stay abroad after studying in a more advanced country, divergence in developing countries is more likely. Second, our model abstracts from capital market imperfection and assumes that every agent can borrow to finance education. Imperfect capital market will lead to a higher chance of divergence in our model, due to the fact that it is likely that there are fewer students who can afford foreign education, as implied by Abramovitz (1986). This aspect is not considered because introducing capital market imperfection to our model would shed little new light on our story, unless the model addresses endogenous mechanism of capital market development in the economic growth process.

An interesting question in regard to foreign education, which is not explicitly addressed in our model, is why students from developing countries typically travel to teachers in developed countries, rather than the other way around. One possible explanation is that researchers have more positive externality from other researchers and are more productive in creating new knowledge when surrounded by more knowledgeable colleagues. In our model, we assume that knowledge accumulation depends on the number of colleague researchers due to specialization in research. If we extend the model to assume that knowledge accumulation is affected by the knowledge level of colleagues as well as by their number, sending students to more advanced countries will pay more, but the aforementioned two counteracting forces and thus the model’s implications will prevail.

Our study suggests a few policy implications. Developing countries with very low knowledge or income levels should not select the most advanced countries for knowledge import. Instead, they should opt for moderately advanced countries. Second, governments in developing countries should provide financial aids to students abroad at least until those countries achieve
the level of human capital high enough for catching-up. Third, selecting host countries which are close in distance or have similar cultural backgrounds may also help maximize the benefit of knowledge import for developing countries.
Appendix

A. Denote \( z_t = \frac{H_t}{H_{t-1}} \). From equation (17), \( z_{t+1} = 1 + \alpha u \left( \beta L / (1 + \beta) \right)^{1+\gamma} \left( z_t \right)^{-1-\gamma} \). The following diagram shows the dynamics of this first-order difference equation when \( \gamma > 0 \). For the existence and the stability of the steady state where \( z_t \) is constant over time, the slope of curve A in the neighborhood of point E should be less than one in absolute value. The condition is \( (1+\gamma)(1-1/z^*) < 1 \) where \( z^* \) is the steady state value. This condition is automatically satisfied when \(-1 < \gamma \leq 0\).

![Diagram showing the dynamics of the first-order difference equation](image)

B. Proof of Proposition 1.

The income growth rate is \( g_t = \alpha u \left( \frac{\beta L}{1 + \beta} \right)^{1+\gamma} \frac{m^d q_t}{m^d} \left[ 1 + \frac{H_t}{H_{t-1}} \cdot \frac{g^d + \Phi(1+g^d)}{g^d + 1} q_t \right]^{-1-\gamma} \). If we take the partial differentiation of the growth rate with respect to \( q_t \), we have

\[
\frac{\partial g_t}{\partial q_t} = (1-\gamma) \frac{H_t}{H_{t-1}} \frac{g^d + \Phi(1+g^d)}{g^d + 1} q_t.
\]

C. Proof of Proposition 3.

From equation (18), a steady state value of \( h \) should satisfy the equation:

\[
(18a) \quad (1+g^d)h - h = \alpha u \left( \frac{\beta L}{1 + \beta} \right)^{1+\gamma} \frac{m^d}{m^d} \left( \frac{h}{h + (g^d + \Phi(1+g^d)/m^d)} \right)^{1+\gamma}, \text{ or}
\]

\[
(18b) \quad h = \Gamma_2 \left( \frac{h}{h + \Gamma_1} \right)^{1+\gamma},
\]

where \( \Gamma_1 = g^d + \Phi(1+g^d)/m^d \), and \( \Gamma_2 = \alpha u \left( \beta L / (1 + \beta) \right)^{1+\gamma} m / (m^d g^d) \).

There is thus a steady state at \( h = 0 \) which satisfies the equation. Other steady states can exist at the values of \( h \) that solve the equation:

\[
(18c) \quad h + \Gamma_1 = \Gamma_2 \left( \frac{h}{h + \Gamma_1} \right)^{1+\gamma} h^{\gamma(1+\gamma)}.
\]

We can graphically show the solutions of equation (18c) in the following diagram.
Line $A$ and $C$ correspond to the left-hand side and the right-hand side of equation (18c), respectively. Line $B$ is tangent to $C$ with the same slope as line $A$ which is one. We can show that

$$v_1 = \Gamma_2 \gamma (1 + \gamma)^{(1 + \gamma)}$$

and $v_2 = \Gamma_2 \gamma (1 + \gamma)^{(1 + \gamma)}$.

If $v_2 < \Gamma_1$, equation (18c) does not have a solution and $h=0$ is the unique steady state. There exist one more steady state at $h=v_1$ if $v_2 = \Gamma_1$. If $v_2 > \Gamma_1$, there are two additional steady states at $h = h^*$ and $h^{**}$ where it can be shown that $h^* < \gamma \Gamma_1 < v_2$ and $h^{**} > v_2$.

To check the stability of the steady states, let $x_t = h_t$, $y_t = h_{t-1}$. We can then transform equation (18) to a system of simultaneous first-order difference equations:

$$x_{t+1} = \frac{1}{1 + g^d} x_t + \frac{g^A}{1 + g^d} \Gamma_2 \left( \frac{y_t}{y_t + \Gamma_1} \right)^{(1 + \gamma)} = f(x_t, y_t)$$

$$y_{t+1} = x_t \equiv g(x_t, y_t)$$

Denote the matrix of first-order derivatives of this simultaneous difference equation system as $J$:

$$J = \begin{bmatrix} f_x & f_y \\ g_x & g_y \end{bmatrix} = \begin{bmatrix} \frac{1}{1 + g^d} \left(1 + \gamma\right) g^d & \frac{1}{1 + g^d} \Gamma_2 \left(\gamma \Gamma_1 \right)^{(1 + \gamma)} \\ \frac{1}{1 + g^d} \Gamma_2 \left(\gamma \Gamma_1 \right)^{(1 + \gamma)} & 0 \end{bmatrix}.$$

We can shown that the eigenvalues of matrix $J$ evaluated at $(x_t, y_t) = (0,0)$ are zero and $1/\left(1 + g^d\right)$ which are both less than 1 in absolute value. Therefore, the steady state at $h=0$ is locally stable. The steady state at $h = v_1$ when $v_2 = \Gamma_1$ can be shown to be locally unstable since one of the eigenvalues is equal to one. In case where we have two more steady states besides $h=0$, we can also show that the steady state at $h = h^*$ is unstable and the steady state at $h = h^{**}$ is stable.

**D. Proof of Proposition 4.**

Suppose $v_2 > \Gamma_1$ and thus $h = h^*$ satisfies equation (18b) in appendix C. Total differentiating equation (18b) with respect to $h^*$, $\Gamma_1$, and $\Gamma_2$, we have

$$\left(1 + \gamma\right) \left(h^* + \Gamma_1\right)^{(1 + \gamma)} = -1 \left(h^* + \Gamma_1\right)^{(1 + \gamma)} d\Gamma_1 + \left(h^* + \Gamma_1\right)^{(1 + \gamma)} d\Gamma_2.$$
\[ \frac{\partial h^*}{\partial \Gamma_1} > 0 \text{ and } \frac{\partial h^*}{\partial \Gamma_2} < 0. \]

\[ \frac{\partial h^*}{\partial \Phi} > 0 \text{ follows from the first inequality. } \frac{\partial h^*}{\partial g^A} > 0 \text{ comes from the fact that } \frac{\partial \Gamma_1}{\partial g^A} = 1 + \Phi/m^4 > 0, \]

and \[ \frac{\partial \Gamma_2}{\partial g^A} = -\Gamma_2/g^A < 0. \]
Bibliography


Heston, Alan, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), 2002.


Parameter values used in these simulations are: $\gamma = 2$, $\beta = (0.985)^{20}$, $g^A = (1.015)^{20} - 1$, $m^A = m$, $\Phi/m = 0.03/(1+g^A)$, $\varepsilon u L_r (1+\gamma)^{-1} = g^A(L_r/L)^{-1-\gamma} = g^A(0.3)^{-1-\gamma}$. One time period is 20 years. The equation $\varepsilon u L_r (1+\gamma)^{-1} = g^A(L_r/L)$ is from the assumption that the host country is on the balanced growth path without knowledge import: i.e. $\varepsilon u L_r (1+\gamma)^{-1} = g^A$. The host developed country is assumed to grow at the annual rate of 1.5 percent. The ratio of researchers to total labor is assumed to be 0.3.
### Table I  Cross-Country Disparity in Per Capita Income

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of countries included</th>
<th>GINI Coefficient</th>
<th>P90/P10</th>
<th>P90/P75</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>110</td>
<td>0.4699</td>
<td>10.7360</td>
<td>2.0677</td>
</tr>
<tr>
<td>1970</td>
<td>115</td>
<td>0.4900</td>
<td>13.7530</td>
<td>1.8667</td>
</tr>
<tr>
<td>1980</td>
<td>124</td>
<td>0.4928</td>
<td>15.9210</td>
<td>1.9483</td>
</tr>
<tr>
<td>1990</td>
<td>135</td>
<td>0.5092</td>
<td>21.1200</td>
<td>1.8233</td>
</tr>
<tr>
<td>2000</td>
<td>133</td>
<td>0.5108</td>
<td>25.2880</td>
<td>2.0857</td>
</tr>
</tbody>
</table>

Note: The inequality measures in this table are calculated from the *Penn World Table* data (2002). A country is taken as a basic unit of observation.

### Table II  Variables used and summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTH</td>
<td>Average growth rate of real per-capita income over a 7-year lead period (1969-76, 78-85, or 85-92) [PWT]</td>
<td>1.58</td>
<td>3.12</td>
</tr>
<tr>
<td>GTH_ALL</td>
<td>Average growth rate of real per capita income over the period 1969 – 2000 [PWT]</td>
<td>1.64</td>
<td>2.25</td>
</tr>
<tr>
<td>GAP</td>
<td>Weighted average of real per capita incomes in host countries divided by per capita income in home country [PWT]</td>
<td>5.99</td>
<td>5.83</td>
</tr>
<tr>
<td>INVGAP</td>
<td>Weighted average of initial GDP shares of investment in host countries divided by initial GDP shares of investment in home country [PWT]</td>
<td>2.17</td>
<td>2.26</td>
</tr>
<tr>
<td>DIST</td>
<td>Weighted average of distances in 100 kilometers between home country and host countries [MSE]</td>
<td>54.42</td>
<td>32.48</td>
</tr>
<tr>
<td>LANG</td>
<td>Weighted average of dummy variables $L_{ij}$’s where $L_{ij}$ =1 if home country $i$ and host country $j$ have the same language [EB]</td>
<td>0.55</td>
<td>0.40</td>
</tr>
<tr>
<td>RELI</td>
<td>Weighted average of dummy variables $R_{ij}$’s where $R_{ij}$ =1 if home country $i$ and host country $j$ have the same religion [EB]</td>
<td>0.44</td>
<td>0.37</td>
</tr>
<tr>
<td>COLONY</td>
<td>Weighted average of dummy variables $C_{ij}$’s where $C_{ij}$ =1 if home country $i$ used to be a colony of host country $j$ [EB]</td>
<td>0.14</td>
<td>0.23</td>
</tr>
<tr>
<td>HOSTOPEN</td>
<td>Weighted average of openness measures (GDP share of trade volume) in host countries over a 7-year lead period [PWT]</td>
<td>35.5</td>
<td>15.6</td>
</tr>
<tr>
<td>HOSTGTH</td>
<td>Weighted average of average per capita income growth rates in host countries over a 7-year lead period [PWT]</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>SCHYR</td>
<td>Average schooling years in the population 15 years and over in the initial year (1969, 78, or 85) [BL]</td>
<td>4.69</td>
<td>2.75</td>
</tr>
<tr>
<td>INV</td>
<td>Average GDP share of domestic investment over a 7-year lead period [PWT]</td>
<td>15.8</td>
<td>8.91</td>
</tr>
<tr>
<td>POPGTH</td>
<td>Average population growth rate over a 7-year lead period [PWT]</td>
<td>0.02</td>
<td>0.01</td>
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<tr>
<td>GOV</td>
<td>Average GDP share of government spending over a 7-year lead period [PWT]</td>
<td>21.7</td>
<td>12.1</td>
</tr>
<tr>
<td>OPEN</td>
<td>Average openness over a 7-year lead period [PWT]</td>
<td>66.5</td>
<td>45.3</td>
</tr>
<tr>
<td>INFLA</td>
<td>Average inflation rate over a 7-year lead period [PWT]</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>STD</td>
<td>Population share of the number of students abroad [SA]</td>
<td>0.98</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Data source: PWT (Penn World Table, 2002), MSE (map search engine at www.indo.com/distance), EB (Encyclopedia Britannica), BL (Barro and Lee, 1993), SA (Statistics of Students Abroad)
### Table III  Regressions for Economic Growth

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1) GTH Fixed effects</th>
<th>(2) GTH Fixed effects</th>
<th>(3) GTH Fixed effects</th>
<th>(4) GTH Random eff.</th>
<th>(5) GTH OLS</th>
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</thead>
<tbody>
<tr>
<td>GAP</td>
<td>0.6576</td>
<td>0.2097</td>
<td>0.3283</td>
<td>0.3177</td>
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<tr>
<td></td>
<td>3.10</td>
<td>2.48</td>
<td>2.58</td>
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<td></td>
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<tr>
<td>GAPSQ</td>
<td>-0.0158</td>
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<td>-0.0129</td>
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</tr>
<tr>
<td></td>
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<td>INVGAP</td>
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<td>0.33</td>
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<tr>
<td></td>
<td>-3.98</td>
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<td>-2.66</td>
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<tr>
<td>INV</td>
<td>0.1534</td>
<td>0.1173</td>
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<td></td>
<td>4.11</td>
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<td>POPGTH</td>
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<td></td>
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<td>1.04</td>
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<td>INFLA</td>
<td>0.0191</td>
<td>0.0443</td>
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<td></td>
<td>0.29</td>
<td>0.51</td>
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| Adj. R-sq | 0.2897 | 0.2608 | 0.2570 | 0.2907 | 0.2660 |
| Observations | 278    | 202    | 202    | 202    | 202    |

Note: Rows show the estimated coefficient $\beta$ and $\beta/S_\beta$ for each variable where $S_\beta$ is standard deviation.

Countries included in this and the next table: Algeria, Benin, Botswana, Cameroon, Central African Republic, Egypt, Gambia, Ghana, Kenya, Lesotho, Malawi, Mali, Mauritius, Mozambique, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, Uganda, Congo, Zimbabwe, Hong Kong, India, Iran, Israel, Japan, Jordan, Korea, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Barbados, Canada, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Trinidad and Tobago, United States, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela, Australia, Fiji, Indonesia, New Zealand, Papua New Guinea, China, Hungary, Poland.
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Predicted threshold | 0.2064 | 0.2152 | 0.1599 | 0.1805 |
Log likelihood     | -157.35 | -157.66 | -137.82 | -108.54 |
Observations       | 242    | 242    | 215    | 187    |

Note: Rows show the estimated coefficient $\beta$ and $\beta/S_{\beta}$ for each variable where $S_{\beta}$ is standard deviation.