A Survey on the Relationship between Education and Growth with Implications for Developing Asia

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Abstract

This paper surveys the empirical and theoretical link between education and growth in the growth process of Asian countries. Particular attention is paid to the link between education and productivity, and to models that characterize key features of growth processes of Asian countries. Empirical studies show that these key features include liability to falling into poverty traps, focusing more on technology adoption rather than creation, technology–skill mismatch, and technology-appropriate capital. The surveyed studies provide policy implications for each of these features as follows. To avoid the poverty trap and for efficient adoption of technologies, accumulation of human capital—specifically general human capital—and width of human capital are crucial. To avoid the technology–skill mismatch, the speed of technology upgrading should be appropriate to take full advantage of learning-by-doing and the earning potential of the current stock of specific human capital. Finally, depending on the stage of development, countries should properly balance investments between general and specific human capital, width and depth of human capital, basic and development research, and primary and secondary and tertiary education.
I. Introduction

“Until the 1950s economists generally assumed that labor power was given and not augmentable. The sophisticated analyses of investments in education and other training by Adam Smith, Alfred Marshall, and Milton Friedman were not integrated into discussions of productivity. Then T. W. Schultz and others began to pioneer the exploration of the implications of human capital investments for economic growth and related economic questions. Human capital analysis starts with the assumption that individuals decide on their education, training, medical care, and other additions to knowledge and health by weighing the benefits and costs. Benefits include cultural and other non-monetary gains along with improvement in earnings and occupations, while costs usually depend mainly on the foregone value of the time spent on these investments.”

Becker (1992, 43)

There are several ways through which human capital—the ability and efficiency of people to transform raw materials and capital into goods and services—affects economic growth. The accumulation of human capital improves labor productivity and increases the returns to capital. A well-educated workforce is also essential for the adoption and diffusion of technology to take place.

Developing Asia's stock of human capital—its well-educated labor force—is often cited as one of the critical factors in the region’s rapid economic growth. This argument is supported by the region's record in educational attainment over the past 4 decades. In 2010, its population aged 15 years and over had an average of 7.8 years of schooling, from just 4.1 years in 1970. Nonetheless, progress in educational attainment has not been uniform across countries and subregions, and the links between education, on one hand, and productivity and income growth, on the other, have not been always clear.

This paper surveys the link between education and growth in the growth process. Particular attention is paid to the link between education and productivity; and models that characterize key features of growth processes of Asian countries will be closely looked at.

The rest of the paper is organized as follows. Section II reviews existing empirical literature to identify key features of education in the growth process of Asian economies...
in particular and developing economies in general. The subsequent four sections review the theoretical literature on each of the identified key features. Specifically, Section III surveys the literature on the technology-adopting role of education and multiple equilibria. Section IV reviews implications arising from the difference between general and specific human capital stocks. Section V discusses the role of composition of human capital in the growth process. Section VI looks at issues related to directed technical change. The final section provides a summary.

II. Review of Empirical Literature

Numerous empirical studies have investigated the link between education and growth and/or productivity. This section highlights several studies deemed particularly important and relevant in identifying the key features relevant to developing economies.

Collins and Bosworth (2003), analyzing data from 84 countries for the period 1960 to 2000, provide empirical evidence that Asian countries show a wide variety of growth processes and patterns. Using their growth accounting of various countries during 1960–2000, we can compare the growth performance among Asian and industrial countries. The People’s Republic of China (PRC) outperformed industrial countries in all three components of income growth: physical capital per capita accumulation, human capital accumulation, and total factor productivity (TFP) growth during 1960–2000; while East Asian countries (except for the PRC) also fared better in the first two components, almost registering equal TFP growth. In contrast, South Asia showed similar performances in the first two components, underperforming in TFP growth. East Asia and South Asia performed slightly better than Latin America and Africa.

Easterly and Levine (2002) characterize key features of global growth processes by five stylized empirical facts. For example, their first stylized fact is that TFP, not capital accumulation, accounts for a substantial fraction of cross-country differences. Their second stylized fact is “There are huge, growing differences in GDP per capita. Divergence—not conditional convergence—is the big story. Over the past two centuries, the big story is that the difference between the richest countries and poorest countries is growing” (Easterly and Levine 2002, 2). The third stylized fact is “Growth is not persistent over time. Some countries ‘take off’, others are subject to peaks and valleys, a few grow steadily, and others have never grown” (Easterly and Levine 2002, 2).

Acemoglu and Zilibotti (2001) highlight the importance of technology–skill mismatch by providing evidence that technology–skill mismatch could explain a large fraction of the observed output per worker variations in the data. Using 27 industry data including Colombia, India, Malaysia, the Philippines, Turkey, and weighted average data of less developed countries, they show that with a higher skill intensity in the United States (US)
of an industry in these countries comes a lower TFP relative to the US. This is because the higher skill intensity rank in the US of the industry of these countries implies that the industry has the higher level of technology, i.e., the technology mismatches the skill of the industry to a large extent. Islam (2010) using a panel data set of 87 sample countries over the period of 1970 to 2004 shows that the effect of skilled human capital on growth increases as the distance to the technology frontier narrows, but this is true only for high- and medium-income countries. They also show that a larger stock of old workers with tertiary education yields higher growth for high- and medium-income countries, while young workers with secondary education do for low-income countries. Ha, Kim, and Lee (2009) also provide empirical evidence, using panel data covering 1989–2000 from Japan; the Republic of Korea; and Taipei, China; as the distance to the technology frontier narrows, basic research and development (R&D) investment (i.e., highly skilled labor) shows the higher growth effect than development R&D investment (i.e., less skilled labor). They also provide evidence that the quality of tertiary education has a significantly positive effect on the productivity of R&D.

Based on these observations, this survey includes models focusing on the topics of multiple equilibria, poverty trap, technology adoption, directed technological change, and distance to the technology frontier.

III. Technology-Adopting Role of Education and Multiple Equilibria

As several researches including Benhabib and Spiegel (1994) show, income growth is not correlated with the growth of human capital but with its level. This implies that the role of human capital in technology adoption and creation, and the complementarity of technology and skill as opposed to their being production inputs, deserves to be more emphasized. This point is nicely elaborated by Easterly and Levine (2002, 10):

Incorporating estimates of human capital accumulation into these aggregate growth accounting exercises does not materially alter the findings. TFP growth still, in the average country, accounts for more than half of output per worker growth. Moreover, the data suggest a weak—and sometimes inverse—relationship between improvements in educational attainment of the labor force and output per worker growth.

Easterly and Levine add, “Benhabib and Spiegel (1994) and Pritchett (1996) show that increases in human capital resulting from improvements in the educational attainment of the work force have not positively affected the growth rate of output per worker. It may be that, on average, education does not effectively provide useful skills to workers engaged...”
in activities that generate social returns. There is disagreement, however. Krueger and Lindahl (1999) argue that measurement error accounts for the lack of a relationship between growth per capita and human capital accumulation. Hanushek and Kimko (2000) find that the quality of education is strongly linked with economic growth. However, Klenow (1998) demonstrates that models that highlight the role of ideas and productivity growth do a much better job of matching the data than models that focus on the accumulation of human capital. More work is clearly needed on the relationship between education and economic development” (Easterly and Levine 2002, 10–11).

Nelson and Phelps (1966) first formalized the idea of the role of human capital in technology diffusion and adoption. Before their work, Schultz (1963, 40) stated similar ideas as “Economic growth, under modern conditions, brings about vast changes in job opportunities. Schooling in this connection is valuable because it is a source of flexibility in making these occupational and spatial adjustments.” Similarly Nelson and Phelps also stated that “education enhances one’s ability to receive, decode, and understand information and that information processing and interpretation is important for performing or learning to perform many jobs” (Nelson and Phelps 1966, 69); and that “the better educated farmer is quicker to adopt profitable new processes and products since, for him, the expected payoff from innovation is likely to be greater and the risk likely to be smaller” (Nelson and Phelps 1966, 70).

A simple scatter plot of initial human capital levels and subsequent TFP growth over 1970–2009 is shown in Figure 1. The raw correlation between these two variables is clearly positive, suggesting that nations with larger initial human capital stocks tend to exhibit higher TFP growth, holding all else constant.
The formal model by Nelson and Phelps (1966) is a single equation indicating that technological improvement is expressed as a cross product of the level of human capital and the technology gap by

\[ \dot{A}(t) = \Phi(h)[T(t) - A(t)] \quad \text{with} \quad \Phi(0) = 0, \quad \Phi'(h) > 0 \]

\[ T(t) = T_0 \lambda^t, \quad \lambda > 0 \]  

where \( T(t) \) represents the technology frontier, \( h \) human capital, and \( \Phi(h) \) the absorptive capacity for new technologies.

This implies that the larger one country’s technology gap is, the more technology spillovers it enjoys. Moreover, the higher level of human capital it has, the higher level of technology it can adopt. Thus, the benefit of education becomes greater with the higher rate of technological change. Additionally this implies that the level of human capital is correlated with the growth, not the level, of income.

Benhabib and Spiegel (1994 and 2005) provide variations of the Nelson-Phelps model and implement empirical studies. Their single equation model (Benhabib and Spiegel 1994) is
where $A_t(t)$ is TFP, $g(H_i(t))$ is the component of TFP growth that depends on the level of education $H_i(t)$ in country $i$, and $c(H_i(t))(\frac{A_m(t)}{A_i(t)} - 1)$ represents the rate of technology diffusion from the leader country $m$ to country $i$.

The above equation representing the technological progress consists of two parts. The first part is an increasing function in human capital representing technology creation. The second part is expressed as a cross product of the level of human capital and the technology gap representing the rate of technology diffusion from the leader country to less developed countries. Technology diffusion and “catch-up” assures that despite scale effects and educational differences, all countries eventually grow at the same rate.

Some economies in developing Asia have in fact benefited from technological spillover effects over the past few decades. The PRC and Thailand, for instance, were far behind the US in TFP in 1970 (Figure 2). But productivity in both countries has grown impressively since, reaching an average TFP growth of above 2%. More to the point, economies with a more educated workforce in 1970 (including Hong Kong, China; Malaysia; and Taipei, China) registered rapid productivity growth between 1970 and 2005, conditional on their distance to the technological frontier, in effect confirming the Benhabib–Spiegel hypothesis.

On the other hand, a counterexample was the Philippines. Endowed with a relatively well-educated labor stock in 1970, the country did not perform particularly well in productivity growth. Son (2008) explains that this may be due to mismatches between skills learned in school and labor market requirements.
Figure 2: Technology Gap with the US and Subsequent Total Factor Productivity Growth, 1970

An alternative logistic model of technology diffusion (Benhabib and Spiegel 2005) has an extra term acting as a technology barrier, to decrease the rate of diffusion as the distance to technology frontier increases (sharing the same idea with Basu and Weil's 1998 “appropriate technology”). An additional assumption of technology barrier derives a logistic relationship. Higher levels of education increase the adoption rate of new technologies, thus raising growth. Lower education levels decrease the adopting rate of new technologies due to technology barriers caused by the lower level of technology.

Basu and Weil (1998) consider a logistic model of diffusion that allows for barriers to imitation, leading to divergence in world income. Their results support the logistic specification for a cross-section of nations from 1960 through 1995. They also find that 22 of the 27 nations whose human capital level is lower than the critical level achieved lower growth over the next 35 years. However, they do not consider the effect of different human capital composition on growth.
Azariadis and Drazen (1990) construct an overlapping generations (OLG) model with physical and human capital. Their basic idea is based on the assumption that aggregate human capital has positive externalities such that there can exist two steady state equilibria.

Figure 3 plots average annual growth in per capita GDP from 1970 to 2005 against a measure of relative labor quality in 1970, the (per capita) GDP-to-education attainment ratio.

The key observation is that no data points appear in the upper right-hand side of the plot, which appears to be consistent with the weaker form of the threshold hypothesis. No country was able to grow quickly during the sample period without the benefit of a highly qualified labor force. And all those that did grow quickly (the PRC, the Lao People’s Democratic Republic, the Maldives, Mongolia, and Viet Nam) in developing Asia possessed a workforce that was exceptionally well qualified, given the starting levels of their per capita incomes.

Figure 3: Growth versus Human Capital, 1970–2005

Figure 3 also displays a “frontier” of economic performance. On this frontier, or close to it, lie countries whose growth rates are the highest given their education-to-per-capita-GDP ratio or, more generally, their development stage. Some countries such as Hong Kong,
China; Singapore; and Thailand are mapped close to the frontier in Figure 3. But others such as Cambodia, Papua New Guinea, and the Philippines keep a good distance below the frontier, which have been expanding much more slowly than the qualifications of their working population would seem to warrant.

The key mechanism of the Azariadis and Drazen (1990) model producing multiple equilibria is human capital production function. It is a usual Uzawa-Rosen type, with the efficiency of human capital accumulation increasing in the level of the aggregate human capital, of

\[ h'_i = (1 + \gamma(\bar{h}_t)u'_t)\bar{h}_t, \text{ with } \gamma' > 0, \]  

where \( h'_i \) is human capital of agent \( i \), \( \bar{h}_t \) the aggregate human capital, \( \gamma \) the efficiency of human capital accumulation, and \( u'_t \) time investment in human capital at time \( t \).

Bowman and Anderson (1963) argue that drawing on data from the 1950s, a literacy rate of 30%–40% is a precondition for rapid growth (Azariadis and Drazen 1990, 513). The mechanism goes as follows.

The low (bad) equilibrium is derived from the following process: An initial amount of the aggregate human capital less than a certain threshold level leads to no investment in human capital since its marginal return is less than its opportunity cost. Thus it ends up in a steady state of a poverty trap without economic growth.

On the other hand, the high (good) equilibrium happens when an initial amount of the aggregate human capital higher than a certain threshold level induces a constant investment in human capital since its marginal return is larger than its opportunity cost. This yields a balanced growth path where income and two capitals increase at a constant rate.

Similarly, Redding (1996) gives an OLG model in which old agents are managers while young ones are workers. Old agents of the previous generation, owning firms, invest in R&D to raise productivity. Meanwhile, young agents of the current generation decide how much to invest in education, depending on labor productivity as determined by the size of R&D investment that old agents make. On the other hand, old agents decide how much to invest by observing the level of education investment of young agents. In the model, output is determined by the cross product of a function increasing in R&D investment and another function increasing in education investment as:

\[ Y = A(R) \cdot F(H), \]  

where \( R \) represents R&D investment, and \( H \) investment in education. The \( \beta \) fraction of output is distributed to old agents, and the rest to young agents, where \( 0 < \beta < 1 \).
Especially with the lumpiness of R&D investment, there can exist multiple equilibria consisting of low education–low R&D investment, and high education–high R&D investment. It is because the lower (or higher) level of one type of investment is executed, the lower (or higher) the marginal product of the other type of investment becomes. This mechanism provides a room for government policies to raise welfare by coordinating these two types of investments.

Basu and Weil (1998) explain the existence of long-term stagnant countries by presenting a model in which technology improvements diffuse only to countries whose technology levels are close to that of the originating country. In other words, more advanced technologies cannot diffuse from rich to poor countries if their technology gaps are large enough.

Basu and Weil describe their main point well as an advance in transportation technology in Japan taking the form of a refinement of the newest train. Such an advance may have very few spillovers to the technology of the transportation sector in Bangladesh, which relies in large part on bicycles and bullock carts.

To model “appropriateness”, Basu and Weil index technologies by capital–labor ratio \( k \). In a closed economy using the technology of capital–labor ratio \( k \), its available technologies improve by

\[
\dot{A}(j,t) = \beta(\Lambda^*(j) - A(j,t)) \quad \text{if} \quad k - \gamma < j < k + \gamma \\
= 0, \quad \text{otherwise.}
\]

where \( \Lambda^*(j) \) represents the technology frontier for the technology of capital–labor ratio \( j \).

The level of technology that is appropriate for capital–labor ratios within a neighborhood band of a country’s current capital–labor ratio increases when producing at some capital–labor ratio.

However, the higher the growth rate one country has, the slower its income can grow, since it has less time to stay in the band of capital–labor ratios whose technologies are being simultaneously improved.

In an open economy, technologies can be simultaneously improved by spillovers from multiple countries having similar capital–labor ratios by

\[
\dot{A}(j,t) = \beta(\Lambda^*(j) - A(j,t)) \sum_i I(k_i - \gamma < j < k_i + \gamma)
\]

where \( i \) represents trading partner countries.

Countries with similar saving rates will show the same growth rate, since the lower-saving countries will get technology spillovers from higher saving ones within this club. But if
countries have very different saving rates, then their growth rates can be quite different. Because of this, countries with various saving rates form a number of different clubs. Each club has different growth rates, while countries within one club converge to an identical income level.

IV. General versus Specific Human Capital

The following quote from Becker (1992, 44) well explains the concepts of general (and (firm-specific) human capital.

One of the most influential theoretical concepts in human capital analysis is the distinction between general and specific training or knowledge (see Becker [1962], and Oi [1962]). By definition, firm-specific knowledge is useful only in the firms providing it, whereas general knowledge is useful also in other firms. Teaching someone to operate an IBM-compatible personal computer is general training, while learning the authority structure and the talents of employees in a particular company is specific knowledge. This distinction helps explain why workers with highly specific skills are less likely to quit their jobs and are the last to be laid off during business downturns. It also explains why most promotions are made from within a firm rather than through hiring—workers need time to learn about a firm’s structure and “culture”—and why better accounting methods would include the specific human capital of employees among the principle assets of most companies.

While Becker’s distinction between the two types of human capital depends on whether knowledge and skills can be applied to other firms, in this section the distinction relies on whether they can be applied to other technologies. In other words, in this section, specific human capital (SHC) can help operate only one specific technology, whereas general human capital (GHC) helps build any type of SHC to operate any technology. This is why GHC lowers the cost of adopting new technologies.

Kim and Kim (2000) formalize the idea of the role of GHC in lowering the cost of technology adoption and of labor migration.

General human capital (\(h^g\)), helping workers adopt any type of industry-specific human capital, accumulates by education through a Uzawa-Rosen type production function of

\[
h_{t+1}^g - h_t^g = Bu_t h_t^g, \tag{7}
\]

where \(u_t\) is the time investment in GHC, and \(B\) the efficiency in the accumulation of GHC.
Specific human capital represents specific skills and know-how to produce goods. GHC can help acquire SHC by helping adopt more efficient technologies through the relationship of

$$ h^i_t = \theta h^o_t $$

where $h^i_t$ represents the SHC for i-sector, and $\theta$ the efficiency of the adoption. This implies that the higher the level of GHC one holds, the higher the level of SHC one can adopt when technological changes occur.

With a ratio of initial GHC to SHC lower than a certain threshold level, one country will get into a poverty trap, since it does not accumulate GHC sufficiently to adopt new technologies. It is not only because a small GHC creates a small SHC, but also because a high level of the current SHC represents a large opportunity cost to be sacrificed when adopting new technologies.

This mechanism also implies that open trade policies can help countries get out of a poverty trap by providing more incentives to accumulate GHC and thus be able to adopt new technologies. It is because an open trade system provides opportunities for each country to migrate to and specialize in the sector with the highest productivity shock among all sectors with different shocks in each period. This specialization is made possible by the accumulation of GHC.\footnote{In Bertocci and Spagat (1998), GHC represents only a superior social status affecting preference, not production opportunities.}

Krueger and Kumar (2004) explain the growth difference between Europe and the US by constructing a theoretical model as well as implementing its calibration. They focus on the different behaviors of investing in general and specific HC. The mechanism of their model goes as follows.

Firms pay higher adoption cost to adopt more efficient technologies. To migrate to firms adopting more efficient technologies, workers must get general education by paying tuition that decreases in their ability. Even though workers with general education sacrifice their labor efficiency, when migrating to high-tech firms, they get higher wages due to higher productivity of the firms. The society's basic technology level is the average technology level across all high-tech firms.

The calibration based on their model finds that the growth difference between European countries and the US is explained mainly by the differences in entry cost, labor firing cost, and education policies. These labor market frictions lower the labor mobility from lower- to higher-technology sectors, decreasing aggregate productivity, wage rates, income, and basic technology level. This inefficiency will increase with the growth rate of available technologies.
Krueger and Kumar (2004, 167) explain: “European education policies that favored specialized, vocational education might have worked well, both in terms of growth rates and welfare, during the 60s and 70s when available technologies changed slowly. However, in the information age of the 80s and 90s when new technologies emerged at a more rapid pace, they might have contributed to suboptimally slow growth and increased the growth gap relative to the US.”

The basic idea of the model is not new: General education helps workers migrate to higher-productivity sectors, increasing growth rate. However, the novelty of Krueger and Kumar’s model is its calibration to explain the growth difference between European countries and the US, based on the differences in labor market frictions and education subsidies.

Ehrlich (2007) shares the identical idea about the economic performance difference between European nations and the US, by focusing on the US political-economic system that can provide higher US yield rates on human capital.

Kim and Lee (2009) explicitly model a micro-mechanism of the role of human capital in technology adoption in the dimension of width and depth of human capital using an OLG model. Width of human capital represents the number of various specific knowledge points that human capital contains.

The key idea of the micro-mechanism is that the more closely one agent’s acquired knowledge is related to the knowledge needed to adopt a new technology, the less time the agent spends in adopting the technology. Wider human capital structure lowers the expected cost of adopting future technologies, because the expected distance between one agent’s acquired knowledge and the knowledge needed to adopt a new technology becomes smaller.

Depth of human capital determines the level of specific skill that helps operate the new technology to be adopted. Higher quality of knowledge, representing depth of human capital and accumulated when young, enables old agents to adopt higher levels of specific skills to run the adopted new technology.

The adoption time cost \( I_{At} \) is described by

\[
I_{At} = \min_{x \in \{N_t \text{ elements}\}} a|x - s| \cdot Q_t, \tag{9}
\]

where \( N_t \) represents the width, \( Q_t \) the depth, and \( s \) the knowledge point of the new technology to be deciphered and adopted.

This setup implies that economies can have different growth paths depending on their initial structure of human capital stock. If one economy’s ratio of width to depth of human
capital is above a certain threshold ratio, thus having a lower technology adoption cost, the agents always increase investment in human capital and adopt new technologies, resulting in higher growth rates of income and human capital. If the ratio is below the threshold ratio and has a higher adoption cost, the economy shows decelerating growth rates of human capital and income over time, resulting in a poverty trap with no human capital accumulation and no technology adoption.

V. Composition of Human Capital and Growth

There are two sources of technological progress, namely, adoption and creation of new technologies. These two sources require different types of human capital, with unskilled human capital better suited to adoption, and skilled to creation. The appropriate composition of human capital for economic growth depends on one country’s development stage proxied by the distance to the technology frontier. Thus, the impact of each type of human capital on growth should depend on a country’s development stage. Also, from the argument of Krueger and Lindahl (2001) that education is statistically significantly and positively associated with subsequent growth only for the countries with the lowest level of education, we can infer that the role, and thus, the impact on growth of different types of human capital can vary depending on one country’s stage of development.

Acemoglu, Aghion, and Zilibotti (2006, 37) motivate their model by saying, “In his famous essay, Economic Backwardness in Historical Perspective, Gerschenkron (1962) argued that relatively backward economies such as Germany, France, and Russia during the nineteenth century could rapidly catch up to more advanced economies by undertaking large investments and adopting frontier technologies. He emphasized that certain ‘non-competitive’ arrangements, including long-term relationships between firms and banks, as well as large firms and state intervention, might facilitate such convergence.”

Acemoglu, Aghion, and Zilibotti present a theoretical model describing the above implication, in which the population consists of fixed fractions of capitalists, managers, and workers. There exist two different business strategies: big investment strategy incurring a considerable fixed cost whose profit is not sensitive to the skill level of the manager; and high-tech business strategy whose scale is small and profitability depends on the manager’s skill to create technologies. The aggregate production function is given by

$$y_t = \frac{1}{\alpha} N_t^{1-\alpha} \left( \int_0^1 A_t(u) u x_t(u) u \, du \right)$$

(10)
where \( At(\nu) \) is productivity in sector \( \nu \), \( x_t(\nu) \) is the flow of intermediate good \( \nu \) used in final good production, \( N_t \) is the number of production workers, and \( \alpha \in (0,1) \). Subscripts mean “time” and is expressed as

\[
A_t(\nu) = S_t(\nu) \left[ \eta A_{t-1} + \gamma_t(\nu) A_{t-1} \right]
\] (11)

where \( S_t(\nu) \in \{\sigma, 1\} \) is the size of the project, with \( S_t(\nu) = \sigma < 1 \) corresponding to a small project and \( S_t(\nu) = 1 \) corresponding to a large project. The term \( \gamma_t(\nu) \) denotes the skill level of the entrepreneur, \( \eta A_{t-1} \) represents technology adoption, while \( \gamma_t(\nu) A_{t-1} \) represents technology creation.

To increase the productivity expressed by equation (11), capitalists want to raise the size of the project with a lower level of their current productivity. This then diminishes the role of technology creation. However, since it necessitates a fixed cost for large investment projects, the market should be protected to a certain level to provide positive earnings to firms. In this case, unskilled managers cannot be screened out, since positive profits protect them to remain in the market. With the continuous protection of the market, the economy can get stuck in a nonconvergence trap especially through long-term relationship and lobbying.

However, equation (11) implies that as the distance to the technology frontier decreases (i.e., \( A_{t-1} \) increases, or technology creation becomes more important than adoption), selecting skilled entrepreneurs becomes more important to increase productivity, relying more on technology creation than adoption.

At this stage, government should make markets more competitive. Then, large projects cannot be undertaken, because competitive earnings cannot support their fixed cost. The model implies that as one country’s distance to the frontier narrows, technology creation, more competitive market policies, and supply of skilled entrepreneurs will become more important.

They also conduct empirical studies, which show that while there is a strong negative relationship between growth and distance to the frontier for countries with high barriers, the relationship is much weaker for countries with low barriers.

Figure 4 highlights a possible technology and skill mismatch. There is a substantial number of economies that still register very low education attainment, while the technology gap has narrowed significantly relative to the US. In developing Asia, countries such as India, Nepal, and Pakistan seem to lack the required level of skills given the narrowed distance from the technology frontier. They may experience the technology and skill mismatch, which would drag economic growth.
Figure 4: Technology and Skill Mismatch in Developing Asia, 2005

- Developing Asia  
- Rest of the World

ARM = Armenia; BAN = Bangladesh; BRU = Brunei Darussalam; CAM = Cambodia; FIJ = Fiji Islands; HKG = Hong Kong, China; IND = India; INO = Indonesia; KGZ = Kyrgyz Rep.; KOR = Republic of Korea; LAO = Lao People’s Democratic Republic; MAL = Malaysia; MLD = Maldives; MON = Mongolia; NEP = Nepal; PAK = Pakistan; PHI = Philippines; PNG = Papua New Guinea; PRC = People’s Rep. of China; SIN = Singapore; SRI = Sri Lanka; TAP = Taipei, China; THA = Thailand; TON = Tonga; US = United States; VIE = Viet Nam.

Note: Data cover 98 economies.
Sources: Park (2010) and Barro and Lee (2010).

Vandenbussche, Aghion, and Meghir (2006) present a theoretical model and implement empirical studies by extending the model of Benhabib and Spiegel (1994) and considering the effect of human capital composition. They also assume unskilled human capital is better suited to technology adoption and skilled human capital to creation ($\sigma > \varphi$). Each type of human capital’s impact on growth depends on a country’s level of technological development (distance to the technology frontier).

Each type of human capital’s impact on growth depends on a country’s level of technological development (distance to technology frontier). Final output $y$ is produced by

$$y_t = \int_0^1 A_{it}^{1-\alpha} x_{it}^\alpha \, di$$

(12)

where $\alpha \in (0,1)$, $A_{it}$ represents the productivity of sector $i$, and $x_{it}$ the intermediate good $i$.

$$A_{it} = A_{it-1} + \lambda [u_{mit}^\sigma s_{mit}^{1-\sigma} (\bar{A}_{i,t-1} - A_{i,t-1}) + \gamma u_{nit}^\varphi s_{nit}^{1-\varphi} A_{i,t-1}]$$

(13)
where $\bar{A}_{t-1}$ is the world productivity frontier; $A_{t-1}$, the country’s productivity frontier at the end of period $t-1$; $u_{nit}$ (resp. $s_{nit}$) the amount of unskilled (or skilled) labor input used in imitation in sector $I$; $u_{nit}$ (resp. $s_{nit}$) the amount of unskilled (or skilled) units of labor used by sector $I$ in innovation; $\sigma$ (resp. $\varphi$) the elasticity of unskilled labor in adoption (or creation); $\gamma > 0$ the relative efficiency of creation compared to adoption in generating productivity growth; $\lambda > 0$ the efficiency of the overall process of technological improvement; and $\sigma > \varphi$. The model implies that the effect of skilled human capital on growth becomes stronger as one country’s distance to the technology frontier narrows.

Using a panel dataset covering 19 countries of the Organisation for Economic Co-operation and Development (OECD) between 1960 and 2000, Vandenbussche, Aghion, and Meghir show that as a country moves closer to the technology frontier, tertiary level education becomes increasingly more important for growth than primary and secondary education, and that the effect of skilled human capital on growth becomes stronger in countries that are closer to the technology frontier.

Ha, Kim, and Lee (2009) present a theoretical model and empirical evidence to explain the observation that a country tends to rely more on technology creation than adoption, and to invest more in basic research than in development (thus in skilled labor than in unskilled), as its distance to the technology frontier narrows.

Ha, Kim, and Lee (2009) unlike Vandenbussche, Aghion, and Meghir (2006) distinguish the process of research into basic and development research, which endogenizes the composition of labor supply with different skill levels.

Using Romer’s variety expansion model, the level of technology is derived as

$$T = G_{C_{t-1}}^{-\alpha^{-1}}((1 + d)\frac{1}{\alpha^{-1}}A_{D_{t-1}}U + \kappa(1 + d + BS)\frac{1}{\alpha^{-1}}A_{C_{t-1}}H),$$

where $G_{D_{t}}$ represents the level of the pool of total basic ideas available for technology adoption at time $t$; $G_{C_{t}}$ that available for technology adoption; $\alpha > 1$, $A_{C_{t}}$ ($A_{D_{t}}$) the level of nonappropriable specific knowledge of the industry accumulated through learning by doing in the technology creation sector (technology adoption sector); $U$ less skilled workers; $S$ skilled workers; $H$ highly skilled workers; $\kappa > 1$; and $d$ represents the distance to technology frontier.

The fraction of technology of $G_{C_{t-1}}^{-\alpha^{-1}}(1 + d)\frac{1}{\alpha^{-1}}A_{D_{t-1}}U$ comes from technology adoption activities, while that of $G_{C_{t-1}}^{-\alpha^{-1}}\kappa(1 + d + BS)\frac{1}{\alpha^{-1}}A_{C_{t-1}}H$ from technology creation. Thus, we can easily see that as the distance to the technology frontier narrows, the relative importance of technology creation (and thus, of highly skilled human capital) increases.
The model shows that economic growth becomes more positively correlated with the level of skilled (or highly skilled) human capital and basic research activities in technology creation, when one country’s distance to the technology frontier gets narrower. It also shows that, as it gets narrower, the more an increase in the efficiency of education system for highly skilled workers raises the level of basic research, the supply of highly skilled labor, and the rate of growth.

Empirical analyses using panel data covering 1989–2000 from Japan; the Republic of Korea; and Taipei, China show that the narrower the distance to the technology frontier, the higher the growth effect of basic R&D (thus, of highly skilled labor). This indicates that the bigger the share of basic R&D matters for economic growth, the narrower the distance to the technology frontier. Finally it also shows that the quality of tertiary education has a significantly positive effect on the productivity of R&D.

Aghion et al. (2009) extend the model of Vandenbussche et al. (2006) into a multisectoral version, and implement empirical studies more carefully, using the US panel data. They avoid an endogeneity problem by using exogenous education expenditures, patents proxies for technology frontier measure, and others. They find positive growth effects of exogenous shocks to investments in 4-year college education for all states. They do not find that exogenous shocks to investment in 2-year college education foster growth.

Aghion et al. (2009) also find that exogenous shocks to research-type education have positive growth effects only in states with a fairly narrower distance to the technology frontier. For example, California, Massachusetts, or New Jersey may benefit more from an investment in Mississippi’s research universities than Mississippi does. Finally, they show that innovation is a very plausible channel for externalities from research and 4-year college type education. Exogenous investments in both types of education increase patenting of inventions. Their model is similar to the model of Vandenbussche et al. (2006) except for an additional migration technology: By spending $\propto \bar{A}$, a skilled worker can migrate to other frontier states at time $t+1$, where $\mu$ is uniformly distributed between 0 and $M$.

Thus, a skilled worker attempts to migrate if and only if

$$ (\bar{w}_{t+1} - w_{t+1}) - \propto \bar{A} \geq 0 $$

(15)

where $w_{t+1}$ (resp., $\bar{w}_{t+1}$) is the (skilled) wage in the country (at the frontier).
The migration mechanism of this multisectoral model reinforces the relationships that they attempt to verify.

Aghion and Durlauf (2007a) argue that when considering the policy implications related to the relationship between human capital and growth, the effect of various compositions of human capital on growth depending on development stage should be taken into consideration. The relevant models include Vandenbussche et al. (2006), Aghion et al. (2009), and others.

Based on the results of these models, Aghion and Durlauf (2007a, 21) argue that “For Europe to put the emphasis on primary/secondary education was fine as long as Europe was technologically far from the US and therefore relying more on imitation as a main source of growth, but that now that the growth potential of imitation is wearing out, it becomes more urgent to invest more in higher education in order to foster innovation. Further evidence shows that the IT and globalization waves of the 1980s have further increased the growth potential of higher education investment in all OECD countries.”

For Latin American countries, Aghion and Durlauf (2007a, 23) also argue that “the economies in Latin America not only underinvest in education, they also misinvest in education. Indeed, the analysis in Vandenbussche et al. (2006) suggests that given Latin American countries’ distance to the world productivity frontier, they should invest more, not less, in primary and secondary education than OECD countries; and that they should invest less, not more, in tertiary education…. Brazil invests 10.8% in primary, 11.2% in secondary, and 48.87 in tertiary.”

By comparison, the US invests 21.6% in primary, 24.4% in secondary, and 26% in tertiary education. Thus, Brazil overinvests in tertiary education, which Aghion and Durlauf (2007a) take as resulting from a long history of excessive income and wealth inequality and of capture of the political system by the well-off who would enjoy almost exclusive access to higher education. Aghion and Durlauf (2007a) do not recommend that Latin American countries give up on higher education all together, but they emphasize more primary, secondary, and undergraduate education. Aghion and Durlauf (2007b) conclude that new growth theory combined with suitable growth regressions has the potential to deliver growth policy recommendations.
VI. Directed Technical Change

“Directed technical change” describes a situation where technological change is not exogenously given, but is biased toward particular factors as determined by the profit motives of technology innovators. The following quote from Acemoglu (2002, 806) explains this.

For many problems in macroeconomics, development economics, labor economics, and international trade, whether technical change is biased towards particular factors is of central importance. This paper synthesized some recent research on the determinants of biased technical change. The presumption is that the same economic forces—profit incentives—that affect the amount of technical change will also shape the direction of technical change, and therefore determine the equilibrium bias of technology. I argued that this perspective helps us understand a number of otherwise puzzling patterns.

Acemoglu (1998 and 2002) assumes that directed technical change happens endogenously as a result of innovators’ profit-maximizing behavior. This idea implies that technical change can be directed to the more abundant factor, since it has a bigger market. This is called “market size effect.” This can help explain why skill premium decreased in the 1970s as the number of college graduates in the US rapidly increased, and at the same time why it increased during the 1980s.

It can also help explain why technical change was directed toward unskilled workers during the late 18th and early 19th centuries, and toward skilled workers in the past 60 years. These can be explained by answering which factor is abundant.

There exist two competing forces determining to which factor technical change will be directed based on relative profitability: (i) the price effect, through which technology monopolists develop technologies used to produce more expensive goods; and (ii) the market size effect, which induces technical changes to produce technologies that use the more abundant factor to have a larger market. The market size effect induces rapid technological improvements favoring abundant factors, while the price effect does favor scarce factors.

The elasticity of substitution between the factors determines which one of these two effects dominates. If the elasticity of substitution is sufficiently large, the market size effect dominates since abundant factors can have a larger market. If the elasticity of substitution is low, the price effect dominates since prices of scarce factors become much higher.
Final goods are produced by
\[ Y = \gamma Y_L^{\frac{\epsilon - 1}{\epsilon}} + (1 - \gamma) Y_Z^{\frac{\epsilon - 1}{\epsilon}} \]
\[ Y_i = \frac{1}{1 - \beta} (\int_0^{N_i} x_i(j)^{\gamma - \beta} dj)^{\frac{\gamma}{\gamma - \beta}} \quad i = L \text{ or } Z. \]  
(16)

where \( L \) and \( Z \) are the total supplies of the two factors, assumed to be fixed. The \( i \)-intensive good \( (Y_i) \) is produced from labor \( (i) \) and a range of intermediate goods \( (x_i) \). The number of intermediate goods that can be used with labor is \( N_i \). \((i = L \text{ or } Z)\).

The relative profitability of creating new intermediate goods for \( Z \) is described by:
\[ \frac{V_Z}{V_L} = \frac{1}{\beta} \frac{Z}{L} = \frac{1 - \gamma}{\gamma} (\frac{N_Z}{N_L})^{\frac{\gamma - 1}{\gamma}} (\frac{Z}{L})^{\frac{\gamma - 1}{\gamma}} \]  
(17)

The relative factor prices \( w_Z / w_L \) is described by
\[ \frac{w_Z}{w_L} = \frac{1}{\beta} \frac{N_Z}{N_L} = \frac{1 - \gamma}{\gamma} (\frac{N_Z}{N_L})^{\frac{\gamma - 1}{\gamma}} (\frac{Z}{L})^{\frac{\gamma - 1}{\gamma}} \]  
(18)

Assume that the least developed countires are less abundant in skilled workers than the North, so \( H'/L' < H/L \).

It is also derived as
\[ \frac{\partial Y'/Y}{\partial N_H/N_L} = \frac{1 - \beta}{\sigma} (\frac{N_H}{N_L})^{\frac{\sigma - 1}{\sigma}} (\frac{H'}{L'})^{\frac{\sigma - 1}{\sigma}} - (\frac{H}{L})^{\frac{\sigma - 1}{\sigma}} \]  
(19)

Since \( H'/L' < H/L \), the above equation implies that when \( \sigma > 1 \), i.e., when the two factors are gross substitutes, an increase in \( N_H / N_L \) increases the income difference between the LDCs and the North. Irrespective of the value of the elasticity of substitution, the North’s directed technical change that produce technologies too skill-biased for the LDCs makes the income difference between them larger. This result is intuitive: there are more skilled workers in the North, and technology monopolists in the North develop technologies appropriate for skilled workers (i.e., when \( \sigma > 1 \), higher \( N_H / N_L \), and when \( \sigma < 1 \), lower \( N_H / N_L \)). This implication is empirically studied in Acemoglu and Zilibotti (2001).

Contrary to the assumptions of this model, technology–skill mismatch to a certain degree can be beneficial to the society by increasing both quantity and quality of higher education in response to the mismatch. Using the North’s technology increases the wage rate of skilled labor, resulting in an increase in its supply and in TFP in the LDCs. Considering this and higher level of social returns of education, moderate technology–skill mismatch can increase human capital and growth.
VII. Conclusion

There exist several features that uniquely characterize the development processes of Asian countries, such as liability to falling into poverty traps, focusing more on technology adoption rather than creation, technology–skill mismatch, and “technology-appropriate capital.” This paper surveyed several recently developed models, focusing on the relationship between education and growth that can explain the above features characterizing the growth process of developing Asia’s experiences. The surveyed studies provide policy implications for each of these features as follows.

To avoid the poverty trap, countries should accumulate human capital, general human capital; and that width of human capital should be above a certain threshold level. For efficient adoption of technologies, accumulation of human capital—specifically general human capital—and width of human capital are crucial. The data for both developed and developing economies support this argument. No country grew quickly without the benefit of a highly qualified labor force. In Asia, all those that grew quickly possessed a workforce that was exceptionally well qualified.

To avoid the technology–skill mismatch, the speed of technology upgrading should be appropriate to take full advantage of learning-by-doing and the earning potential of the current stock of specific human capital. In developing Asia, the data shows that some of the population in South Asia seem to lack the required level of skills given the narrowed distance from the technology frontier.

Finally, depending on the stage of development, countries should properly balance investments between general and specific human capital, width and depth of human capital, basic and development research, and primary and secondary and tertiary education.
References


About the Paper
Yong Jin Kim and Akiko Terada-Hagiwara survey the empirical and theoretical link between education and growth in the growth process of Asian countries. Particular attention is paid to the link between education and productivity, and to models that characterize key features of growth processes of Asian countries. Empirical studies show that these key features include liability to falling into poverty traps, focusing more on technology adoption rather than creation, technology–skill mismatch, and appropriate capital.

About the Asian Development Bank
ADB’s vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries substantially reduce poverty and improve the quality of life of their people. Despite the region’s many successes, it remains home to two-thirds of the world’s poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.