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**Growth Gains from Trade and Education**

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**Abstract**

This paper presents a multisector growth model where education enhances general human capital, which is essential for increasing or maintaining the mobility of workers across industries. The paper shows that education, combined with international trade, can affect growth positively in the long run by raising workers' ability to adapt and move easily to industries with the greatest productivity in each period. Depending on the initial ratio of general-to-specific human capital stock, *multiple equilibrium growth paths* can exist, including a poverty trap. If the ratio is not substantially low, trade liberalization can allow an economy in a poverty trap to transform into one with continuous education and higher output growth.

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## I. INTRODUCTION

This paper addresses the joint effect of international trade and education on economic growth. In particular, we examine the effects that general human capital, acquired through education, have on the mobility of workers in outward-oriented developing countries. Education increases the workers' ability to adapt and move to new jobs, which, combined with international trade, permits workers to specialize in economic activities in sectors with higher rates of technological progress. In contrast, under autarky or in the absence of general human capital, an economy will not specialize in the production of a good that undergoes the fastest technology advance.

The remarkable growth of the outward-oriented Asian NIES such as Hong Kong, Korea, Singapore and Taiwan has generated literature on endogenous growth which explores the links between international trade, human capital accumulation and economic growth (e.g., Lucas (1988, 1993), Stokey (1991a, 1991b), Young (1991), Rivera-Batiz and Romer (1991), Matsuyama (1992) and Galor and Zeira (1996)).<sup>2</sup> For example, Lucas (1988) presents a growth model where the main engine of growth is the accumulation of human capital through learning-by-doing, where the rate of such learning differs across sectors. In his model, the economy can grow more rapidly by opening up, provided that its comparative advantage, at the time of opening, is in an industry with faster learning-by-doing. Stokey (1991a) examines the relationship between North-South trade and growth in a model where learning exhibits spillovers among goods. Along similar lines, Young (1991) uses a model with bounded learning-by-doing and spillovers to argue that free trade could lead to a decline in the rates of GDP growth of less developed countries. Stokey (1991b) discusses the effect of international trade in a model where human capital investment has a positive external effect. Finally, Galor and Zeira (1996) presents a model where international trade, by increasing the relative price of goods produced by high skilled workers, affects the returns to human capital.

In contrast to the existing models on trade and growth, this paper presents a different mechanism in the trade-human capital-growth link: the mobility of workers which is enhanced by school education. It demonstrates the specific role of school education in fostering growth by raising the mobility of workers, and by doing so, to explain the phenomenon of the outward-oriented Asian NIES which have experienced not only fast income growth, but also rapid increases in school education and high mobility of workers. Specifically, the paper asks two major sets of questions: (i) What is the role of general (or non-industry specific) knowledge acquired through school education in the growth of outward-oriented developing countries?; and (ii) Why do some outward-oriented countries like the East Asian NICS experience rapid growth with rapid increases in education while some countries like the Philippines remain trapped in poverty with low education? And how can trade liberalization lead a country out of a poverty trap and set it on to a rapid growth path?

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<sup>2</sup> For the issue of trade and growth in models without human capital, see Grossman and Helpman (1991).

To answer these questions, this paper presents a multi-sector general equilibrium model which formalizes the specific role of education in increasing or maintaining the mobility of workers who face uncertain technological changes across industries.<sup>3</sup> In the model, many industries undergo technological changes in each period, which differ across industries and over time. To capture the role of education in times of rapid technological change, the model distinguishes two kinds of human capital. One is specific human capital, by which we mean an industry-specific (or a good-specific) knowledge, skills and know-how of production: a specific human capital can be used to produce only the corresponding specific good, not for the other goods. The other is general human capital: non-industry-specific, general knowledge accumulated primarily through school education. Industry-specific human capital can be accumulated not only through on-the-job-training and job experience, but also with the help of school education on general human capital. The general human capital allows workers to acquire any type of industry-specific human capital, and consequently to move easily to other industries.<sup>4</sup> Therefore, education which increases general (non-industry-specific) human capital is essential to increase or maintain the mobility of workers. Note that a few very recent papers have explored the distinction between general and specific human capital, but not in the context of trade and growth (see Bertocchi and Spagat (1998) and Zeira (1998)).<sup>5</sup> In addition, there is a difference in the concepts of general and specific human capital between this paper and the other contributions. For example, Bertocchi and Spagat (1998) focus on a hierarchical differentiation between general and technical education, with a greater income share parameter of producing a good (and a superior social status) attached to general. So general human capital stands for social status in their one-good model, whereas it represents agents's mobility across sectors in our multi-sector model. The human capital accumulated by technical education in their model also differs from industry-specific human capital in our model. In our model, technical education which raises practical skills that can be used in various industries is considered as enhancing non-industry specific (or general) human capital rather than a specific human capital.

Two key conclusions are reached from the model. First, we show that international trade, *combined with education*, can have a positive growth effect. If countries close their markets, they will have to produce all the commodities and consequently the growth rate of aggregate output will depend on the average rate of technical progress of industries. In

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<sup>3</sup> In most cases, people do not have sufficient information on what kind of technological progress will be made in each industry of an economy over 10 years, and hence which sector will be the one with the highest productivity after 10 years. (see Harberger (1990))

<sup>4</sup> Several economists such as Schultz (1963, 1975), Nelson and Phelps (1966) and Welch (1970) have suggested that a primary role of education is to increase a worker's ability to adapt to changing conditions in technologies or price incentives. For example, Schultz (1963) argues: "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." (P. 40 in Schultz (1963))

<sup>5</sup> Zeira (1998) presents a model of one final good, and addresses the issue of unemployment, caused by technology progress and subsequent obsolescence of existing technology-specific human capital.

contrast, if countries open their markets and have high levels of general education, people move easily to, and specialize in, the sector with the greatest productivity in each period. This leads the long-run growth rate of the countries to depend on the technical progress of the sector which progresses most rapidly. Hence the countries with trade tend to have faster overall technical progress and income growth in the long-run.<sup>6</sup> In particular, general human capital acquired through education plays a crucial role in determining whether international trade will have a positive effect on growth. Where general human capital does not exist but only industry- or good-specific training exists, workers cannot easily move to other industries even when international trade is allowed. As a result, without general human capital, even in an open economy, the growth rate will depend on the average rate rather than the maximum rate of technical progress.

Second, this paper shows that: (a) multiple equilibria can exist, including the poverty trap with no further education and slow growth;<sup>7</sup> (b) trade liberalization can transform such an economy into one with increasing education attainment and higher growth, provided that the initial ratio of general to industry-specific human capital stock is not substantially low.<sup>8</sup> Consider the case where knowledge obtained from school and job experience overlap each other so that workers with much job experience are taught in school what they have already learned from job experience. Then, if workers have much lower general human capital stock (or education) than firm-specific or industry-specific human capital stock (or job experience), the general education they receive in the initial period only helps to close the initial gap between the two types of human capital, similar to sunk cost. In particular, when the initial ratio of general to specific human capital is below a threshold level, sunk cost will be rather large compared to the expected gains from receiving general education. Therefore they will not receive any education. In this case the economy is in a poverty trap with low growth and no further education. However, trade liberalization in a low-growth country can raise the gains from receiving general education above the sunk cost, if the initial ratio is not substantially low. As a result, with opening markets, the country in a poverty trap can move to a different equilibrium path with continuous education growth, faster overall technological progress and higher output growth. The existence of such multiple equilibria and the role of international trade in increasing education and growth may explain the coexistence of the poverty trap

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<sup>6</sup> In our model, this is true, even though the rate of technical progress in each sector is not affected by trade. There are several recent papers which empirically illustrated that openness of trade has a positive relationship with the speed and magnitude of productivity growth in small developing countries. For example, Edwards (1993), using 54 countries data set, found that more open countries tend to have faster rates of productivity growth than less open economies. Kim and Topel (1992) showed that the correlation between the labor productivity growth and export growth of the manufacturing sectors in Korea is nonnegligible and positive.

<sup>7</sup> For the most recent survey on the literature on multiple equilibria and growth, see Benhabib and Farmer (1998), Ch. 6 of *Handbook of Macroeconomics Volume 1*.

<sup>8</sup> The empirical relevance of human capital stock level or educational attainment as engine of growth has been most recently documented by Benhabib and Spiegel (1994). Using a cross-country data, they found that human capital can play a role in economic growth, for example, as a determinant of total factor productivity.

experienced in some inward-oriented developing countries and the growth miracle enjoyed by outward-oriented Asian NICS (see Lucas (1993)).

The paper is organized as follows. Section II describes the equilibrium growth in the economy without trade and with it. In Section III we show that trade, with the help of general human capital, increases the growth rate. Section IV discusses multiple equilibria including the poverty trap and the effects of trade liberalization. Finally, the conclusions are presented in Section V.

## II. BASIC MODEL

This section presents an endogenous growth model with two types of human capital: specific and general. In particular, this section focuses on two simple cases: one where industry-specific human capital is raised only through general education, and the other where it is augmented only through specialized education, and examines how the growth rate here is determined in a closed economy and an open economy, respectively.

### A. THE ECONOMY WITHOUT TRADE

#### 1. CASE OF GENERAL EDUCATION

*Consumers* The model economy consists of a large number of infinitely-lived identical agents who consume  $n$  different types of goods. Each agent maximizes the following intertemporal utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^1, c_t^2 \dots c_t^n) \quad (1)$$

where  $E_t$  denotes the expectation given information known at time  $t$ ;  $c_t^i$  is consumption of the  $i$ -th good at  $t$ ; and  $\beta$  is the subjective discount factor. Further, the momentary utility function takes the additive and logarithmic form:

$$u(c_t^1, c_t^2 \dots c_t^n) = \sum_{i=1}^n \log c_t^i \quad (2)$$

A distinguishing feature of this model is that there are two kinds of human capital. The first type is specific human capital, which takes the form of an industry- or a sector-specific knowledge, skill and know-how and is the only factor of production for specific commodities ( $h_t^i$ ,  $i = 1, \dots, n$ ). Specific human capital can be used to produce only the corresponding specific good, not for the other goods. So for the  $k$ -th industry-specific human capital, it holds that  $y_t^k = f(h_t^i)$  is positive for  $i = k$  and zero for  $i \neq k$  where  $y_t^k$  is the output of the  $k$ -th industry. The second type is general human capital ( $h_t^g$ ), which is non-sector-specific general knowledge and is an essential input for acquiring specific skills in new jobs. General human capital here includes not only basic knowledge of reading, writing, arithmetic, but also practical skills, raised by technical education, that can be applied to various industries.

General human capital is raised through school education. In particular, we assume that the accumulation of general human capital is a linear function of time devoted to general education,  $u_t$ , as follows:

$$h_{t+1}^g - h_t^g = Bu_t h_t^g \quad (3)$$

where  $B$  represents how efficiently the agent produces general human capital.<sup>9</sup>

Specific human capital may be acquired either through general human capital or industry-specific training. We here focus on the case where specific human capital can be acquired only through general human capital. Suppose that the formation of workers' job-specific human capital is expressed as:

$$h_t^i = \theta^i h_t^g, \quad \text{for all } i \quad (4)$$

where  $\theta^i$  captures how efficiently a given amount of general human capital can be transformed into the  $i$ -th sector specific human capital.<sup>10</sup>

The above formulation indicates that as workers accumulate more general human capital, they can learn more sector-specific knowledge or skills. In addition, general human capital ( $h_t^g$ ) can be transformed into any type of specific human capital ( $h_t^i$ ) without any cost.<sup>11</sup>

Using the general knowledge they have already accumulated in school, workers can acquire

<sup>9</sup> In order to simplify the model and to underline the role of general human capital, we assume human capital accumulation to be affected solely by time spent on education, and do not model the effects of borrowing constraints on education expenditures. The role of imperfect capital markets for education finance is undoubtedly important in the real world, and has been studied extensively in various settings (e.g., Becker and Tomes (1979), Loury (1981), and more recently by Fernández (1998), Fernández and Gali (1997), Fernández and Rogerson (1998), Banerjee and Newman (1991), Galor and Zeira (1993), and De Gregorio and Kim (1999), among others). For example, Fernández and Rogerson (1998) evaluate the quantitative impact of education-finance reforms (of alleviating borrowing constraints) by calibrating a dynamic general equilibrium model using U.S. data.

<sup>10</sup> We could modify equation (4) so that general human capital should be combined with on-the-job training to be transformed as specific human capital. For example, we could assume that workers' specific human capital is a function of their general human capital and on-the-job-training as:  $h_t^i = \theta(x_t^i) h_t^g$ , where  $x_t^i$  represents the time spent on on-the-job training. Further, we assume that  $\theta(x_t^i)$  takes the following step function:  $\theta(x_t^i) = 0$  for  $x_t^i < x$  and  $\theta(x_t^i) = 1$  for  $x_t^i \geq x$  where  $x \in (0, 1)$ . In this case, we can easily show that our main results are robust to such modification. Or we could introduce a slightly different assumption that workers first acquire general human capital for initial periods and then use job experience later to raise sector-specific human capital. In this case also, we can show that such modification does not alter the main results of the paper.

<sup>11</sup> The above formulation (4) does not explicitly consider any direct cost of migration between sectors. We also may introduce direct cost of moving into different jobs. In this case, workers will migrate to the sector which maximizes their discounted utility minus the disutility caused by the migration cost. However, such extension does not affect the main qualitative results of this paper.

any type of industry- or job-specific knowledge. Particularly when they move to a new job, they can obtain the specific human capital required for a new job using the same general knowledge that they have used for the current job. So they do not have to make new investment in human capital to acquire new specific human capital. Hence, with general knowledge which is already accumulated, workers can move in different jobs easily. In this way, the existence of general human capital increases the mobility of workers between sectors, compared to the case of its absence. Without general human capital, workers would have to accumulate new specific human capital every time they move to a new job, which is very costly.

For simplicity, the transformation efficiency parameter,  $\theta^i$ , is assumed to be identical at one across sectors. This implies that  $h_t^i$  is identical for all industries. Then equation (4) for the formation of specific human capital can be simplified as:

$$h_t^i = h_t^g \quad \text{for all } i. \quad (5)$$

The agents are endowed with one unit of non-leisure time in each period of their life, which is allocated to education or work:

$$u_t + \sum_{i=1}^n l_t^i = 1 \quad (6)$$

where  $l_t^i$  is the labor supply for the  $i$ -th industry at time  $t$ .

In addition, the agents are assumed to work for only one job in each period. So if an agent works for the  $k$ -th industry, his labor supplies to the other industries are zeros:

$$\text{if } l_t^k > 0, \text{ then } l_t^i = 0 \quad \text{for all } i \neq k. \quad (7)$$

However, with the help of general human capital, the agents can move easily to different jobs in subsequent periods.

The agents' current income is derived solely from the supply of their effective labor. The agents spend the current labor income on the current consumption of  $n$  different types of goods. Thus, without international trade, the agents who currently work in the  $k$ -th sector face a budget constraint of the form:

$$\sum_{i=1}^n p_t^i c_t^i = \sum_{i=1}^n w_t^i h_t^i l_t^i \quad (= w_t^k h_t^k l_t^k) \quad (8)$$

where  $p_t^i$  is the domestic price of the  $i$ -th good and  $w_t^i$  is the real wage rate for one unit of effective labor in the  $i$ -th industry at time  $t$ .



The agents choose consumption, labor supply and educational investment to maximize utility, taking prices as given. Under the assumption of interior solutions, the Euler condition of the worker in the  $k$ -th sector takes the following form:

$$w_t^k h_t^k \frac{u'(c_t^i)}{p_t^i} = E_t \sum_{s=1}^{\infty} \frac{\beta^s u'(c_{t+s}^i)}{p_{t+s}^i} \max_{(j=1 \dots n)} [w_{t+s}^j h_{t+s-1}^g l_{t+s}^j B] \quad \text{for } i = 1, 2 \dots n \quad (9)$$

This condition reveals that the marginal loss of sacrificing current consumption is equal to the marginal gain from increases in general human capital and subsequent increases in future consumption.

The optimal distribution of current consumption across commodities for a given realization of technology shocks at time  $t$  is given by:

$$\frac{u'(c_t^i)}{p_t^i} = \frac{u'(c_t^j)}{p_t^j} \quad \text{for all } i \quad (10)$$

which, under the assumption of logarithmic utility function, implies

$$p_t^i c_t^i = p_t^j c_t^j \quad \text{for all } i. \quad (11)$$

This equation tells us that agents distribute their income equally for the consumption of each good.

The agents' optimal labor supply for each industry depends on their relative wage earnings across sectors. If wage earnings for a unit of labor is highest in a sector, the agents will supply labor to the sector. But if wage earnings for a unit of labor is identical across sectors:

$$w_t^i h_t^i = w_t^j h_t^j \quad \text{for } i = 1, 2 \dots n, \quad (12)$$

then the agents are indifferent about working in any sector. We will see below that (12) holds in competitive equilibrium.

*Firms* The model economy also has many firms, each of which produces one of  $n$  different types of goods. We assume that the only input for production of each commodity is labor adjusted by industry-specific human capital.<sup>12</sup> In particular, a constant-returns-to-scale production function of effective labor ( $h_t^i l_t^i$ ) is assumed as follows:

$$y_t^i = A_t^i h_t^i l_t^i \quad (13)$$

where  $A_t^i$  represents the marginal product of effective labor.

<sup>12</sup>An introduction of physical capital complicates the solutions, but does not alter the main results of the paper.

We assume that each of the technology parameters,  $A_t^1, A_t^2, \dots, A_t^n$ , follows a stochastic process exogenous to this economy as follows:

$$A_t^i = \lambda_t^i A_{t-1}^i \quad \text{for all } i \quad (14)$$

where  $\lambda_t^i$  captures the size of a technological change in the  $i$ -th industry at time  $t$ .

Further, we assume that, at time  $t$ ,  $\lambda_t^i$  is known but  $\lambda_{t+s}^i$  (where  $s \geq 1$ ) is not revealed. After technology shocks are revealed at the beginning of time  $t$ , firms choose effective labor to maximize their value, taking prices as given. The firm's first-order condition for optimal labor employment is:

$$p_t^i A_t^i = w_t^i \quad (15)$$

which implies that the real wage rate is equal to the marginal product of effective labor.

*Competitive Equilibrium* In this economy, without international trade, a competitive equilibrium is determined as follows. The consumer's maximization problem yields a set of demand functions for consumption and a supply function of effective labor. Likewise, the firm's optimization behavior yields demand functions for effective labor and supply of output in terms of price parameters. The equilibrium labor supply, education and growth rate are then obtained from the market clearing conditions. The goods market clearing condition, or resource constraint of the closed economy, is as follows:

$$Nc_t^i = Ny_t^i \quad \text{for all } i = 1, 2, \dots, n. \quad (16)$$

where  $N$  is the population of the economy;  $c_t^i$  is per capita consumption; and  $y_t^i$  is per capita output of the  $i$ -th good at time  $t$ .

This resource constraint, together with equations (11) and (15), guarantees that equation (12) holds, and yields:

$$w_t^i h_t^i L_t^i = w_t^j h_t^j L_t^j \quad (17)$$

where  $L_t^i$  is the aggregate labor supply for the  $i$ -th industry.

Then the aggregate labor supply for each industry is given by:

$$L_t^i = (1 - u_t) \frac{N}{n} \quad \text{for all } i = 1, 2, \dots, n. \quad (18)$$

This equation implies that the economy, without international trade, does not specialize in any industry, and labor supply is distributed equally across sectors.

*Long-run Growth Rates* Implementing the market clearing condition, we now focus on the equilibrium growth path where human capital grows at a constant rate over time. The constant growth rate of human capital can be calculated as follows. Under the assumption of

logarithmic utility function, the Euler condition of the worker in the  $k$ -th sector can be rewritten as:<sup>13</sup>

$$\frac{w_t^k h_t^k}{n p_t^i c_t^i} = E_t \sum_{s=1}^{\infty} \frac{\beta^s}{n p_{t+s}^i c_{t+s}^i} (w_{t+s}^k h_{t+s}^g l_{t+s}^k B) \frac{h_{t+s-1}^g}{h_{t+s}^g} \quad (19)$$

which, using the conditions (3), (7) and (8) can be simplified as:

$$\frac{1}{l_t^k} = E_t \sum_{s=1}^{\infty} \frac{\beta^s B}{1 + B u_{t+s-1}} \quad (20)$$

On the equilibrium growth path where the growth rate of human capital,  $g_{t+1}^h$ , and time devoted to education,  $u_t$ , are constant over time at  $g^h$  and  $u$ , the following holds:

$$\frac{1}{(1-u)} = E_t \sum_{s=1}^{\infty} \frac{\beta^s B}{1 + B u} = \frac{B \beta}{(1-\beta)(1 + B u)} \quad (21)$$

Then the equilibrium growth rate of human capital and time devoted to education can be derived as:

$$g^h = \beta(1 + B) - 1 \quad \text{and} \quad u = \frac{(\beta(1 + B) - 1)}{B} \quad (22)$$

which implies that as long as  $\beta(1 + B) > 1$ , the model will feature positive human capital growth and education.

Along this growth path with positive education, the long-run growth rate of aggregate output is calculated as follows. We define the long-run growth rate of GNP as a limit of  $T$ -period geometric average growth rate:  $g = \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n p_t^i y_{t+T}^i}{\sum_{i=1}^n p_t^i y_t^i} \right]^{\frac{1}{T}} - 1$ . Note that our production function implies that the output growth of each good at time  $t$ ,  $g_{t+1}^i$ , can be broken down into the growth rate of human capital and the rate of technological progress:  $g_{t+1}^i = \lambda_{t+1}^i (1 + g_{t+1}^h) - 1$ .

Using the above formulation on the growth rate of individual goods with equation (11) or  $p_t^i = \frac{p_t^n y_t^n}{y_t^i}$ , the long-run growth rate for autarky ( $g^{NT}$ ) can be calculated as:

$$\begin{aligned} g^{NT} &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n p_t^i y_{t+T}^i}{\sum_{i=1}^n p_t^i y_t^i} \right]^{\frac{1}{T}} - 1 \\ &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n p_t^i y_{t+T}^i}{n p_t^n y_t^n} \right]^{\frac{1}{T}} - 1 \\ &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n (\prod_{s=1}^T (g_{t+s}^i + 1))}{n} \right]^{\frac{1}{T}} - 1 \end{aligned}$$

<sup>13</sup>From equations (5) and (12), we have  $\max_{(j=1 \dots n)} [w_{t+s}^j h_{t+s-1}^g l_{t+s}^j B] = w_{t+s}^k h_{t+s-1}^g l_{t+s}^k B$ .

$$\begin{aligned}
 &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n (\prod_{s=1}^T \lambda_{t+s}^i)}{n} \right]^{\frac{1}{T}} \beta(1+B) - 1 \\
 &= (\lambda^{avg}) \beta(1+B) - 1
 \end{aligned} \tag{23}$$

where  $\lambda^{avg} = \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n (\prod_{s=1}^T \lambda_{t+s}^i)}{n} \right]^{\frac{1}{T}}$  represents the average of sectoral long-run rates of technical progress.

This result shows that, without international trade, economic growth depends on the average level of long-run technical progress of industries,  $\lambda^{avg}$ . If countries close their markets, they will have to produce all the commodities as indicated by equation (18), and consequently the growth rate of aggregate output will depend on the average rate of technical progress of industries.<sup>14</sup>

## 2. CASE OF SPECIFIC EDUCATION

To illustrate the role of general human capital in determining growth effects of trade, it is instructive to analyze the opposite case. Assume that there exists only industry-specific education which can increase only one type of specific human capital, and consequently the mobility of workers is substantially limited. In particular, suppose that the accumulation of specific human capital is a linear function of time devoted to industry- or good-specific training,  $u_t^i$ , as follows:

$$h_{t+1}^i - h_t^i = B^i u_t^i h_t^i \tag{24}$$

where  $B^i$  represents how efficiently the workers produce the  $i$ -th specific human capital. Assume that  $B^i$ 's are identical at  $B^S$  across sectors.

In addition, the workers allocate one unit of non-leisure time in each period to  $n$  types of industry-specific training or work:

$$\sum_{i=1}^n u_t^i + \sum_{i=1}^n l_t^i = 1. \tag{25}$$

For simplicity suppose that there are  $n$  groups of workers at time  $t$  with same number of workers in each group. The workers in the  $k$ -th group have greater specific human capital in the  $k$ -th sector than the other sectors ( $h_t^k > h_t^j$  for all  $j \neq k$ ). Further, the amount of the  $k$ -th specific human capital ( $h_t^k$ ) of the workers in the  $k$ -th group is equal to  $h_t^j$  of the workers in the  $j$ -th group.

<sup>14</sup>In this closed economy, workers can move easily to any sector with the help of general human capital. However, gains from maintaining their mobility is not as important as in the open economy. This is because, in autarky equilibrium, workers can earn the same wage earnings regardless of whether they stick to the current job or move to different jobs.

Under these assumptions, it can be shown that, along the equilibrium growth path where human capital grows at a constant rate, the Euler condition for the workers in the  $k$ -th group at time  $t$  is given by:

$$\frac{w_t^k h_t^k}{p_t^i c_t^i} = E_t \sum_{s=1}^{\infty} \frac{\beta^s}{p_{t+s}^i c_{t+s}^i} \max_{(j=1 \dots n)} [(w_{t+s}^j h_{t+s}^j l_{t+s}^j B^S)^{\frac{h_{t+s}^j-1}{h_{t+s}^j}}] \quad \text{for all } i. \quad (26)$$

In equation (26), the optimal choice of specific human capital depends on the relative wage earnings across sectors ( $w_{t+s}^j h_{t+s}^j$  where  $s \geq 1$ ). It can be shown that, in this closed economy, equilibrium wages are solved to be identical across sectors:  $w_t^k = w_t^j$ . Then it follows that, for the workers in the  $k$ -th group,  $w_{t+s}^k h_{t+s}^k > w_{t+s}^j h_{t+s}^j$  for all  $j \neq k$ , since  $h_t^k > h_t^j$ .

Then the Euler equation can be rewritten as:

$$\frac{w_t^k h_t^k}{p_t^i c_t^i} = E_t \sum_{s=1}^{\infty} \frac{\beta^s}{p_{t+s}^i c_{t+s}^i} (w_{t+s}^k h_{t+s}^k l_{t+s}^k B^S)^{\frac{h_{t+s}^k-1}{h_{t+s}^k}} \quad (27)$$

This implies that the optimal investment strategy for the workers in the  $k$ -th group is to continue to accumulate the  $k$ -th industry-specific human capital and stick to the  $k$ -th sector. This is because, without general human capital, it is very costly for the workers who have accumulated the  $k$ -th specific human capital,  $h_t^k$ , to build up different types of specific human capital.<sup>15</sup>

Using the Euler equation, the long-run growth rate in an autarky ( $g^{NT}$ ) is calculated as:

$$g^{NT} = (\lambda^{avg})\beta(1 + B^S) - 1 \quad (28)$$

This tells us that in a closed economy the growth rate of an autarky depends on the average of technical progress of industries,  $\lambda^{avg}$ , in the absence of general education as it does in its presence.

## B. THE ECONOMY WITH TRADE

In this subsection, we shall examine how the growth rate in an open economy is determined, for the case of general education and specialized education, respectively. Except for the presence of international trade, the model economy here is identical to the model in the previous subsection.

<sup>15</sup>There is an opportunity cost of moving to new jobs, which affects the mobility of workers. When an individual who currently works in the  $k$ -th sector moves to the  $j$ -th sector next period, the one period net opportunity cost (opportunity cost - gain) can be measured by  $w_t^k h_t^k - w_t^j h_t^j$ . The opportunity cost is a decreasing function of the  $j$ -th specific human capital,  $h_t^j$ , and an increasing function of the  $k$ -th specific human capital,  $h_t^k$ . Hence, more accumulation of a type of specific human capital compared with the others implies greater opportunity cost of moving into different jobs and more limited mobility.

## 1. CASE OF GENERAL EDUCATION

In an open economy, international trade allows agents to purchase any good at international prices and, hence, the agents face a budget constraint of the form:

$$\sum_{i=1}^n p_t^{f,i} c_t^i = w_t^{i^*} h_t^{i^*} l_t^{i^*} \quad (29)$$

where  $p_t^{f,i}$  is the international price of the  $i$ -th commodity and  $i_t^*$  represents the industry with comparative advantage at time  $t$ .

In the case of general education (where any type of job-specific human capital is augmented only by general education), then the Euler condition for the optimization problem of any worker takes the following form:

$$w_t^{i^*} h_t^{i^*} \frac{u'(c_t^i)}{p_t^{f,i}} = E_t \sum_{s=1}^n \frac{\beta^s u'(c_{t+s}^i)}{p_{t+s}^{f,i}} [w_{t+s}^{i^*} h_{t+s-1}^g l_{t+s}^{i^*} B] \quad \text{for all } i \quad (30)$$

where  $i_{t+s}^*$  denotes the industry with comparative advantage at time  $t + s$ .

In this small open economy, the optimal condition of labor supply for each good depends on the relative wage rates. Unlike in a closed economy where wages are equalized across industries through adjustment of prices, wages for a unit of labor could differ across industries in a small open economy where the prices of goods are given at international levels. Hence there is an industry whose unit labor wage is the highest. If the wage rate of the  $i_t^*$ -th industry is the highest in this economy at time  $t$  (i.e.,  $w_t^{i^*} = \max_{(i=1,2,\dots,n)} [w_t^i]$ ), the optimal labor supply of any agent for each industry is as follows:

$$l_t^i = \begin{cases} 1 - u_t & \text{if } i = i_t^* \\ 0 & \text{otherwise.} \end{cases} \quad (31)$$

which gives the following aggregate labor supply for each industry:

$$L_t^i = \begin{cases} (1 - u_t)N & \text{if } i = i_t^* \\ 0 & \text{otherwise.} \end{cases} \quad (32)$$

This result tells us that the economy, with international trade, specializes in one industry in each period, and labor supply is concentrated only in the industry with comparative advantage in that period.

Corresponding to the labor supply, there is only one industry which runs in this economy at time  $t$ , which is the  $i_t^*$ -th industry. Under the assumption of constant returns to scale production, the firm's first-order condition for optimal labor employment in this industry is:

$$p_t^{f,i^*} A_t^{i^*} = w_t^{i^*} \quad (33)$$

where  $A_t^{i*}$  is the technology level at time  $t$  of the industry with comparative advantage at time  $t$ .

By the same procedure as in the closed economy, the competitive equilibrium yields the growth rate on the equilibrium growth path where human capital grows at a constant rate. Using the above equilibrium conditions and the assumption of logarithmic utility function, the equilibrium growth rate of human capital, both general and specific, is given by:

$$g^h = \beta(1 + B) - 1. \quad (34)$$

To simplify the calculation of the growth rate of GNP, we make some assumptions on the determination of prices in the international market. Assume that there are  $n$  countries in the world, which are identical in every aspect except technology, and that there are an infinite number of firms in each country, which allows the competitive markets to work. Assume also that there is a symmetry in technology and human capital and that the size of population is identical across countries. Then  $n$  different countries have comparative advantages in different industries owing to the difference in technology, and the amount of world output,  $y_t^{f,i}$ , is identical for all commodities:  $y_t^{f,i} = y_t^{f,j}$ . In addition, the equilibrium condition in the international market, together with the first-order conditions, yields:  $p_t^{f,i} y_t^{f,i} = p_t^{f,j} y_t^{f,j}$  for all  $i, j = 1 \dots n$ . It then follows that

$$p_t^{f,i} = p_t^{f,j} \quad \text{for all } i, j = 1, \dots, n. \quad (35)$$

This tells us that prices in the international markets are identical across commodities in any period.

In the case of general education, we then can calculate the long-run growth rate in an open economy,  $g^T$ . Using  $\lim_{T \rightarrow \infty} \left[ \frac{A_{t+T}^{i*}}{A_t^{i*}} \right]^{\frac{1}{T}} = 1$ , together with equations (34) and (35), the long-run growth rate is derived as follows:

$$\begin{aligned} g^T &= \lim_{T \rightarrow \infty} \left[ \frac{p_t^{f,i_{t+T}} y_{t+T}^{i_{t+T}}}{p_t^{f,i_t} y_t^{i_t}} \right]^{\frac{1}{T}} - 1 \\ &= \lim_{T \rightarrow \infty} \left[ \frac{A_{t+T}^{i*}}{A_t^{i*}} \right]^{\frac{1}{T}} \beta(1 + B) - 1 \\ &= \lim_{T \rightarrow \infty} \left[ \frac{(\prod_{s=1}^T \lambda_{t+s}^{i_{t+s}}) [A_t^{i_{t+T}^*}]}{A_t^{i_t^*}} \right]^{\frac{1}{T}} \beta(1 + B) - 1 \\ &= \lim_{T \rightarrow \infty} \left[ \prod_{s=1}^T \lambda_{t+s}^{i_{t+s}} \right]^{\frac{1}{T}} \beta(1 + B) - 1 \\ &= \lambda^{max} \beta(1 + B) - 1 \end{aligned} \quad (36)$$

where  $A_t^{i*}$  and  $A_{t+T}^{i*}$  are the technology levels at time  $t$  and time  $t + T$  of the industry with comparative advantage at time  $t + T$ ; and  $\lambda^{max} = \lim_{T \rightarrow \infty} [\prod_{s=1}^T \lambda_{t+s}^{i*}]^{\frac{1}{T}}$  is the rate of technological progress of the sector with the highest long-run technical progress.

The result shows that in the presence of both trade and general education, the long-run growth rate of GNP depends on the rate of technical progress of the industry experiencing the fastest technological progress over time,  $\lambda^{max}$ .<sup>16</sup> This is in sharp contrast with the autarky case where the growth rate depends on the average rate of technical progress of industries.

## 2. CASE OF SPECIFIC EDUCATION

Now consider an open economy where general human capital does not exist, and any type of specific human capital is augmented by industry-specific education. In this case, the Euler condition for the workers in the  $k$ -th group (described in Section 2.1.2) can be written as:

$$\frac{w_t^k h_t^k}{p_t^{f,i} c_t^i} = E_t \sum_{s=1}^{\infty} \frac{\beta^s}{p_{t+s}^{f,i} c_{t+s}^i} \max_{(j=1 \dots n)} [(w_{t+s}^j h_{t+s}^j l_{t+s}^j B^S) \frac{h_{t+s-1}^j}{h_{t+s}^j}] \quad (37)$$

The optimal path of specific human capital, which maximizes the right side of the Euler equation, depends on the relative size of  $h_t^k$  and  $h_t^j$  ( $j \neq k$ ) and the stochastic process of technical progress. When the ratio ( $h_t^k/h_t^j$ ) for the workers in the  $k$ -th group is very large, say infinity, it can be shown that the workers in an open economy continue to accumulate the  $k$ -th sector-specific human capital and stick to the  $k$ -th sector.

Further, when there exists persisting uncertainty in technical progress, the optimal strategy for the workers in the  $k$ -th group is likely to stick to the  $k$ -th industry. Suppose that the expected long run technical progress at time  $t$  is identical across sectors (this does not rule out the possibility that the realized long run technical progress differs across sectors). In this case, we can show that as long as the difference between  $h_t^k$  and  $h_t^j$  ( $j \neq k$ ) exceeds certain threshold levels, the expected utility from continuing to invest in the  $k$ -th sector is the greatest, and hence workers continue to accumulate the  $k$ -th specific human capital and stick to that industry.

In the above cases, we can calculate the long-run growth rate in an open economy,  $g^T$ . Using equation (35) (i.e.,  $p_t^{f,i} = p_t^{f,j}$  for all  $i, j$ ), the long-run growth rate of an open economy

<sup>16</sup>In the short run, the industry with the highest productivity may not be consistent with the industry with the most rapid technological progress. However, the influence of the current level of productivities across sectors,  $A_t^i$ s, on the growth rate will decline over time. Even though for some periods the industry with lower long-run technical progress may have comparative advantage, as time goes on, the industry with the highest frequency of technical progress would show up as the industry with comparative advantage since it grows most rapidly in the long run.



$(g^T)$  is derived as:

$$\begin{aligned}
 g^T &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n p_t^{f,i} y_{t+T}^i}{\sum_{i=1}^n p_t^{f,i} y_t^i} \right]^{\frac{1}{T}} - 1 \\
 &= \lim_{T \rightarrow \infty} \left[ \frac{\sum_{i=1}^n y_{t+T}^i}{\sum_{i=1}^n y_t^i} \right]^{\frac{1}{T}} - 1 \\
 &= \lim_{T \rightarrow \infty} \left[ \sum_{i=1}^n \left( \prod_{s=1}^T (1 + g_{t+s}^i) \epsilon^i \right) \right]^{\frac{1}{T}} - 1 \\
 &= (\lambda^{avg'}) \beta (1 + B^S) - 1
 \end{aligned} \tag{38}$$

where  $\epsilon^i = \frac{y_t^i}{\sum_{i=1}^n y_t^i}$ , and  $\lambda^{avg'} = \lim_{T \rightarrow \infty} \left[ \sum_{i=1}^n \left( \prod_{s=1}^T \lambda_{t+s}^i \right) \epsilon^i \right]^{\frac{1}{T}}$  is the weighted average of sectoral long-run rates of technical progress.

It can also be the case that the workers' optimal strategy under uncertainty is to diversify investment in specific human capital across sectors, either fully or partially, rather than to specialize in a specific sector. Such a diversification could occur when the number of goods is small and the difference between  $h_t^k$  and  $h_t^j$  is very small for workers in any group. In an extreme, consider a case where there exist only two goods ( $i = 1, 2$ ), and  $h_t^1$  is equal to  $h_t^2$  in the initial period. In addition, suppose that sectoral difference in technology shocks is large, and  $B = B^S$ . Then, risk-averse agents would invest in both types of specific human capital to avoid a huge fluctuation in wage income, although they use only one type of specific human capital in each period. To accumulate more than one type of specific human capital, they then will have to substantially reduce their labor supply to the sector with higher productivity in the future since  $l_{t+s}^{i*} = 1 - u_{t+s}^1 - u_{t+s}^2$ . This is in contrast with the case of general education where the labor supply will be much larger since  $l_{t+s}^{i*} = 1 - u_{t+s}$ . This suggests that, in an uncertain world, general education commands a premium over specialized education.<sup>17</sup> Further, if we consider the case of more than two goods, we can easily see that the premium of general education increases with the number of the goods,  $n$ .

Moreover, in the absence of general human capital, the agents would fully diversify when  $n = 2$ , but when  $n$  is large, they are more likely to partially diversify (i.e., invest in a subset of  $n$  specific human capital), because marginal gains from increasing the number of specialized education would be decreasing for a large  $n$ . Consequently, the mobility of

<sup>17</sup>The premium here can be calculated as the difference between the values of investment in general human capital and diversified investment in the specific human capitals. The value (in terms of utility) of one unit of time invested in general human capital is represented by the right side of (30), while the value of one unit of time invested in two specific human capital is given by  $E_t \sum_{s=1}^n \frac{\beta^s u'(c_{t+s}^i)}{p_{t+s}^{f,i}} [w_{t+s}^{i*} h_{t+s-1}^{i*} l_{t+s}^{i*} B]$ . Then the result of a positive premium easily follows from the fact that labor supply  $l_{t+s}^{i*}$  is larger in the case of general human capital than the case of diversified specific human capital.

workers will be limited, and the growth rate will depend on an average of sectoral technological progress.

### III. GROWTH EFFECT OF INTERNATIONAL TRADE

In this section, we shall compare the growth effect of trade in the cases of general education and specialized education, and show that when workers can move easily to any sector with the help of general human capital, international trade is more likely to bring about a positive growth effect in the long run.

#### A. CASE OF GENERAL EDUCATION

In the case of general education, the long-run growth effect of trade, measured by the difference between the growth rates in the presence of trade and in the absence of it, is given by:

$$\Delta g \equiv g^T - g^{NT} = (\lambda^{max} - \lambda^{avg})\beta(1 + B) \quad (39)$$

This indicates that the growth effect depends on  $(\lambda^{max} - \lambda^{avg})$  and on two parameters: efficiency of education and subjective discount rate. It is obvious that the maximum rate of technical progress  $(\lambda^{max})$  is not less than the sectoral average  $(\lambda^{avg})$ , and hence the growth rate of open economy is not less than the growth rate of autarky. That is, the growth effect of international trade is non-negative in the case of general education.<sup>18</sup>

Particularly when at least one sector has different long run technical progress from the others, international trade has a positive growth effect. One realistic example is the following case where the rate of technological progress at time  $t$ ,  $(\lambda_t^i)$ , follows a Bernoulli process with the probability of  $\pi_t^i$  as follows:

$$\lambda_t^i = \begin{cases} \lambda & \text{with probability } \pi_t^i \\ 1 & \text{otherwise.} \end{cases} \quad (40)$$

In this case, the probability of technical progress can differ across industries and over time, and hence there is always a chance that the sector of comparative advantage changes over time. In addition, there can be persisting uncertainty about the sector with the highest

<sup>18</sup>When utility function takes a logarithmic form, the growth rate of human capital  $(g_{t+1}^h)$  is  $\beta(1 + B)$  regardless of the rate of technical progress. However, if utility function takes a more general CRRA form as  $u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}$ , the growth rate of human capital  $(g_{t+1}^h)$  can be affected by the rate of technical progress, depending on the elasticity parameter,  $\sigma$ . If  $\sigma$  is less (greater) than one,  $g_{t+1}^h$  increases (decreases) with the rate of technical progress. Regardless of the value of  $\sigma$ , however, the growth rate of output  $(g_{t+1})$  increases with the rate of technical progress. Hence the positive growth effect of international trade continues to hold in a more general case of CRRA utility function.

productivity in the long run ( $\lim_{T \rightarrow \infty} [A_{t+T}^{i*}]$ ). Hence this is consistent with the realistic situation where people do not have sufficient information as to which sector would have the highest productivity in 10 years and which sector would experience the most rapid technological change over time (see Harberger(1990)). Further, the rate of long run technical progress ( $\lim_{T \rightarrow \infty} [\prod_{s=1}^T \lambda_{t+s}^i]^{\frac{1}{T}}$ ) can differ across sector. Hence the growth rate of an open economy can be greater than the growth rate of an autarky. <sup>19</sup>

The above result shows that international trade, combined with general education, can increase the growth rate of an economy in the long run as long as there is difference in the long run rate of technical progress across sectors. This result is intuitively clear. If countries open their markets and have high levels of general education, workers can move easily to, and specialize in, the sector with the greatest productivity in each period. This leads the long-run growth rates of the countries to depend on the technical progress of the sector which progresses most rapidly. Hence the countries with trade can have more rapid overall technical progress and higher income growth in the long-run. <sup>20</sup>

Note that the result extends the proposition of gains from trade, which has been discussed in existing literature mainly in terms of static efficiency gains or a level effect, into a proposition of the dynamic gains from trade in the sense that it increases the growth rate. <sup>21</sup> As long as countries have different long-run rate of technological changes across industries, international trade with the help of general human capital allows countries to specialize in the

<sup>19</sup>Another example is the following case where the rate of technological progress at time  $t$  ( $\lambda_t^i$ ) follows a random walk with drift as follows:  $\lambda_{t+1}^i = \lambda_t^i + \epsilon_t$  where  $\epsilon_t \sim i.i.d.$  In this case, at any point in time, workers form a conditional expectation on the industry with the most rapid technical progress in the long run based on the current technology shocks since  $\max[E(\lambda_{t+s}^i | \lambda_t^i)] = \max[\lambda_t^i]$ . But  $\max[\lambda_t^i]$  can change over time and hence the prediction on the sector with long run comparative advantage changes over time.

<sup>20</sup>One period growth rate in an open economy at time  $t$ , ( $g_{t+1}^T$ ), can be lower than that of a closed economy. For example, in the case where the  $i$ -th industry continues to have the highest productivity at time  $t$  and  $t + 1$ , but does not experience any technological progress between time  $t$  and time  $t + 1$ , it holds that  $\frac{A_{t+1}^{i*}}{A_t^{i*}} (=1)$  is less than  $\lambda_{t+1}^{avg}$  and hence the growth rate at time  $t + 1$  of an open economy is lower than that of an autarky. However, the  $T$ -period growth rate of open economy ( $g_{t,T}^T = [\frac{\sum_{i=1}^n p_t^{f,i*} y_{t+T}^{i*}}{\sum_{i=1}^n p_t^{f,i} y_t^{i*}}]^{\frac{1}{T}} - 1$ ), will exceed that of autarky as  $T$  gets larger and larger, as long as technological progress differs across sectors.

<sup>21</sup>The existence of spillovers across sectors or countries might affect the magnitude of positive growth effects of trade. For example, consider a case where there is a spillover from the best technology to the rest. Then the growth rate of the maximum and the average technological progress could be the same, and hence the long-run growth rate will be the same regardless of trade. However, as long as there is no perfect spillover, the proposition of the positive growth effect of trade still holds.

industry with the fastest technical progress in each period and subsequently in the long run, which raises the growth rate of all countries. This is the dynamic gains from trade.<sup>22</sup>

### B. CASE OF SPECIFIC EDUCATION

A comparison of the cases of general education and industry-specific education illustrates how critical is general human capital in inducing a positive growth effect of trade. In the case of specialized education, the long-run growth effect of trade is calculated as:

$$[\lambda^{avg'} - \lambda^{avg}](1 + B^S). \quad (41)$$

Therefore, the sign of the growth effect can even be negative, depending on the initial distribution of output across sectors,  $\epsilon^i$ . For example, if the sectors with higher initial technology levels undergoes slower technological progress later, it holds that  $\lambda^{avg'} < \lambda^{avg}$  and hence the growth effect of international trade is negative.

This suggests that general human capital acquired through general education plays a crucial role in determining whether international trade will have a positive effect on growth. With only sector-specific or industry-specific education, even when international trade is allowed, workers cannot easily move to other sectors, because it is very costly to acquire specific human capital required for the jobs in the other sectors. As a result, the growth rate will depend on an average rate rather than the maximum rate of technological progress even in an open economy, if there is no general human capital.

### IV. POVERTY TRAP AND TRADE LIBERALIZATION

In Section 2-3, we studied two simple cases: where sector-specific human capital can be increased only through general education and where it can be raised only by specialized education. Now, we shall extend the model into a more general case where specific human capital can be raised either by general education or by industry-specific education including job experience and training. This extension is particularly interesting because, in the general case, multiple equilibria can exist, including the one with no general education and slow growth. In addition, trade liberalization can pull an economy out of a low growth trap, provided that the initial level of general education is not substantially low compared to specific human capital stock.

<sup>22</sup>It is also noteworthy that, in this model, the growth effect of trade is obtained even when the introduction of trade itself does not affect the rate of technological progress in each industry (i.e.,  $\lambda^i$ ). Trade here, by altering the resource allocation, raises the overall technological progress of the economy (from  $\lambda^{avg}$  to  $\lambda^{max}$ ) without affecting  $\lambda^i$ . If we allow the market opening to accelerate technology transfers of each industry from foreign countries, and hence increase  $\lambda^i$ , the growth effect of trade would be even larger.

### A. TECHNOLOGY OF ACQUIRING SPECIFIC SKILLS

In this section, we assume that workers' specific human capital can be augmented either by general education in schools or by industry-specific education (e.g., on-the-job-training and job experience). The two ways of acquiring industry-specific skills can substitute each other, so that a worker can acquire similar industry-specific or job-specific knowledge from either general education or industry-specific education. We assume that the formation of industry-specific human capital in each period can be described as:

$$h_t^i = \omega^i h_t^g + (1 - \omega^i) h_t^{s,i}. \quad (42)$$

where  $\omega^i$  captures the relative contribution of general human capital to the current specific human capital, and  $h_t^{s,i}$  is the specific human capital which has been raised by industry-specific education. For simplicity, we assume that  $h_t^{s,i} = \gamma_t^i h_{t-1}^i$ , where  $\gamma_t^i$  captures how rapidly the  $i$ -th specific human capital increases without the help of general education.<sup>23</sup>

In addition, the two ways of acquiring industry-specific knowledge can be overlapping. For example, if a worker with twenty-year job experience goes to school to receive general education, a large part of the knowledge he learns in the school may be what he has already learned from job experience. So schooling cannot raise industry-specific knowledge for him as much as for the worker with little job experience. To formalize this idea, we assume that the relative contribution of the general human capital,  $\omega^i$ , is a function of general human capital and specific human capital acquired from non-general education as follows:

$$\omega^i = \begin{cases} 1 & \text{if } h_t^g \geq h_t^{s,i} \\ 0 & \text{otherwise.} \end{cases} \quad (43)$$

This formulation, together with (42), tells us that, when general human capital ( $h_t^g$ ) is greater than job-specific knowledge acquired from non-general education such as job experience and training ( $\gamma^i h_{t-1}^i$ ), workers can learn something new and consequently increase specific human capital ( $h_t^i$ ) through general education in school. But when it is smaller, they learn nothing new and cannot increase job-specific knowledge through general education.

### B. MULTIPLE EQUILIBRIA

The technology of acquiring specific human capital, as described in (42) and (43), can generate multiple equilibria depending on the initial conditions. To illustrate this, rewrite equation (43) for the initial period as:

$$\omega^i = \begin{cases} 1 & \text{if } (1 + B u_0) h_0^g \geq \gamma^i h_0^i \\ 0 & \text{otherwise.} \end{cases} \quad (44)$$

<sup>23</sup>By further specifying  $\gamma_t^i$ , we could easily deal with more special cases of industry-specific education. For example, in case of on-the-job-training, we could express the coefficient as:  $\gamma_t^i = (1 + B^S u_t^i)$ . We could also explicitly introduce learning-by-doing (or job experience) by expressing  $\gamma_t^i$  as a function of time devoted to work in the previous periods. Obviously, the qualitative results of this section for the general case holds for the more special cases as well.

where  $h_0^g$  and  $h_0^i$  are the initial levels of general human capital and specific human capital. The expression indicates that, because of overlapping, general human capital can raise specific human capital only if the initial level of general human capital stock,  $h_0^g$ , is sufficiently large. If the initial level of general human capital ( $h_0^g$ ) is below  $\gamma^i h_0^i$ , a part of the general education the worker receives in the initial period,  $u_0$ , only helps to bridge this gap, similar to a sunk cost.

Under the technology constraint (42) and (44), workers' optimal decision on whether or not they make the initial investment in general human capital depends on the relative size of the utility losses due to the sunk cost and the expected utility gains through increases in general human capital. If the worker's utility loss in the initial period is outweighed by the expected utility gains in later periods, he will take up such sunk cost associated with the initial education. However, if the utility loss exceeds the expected utility gains in later periods, he will not receive the initial education.

To discuss more formally workers' decision on whether they receive the initial education or not, we make some simplifying assumptions. For simplicity, suppose that  $\gamma^i$  are identical at one across sectors,<sup>24</sup> and let  $\alpha_0 (= \frac{h_0^g}{h_0^i})$  be the initial ratio of general to specific human capital stock. In addition, suppose that in the initial period workers receive general education just enough to fulfill the initial gap between their general and specific human capital stock.

Under the assumptions, we can derive and compare the indirect utility of receiving and not receiving initial general education. Let  $W_0$  be the indirect utility of not receiving general education,  $W_0^{NT}$  the indirect utility of receiving general education in a closed economy, and  $W_0^T$  the indirect utility of receiving education in an open economy, respectively. By comparing the indirect utilities, it can then be shown that there exists a unique threshold ratio of general to industry-specific human capital stock for both a closed economy and an open economy. For the case of autarky, there exists a threshold  $\alpha^{NT}$ , above which  $W_0^{NT}$  is greater than  $W_0$ , while for the open economy, there exists an  $\alpha^T$ , above which  $W_0^T$  is larger than  $W_0$ .<sup>25</sup>

<sup>24</sup>We can analyze a more complicated case where  $\gamma^i$ s are high for some sectors and low for others, and hence some types of specific human capital are augmented by specific education including job experience while others are increased by general education. In an open economy, this more general case generates a partial specialization as opposed to a perfect specialization of an economy to one industry. In this case, however, the main qualitative results of the paper does not change.

<sup>25</sup>Under the simplifying assumptions, we have  $W_0^{NT}$  and  $W_0^T$  as follows:  $W_0^{NT} = \sum_{i=1}^n \log[\frac{A_0^i h_0^i}{n}] + n \log(1 - u_0^r) + E_0[\sum_{t=1}^{\infty} \beta^t \sum_{i=1}^n \log[\frac{A_t^i (1+g_t^h)^{t-1} h_0^i (1-u_t)}{n}]]$ , and  $W_0^T = \sum_{i=1}^n \log[\frac{A_0^i h_0^i}{n}] + n \log(1 - u_0^r) + E_0[\sum_{t=1}^{\infty} \beta^t \sum_{i=1}^n \log[\frac{A_t^{i*} (1+g_t^h)^{t-1} h_0^i (1-u_t)}{n}]]$ , where  $u_0^r$  is the initial education required to fulfill the gap between general and specific human capital, and  $A_t^{i*}$  is the technology level of the sector with the highest productivity at time  $t$ .

The existence of the threshold ratio implies that, depending on the initial ratio of general to specific human capital stock, there exist two equilibria: an equilibrium with continuous general education and without it.<sup>26</sup> To illustrate this, consider, for example, the autarky case. First, imagine an autarky economy where  $\alpha_0 < \alpha^{NT}$ . This is the case in which a country has workers with very low initial level of general human capital ( $h_0^g$ ) compared to their specific human capital ( $h_0^i$ ), and hence their utility losses (or sunk cost) from receiving general education in the initial period is too large compared to their utility gains in the subsequent periods. Then it holds that  $W_0^{NT} < W_0$ , and therefore workers do not receive general education. Hence in this case, the economy will likely be trapped in poverty with no general education and slow growth.<sup>27</sup>

Second, consider the case where  $\alpha_0 > \alpha^{NT}$ . This happens when a country has workers with a reasonably high level of initial general human capital ( $h_0^g$ ) compared to specific human capital ( $h_0^i$ ). In this case, workers' utility gain from the initial education is larger than their utility losses in the initial period. Then it holds that  $W_0^{NT} > W_0$ , and consequently workers receive general education in the initial period and thereafter. Hence growth is driven by not only technological progress but also human capital accumulation, so that this economy with a high initial ratio of general to specific human capital tends to have a higher growth than one with a very low level.

### C. TRADE LIBERALIZATION

We now examine how trade liberalization can pull an economy out of a low growth trap and transform it into one with high growth. For this purpose, we compare the utility from receiving initial general education in an open economy and in a closed economy. It can be shown that

$$W_0^T > W_0^{NT}, \quad (45)$$

which tells us that workers have greater utility from receiving initial general education in an open economy than a closed economy. The reason is that under autarky the returns to general education depends on the average of the sectoral wages, while under open economy, it depends on the highest wages, and therefore international trade raises the returns to general education.

<sup>26</sup>This is hardly the first paper to note the role of human capital in determining a poverty trap. Above all, Romer (1990) presents a model where too low initial aggregate human capital of an economy induces low productivity of human capital in the R&D sector, and no investment on it, which leads to stagnation. In a small open economy model, Galor and Tsiddon (1997) suggests that distribution of human capital may play an important role in determining poverty trap. Our model may be seen as contributing to this literature by pointing out the importance of a new variable, the ratio of general to specific human capital, in determining whether a country is trapped in poverty or not.

<sup>27</sup>Increases in specific human capital due to endogenous learning-by-doing could reinforce the equilibrium of poverty trap.

It then follows that

$$\alpha^T < \alpha^{NT}, \quad (46)$$

which suggest that the threshold ratio of an open economy ( $\alpha^T$ ) is lower than that of an autarky ( $\alpha^{NT}$ ). Such a difference in the threshold ratio implies that the growth effect of trade liberalization depends on the initial ratio of general to job-specific human capital stock.

Table 1 illustrates how trade liberalization affects the growth of general education and output in three distinct cases of the initial ratio. In the case where  $\alpha_0 < \alpha^T$  (i.e., where workers' initial general human capital is substantially smaller than specific human capital), in spite of the market opening, sunk cost of initial education is too high compared to the expected utility gains, and therefore trade liberalization cannot encourage human capital growth. In addition, under the assumption that initial technology is equal across sectors, trade liberalization has no effect on the overall technological progress, and hence the growth effect of international trade is zero. In the case where  $\alpha_0 > \alpha^{NT}$  (i.e., where workers have a high initial ratio of general to specific human capital), trade liberalization does not affect the accumulation of human capital, but—with the help of general human capital—accelerates overall technical progress from  $\lambda^{avg}$  to  $\lambda^{max}$ , as in Section 2-3. Hence the growth effect of international trade is:  $[\lambda^{max} - \lambda^{avg}]\beta(1 + B)$ , which is non-negative.

Our particular interest is in the intermediate case where  $\alpha^T < \alpha_0 < \alpha^{NT}$ , since this is the case where trade liberalization can break an economy out of a poverty trap. This happens when workers have a low but not substantially low initial general human capital compared to specific human capital. In this case, without international trade, workers do not receive general education because of large sunk costs related to initial general education (note that  $\alpha_0 < \alpha^{NT}$ ). However, if the country opens the markets, the return to general human capital increases. As a result, workers' utility gains from receiving general education increases from  $W_1^{NT}$  to  $W_1^T$ , and the threshold ratio decreases from  $\alpha^{NT}$  to  $\alpha^T$ . Since  $\alpha_0 > \alpha^T$ , the welfare gain is large enough to offset the sunk cost. Therefore workers who did not receive general education before, will start to receive general education. Then, an economy which used to be in an equilibrium with no general education can move to one with continuous education, and the rate of human capital growth increases from zero to  $\beta(1 + B) - 1$ . In addition, as workers start to use general human capital to raise their industry-specific human capital, international trade combined with general human capital increases the rate of overall technological progress from  $\lambda^{avg}$  to  $\lambda^{max}$  as shown in Section 2. Consequently, trade liberalization raises output growth from  $\lambda^{avg} - 1$  to  $\lambda^{max}\beta(1 + B) - 1$ . That is, trade liberalization can transform a poverty-trapped economy with no general education and slow growth into one with continuous education growth, faster overall technological progress and higher output growth.

The conclusions about the existence of multiple equilibria and the role of international trade in pulling an economy out of a low growth trap, are of significant interest in explaining various growth experience across countries and over time. We are particularly interested in the case where  $\alpha^T < \alpha_0 < \alpha^{NT}$ , since it may explain the coexistence of the poverty trap experienced in many developing countries and the growth miracles enjoyed by the



export-oriented Asian NICS. The above discussion indicates that, in this case, two economies with similar initial conditions can follow totally different growth paths depending on whether or not international trade is promoted. Consider, for example, the Philippines and Korea, which showed similarity in many respects, including per capital income, production structure and secondary school enrollment in early 1960s (see Lucas (1993)). However, the Philippines opened its market only in the late 1980s, while Korea opened up during the mid-1960s (see Sachs and Warner (1995)). Then the Philippines suffered slow growth and low education, while Korea experienced rapid economic growth and rapid increases in education for the last three decades.<sup>28</sup> In particular, Korean per capita income growth jumped up in the mid-1960s from 2 percent of the previous decade, and has since stayed at 6-7 percent a year on average.<sup>29</sup>

Table 1. Initial Education Level and Growth Effect of Trade

	$\alpha_0 < \alpha^T$	$\alpha^T < \alpha_0 < \alpha^{NT}$	$\alpha_0 > \alpha^{NT}$
closed economy	$g^h = 0$ $g^{NT} = \lambda^{avg} - 1$	$g^h = 0$ $g^{NT} = \lambda^{avg} - 1$	$g^h = \beta(1 + B) - 1$ $g^{NT} = \lambda^{avg} \beta(1 + B) - 1$
open economy	$g^h = 0$ $g^T = \lambda^{avg} - 1$	$g^h = \beta(1 + B) - 1$ $g^T = \lambda^{max} \beta(1 + B) - 1$	$g^h = \beta(1 + B) - 1$ $g^T = \lambda^{max} \beta(1 + B) - 1$
growth effect of trade	$\Delta g = 0$	$\Delta g = \lambda^{max} \beta(1 + B) - \lambda^{avg}$	$\Delta g = \lambda^{max} \beta(1 + B) - \lambda^{avg} \beta(1 + B)$

## V. CONCLUDING REMARKS

This paper presents an endogenous growth model where general human capital acquired through general education is essential to increase or maintain the mobility of workers across industries. This model suggests that international trade and general human capital, reinforcing each other, can have a positive growth effect in the long run. When trade is allowed, general human capital allows workers to specialize in the sector with the highest productivity in every period. This specialization induces the growth rate of the economy to

<sup>28</sup>If we take the speed of changes in production structure as a proxy for mobility, we can find a much higher mobility in Korea. For example, Korean industrial production as a share of GDP changed rapidly from 25 percent in 1965 to 43 percent in 1987, compared to the Philippines' slow change from 28 percent to 33 percent.

<sup>29</sup>Our result on multiple equilibria also suggests an explanation why Britain failed to move to a fast growing path in the early twenties. Britain stayed heavily in the old industries before World War I, while other countries such as Germany and the United States moved fast to new industries. An explanation may be found in the fact that, in the late nineteenth, Britain had lower education level compared to the other European countries. For example, the school enrolment ratio (measured by the fraction of those aged 5-19 enrolled at primary or secondary school) of Britain in 1890 was 0.39 compared to the other European's 0.58 (see Crafts (1985)). This low education or general human capital may have induced Britain to stay heavily in the old industries.

depend on the technical progress of the sector which progresses most rapidly in the long run.<sup>30</sup> By contrast, without either international trade or general human capital, the economy's growth rate depends on the average technical progress of all industries. Clearly, then, a more outward-oriented economy shows more rapid economic growth. The paper also shows that, depending on the initial ratio of general to specific human capital stock, there exist two equilibrium growth paths: one of high growth and continuous general education, and the other a poverty trap with slow growth and low education. Further, it shows that if the ratio is not substantially low, trade liberalization can allow an economy to shift out of the poverty trap to achieve continuous education and higher output growth.

The current model has some interesting extensions. For example, we might allow for the rate of technological progress in each sector to be determined endogenously. To focus on the allocative effect of trade on the effective rate of technical progress, the current paper assumes that probability distribution of technological changes in each industry is given exogenously. However, we could consider a case in which the probability of having a technological change can also be affected by learning-by-doing, R & D investment, or the accumulated level of education.

In addition, the role of general human capital in raising the growth rate in an open economy could be explored in other contexts. In the current framework, the role of general human capital is to increase the flexibility of workers to migrate across sectors. However, general human capital could also play a crucial role in increasing the adaptability of workers to new technology in any specific sector. It would be interesting to analyze a model where an industry experiencing technological change needs to rely on general human capital in order to adopt new technology, rather than the specific human capital which now has become obsolete.

It would be also interesting if some cross-country data on the ratio of general to industry-specific human capital are well documented. A good proxy for this could be the ratio of schooling to on-the-job-training, though internationally comparable data on on-the-job-training are not easily available. Another good proxy could be the ratio of enrolment in general and technical high schools, which Bertocchi and Spagat (1998) use as a measure of the stratification of society between elite and non-elite. This ratio would serve as a good proxy for the ratio of general to industry-specific human capital as well, if vocational schools focus on industry-specific training. In some countries, particularly in Korea, however, vocational schools focus largely on non-industry-specific human capital, and industry-specific skills are accumulated largely on the job. Considering this, a better proxy may be the sum of students enrolled in general schools and vocational schools—adjusted by the portion of time devoted to general curriculum and non-industry specific vocational skills—divided by the

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<sup>30</sup>The idea of a positive growth effect of a specialization could be also applied to other types of specialization. De Gregorio and Kim (1999) recently presented a model where credit markets allow the more able to specialize in studying and the less able in working, which leads to the acceleration of human capital accumulation and output growth.

number of workers at same age group, though it would take a considerable amount of time and efforts to make the data set.<sup>31</sup>

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<sup>31</sup>Under the strong assumption that vocational schools teach little industry-specific skills, this proxy could be reduced to the ratio of students to workers or the enrollment ratio. Secondary school enrolment in Korea roughly tripled from 35 percent to 95 percent between 1965 and 1986, compared to the Philippines 41 percent to 68 percent. This may indicate that in the initial period (in 1965), it holds  $\alpha^T < \alpha_0^{Korea} < \alpha_0^{Philippines} < \alpha^{NT}$ , (so the Philippines had a slightly higher initial ratio), but trade liberalization led to a rapid increase in education and general human capital in Korea. Of course, this result should be taken with caveat, because of the assumption that vocational schools teach mostly general human capital.

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