ECONOMIC MODELS OF DEVELOPING COUNTRIES IN THE GLOBAL ECONOMY

DISSERTATION

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In this dissertation I present three essays on the economy of developing countries. All of these are related to policy issues. The first essay introduces a model that explains the economic rationale for the observed policy combination of a developing country (inviting foreign direct investment (FDI) through education investment (EDI)) and the interest of a multinational corporation (MNC) about the local labor quality when it contemplates FDI. Information on local labor is the source of a more efficient contract for the MNC with local labor, and the local government can benefit both agents through EDI, FDI and information sharing. It is shown that the government of a country in an earlier stage of development will have a stronger incentive for EDI given FDI. While the MNC also benefits from EDI and information sharing, otherwise it will avoid FDI in that country. In that sense, EDI and FDI have a mutually beneficial and causal relationship. However, the policy tends to benefit the government and the MNC at the expense of local labor welfare.

The second essay introduces a model that can be used to investigate the welfare effects for a developed country which mandates child labor prohibition by their developing country trading partner. Although child labor prohibition in developing countries is often insisted by the government of developed countries and is a crucial issue
in WTO and regional trade negotiations, no theoretical framework exists to explain this situation. I address this issue using human capital accumulation theory and general equilibrium trade theory. I show that the distinction between the short run and the long run effects of child labor policy is very important, both in magnitude and direction of influence. The incorporation of increasing returns to scale technology in the trade model can lead to a situation in which child labor prohibition converts the importer-exporter positions. I show the conditions for positive gains from this conversion. My framework is generally applicable to analyses of policy change which entail human capital accumulation processes.

The third essay introduces an alternative path for economic growth and welfare improvement through economic integration among less developed countries. Depending on the sector, lower production volatilities (higher production stability) resulting from economic integration can have opposite effects on the rate of economic growth: manufacturing is positive, but agriculture is negative. However, economic integration is always welfare improving if it reduces production volatilities of both sectors, regardless if growth rates increase or not. The market equilibrium rate of growth is lower than the optimal growth rate, but the government can achieve the latter through a combined policy of subsidy and production stabilization. Production stabilization also reduces the level of subsidy, even if subsidies alone can achieve the optimal growth rate. While existing growth models have shown the positive effect of production volatility on economic growth and welfare, this model shows possible negative effects of production volatility on economic growth and welfare.
Dedicated to my parents and Tetsu Ishii
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CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 Overview of the Economy of Developing Countries

Overcoming poverty and catching up with the economy of developed countries has long been the primary and ultimate goal of the people and governments of developing countries. However, as the statistics below clearly show, this goal has not been achieved yet. Still worse, the economic inequality between developed and developing countries is increasing, instead of decreasing. The problems originated from this economic gap has never been more serious than today. First, poverty leads to higher population growth. As a result, growing number of people have no basic economic entitlement, which discourages efforts to overcome poverty and inequality. This is a vicious cycle. Second, it is not hard to imagine that growing inequality is the source of hatred and tension in international relations. Without solving this problem, we cannot have a stable, peaceful and prosperous world in the future. I believe that the economy of developing countries is the most urgent and important field in economics.

According to World Development Report 2000/2001 (World Bank 2000), of the world population 6 billion, 2.8 billion (47%) live on less than $2 a day, and 1.2 billion (20%) live on less than $1 a day. 44% of the latter are living in South Asia, 24% living in Sub-Saharan Africa, and 23% in East Asia and Pacific. In East Asia, people living on less than $1 fell from 420 million to 280 million between 1987 and 1998. Yet in South
Asia, Sub-Saharan Africa, and Latin America the numbers have been rising during the same period (World Bank 2000).

How about economic inequality? High income group countries (per capita GNP is higher than $9,265) have only 0.89 billion people (15%), but they dominate 78% of gross world product. On the other hand, low income group countries (per capita GNP is lower than $775) have 2.4 billion people (40%), but they earn only 3.4% of gross world product. The average income of the richest 20 countries is 37 times the average of the poorest 20, and this gap has doubled in the past 40 years.

These problems are likely to be more serious in near future, because world population will grow by some 2 billion in the next 25 years, with 97 percent of that in developing countries. In this dissertation, I would like to make a small contribution to analysis of the economy of developing countries.

Let me move on to the methodologies used in this dissertation. Although there are many different approaches to analyze the economy of developing countries, international microeconomics is perhaps the most promising field, if we address the problem relative to the global economy. There are four main subfields in international microeconomics: international trade, foreign direct investment, economic integration and factor movement. The first three are used in this dissertation.

Another important field to address the above issues is economic growth theory, which is a subfield of macroeconomics. My third essay introduces an endogenous growth

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1 The author calculated from World Bank (2000).
model to investigate the impact of economic integration on economic growth and welfare. Hence, this is an interdisciplinary work. Now let me review the development of literature related to each essay.

1.2 Theory of Foreign Direct Investment

Since Wilfred Ethier (1986) modeled the internalization advantage of foreign direct investment (FDI), the role of information has attracted a great deal of attention in FDI theory (Ethier and Markusen 1996). Both of these show the merit of FDI over licensing contracts. Information transactions with a local firm are costly and should be internalized due to difficulty of making incentive compatible contracts (Ethier 1986). Furthermore, with an arms-length contract, one firm informs another firm of its production technology secrets, which may give the licensee incentive to defect from the contract and become a competitor (Ethier and Markusen 1996). These types of situation can be avoided with FDI, since information is internalized.

Horstmann and Markusen (1996) also address the role of information and FDI. They investigate the mode of entry chosen by a multinational corporation (MNC): FDI or licensing contract. The merit of the former is that the MNC can avoid transaction costs, while the merit of the latter is that the MNC can avoid a costly mistake by incorrectly assessing market size. Demand information in the local economy plays a crucial role where the local firm has an advantage over the MNC.

In all of these models, the transaction of information (about technology or market demand) with a local firm is costly thus providing an incentive for the MNC to choose FDI. The models further assume that the final goods produced abroad by the MNC
licensing or FDI) must be consumed in the local economy. Exportation of goods from the local economy is not an option for the MNC, thus making the local final good (output) market critical. Unlike earlier works, in the first essay I focus on FDI within the context of a developing country. As such, three additional considerations are important: information about local labor quality, high export-to-sales ratios and the role of governments (Hayami 1995, United Nations 1999, McMilan, Pandolfi and Salinger 1999). In the first essay, I provide a mechanism by which both the MNC and local government can gain by making (inviting) FDI and sharing information about local labor. And, as an incentive for the local government to invest in education (EDI), it must increase the value of the information that is shared by the government and the MNC. Promotion of education can also aid in attracting a competitive firm. I propose a model consistent with these considerations.

1.3 Child Labor Issue in Trade Models

Child labor use in developing countries is an important topic in international trade negotiations. It is not uncommon for the developed country to insist upon the prohibition of child labor use in the developing country. The efficacy of using trade sanctions and other devices to enforce child labor prohibition has many dimensions and continues to be a hot topic of debate in the Doha Development Round (Bhagwati 2002). A framework to address this issue, however, is conspicuously absent from the trade literature.

Recognizing this need and that their model could offer little insight to international trade

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2 As shown in chapter 2, this is true especially for FDI in South East Asian countries.
3 President Clinton signed a treaty committing the U.S. to international laws that ban the worst forms of child labor (ILO convention 182) on December 2, 1999. The day before, at the WTO meeting in Seattle, Clinton urged trade ministers from 135 countries of WTO to search for ways to tie trade agreements to worker rights (Seattle Times 1999).
issues, Basu and Van (1998) identify the urgent need for an analytical framework which includes the trade dimension. In the second essay I respond to this calling, by developing a model to examine the economic effects on a developed country when it imposes child labor prohibition on its developing country trading partner.

Fischer and Serra (1998) show the effects of imposing standards as means of trade protection; child labor as a case in point. They consider the situation of a duopoly with one good and the effects of government set standards on the profits of the domestic firm. This model, however, is inadequate to analyze child labor policy because inter-temporal changes in factor endowments and factor movements among industries are not allowed. A multi-good and multi-period model is required. In the second essay I overcome this deficiency by deriving a two good, two factor and multi-period (continuous time) model.

Findlay and Kierzkowski (1983) incorporated the formation of human capital into a trade model within a general equilibrium framework. Many extensions and adaptations have followed. Flug and Galor (1986) applied the Findlay-Kierzkowski (F-K) model to examine the impact of a minimum wage on the trade pattern. Miyagiwa (1989) applied the F-K model to examine the impact on the employment and national income of an exogenous increase in physical capital in a small minimum-wage economy. Wooton (1991) transformed the F-K model into an overlapping generation type model and endogenized both physical and human capital accumulation. In the second essay, I too transform the F-K model to correctly examine the impact of child labor prohibition on the economic welfare of a developed country.
1.4 Literature on Economic Integration, Production Stability and Economic Growth


The macroeconomic literature has modeled the relationship of consumer saving decisions to income uncertainty (Sandmo 1970, Carroll 1992, Caballero 1991). To a much lesser extent, some economic growth models incorporate income uncertainty due to production shocks and investigate the effects of production volatility change on growth rates (Newbery and Stiglitz 1981, Smith 1996, Canton 1996). All these models conclude higher volatility in production leads to higher precautionary savings, which leads to higher investment and growth rate.

While some empirical studies support the positive relationship between production volatility and average growth rates in developed countries (Kormendi and Meguire 1985, Grier and Tullock 1989), one frequently cited study (of production shock, precautionary savings and economic growth), does not (Smith 1996). In his simulation study based on his own theoretical model, Smith found that the precautionary saving motive raises average growth rates by only 0.1% from the case without it.

The positive relationship between production shock volatility and growth rates in developed countries could neither be confirmed empirically. An ARCH-M model was
estimated using time series data for three developed countries (US, UK and Japan) to test
the production volatility-growth relationship (Smith 1996). Of the three, only Japan had
a strong positive result; the US had insignificant estimate and UK had a negative sign.
Again, this result sheds doubt on the impact of production shocks on the economic
growth of developed countries.

   On the other hand, the claim for developing countries is that production stability is
Especially, instability of agricultural production can adversely affect investment,
production growth and consumption, which in turn can damage the economic growth of
the country (Eicher and Staatz 1998, Abler, Tolley and Kripalani 1994). Additionally,
Ramey and Ramey (1995) found that countries with higher production volatility have
lower growth rates in contrast to the positive relationship of Kormendi and Meguire
(1985) and Grier and Tullock (1989).

   However, application of existing growth theory to an LDC suggests that higher
production volatility would grow the economy. The third essay explores the possibility
of a negative volatility effect on economic growth and welfare. Another inadequacy of
existing models is that none provides the specific source of production volatility change;
it is assumed exogenous. In the third essay, it is shown that economic integration likely
reduces production volatility.

   Some theoretical work examines the effect of economic integration on economic
growth. Economic integration between countries of similar sizes and resource

\footnote{Aizenman and Marion (1993) modeled the effect of policy fluctuation in tax regime on economic growth. However, their analysis is on volatility of policy itself rather than production volatility affected by government policy.}
endowments can lead to higher growth rates through increased information flows of
general scientific knowledge (Rivera-Batiz and Romer 1990) and through increased
entrepreneurial competition (Grossman and Helpman 1991b). In the third essay, I show
alternative path for economic growth through economic integration among LDCs. In
particular, economic integration reduces production volatility (increases production
stability), which can facilitate both higher economic growth rates and welfare
improvement through lower income uncertainty and higher returns from investment.

1.5 Organization of Dissertation

This dissertation is organized as follows. In Chapter 2, I develop a model that
explains the economic rationale for the observed policy combination of a developing
country (inviting FDI through EDI) and the interest of a MNC about the local labor
quality when it contemplates FDI. Information on local labor is the source of a more
efficient contract for the MNC with local labor, and the local government can benefit
both agents through EDI, FDI and information sharing. In the model a new concept term
*take-off point*, the point at which the government starts making EDI, is introduced. The
behavior of *take-off point* is the main focus of the model.

In Chapter 3, I introduce a model that can be used to investigate the welfare effects
for a developed country which mandates child labor prohibition by their developing
country trading partner. I address this issue using human capital accumulation theory and
general equilibrium trade theory. I make several important transformations on Findlay-
Kierzkowski Model to adequately address the issue. Especially decomposing the model
into two systems enables us to clearly distinguish the long run from the short run effects
of child labor prohibition. The incorporation of increasing returns to scale technology in
the trade model can lead to a situation in which child labor prohibition converts the
importer-exporter positions. I show the conditions for positive gains from this
conversion.

In Chapter 4, I develop an endogenous growth model to show the possible link
between economic growth and production stability resulted from economic integration,
which cannot be explained by existing models. Welfare implications are even stronger;
economic integration is always welfare improving if it reduces production volatilities of
both sectors, regardless if growth rates increase or not. While, the market equilibrium
rate of growth is lower than the optimal growth rate, but the government can achieve the
latter through a combined policy of subsidy and production stabilization. Production
stabilization also reduces the level of subsidy, even if subsidies alone can achieve the
optimal growth rate.
CHAPTER 2
FOREIGN DIRECT INVESTMENT AND EDUCATION INVESTMENT BY THE DEVELOPING COUNTRY

2.1 Introduction

Ethier (1986), and Ethier and Markusen (1996) show the merit of FDI over licensing contracts because FDI can internalize technological information. Horstmann and Markusen (1996) also show the merit of FDI internalizing market demand information. All of these emphasize the internalization advantage of FDI. These models have another common assumption: the final goods produced abroad by the MNC (licensing or FDI) must be consumed in the local economy. Exportation of goods from the local economy is not an option for the MNC. Unlike earlier works, in this essay we focus on FDI within the context of a developing country. As such, three additional considerations are important: information about local labor quality, high export-to-sales ratios and the role of governments (local or national).

For a developing country, the output market itself maybe relatively unimportant; however, its role as a production center for the MNC can be very important (Hayami 1995, McMilan, Pandolfi and Salinger 1999). Since the skilled wage rate is generally lower than in the developed country, production operations within the developing country are typically more profitable for the MNC.
For many industries, the importance of the local labor market relative to the local output market is dramatic. This is typical in East Asia. In 1995, for instance, 27.4 percent of the workers in Japanese electrical products industry lived abroad, while for the automobile and nonferrous metal industries these numbers were 32.3 and 36.5 percent, respectively. FDI is very important for the local labor market. The share of employment within the electrical products industry held by Japanese firms was 38.8 percent in Singapore, 37.3 percent in Indonesia, 38.0 percent in the Philippines and 28.2 percent in Malaysia. For the automobile industry the employment shares were 34.3 percent in Indonesia and 30.9 percent in Malaysia.5 While Japanese firms employ a large number of local workers, a large portion of final good sales are exported.

For Japanese firms within the ASEAN 4 (Indonesia, Thailand, the Philippines and Malaysia), the ratio of exports to total local sales in 1996 was 79 percent for the electrical products industry, 57.6 percent for the precision machinery industry and 54.0 percent for the textile industry (Fukao and Amano 1998). For all industries 18.1 percent of the total exports in 1996 of the Philippines was by Japanese firms. For Malaysia and Thailand total exports by Japanese firms were 17.7 and 17.3 percent, respectively (MITI 1999). In contrast to the model assumptions set forth in previous models (Ethier, Ethier and Markusen; Horstmann and Markusen), these numbers clearly argue that exporting abroad by a MNC must be an option. There is a need for a model which allows the MNC to gain from using local labor while not being constrained by the size of the output market of the host country.6

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5 All of these are data for 1995, cited from Fukao and Amano (1998).
6 Glass and Saggi (1999) introduced a model in which MNCs export all commodities to a third country, but it does not include information transactions including about local labor quality.
It is also common for the government (local or national) of a developing country to entice the MNC to enter with evidence of a high quality local labor force. This practice is typified by government investment in education (United Nations 1999, McMilan, Pandolfi and Salinger 1999). As a result, revelation of information about local labor quality and education investment (EDI) is the often used policy of the local government, as it hosts (or seeks to host) the MNC.\(^7\) By the same token, the MNC has an equally strong interest in information about the local labor force, as it is a key determinant of the cost of operating in a developing country (Ito 1996, Urata 2002).

South East Asian countries have indeed increased their investments in education (EDI). The education budgets in the ASEAN 4 countries increased dramatically during the 1980s and 1990s. In the Philippines the education budget was 6.7 trillion pesos in 1983, 33.5 trillion pesos in 1990 and 61.7 trillion pesos in 1995, representing real (after CPI deflated) annual increases of 16.4 and 8.5 percent, respectively. Of the total country expenditures the budget share for education was 12.0 percent in 1983, 12.9 percent in 1990 and, 16.6 percent in 1995. In Malaysia, the budget for education was 3.9 billion ringgit in 1983, 6.6 billion ringgit in 1990 and 10.6 billion ringgit in 1995, representing real (CPI deflated) annual increases 6.4 and 7.3 percent, respectively. The budget share of education in Malaysia was 15.1 percent in 1983, to 18.5 percent in 1990 and 20.4 percent in 1995. In Indonesia, real (CPI deflated) annual increases the budget for education were 13.8 and 10.1 percent for the 1983-99 and 1990-95 periods, respectively.\(^8\)

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\(^7\) See Collins and Bosworth (1996) and Bloom, Sachs, Collier and Udry (1998) for the policy of East Asia: the combination of promotion of education and outward-oriented economy.

\(^8\) Author computed from Asian Development Bank (2001) data.
Additional evidence is that the number of students in the government-run vocational training institutes in the ASEAN 4 countries more than doubled during the 1980s. About 60 percent of these students studied mechanics while more than 20 percent studied electrical engineering (Nippon Foundation 1996). FDI in this region also increased rapidly during the 1980s. The annual flow of FDI into ASEAN countries by Japanese manufacturers was about 400 million dollars in 1981 which increased to 1.5 billion dollars by 1989 (MITI 1990).

In this essay, we provide a mechanism by which both the MNC and local government can gain by making (inviting) FDI and sharing information about local labor. And, as an incentive for the local government to invest in education (EDI), it must increase the value of the information that is shared by the government and the MNC. Promotion of education can aid in attracting a competitive firm. We propose a model consistent with these considerations.

In our benchmark model, the MNC seeks to maximize profit through principal agent contracts with local (skilled and unskilled) workers. However, as it only knows the probability distribution of the composition of skilled labor, it has a strong interest in more precise information (the exact portion of local labor in the category “skilled labor”). Precise information on local labor will lead to a more efficient contract and is the source of information rent. The local government, which has superior information about the local labor force, takes advantage of the MNC by tax its profits. In turn, the local government has an incentive to use these tax revenues for education (EDI) because this raises the value of information and, thus, profits of the MNC. One strategy for the local government may be to tax profits and use the added revenues to promote education.
The importance of the relationship between FDI and the policy of the local
government has been recognized in the literature (Horstmann and Markusen 1987, Glass
which the government of a developing country subsidizes the MNC to earn rents through
technology transfer and/or wage increases. However, the model we develop differs in
several respects. First, in the Glass-Saggi model (G-S) the government is a social welfare
maximizer as it seeks to maximize the welfare of both local labor and the host country
firm. However, in our model the government is one of the players which may try to
maximize its own income or the welfare of the local labor through taxation and EDI. Its
interest could either be the same or different from that of local labor. In this sense we
better reflect reality in many developing countries, in that the government may place a
higher priority on income over the welfare of local labor. Second, the G-S model
assumes that the local government directly subsidizes the MNC. Here we differ again in
that we allow local government to share labor information with the MNC, enabling it to
earn even greater profit. We are the first to model the relationships among FDI, EDI, and
the rents accruing from local labor information.

Our arguments are developed as follows. In section 2.2, the basic characteristics of
the model are introduced. In section 2.3, the properties of information rent are derived
and the MNC’s entry point is defined. In section 2.4, we investigate the policy of the
local government which chooses the tax rate and level of investment in education to
maximize its income. In section 2.5, the welfare effect of the policy is illustrated where

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9 In section 2.5, it is shown that the policy which maximizes tax income and that which maximizes welfare
of local labor is quite different in our model.
we show that the local government’s policy can benefit both itself and the MNC. It is also possible that the policy may benefit the government and MNC at the expense of local labor. Finally, conclusions follow in section 2.6.

2.2 Model Description

Information about the quality of local labor plays an important role in our model. The information gap between the local government and the MNC creates information rent which provides the incentive to promote education.

The local government has superior information on the local labor force (composition of the skilled labor) over the MNC seeking to move production to the developing country. The MNC has a profit motive in acquiring labor quality information. Because higher MNC tax revenues flow from higher MNC profits, the local government takes advantage of the MNC’s interest in labor information by investing in education and revealing it.

An interesting aspect of our model is that the MNC may actually provide incentives to invest more in education by simply inquiring about the level of education (in another context the local government may want to reveal the information in order to augment the MNC profits). By so doing, both agents are always at least as well off as if they did nothing. In the following sections, it is shown that this strategy set (inquiry about local labor by the MNC, taxing the profit, and use of the revenues for education) can be made incentive compatible.

In addition, information sharing may give both sides the incentive to invest (FDI and EDI), which may not happen without the other. An interesting aspect is that greater

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10 We assume that the MNC does not have the option to license the local firm due to high merit of internalizing technological information.
investment tends to occur during the early stages of development (low expected education level) and when there is a high potential for growth (low cost of education). However, without information sharing the MNC will avoid the country during the early development stage, and the local government will not invest in education (EDI) without FDI. But, information sharing initiates investments by both agents.

However, it is possible that the education level chosen by the local government will be considerably higher than that which maximizes the welfare of local labor. In this case the local government would increase its own income and the MNC’s profit at the expense of local labor.

2.3 Information Rent

Suppose an MNC wishes to move a factory to a developing country.\textsuperscript{11} The firm sells the product competitively as a price taker in the global market; thus, it can sell as much of the product as it wants at $p=1$ (price is normalized at one). Within the developing country the labor supply for the specific industry is fixed (also normalized at one).\textsuperscript{12} There are two types of labor (skilled and unskilled), but neither quality is observable before they start working. The greater the level of education, the greater the proportion of skilled labor. So, the composition of skilled labor, which is denoted as $P$, is also the indicator of the level of education. Although the MNC does not have precise information about the local composition of skilled labor ($P$), we posit that its distribution and mean

\textsuperscript{11} The decision of MNC entering the region depends on reservation profit, which is introduced later.
\textsuperscript{12} Alternatively we can assume that there is an unpaid factor whose volume is fixed (Ito and Oyama 1985). Also, hosting two firms in this industry is not possible because the first firm would reach capacity.
\( (P) \) is known.\(^{13} \) Knowing this probability distribution, the MNC seeks to design a profit maximizing contract. This contract will bring about a lower profit than if \( P \) is known with certainty.

If the MNC knows the real value of \( P \), it implements a standard principal agent problem. Following Varian (1978) and Kreps (1990),

\[
\begin{align*}
\max_{x_1, x_2, s_1, s_2} & \quad P(x_1 - s_1) + (1 - P)(x_2 - s_2) - F \\
\text{s.t.} & \quad s_1 - c_1(x_1) \geq 0 \\
& \quad s_2 - c_2(x_2) \geq 0 \\
& \quad s_1 - c_1(x_1) \geq s_2 - c_1(x_2) \\
& \quad s_2 - c_2(x_2) \geq s_2 - c_2(x_1),
\end{align*}
\]

where, \( i = \) type of labor (1 if skilled, 2 if unskilled), \( x_i \) is the production level of each labor type, \( s_i \) is the salary of each labor type, \( c_i \) is the disutility from working for each labor type, and \( F \) is fixed setup cost for the foreign operation. We assume that

\[ c_1(x) < c_2(x), 0 < c'_1(x) < c'_2(x) \text{ and } 0 < c''_1(x) < c''_2(x). \]

The first two constraints are the participation constraints which secures each type of labor their reservation utility. The next two are the incentive compatibility constraints which ensure that skilled labor achieves a higher utility by choosing \( x_1, s_1 \) than \( x_2, s_2 \) and the opposite is true for the unskilled labor. These are necessary to successfully distinguish skilled from unskilled labor. Solving this problem for a given \( P \) leads to the first order conditions,

\[ s_1 = c_1(x_1) + [s_2 - c_1(x_2)], \quad (2.1) \]

\(^{13} \) This assumes the situation in which the MNC knowing the statistics of \( P \) for a larger region tries to infer one for the specific area. We also could assume that disutility functions \( c_1(x_1) \) and \( c_2(x_2) \) are hidden information to the MNC. However, no principal agent model exists in which both the type of each individual and the disutility function of each type is hidden information.
\[ s_2 = c_2(x_2), \quad (2.2) \]
\[ c'_1(x_1) = 1, \quad (2.3) \]
\[ c'_2(x_2) = 1 + \frac{P}{1-P}[c'_1(x_2) - c'_2(x_2)]. \quad (2.4) \]

This optimization problem yields the optimal strategy vector \( (x_i(P), s_1(P), x_2(P), s_2(P)) \). However, if the MNC does not know the real value of \( P \), but knows only its probability distribution, the best strategy is to choose the target value of \( \tilde{P} \) as,

\[
\max_{\tilde{P}} \left[ \int_0^\tilde{P} [\tilde{P}(x_1(\tilde{P}) - s_1(\tilde{P})) + (1 - \tilde{P})(x_2(\tilde{P}) - s_2(\tilde{P}))]f(\tilde{P})d\tilde{P} - F \right]
= \max_{\tilde{P}} \left[ \int_0^\tilde{P} H(\tilde{P})f(\tilde{P})d\tilde{P} \right] - F.
\Rightarrow \tilde{P}^* = \arg\max_{\tilde{P}} \left[ \int_0^\tilde{P} H(\tilde{P})f(\tilde{P})d\tilde{P} \right].
\]

where, \( f(\tilde{P}) \) is the known probability distribution of \( \tilde{P} \), \( H(\tilde{P}) \) is MNC’s surplus from the principal agent contract using \( \tilde{P} \), and \( \tilde{P}^* \) is the target value which maximizes expected profit.

This solution will yield the target value \( \tilde{P}^* \), and hence the strategy vector \( (x_1(\tilde{P}^*), s_1(\tilde{P}^*), x_2(\tilde{P}^*), s_2(\tilde{P}^*)) \). This strategy can distinguish types of labor, because the incentive compatibilities must be satisfied at a chosen level of \( \tilde{P}^* \). However, it may be inefficient in the sense that profits may be lower than those based on the real \( P \).

Derivation of the optimal target value \( \tilde{P}^* \) requires an assumption about the probability distribution of \( \tilde{P} \) and the degree of convexity of \( H(\tilde{P}) \) in \( \tilde{P} \) (convexity of \( H(\tilde{P}) \) with respect to \( \tilde{P} \) is proved in Appendix A). If \( \tilde{P} \) is distributed uniformly between 0 and 1 and convexity is small, then the loss from choosing a high target value is
small. In this case the target could be \( \tilde{P}^* = 1 \), because \( H(\tilde{P}) \) is a non-decreasing function of \( \tilde{P} \) (proof in Appendix A). However, as the variance of the probability distribution around the mean decreases and the convexity of \( H(\tilde{P}) \) increases, the target value \( \tilde{P}^* \) approaches the mean \( \bar{P} \). To illustrate, we assume the target value of \( \tilde{P}^* \) chosen by the MNC is \( \bar{P} \). In this case, the MNC can calculate its profit from this contract for each real value of \( P \). We denote \( \bar{x}_1(\bar{P}), \bar{x}_1(\bar{P}), \bar{x}_2(\bar{P}), \bar{x}_2(\bar{P}) \) as the strategy chosen by the firm. This strategy successfully distinguishes skilled from unskilled labor regardless the real value of \( P \), implying that profits earned from skilled labor and from unskilled labor are fixed. Profit for this strategy is,

\[
\Pi(P, \bar{P}, F) = P[\bar{x}_1 - \bar{x}_2] + (1 - P)[\bar{x}_2 - \bar{x}_1] - F = a(\bar{P}) - F + b(\bar{P})P,
\]

where, \( a = \bar{x}_2 - \bar{x}_1, a'(\bar{P}) \leq 0, b = \bar{x}_1 - \bar{x}_2 + \bar{x}_2 \geq 0, b'(\bar{P}) \geq 0 \). Equation (2.5) is the reservation profit of the MNC. It is shown in Figure 2.1 as a positively sloped linear function of \( P \). \( a(\bar{P}) \) is profit from the contract with unskilled labor; which is non-increasing in \( \bar{P} \). \( b(\bar{P}) \) is the difference in profits between the contract with skilled labor and that with unskilled labor; it is non-negative, and non-decreasing in \( \bar{P} \).

If the firm knows the real value of \( P \), optimal profit is,

\[
\Pi^*(P, F) = P(x_1^*(P) - s_1^*(P)) + (1 - P)(x_2^*(P) - s_1^*(P)) - F.
\]

Information rent is then the difference between equations (2.6) and (2.5),

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14 If the MNC is the risk averse, it is more likely that \( \bar{P} \) will be chosen as the target value.

15 \( a(\bar{P}) - F \) is the intercept and \( b(\bar{P}) \) is the slope of reservation profit in Figure 2.1; \( b \geq 0 \) comes from the first order conditions of the principal agent contract and; \( a'(\bar{P}) \leq 0, b'(\bar{P}) \geq 0 \) come from non-decreasing and convexity of optimal profit.
\[ R(P, \bar{P}) = \Pi^*(P, F) - \Pi(P, \bar{P}, F) \]
\[ = P(x_1^*(P) - s_1^*(P)) + (1 - P)(x_2^*(P) - s_1^*(P)) - \left[ a(\bar{P}) + b(\bar{P})P \right]. \]  
(2.7)

Optimal profit \( \Pi^*(P, F) \) is non-decreasing and convex in \( P \). On the other hand, reservation profit \( \Pi(P, \bar{P}, F) \) is non-decreasing and linear in \( P \). These two are equal at \( P = \bar{P} \) which means that, if the target value of \( P \) is equal to the real value of \( P \), information rent is zero and, there is no loss of efficiency. At any other point \( \Pi^*(P, F) > \Pi(P, \bar{P}, F) \). Reservation profit is shown in Figure 2.1 as the tangency line at \( \bar{P} \) to the optimal profit. Vertical distance between the two is information rent which is shown in Figure 2.2.\(^\text{16}\)

![Graph showing optimal profit and reservation profit](image)

Figure 2.1: Optimal profit and reservation profit.

\(^{16}\) In Figure 2.2, information rent is larger on the right side of \( \bar{P} \) than on the left side, but the relative size does not affect our analysis.
Figure 2.2: Information rent. It increases for any level of $P$ larger than $\bar{P}$, as $\bar{P}$ decreases.

Information rent increases for any level of $P$ larger than $\bar{P}$, as the expected (target) value $\bar{P}$ decreases (proof in Appendix B),

$$-\frac{\partial R(P, \bar{P})}{\partial \bar{P}} = -\frac{\partial (\Pi^*(P, F) - \Pi(P, \bar{P}, F))}{\partial \bar{P}} = \frac{\partial \Pi(P, \bar{P}, F)}{\partial \bar{P}} \geq 0 \quad \text{for} \quad P > \bar{P}. \quad (2.8)$$

The downward shift of $\bar{P}$ will shift the point of tangency between $\Pi^*(P, F)$ and $\Pi(P, \bar{P}, F)$ to the left. If this occurs information rent at any point to the right of $\bar{P}$
increases. This situation is shown in Figure 2.2 as the shift of $R(P, \overline{P})$ to the left. The lower the expectation of $P$, the greater the information rent for any $P$ larger than $\overline{P}$.

The *entry point* of MNC can now be defined, given that the real quality level of local labor ($P$) is unknown to the MNC. In this case the entry decision depends on whether or not its expected reservation profit is non-negative.

From equation (2.5) expected reservation profit is given as,\footnote{The MNC cannot consider the probability of EDI by the local government without the information about the cost of education, which is not accessible at least before the entrance.}

$$E\{\Pi(P, \overline{P}, F)\} = \{d(\overline{P}) - F\} + b(\overline{P})\overline{P}.$$  

Because this equation has the same form as optimal profit function, it is convex and non-decreasing in $\overline{P}$. Denote $\overline{P}_e$ as the value of $\overline{P}$ which makes this equation equal to zero.

Then, any value of $\overline{P}$ greater than $\overline{P}_e$ will yield a positive reservation profit. Hence, the MNC’s decision to enter depends on the values of $\overline{P}$ and $F$. The decision is to enter if $\overline{P} \geq \overline{P}_e(F)$; otherwise do not enter, where $\overline{P}_e(F) > 0$.

In other words, the higher the expected $P$ (level of education) the more likely the MNC will enter, and the higher the setup cost ($F$) the less likely it will enter. In Figure 2.3, the expected reservation profit for a given $F$ is depicted as an increasing convex curve. As long as current $\overline{P}$ is higher than $\overline{P}_e(F)$ the MNC will enter the developing country. As the setup cost increases the expected reservation profit decreases; $\overline{P}_e(F)$ shifts to right and the range of $\overline{P}$ which allows the MNC to enter becomes smaller.
Figure 2.3: Expected reservation profit. MNC enters the developing country if

\[ \bar{P} \geq \bar{P}_e(F) \], where \( \bar{P}_e(F) > 0 \).

2.4 Local Government Policy

With the principal agent contract strategy, the MNC has a strong profit motive in information about the quality of local skilled labor. The local government can take advantage of that interest by investing in education (EDI) as it seeks to maximize tax revenues less education cost. As such, the local government provides an incentive to the MNC to acquire information about labor force composition, taxes its profits and invests the tax revenue in education.\(^{18}\) We begin by assuming low setup costs so that optimal profit is positive even at the lowest level of \( P \) (\( P=0 \)). This assumption leads to the

\(^{18}\) Here it is assumed that the tax revenue from the entering MNC is only the resource for additional education investment.
situation in which the MNC does not change its entry decision before and after information sharing, it enters anyway. The case in which MNC does change its decision has important welfare implications, and it is investigated as the “matching effect” discussed in the latter half of the following section. This optimization problem of the local government takes the form,

$$\max_{P,F} \left[ \Pi^* (P, F) - \int_0^P C(P) dP \right]$$

subject to

$$\tilde{P}^* = \arg \max_P \left[ \int_0^P H(\tilde{P}) f(\tilde{P}) d\tilde{P} - F \right]$$

$$\Pi(\tilde{P}^*, P, F) = P(x_1(\tilde{P}^*) - s_1(\tilde{P}^*)) + (1 - P)(x_2(\tilde{P}^*) - s_2(\tilde{P}^*)) - F$$

$$\max_{x_1, x_2, s_1, s_2} (1 - t) \Pi^* (P, F) = (1 - t) \left[ P(x_1 - s_1) + (1 - P)(x_2 - s_2) - F \right]$$

where, $t$ is the tax rate on the MNC profit, $P$ is the portion of the labor force which is skilled after EDI, $P_0$ is the portion of skilled labor before EDI, $C(P)$ is the marginal cost of education, $\tilde{P}^*$ is the target value of $P$ chosen by the MNC, $\Pi^* (P, F)$ is optimal profit of the MNC knowing the real value of $P$, and $\Pi(\tilde{P}^*, P, F)$ is reservation profit i.e., the profit of the MNC when its decision depends on the target value $\tilde{P}^*$.

This constrained optimization problem has a double principal agent structure. The local government is the principal to the MNC and the MNC is the principal to local labor. Given the principal agent strategy of the MNC against local labor, the local government
chooses the tax rate and the composition of skilled labor to maximize tax revenue less the cost of education. The first two constraints correspond to the optimization of the MNC with information about the probability distribution of $P$, the composition of skilled labor. As we assumed in the previous section, the MNC chooses $\tilde{P}^* = \bar{P}$, which means that the target value of $P$ is set to its expected value. The third constraint corresponds to the after tax profit maximization of the MNC, given the real value of $P$. Because the tax rate is exogenous to the MNC, this constraint is equivalent to the optimization of the standard principle agent described earlier. The fourth constraint guarantees that the after tax MNC profit is larger than or equal to the reservation profit. The fifth constraint guarantees the local government tax revenue less the cost of education is not negative.

From the first four constraints we have,

$$\Pi^*(P, F) - \Pi(P, \bar{P}, F) - t\Pi^*(P, F) = 0.$$  
$$\Rightarrow R(P, \bar{P}) - t\Pi^*(P, F) = 0,$$

where $R(P, \bar{P})$ is the information rent defined in earlier, which does not depend on setup cost ($F$). Substitution of this into the objective function and into the fifth constraint results in the following local government optimization problem,

$$\max_{P,t} R(P, \bar{P}) - \int_{P_0}^{P} C(P)dP$$  
$$\text{s.t. } R(P, \bar{P}) - \int_{P_0}^{P} C(P)dP \geq 0$$  
$$\Rightarrow (1-t)\Pi^*(P, F) = \Pi(P, \bar{P}, F) \Leftrightarrow t = \frac{R(P, \bar{P})}{\Pi^*(P, F)}.$$  

(2.9)  
(2.10)  
(2.11)
The local government chooses $P$ so as to maximize the information rent less the cost of education. It then sets the tax rate so that the *after tax* profit of the MNC is equal to reservation profit at $P$.

From Figure 2.2 we know that the marginal information rent is negative at any point $P < \bar{P}$ and is positive at any point $P > \bar{P}$. Also, marginal rent is increasing everywhere. Marginal information rent (MR) and marginal education cost (MC), which is assumed constant, are shown in Figure 2.4. Because MR is increasing everywhere while MC is constant, marginal profit for the local government is increasing everywhere.\(^{19}\)

\[ \text{Figure 2.4: Marginal information rent (MR) and marginal education cost (MC).} \]

\(^{19}\) Assumption of constant marginal cost (MC) is made for expository reason. Changing this assumption does not affect arguments in the text. Neither of the following two cases changes the arguments: decreasing MC or increasing MC which intersects with MR only once. When increasing MC intersects with MR twice, the second intersection becomes the destination of the jump-process (explained later) instead of $P=1$. 

26
The conventional maximization rule (MR=MC) does not apply here. Rather, the optimal value of P is 1 or 0 depending on at which point the information rent less the cost of education is greater. But, since we assume that the current value of P cannot decrease, either P=1 or the current level P_0 will be chosen.

Figure 2.5: As long as P_0 < P_t there is no incentive for EDI; however, once P_0 equals P_t the government immediately jumps to P=1. This point (P_t) is the *take-off point*.

Suppose that a developing country has the current value P_0=P_t so that the area B+C =A+B+D in Figure 2.5. The area B+C corresponds to the total information rent at P=1; A+B corresponds to the total education cost required to reach P=1 from Pt, and; D corresponds to the information rent earned by retaining the current level of education P_t. Thus, the government is indifferent between choosing the current level P_t and P=1. Any
local government whose current $P_0$ is lower than $P_t$ has no incentive to invest in education because its cost exceeds the rent it can earn. Any local government whose level of current $P_0$ is higher than $P_t$ has the incentive to choose $P=1$. As long as $P_0 < P_t$ there is no incentive for EDI; however, once $P_0$ equals $P_t$ the government immediately jumps to $P=1$. This sudden change is because the marginal profit of the government is increasing everywhere, and it has no ability to reduce the value of $P$. We term this point ($P_t$) the \textit{take-off point}.

An interesting property of \textit{take-off point} $P_t$ is that it decreases as the expectation of $\bar{P}$ decreases. As shown in Figure 2.2, marginal rent to the right of $\bar{P}$ increases as the expected value of $P$ decreases. Consequently the \textit{take-off point} $P_t$ moves to the left, because the cost of reaching $P=1$ from old $P_t$ is now less than the rent it can earn. This means that as the MNC’s expectation of $\bar{P}$ goes down, the local government has the incentive to jump to $P=1$ at lower level of $P_0$. This situation is shown in Figure 2.6 in which the shift of expectation $\bar{P}$ to $\bar{P}'$ causes a leftward shift of MR to $MR'$ and $P_t$ to $P_t'$. 
Figure 2.6: The *take-off point* ($P_t$) decreases as the expectation ($\bar{P}$) decreases.

Furthermore, the *take-off point* is an increasing function of marginal cost. In Figure 2.5, an increase in marginal cost will shift MC up without changing MR. Total education cost is now greater than total rent at $P_t$. So, $P_t$ must move to the right. As marginal cost increases, the *take-off point* also increases, and there will be no incentive to invest in education regardless the value of $P_0$ when MC intersects with MR at $P=1$.

Setup cost does not shift the *take-off point*. This is because it neither changes the value of information rent on local labor nor the cost of education. But, setup cost does affect the entry decision of the MNC and it has important welfare implications for the local government (investigated in the next section). So far, given the principal agent contract of the MNC, the local government jumps to the maximum level of education at
the *take-off point*. The lower the expected level of education and the cost of education, the lower the *take-off point*.

This jump process shows some similarity to the popular multiple equilibria problem of economic development. Considerable literature recognizes the deadlock in the multiple equilibria of developing countries (Murphy, Shleifer and Vishny 1989, Becker, Murphy and Tamura 1990). In Becker, Murphy and Tamura there is little incentive to invest in education during the early stages of the economic development so that the economy is trapped in the lower equilibrium. But, our model shows the opposite results are possible.

Suppose that a region within a developing country hosts an MNC. Where, the probability distribution of the level of education within the entire country is known, but the exact level of education of the region is not known. Then the host country (or regional) government has an incentive to reach the maximum level of education from the *take-off point*. Besides, the *take-off point* gets lower as the known expected level of the education of the country gets lower. The lower the expectation (country in early stage of development), the lower the *take-off point*. This shows the distinct possibility of the jump occurring during the early stages of economic development, and may shed light on remarkable differences in economic development among regions within a country.\(^20\)

Now we investigate the tax rate \(t\) for the MNC. Repeating equation (2.11), the tax rate chosen by the local government is,\(^21\)

\[^20\] In Appendix C we introduced two types of MNC (competitive and non-competitive) and show the case in which the local government invests in education to attract a competitive MNC, as claimed in McMilan, Pandolfi and Salinger (1999).

\[^21\] As shown in Appendix C equation (2.11) is binding for the competitive MNC. Therefore the tax rate shown here is true for any entering MNC when censoring is successful.
If the current $P_0$ is located on or to the right of the take-off point $P_t$, the local government will increase education level to $P=1$ with tax rate,

$$t = \frac{R(P, \bar{P})}{\Pi^*(P, F)} = 1 - \frac{\Pi(P, \bar{P}, F)}{\Pi^*(P, F)}.$$

If the current level $P_0$ is located to the left of the take-off point $P_t$, the local government retains the current level of education with the tax rate,

$$t = 1 - \frac{\Pi(1, \bar{P}, F)}{\Pi^*(1, F)} = \text{constant, given } P_0 \geq P_t.$$

This has the highest value at $P_0=0$ and lowest value $t=0$ at $P_0=\bar{P}$. After passing $\bar{P}$, the tax rate increases (the properties of the tax rate for $P_0<P_t$ are derived in Appendix D).

The tax rate relationship is shown for two cases:

i) When the expected value $P$ and marginal cost of education are high such that $P_t > \bar{P}$ (Figure 2.7).
ii) When the expected value of $P$ and marginal cost of education are low such that $P_t < \bar{P}$ (Figure 2.8).
In both cases the tax rate decreases as $\overline{P}$ is approached from the left (increasing afterwards for only the first case) then suddenly jumps at the *take-off point* ($P_t$) and remains constant afterward. As a decrease in $\overline{P}$ shifts $P_t$ to the left, the jump occurs at a lower point. A decrease in $\overline{P}$ also decreases tax rate to the left of $\overline{P}$, but increases tax rate in right of $\overline{P}$. A decrease in $F$ shifts the tax rate down everywhere, except at $\overline{P}$ in Figure 2.7.

### 2.5 Welfare Analysis

In this section we investigate the welfare effects of FDI, EDI, and information sharing between agents. There are two kinds of welfare gains from this strategy set. The
first is due to EDI and a more efficient local labor contract, given that the MNC enters the country anyway (efficiency gain effect). The second is the gain from the policy when MNC enters the region due to the information sharing (matching effect). The latter benefit emerges when the country is in the early stage of development with a strong potential for further development.²² We also investigate the policy effects on the welfare of local labor.

2.5.1 Efficiency Gain Effect

Here we retain the assumption that the MNC enters the region with or without information sharing. The optimization problem given in section 2.4 satisfies the incentive compatibility for both the local government and the MNC; the former earns non-negative tax revenue less education cost, and the latter earns after tax profit greater than or equal to its reservation profit. So, neither agent has an incentive to deviate from its own strategy given that of the other (Nash equilibrium). Actually, were it not for the hidden type of MNC, the local government would have perfect information which would lead to a Pareto efficient contract. The problem is to determine the situation in which each agent is strictly better off than without this strategy set.

From the tax rate analysis discussed previously we know that the local government earns positive tax revenue except when \( P_0 = \bar{P} \), given \( \bar{P} \leq P_t \). This case corresponds to \( P_0 = \bar{P} \) in Figure 2.7. Tax revenue is always greater than education cost, because the local government can choose zero education cost simply by retaining the current level.

We can conclude that the local government is strictly better off, except when

²² Hidden type of MNC may cause some welfare cost to the local government (Appendix C).
\[ P_0 = \bar{P}, \text{ given } \bar{P} \leq P_t \]

Can the MNC increase profits by acquiring information about local labor? From equation (2.11), the after tax MNC profit is always equal to reservation profit at \( P \),

\[(1 - t)\Pi^*(P, F) = \Pi(P, \bar{P}, F).\]

If the MNC enters the region without information sharing, its profit would be the reservation profit for the current \( P_0 \) which is given by \( \Pi(P_0, \bar{P}, F) \). From equation (2.5) the reservation profit is a linearly increasing function of \( P \), so that

\[ \Pi(P, \bar{P}, F) > \Pi(P_0, \bar{P}, F), \text{ if and only if } P > P_0. \]

In other words, the MNC is strictly better off whenever the local government is induced to invest in education (the case in which the current \( P_0 \) was larger than \( P_t \)).

We further conclude that both the local government and the MNC are always as well off as before; the former is almost always strictly better off by utilizing the information rent, and the latter is strictly better off when education investment was induced by the MNC inquiring about the local labor composition. Information is the source of a more efficient contract, and both agents share in the gain.

### 2.5.2 Matching Effect

It was shown earlier that, as the expected level of education decreases, it is less likely for the MNC (without information sharing) to enter the developing country. In Figure 2.3 if \( \bar{P} \) is in the range left of \( \bar{P}_e \), the MNC does not enter because the expected reservation profit is negative.

On the other hand, it was shown that, as the expected level of education decreases, it is more likely that the local government will invest in education given FDI. In Figure 2.6
if \( P_0 \) is to the right of \( P \), the local government invests in education. \( P \) shifts to the left as \( \overline{P} \) decreases, which makes the range over which education investment occurs greater. This inconsistent behavior of the two agents results in failed opportunities for both parties when information sharing is not possible. In the early stage of development (the lower expected level of education) the local government has a stronger incentive for EDI given FDI, but the MNC will likely not want to invest (FDI) in the region. However, we can show the case in which information sharing and EDI induces FDI by the MNC, and this FDI encourages EDI by the local government, each of which does not occur without information sharing. This is the matching effect of the policy.

In order for the matching effect to be realized three conditions must be met. First, the MNC does not invest (FDI) without information sharing (negative expected reservation profit). Second, the local government invests in education (EDI) given FDI. Third, the MNC provides FDI when informed of the tax rate and the improved quality of local labor due to EDI (positive reservation profit after EDI). Accordingly,

\[
\Pi(\overline{P}, \overline{P}, F) < 0 \iff a(\overline{P}) + b(\overline{P}) \overline{P} - F < 0, \quad (2.12)
\]

\[
\Pi^*(1, F) - \Pi(\overline{P}, 1, F) > (1 - P_0)C \iff H(1) - [a(\overline{P}) + b(\overline{P})] > (1 - P_0)C, \quad (2.13)
\]

\[
\Pi(\overline{P}, 1, F) > 0 \iff a(\overline{P}) + b(\overline{P}) - F > 0. \quad (2.14)
\]

Definitions of \( H(P), a(\overline{P}), b(\overline{P}) \) were previously provided. Combining equations (2.13) and (2.14),

\[
H(1) - F - (1 - P_0)C > a(\overline{P}) + b(\overline{P}) - F > 0. \quad (2.15)
\]
The first inequality of equation (2.15) is more easily satisfied, as the expected value ($\overline{P}$) and the marginal cost (C) of education are lower and the initial level of education ($P_0$) is higher. Also, the inequality of equation (2.12) is more easily satisfied as $\overline{P}$ is lower. Hence, as long as second inequality of (2.15) is satisfied, lower $\overline{P}$ is better.

However, when $\overline{P}$ is too low, a negative reservation profit results for the MNC even after positive EDI (second inequality of (2.15) is not satisfied). This is because the lower $\overline{P}$, the higher the tax rate. The allowable range of $\overline{P}$ depends on the value of setup cost (F). Combining (2.12) and (2.15), we have,

$$a(\overline{P}) + b(\overline{P})\overline{P} < F < a(\overline{P}) + b(\overline{P}) .$$

The shaded area in Figure 2.9 shows the range of F and $\overline{P}$ that satisfy the above condition.
Figure 2.9: The shaded area is the range of $F$ and $\bar{P}$ that satisfy the condition

$$a(\bar{P}) + b(\bar{P})\bar{P} < F < a(\bar{P}) + b(\bar{P}) .$$

The allowable range of $F$ becomes larger as the difference between $a(\bar{P}) + b(\bar{P})\bar{P}$ and $a(\bar{P}) + b(\bar{P})$ gets larger. This is zero at $\bar{P} = 0$ and $\bar{P} = 1$, and it is positive everywhere $0 < \bar{P} < 1$, but increasing in $\bar{P}$ near $\bar{P} = 0$ and decreasing in $\bar{P}$ near $\bar{P} = 1$. So, a point $(\bar{P}_m)$ gives the largest allowable range for $F$. After passing $\bar{P}_m$, the range that $F$ can take gets smaller and smaller (proof in Appendix E). From Figure 2.9, we can see that the allowable range of $\bar{P}$ is wider when $F$ is relatively low, and that range of $\bar{P}$ is concentrated in lower range. In summary, the matching effect is more common in the case, in which the country is in an early stage of development, its real quality of labor is
high, and its education cost and MNC’s setup cost are low. On the other hand, when there are different types of MNCs which is hidden information from the local government, added welfare cost may result (investigated in Appendix C).

2.5.3 Local Labor Welfare

Does the optimal level of education chosen by the local government simultaneously maximize the welfare of the local labor? The change in total welfare of local labor with respect to $P$ is,

$$
\frac{d}{dP} \left[ P(s_1 - c_1(x_1)) + (1 - P)(s_2 - c_2(x_2)) \right],
$$

where, $s_1 - c_1(x_1)$ is the skilled labor surplus and $s_2 - c_2(x_2)$ is the unskilled labor surplus.

Using the first order conditions in equations (2.1) to (2.4), the above reduces to (the formal derivation in Appendix F),

$$
\left[ c_2(x_2) - c_1(x_2) \right] - \frac{P}{1 - P^2} \frac{[c_2'(x_2) - c_1'(x_2)]^2}{c_2''(x_2) - Pc_1''(x_2)}.
$$

(2.16)

Increasing $P$ has three effects on local labor. First, as more workers become skilled, more workers have positive surplus. Second, the skilled labor surplus $s_1 - c_1(x_1)$ decreases with $P$. Third, the unskilled labor surplus $s_2 - c_2(x_2) = 0$ does not change, because the first order condition $s_2 = c_2(x_2)$ must be always satisfied. The first effect is expressed as the first term in equation (2.16) which is positive, and the second effect is expressed as the second term which is negative. In other words, more workers have positive surplus by switching to skilled labor, but the surplus per skilled laborer decreases as $P$ increases. The former is the positive and the latter is the negative effect of education. The overall
effect is positive with a low value of P, and it is decreasing in P. Actually, marginal worker surplus becomes negative if P is close enough to 1 (derived in Appendix F); equation (2.16) is positive near P=0 and negative near P=1. Our argument is that if there is only skilled labor, the MNC’s strategy becomes,

\[
\max_{s_i, x_i} (x_i - s_i)
\]

s.t. \( s_i - c_i(x_i) \geq 0 \)

\[ \implies \text{FOCs} \quad s_i = c_i(x_i), \quad c_i'(x_i) = 1. \]

This means that the skilled labor’s surplus \( s_i - c_i(x_i) = 0 \). The strong implication is that when there are only the skilled workers, all workers’ surplus disappears. On the other hand, with any P<1 we have the first order conditions given by equation (2.1) to (2.4).

Given these, skilled labor has a positive surplus because \( s_i - c_i(x_i) > s_2 - c_2(x_2) = 0 \).

So, decreasing P from 1 leads to a higher skilled labor surplus without changing the surplus of unskilled labor (it is zero anyway). The same logic leads to the zero labor surplus in the case of P=0 (all the workers are unskilled). In conclusion, worker surplus starts with 0 at P=0, and ends with 0 at P=1, but strictly positive between 0 and 1. At the lower level of P education has a positive marginal effect and, at a higher level, it has a negative effect on worker welfare. The marginal effect (ME) is shown in Figure 2.10 (see Appendix F for the detail).
Figure 2.10: ME is marginal effect of education on local labor welfare. It is positive near P=0, and negative near P=1. $P^*$ is the point maximizing local labor welfare.

The marginal effect of education on the welfare of local labor is the highest at P=0, and it continues to decrease and becomes negative as P increases. Area A must equal B in Figure 2.10, because the surplus starts with zero at P=0 and ends with zero at P=1. The point between P=0 and P=1 which maximizes the welfare of local labor is denoted as $P^*$. Note that marginal effect has the opposite sign of the marginal information rent for the government. In Figure 2.5 it was shown that marginal information rent had a negative value at a lower value of P ($P<P^*$) and a positive value at a higher value of P ($P>P^*$). Whenever the local government jumps to the maximum level of education, given the incentive to promote education, it simultaneously hurts the welfare of the local labor
for levels greater than $P^*$. It increases both its own and the MNC’s benefit at the expense of local labor.

How will government policy change if it tries to maximize the welfare of the local labor? This optimization problem is the same as shown in section 2.4, except for the objective function. Now the government’s objective is to maximize the total welfare of local labor,

$$\max_{P} \left[ P(s_1 - c_1(x_1)) + (1 - P)(s_2 - c_2(x_2)) \right]$$  \hspace{1cm} (2.9')

subject to

$$R(P, \overline{P}) - \int_{P_0}^P C(P)dP \geq 0$$  \hspace{1cm} (2.10')

$$(1-t)\Pi^*(P, F) = \Pi(P, \overline{P}, F) \iff t = \frac{R(P, \overline{P})}{\Pi^*(P, F)}.$$  \hspace{1cm} (2.11')

First, if the current level of education is higher than the optimal point which is denoted $P^*$ in Figure 2.10, there is no incentive to promote education. Because further promotion of education will result in reduced welfare of local labor, the government will maintain education at the current level.

Second, if the current level of education is lower than $P^*$, we define the take-off point again. Before the take-off point, the government has no incentive to promote education. But, once it reaches the take-off point, the government incentive is to jump to $P^*$. As before, the take-off point is increasing with respect to the marginal cost of education and the expectation of the current level of education by the MNC.

There are some important changes from the tax-income maximizing government. Under the current policy, the government jumps to $P^*$ which is strictly lower than one. Because it jumps to the lower point than before, the budget constraints for education
mandate the *take-off point* to be higher than before. So, both the range where the jump process occurs and the distance of the jump get smaller than for tax-income maximizing government. Any value of $P$ greater than $P^*$, which happens whenever tax-income maximizing government has EDI, damages the welfare of local labor. In that sense, incentives are provided to itself and to the MNC at the expense of local labor. This result is in clear contrast to the conventional belief that skill building in the host country must always benefit local labor (United Nations 1999).

### 2.6 Conclusion

We have developed a model explaining the observed policy combination of a developing country (invitation to an MNC and investment in education) and the interest of a MNC about the quality of the local labor force when it contemplates a foreign direct investment (FDI) decision. Information on local labor is the source of a more efficient local labor contract for the MNC, and the local government can choose a policy which makes both agents better off. Our model also explains investment in education decisions by local government.

The important implication of education investment (EDI) by the local government is that it suddenly jumps to the maximum level of education when it reaches the *take-off point*. But, the local government does not invest in education before it reaches the *take-off point*. An interesting finding is that the *take-off point* becomes lower as the expectation of education level decreases. This means that a country in an early stage of development has the incentive to have a larger leap, which has never been considered in existing multiequbria models.
We also show that the local government promotes education (EDI) in order to invite in a competitive MNC, when the type of MNC is hidden to the local government. The policy has two positive welfare effects: the efficiency gain and matching effect. The latter shows the strong possibility that the government of a country in an early stage of development will have a stronger incentive for EDI given FDI. While the MNC also benefits from EDI and information sharing, otherwise it will avoid FDI. Neither FDI nor EDI occurs without the other (the causal relationship).

On the other hand, the chosen level of education which maximizes the income of the government is not generally optimal for the welfare of local labor. When the government considers the welfare of local labor, the take-off point becomes higher, and it never reaches the maximum level of education. The welfare of local labor decreases when the level of education is sufficiently high. So, the government has the incentive to benefit itself and MNC at the expense of local labor.
CHAPTER 3

HOW DOES CHILD LABOR PROHIBITION IMPACT THE ECONOMY OF A DEVELOPED COUNTRY?

3.1 Introduction

Child labor use in developing countries is an important topic in international trade negotiations. It is not uncommon for the developed country to insist upon the prohibition of child labor use in the developing country. As some 250 million workers under the age of fifteen reside in developing countries, the economic impact of banning child labor has enormous implications for the world economy.\textsuperscript{23} The efficacy of using trade sanctions and other devices to enforce child labor prohibition has many dimensions and continues to be a hot topic of debate in the Doha Development Round (Bhagwati 2002). While it is not my purpose to take sides on the issue of a WTO social clause, I simply seek to provide a theoretical framework useful to predict the economic consequences of such actions. Such a framework, however, is conspicuously absent from the trade literature. Recognizing this need, Basu and Van (1998) call for the development of such a model. In this essay I respond to this calling, by developing a model to examine the economic effects on a developed country when it imposes child labor prohibition conditions on its developing country trading partner.

\textsuperscript{23} ILO convention No. 138 bans child labor (under 15) which has been ratified by 62 countries as of May 20, 1998 (Asahi Shinbun 1998).
Child labor may provide economic benefits to the developed country, largely through the import of less-costly labor intensive goods. However, if children elect to remain in school, in lieu of entering the workforce, these short run gains cannot be realized. On the other hand, in the long run, both the developed and developing countries could lose if children forego the opportunity of improving their productivity through education. Thus, due to this “educational effect”, an assessment of the trade-off between the short run and long effects is necessary. My specific findings are sensitive to the specific intention of the developed country’s insistence on child labor prohibition as well as the allowance for increasing returns to scale.

Basu and Van propose a labor market model with multiple equilibria: one with child labor and one without child labor (due to high adult wage rates). Recognizing that their model could offer little insight to international trade issues, these authors identify the urgent need for an analytical framework which includes the trade dimension. Fischer and Serra (1998) show the effects of imposing standards as means of trade protection; child labor as a case in point. They consider the situation of a duopoly with one good and the effects of government set standards on the profits of the domestic firm. This model, however, is inadequate to analyze child labor policy because inter-temporal changes in factor endowments and factor movements among industries are not allowed. A multi-good and multi-period model is required. In this essay we overcome this deficiency by deriving a two good, two factor and multi-period (continuous time) model.

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24 Also see Becker, Murphy and Tamura (1990) for multiple equilibria with human capital and fertility choice.
analytical framework. As such, child labor prohibition can change factor endowments both directly and indirectly through changes in factor prices.

Findlay and Kierzkowski (1983) incorporated the formation of human capital into a trade model within a general equilibrium framework. Many extensions and adaptations have followed. Flug and Galor (1986) applied the Findlay-Kierzkowski (F-K) model to examine the impact of a minimum wage upon the pattern of trade. Miyagiwa (1989) applied the F-K model to examine the impact on the employment and national income of an exogenous increase in physical capital in a small minimum-wage economy. Wooton (1991) transformed the F-K model into an overlapping generation type model and endogenized the formation of both physical and human capital. In this essay, we too transform the F-K model to examine the impact of child labor prohibition on the economic welfare of a developed country.

We do not embrace some of the assumptions of these models. First is the assumption that there is undifferentiated representative person who chooses to become skilled labor or remain unskilled in random-like fashion. Consequently, each person is indifferent in choosing because her lifetime income is the same in equilibrium. Empirical evidence does not support this assumption. Indeed, there is large gap in lifetime income among different skill groups in both developing and developed countries (World Bank 2000). There is a need for a framework which incorporates this important dimension. In this model we explicitly consider different types of people in the developing country who voluntarily decide to become skilled or unskilled labor. Each individual maintains different skill building efficiency and chooses her level of education deterministically (no arbitrage).
Also, in the F-K model all workers with any positive school years are regarded as skilled; only workers with no schooling are regarded as unskilled. We transform this assumption, by incorporating a threshold value for school years. Workers exceeding this threshold value are regarded as skilled labor; otherwise as unskilled. Each person chooses to be skilled or unskilled so as to maximize her lifetime disposable income.

Another transformation we make is to decompose the F-K model into two systems: Heckscher-Ohlin-Samuelson (HOS) model, and; the developing country labor market which decides the endowment of skilled and unskilled labor. We call the latter system the Skill Building Stage (SBS). It is possible to interpret this separation in two ways: all the variables are simultaneously determined (but the model is separated only for expository reasons) or there is an actual time lag between these systems. Both interpretations are interchangeable but the second has greater economic intuition since it takes time to build skills through education. This is especially true when we assume that current laborers, who have finished their education, cannot go back to school. Schooling decisions depend on the old equilibrium; the new equilibrium would not be reached until all laborers permanently exit the work force. So we assume that an actual time lag between HOS and SBS also exists. Previous research does not investigate the dynamic process of reaching a steady state equilibrium.

There are several merits of separating this model into two components. First, the long run effect can be clearly distinguished from the short run effect. We show later, that these effects can be different not only in size but also in direction. Second, the separation makes transformation of the model more tractable, as demonstrated when we introduce increasing returns to scale.
This essay consists of eight sections. In section 3.2, the basic characteristics of the model are explained. In section 3.3, we derive the effects of endowment changes on the equilibrium in HOS model. In section 3.4, skill building stage of the developing country is introduced, and we illustrate the effect of a change in relative wages. In section 3.5, the welfare impact on the developed country resulting from an endowment change is derived. In section 3.6, the long run and short run effect and implication of child labor prohibition are shown and in section 3.7 we incorporate increasing returns to scale in production of one good, and show the case in which child labor prohibition results in the conversion of exporter-importer positions. Finally, section 3.8 we consider the policy implications of this model.

3.2 Description of Basic Model

The basic model consists of two sub-models: HOS (Heckscher-Ohlin-Samuelson) and SBS (Skill Building Stage). HOS model has two countries (developed and developing), two labor inputs (skilled and unskilled) and two outputs (skilled labor intensive and unskilled labor intensive). In HOS model the two inputs for each country are supplied exogenously (fixed endowment). Output and input prices, quantity demanded, and quantity supplied are endogenously determined.

The skill building stage (SBS) in the developing country takes the factor prices (wage rate) of skilled and unskilled labor as exogenous, but the supply of both labor types are endogenously determined. Both skilled and unskilled labor supplied by the developed country are fixed and do not depend on trade policy.
Child labor prohibition policy will lead to a new steady state equilibrium. In the short run, child labor prohibition directly changes the endowment of unskilled labor in the developing country which is transferred to HOS. Given the new factor endowment, HOS has a new short run equilibrium, and the resultant new wage rate is transferred to SBS. Given new wages, SBS revises the factor endowments which are transferred back to HOS. Continuation of this process converges to the long run equilibrium.

Figure 3.1: HOS (Heckscher-Ohlin-Samuelson) and SBS (Skill Building Stage) system.

There are several merits to separate the model in Figure 3.1. First, it enables us to separately identify the short run and long run effects. As shown in detail later, these should be clearly distinguished because it can take a long time for the system to reach a steady state. Even if the convergence to equilibrium in HOS and its transfer to SBS occur immediately, reaching an equilibrium in SBS takes at least the time length needed for people to revise their education decisions based on new wage rates. Previous papers have analyzed the change in steady state equilibrium without investigating the time path
of adjustment; the steady state equilibrium was reached immediately. Their results could be misleading because many people remain in labor force long time after the policy reform. This feature can have important long run policy implications. Model separation also facilitates ease of incorporating imperfect competition and increasing returns to scale.

3.3 HOS Model

HOS model has two countries (developed and developing), two inputs (skilled and unskilled labor) and two outputs (skilled labor intensive and unskilled labor intensive). The two inputs for each country are supplied exogenously (fixed factor endowment), while output and input prices, and quantity demanded and supplied are determined endogenously.

The sufficient condition for a static HOS model to be viable in each moment is the separability of the intertemporal expenditure decision of each consumer from output prices in each moment. As conventional in the literature, we assume an intertemporal utility function which is identical for all individuals in both countries, typically of the form,

\[ U = \int_{t}^{T} e^{-\rho(t-\tau)} \log u(C_{Xt}, C_{Yt}) d\tau, \]

where \( u \) is homogeneous degree one in consumption goods \((C_{Xt}, C_{Yt})\) and \( \rho \) is the discount factor. We do not specifically assume this formula, but simply separability and identical and homothetic utility function. These assumptions enable each agent to separate her intertemporal expenditure decisions from prices in each moment, then, the

\[^{25}\text{Only Miyagiwa (1989) distinguished the long run effect from the short run in his price-taking small country with one type of labor. However, he did not show how long it takes to reach the long run equilibrium.}\]
static HOS model works in each moment irrespective of the distribution of the intertemporal expenditure decisions.

Good X is skilled labor (H) intensive, and good Y is unskilled labor (L) intensive for any given wage rate (no factor intensity reversal), and the developed country is relatively skilled labor abundant regardless the level of education in the developing country (no factor abundance reversal). We also assume that both goods are produced by the common constant returns to scale technology in both countries, and the price of good Y is the numerie ($P_y =1$) so that other goods and factor prices are measure by one unit of Y. Variables pertaining to the developed county will be distinguished by ″ and to the world by ′.

The imposition of child labor prohibition is analyzed as follows. Suppose there are two different situations $\alpha$ and $\beta$. In both situations free trade and factor price equalization prevails, but the factor endowment of the developing country is influenced by the availability of child labor. Child labor is available in situation $\alpha$, but prohibited in situation $\beta$. However, we do not know the effect that child labor prohibition in situation $\beta$ has on factor endowments. The short run and long run effect can be greatly different, even opposite in direction. We investigate this in the next section (SKILL BUILDING STAGE).

In situation $\beta$ suppose the relative endowment of unskilled labor in the developing country decreases so that $\dot{H} - \dot{L} > 0$ (where $^\hat{}$ denotes rate of change). Because the
endowment of both factors in the developed country is fixed, the world relative
endowment of unskilled labor also decreases so that \( \hat{H} - \hat{L} > 0 \).

The initial consumption ratio \( (C_X^{a*} / C_Y^{a*}) \) depends on the initial equilibrium price
ratio \( (p_X^{a*} / p_Y^{a*}) \), so that \( (C_X^{a*} / C_Y^{a*}) = g(p_X^{a*}) \). Because all the consumers in both countries
have the identical, homothetic utility functions and the same discount factor, an
endowment change does not affect the consumption ratio, if the initial price is preserved.

Given that the initial price ratio is preserved, the consumption ratio remains the same,

\[
(C_X^{a*} / C_Y^{a*}) = g(p_X^{a*}) \Rightarrow \hat{C}_X^* = \hat{C}_Y^*.
\]

For given initial relative output price ratio and factor prices \( (w_H^*, w_L^*) \), the unit factor
requirement is constant,

\[
a_{lx}(w_H^*, w_L^*)X^* + a_{ly}(w_H^*, w_L^*)Y^* = L^*.
\]

The rates of change in outputs \((\hat{X}^*, \hat{Y}^*)\) and in labor endowment \((\hat{L}^*)\) have the following
relationship,

\[
\theta_{lx} \hat{X}^* + \theta_{ly} \hat{Y}^* = \hat{L}^*,
\]
where \( \theta_{lx} \) is the share of unskilled labor used for the production of X and \( \theta_{ly} \) for the
production of Y.

In the same way, we have,

\[
\theta_{hx} \hat{X}^* + \theta_{hy} \hat{Y}^* = \hat{H}^*,
\]

\[26\] The mismatched direction seems possible so that \( \hat{H} - \hat{L} > 0 \) but \( \hat{H}^* - \hat{L}^* < 0 \). This occurs when the
change in relative size of the developing country dominates the change in relative endowment of it.
However, this will be shown impossible later.

\[27\] Perfect competition with constant returns technology and non specialization assumption make factor
prices function of relative output prices, and unit factor requirement the function of factor prices.
where $\theta_{HX}$ is share of skilled labor used for the production of X and $\theta_{HY}$ for the production of Y. Taking the difference between the above two equations, and using $\theta_{LX} + \theta_{LY} = 1$ and $\theta_{HX} + \theta_{HY} = 1$, \[
\hat{H}^* - \hat{L}^* = \left(\theta_{LX} - \theta_{HX}\right)\left(\hat{Y}^* - \hat{X}^*\right) > 0.
\]
Factor intensity difference means $\theta_{LX} < \theta_{HX}$ . Hence we have the following result,
\[
\hat{Y}^* < \hat{X}^*. \tag{3.2}
\]
Because, $C_X^* = X^*$, $C_Y^* = Y^*$, equations (3.1) and (3.2) mean that there is an over supply of good X and an over demand for good Y if the initial output prices are conserved in situation $\beta$. For markets to clear, the price of good X must decrease and that of Y increase. Giffen goods are not allowed for homothetic utility functions, and the supply function is not inversely related to own price either.

**Lemma 3.1:** A decrease (increase) in the relative endowment of unskilled labor in the developing country leads to an increase (decrease) in relative world price of the good which uses unskilled labor intensively.

The Stolper-Samuelson (1941) theorem is satisfied in HOS model, so that an increase (decrease) in the relative world price of good Y will result in higher (lower) relative wages of unskilled labor (Jones, 1965). These results are shown in Figure 3.2.
Figure 3.2: HOS curve shows a negative, and SBS shows a positive relation between relative endowment and wage rate.

The curve in the second quadrant is derived from Stolper-Samuelson Theorem, and the curves in the third and fourth quadrants are derived from Lemma 3.1. We term the negatively sloped curve in the first quadrant the HOS curve. The HOS curve shows the negative relation between the relative endowment of unskilled labor and its relative wage rate in HOS system.

LEMMA 3.2: A decrease (increase) in the relative endowment of unskilled labor in the developing country leads to an increase (decrease) in its relative wage rate.
3.4 Skill Building Stage (SBS)

SBS is the stage in which each person in the developing country tries to maximize her discounted total lifetime disposable income, defined as lifetime earnings minus education cost. Each individual decides her length of education given the prevailing wage rate. However, she cannot decrease completed school years nor can she return to school once she starts working. Suppose the skill building function is,

\[ Q = \sum_i A(\tau_i, I_i)F(K_i, S_i), \]

where \( F \) is homogeneous of degree one in educational capital distributed for type \( i \) (\( K_i \)) and number of students of type \( i \) (\( S_i \)); \( A \) is a non decreasing concave function of time spent on education \( \tau_i \) so that \( \partial A(\tau_i, I_i)/\partial \tau_i \geq 0, \partial^2 A(\tau_i, I_i)/\partial \tau_i^2 \leq 0 \), and; \( I_i \) is the indicator of skill building efficiency which depends on student type (\( i \)). \( A \) is a non decreasing concave function of \( I_i \) so that \( \partial A(\tau_i, I_i)/\partial I_i \geq 0, \partial^2 A(\tau_i, I_i)/\partial I_i^2 \leq 0 \). \(^{28}\) Other properties of function \( A \) are explained below.

Suppose that education capital is supplied publicly at a fixed level, and distributed equally among students as in the F-K model.\(^ {29} \) Then, the skill building function for the type \( i \) is,

\[ q_i = A(\tau_i, I_i)f(k), \quad (3.3) \]

where \( k \) is per capita educational capital. As in F-K and others, we assume that students pay the value of the marginal product to the owner of education capital (teacher). While

\(^{28}\) Alternatively we could have a different function \( A_i \) depending on the type \( i \), and it reflects the productivity difference in skill building among student types. Then \( Q = \sum_i A_i(\tau_i)F(K_i, S_i) \).

\(^{29}\) In the F-K model educational capital is supplied publicly at a fixed level, but is distributed competitively. However, as the model has only one type of student, it is \textit{de facto} equally distributed among students.
F-K and others assume that the educational payment is made in childhood by borrowing in the financial market, this assumption is neither necessary nor realistic. Since in the steady state the demography and the total payments made by the population is constant at each moment in time, it does not matter who is paying whom. In other words, the current worker can pay the current teacher instead of paying to her former teacher. Hence, we assume that each individual begins paying when they start working, and that payment goes to the current teacher. Actually, education in many countries, especially primary and secondary, is government funded by general tax revenues, not by private borrowing.\(^{30}\) The discounted lifetime disposable income of individual type \(i\) is,

\[
\Pi_i = \int_{\tau_i}^{\tau} e^{-\tau} \left[ (wA(\tau_i, I_i) f(k)) - (wA(\tau_i, I_i) f'(k) k) \right] dt
\]

\[
= \frac{e^{-\tau_i} - e^{-\tau}}{r} wA(\tau_i, I_i) \left[ f(k) - f'(k) k \right],
\]

where \(T\) is life expectancy; \(\tau_i\) is time spent in school; \(w\) is wage rate, and; \(r\) is the discount rate. Each type of student chooses her length of education \(\tau_i\) to maximize the lifetime income, which leads to the first order condition,

\[
\frac{\partial A(\tau_i, I_i)}{\partial \tau_i} = \frac{r}{A(\tau_i, I_i)} \frac{1}{1 - e^{-r(T-\tau_i)}}. \tag{3.4}
\]

The rate of growth of skill in each moment depends on the student type,

\[
\frac{\partial A(\tau_i, I_i)}{\partial \tau_i} = \eta_i(\tau_i).
\]

\(^{30}\) This does not necessarily exclude the use of private financial markets which enables each person to transfer income from the working period to schooling period.
Suppose students are ranked according to the efficiency in skill building ($I_i$), so that $I_i$ is increasing in $i$. This means $A(\tau, I_i)$ is increasing in $i$ for any given $\tau$. Suppose further that for any given $\tau$, $\eta_i(\tau) \geq \eta_j(\tau) \iff i \geq j$.

This condition can be transformed to the following condition,

$$\frac{\partial A(\tau, I)}{\partial \tau} \cdot I \geq \left( \frac{\partial A(\tau, I)}{\partial \tau} \cdot \tau \right) \left( \frac{\partial A(\tau, I)}{\partial I} \cdot I \right),$$

which means the joint elasticity is larger than the product of the partial elasticities.\(^{31}\) The representative case satisfying equation (3.5) and the other two conditions

$$\left[ \frac{\partial A(\tau, I_i)}{\partial \tau_i} \geq 0, \frac{\partial A(\tau, I_i)}{\partial I_i} \geq 0 \right]$$

is a Leontief type production function. With this function, elasticity of substitution is zero so that increasing the ability of student ($I_i$) or schooling years ($\tau_i$) alone cannot add skill. We assume our skill building function is similar to Leontief type in the sense that elasticity of substitution is small enough to validate equation (3.5). Hence, skills build up effectively only when the efficiency of student and schooling years are combined.

The right hand side of the first order condition equation (3.4) is an increasing function of $\tau_i$, irrespective of student type. This is depicted as curve AA in Figure 3.3. Note that AA has the same shape for any student type. On the other hand, the left hand side of (3.4) is a non increasing function of $\tau_i$, and has higher value as the type $i$ increases.

\(^{31}\) The alternative interpretation introduced in footnote 6 changes equation (3.5) to

$$\frac{\Delta \left[ \frac{\partial A_i(\tau)}{\partial \tau} \right]}{\Delta i} \cdot i \geq \left( \frac{\partial A_i(\tau)}{\partial \tau} \cdot \tau \right) \left( \frac{\Delta A_i(\tau)}{\Delta i} \cdot i \right).$$
increases due to equation (3.5). This is shown as upward shift of BB to B’B’ in Figure 3.3.

Figure 3.3: AA is the right hand side and BB is the left hand side of equation (3.4).

In Figure 3.3 the intersection of AA and BB gives the optimal school year for student type i. As the person becomes more efficient in skill building, BB curve shifts to B’B’ and the optimal school year increases. Hence, the higher the skill building efficiency (higher the I), the greater the years in school. Also, it can be shown that increases in life expectancy (T).

Suppose there are N people in each generation and they live T years. We depict this in Figure 3.4 as a rectangle with vertical height N (= population in one generation) and horizontal length T (= life expectancy). Each individual corresponds to a point in the
rectangle depending on her type and age. One starts from a point in the left side of the rectangle and moves horizontally to the right as she gets older. After $T$ years she exits the rectangle.

Suppose we place the length of school years chosen by each type of person in the rectangle. This is shown as the bold line in Figure 3.4. For example, $\tau_0$ measures the optimal school year for type $0$ who is the least efficient in skill building. Moving up the vertical side of rectangle, the student becomes more efficient in skill building so that the optimal years in school increases. The most efficient student (type $N$) spends $\tau_N$ years in school. The optimal years in school for other student types is given as points on the bold line.
Figure 3.4: The vertical side corresponds to the types, and the horizontal side corresponds to the lifetime of people.

In Figure 3.4, it is assumed that all N people maintain different levels of efficiency \((I_i)\). It is also assumed the optimal year in school chosen by the least efficient student (type 0) is zero.\(^{32}\) Hence she would work \(T\) years of her life without any education. This is because her skill building is so inefficient that the marginal gain is less than marginal loss of the first year of education, which is given by the left hand side of equation (3.4).\(^{33}\)

\(^{32}\) Actually this assumption is made for expository simplicity. Without affecting the arguments below, we can change the assumption in the following way: the optimal school year chosen by type 0 is positive or those chosen by up to type \(k>0\) are zero.

\(^{33}\) We do not mean that her intellectual ability is so low. But, her social, family and regional background is not appropriate for studying so that her skill building is inefficient.
On the other hand, the most efficient student (type N) chooses the optimal year in school \( \tau_N \). Hence, she would spend \( \tau_N \) years in school and work for \( (T-\tau_N) \) years.

The convenient aspect of Figure 3.4 is that the rectangle also shows the distribution of students and workers at any moment (snap shot), although each person moves from left to right horizontally as she gets older. Because there are \( N \times T \) people in the developing country at any moment, the rectangle shows the total population. Type 0 student would spend zero years in school, while type \( N \) student spend \( \tau_N \) years in school, so that the integral of \( \tau_i \) over 0 to \( N \) gives the total number of students. This is given by the shaded area. The non shaded area is the total number of non student workers in the country.

Now suppose that workers who complete college are regarded as skilled labors. We define the school years required for a college graduate as \( T_U \). When regarded as a skilled worker, she would be paid \( w_H \) which is higher than \( w_L \). \(^{34}\)

Person type \( j_{iu} \), whose optimal school year \( \tau_{j_u} < T_U \), would be indifferent between attending college and earning higher wage or to choosing the optimal school year and earning a lower wage. This means, \( \Pi^{H}_{j_u} = \Pi^{L}_{j_u} \) for type \( j_u \). Then,

\[
\left( e^{-r_{T_u}} - e^{-r_{T}} \right) A(T_u, I_{j_u}) w_H = \left( e^{-r_{\tau_{j_u}}} - e^{-r_{T}} \right) A(\tau_{j_u}, I_{j_u}) w_L
\]

The optimal level of schooling \( \tau_{j_u} \) means \( \left( e^{-r_{T_u}} - e^{-r_{T}} \right) A(T_u, I_{j_u}) < \left( e^{-r_{\tau_{j_u}}} - e^{-r_{T}} \right) A(\tau_{j_u}, I_{j_u}) \).

Student type \( j_u \) would not go to college if the diploma does not increase her wage.

\(^{34}\) We can easily analyze the case in which \( w_H < w_L \). In that case, we will have “quasi unskilled laborers” instead of “quasi college students” in the argument below.
Between \( T_{ju} \) and \( T_u \) years, her marginal gain from education for any fixed wage is less than her marginal opportunity cost, nevertheless, she goes to college in order to obtain a higher wage. That is true for all types between \( ju \) and \( U \) whose optimal school year is exactly \( T_u \). We term the students whose types are between \( ju \) and \( U \) as “quasi college students”.

Higher wages for skilled labor decreases \( ju \), which means even less efficient students go to college and society has more quasi college students. In the same way, higher wages for unskilled labor increases \( ju \), which means more students start working earlier and forego a college education, yielding fewer quasi college students.

In conclusion, the following lemma is derived from equation (3.6), using equation (3.4) and (3.5) (formal proof is given in Appendix G).

**Lemma 3.3**: When the relative wage of unskilled labor increases (decreases), the minimum efficiency required for a college student increases (decreases).

Now, all workers younger than \( T_c \) years are regarded as child laborers. If some type \( j_c \) start working at exactly \( T_c \) years of age, everyone whose type is below \( j_c \) must choose optimal school years less than \( T_c \). Then we have the following result.

\[
\frac{\partial A(T_c, I_{j_c})/\partial T_c}{A(T_c, I_{j_c})} = \frac{r}{1 - e^{-r(T_c-T_c)}} \text{, for some type } j_c.
\]

\[\Rightarrow \text{ For any } j \leq j_c, \tau_j \leq T_c.\]
Figure 3.5: Total number of quasi college students, skilled laborers, child laborers, and adult unskilled laborers.

In Figure 3.5, the shaded area corresponds to the total number of students and non shaded area to the total number of workers at each moment in time. The triangle with the vertical shade is the total number of quasi college students. In the non shaded area, the pentagon H is the total number of skilled laborers, the triangle C is the total number of child laborers, and the pentagon L is the total number of adult unskilled laborers.

Next, let us have the total amount of skilled labor converted to the skill unit. Each point in Figure 3.5 has the height indicating the skill level which depends on the schooling years and her efficiency in skill building. Assuming that the type is
continuously distributed in the developing country, the volume measure of the object whose bottom is pentagon H, is given by,

\[ H = f(k) \left[ (T - T_u) \int_{j_u}^{j} A(T_u, I_j) dj + \int_{j}^{N} (T - \tau_j) A(\tau_j, I_j) dj \right]. \] (3.8)

In the same way, total amount of unskilled labor measured by the skill unit is,

\[ L = f(k) \int_{0}^{j} (T - \tau_j) A(\tau_j, I_j) dj. \] (3.9)

Of this, the total amount of unskilled child labor measured by the skill unit is,

\[ L_c = f(k) \int_{0}^{c} (T - \tau_j) A(\tau_j, I_j) dj. \] (3.10)

Next, we need to investigate the impact of a higher relative wage for unskilled laborers \((w_L/w_H)\) on the supply of each kind of labor in SBS. From equation (3.4) the optimal level of schooling does not change as wages change, as long as she continues as skilled or unskilled labor. But, wage changes affect the minimum efficiency requirement for college students, which leads to a change in the endowment of each labor type. From Lemma 3.3, the minimum efficiency requirement for college students increases as the relative wage of unskilled labor increases. This is shown in Figure 3.6 as the shift of \(j_u\) to \(\tilde{j}_u\).

When the minimum efficiency requirement for college students \(J_u\) increases, the number of quasi college students decreases by area corresponding to trapezoid A, the number of skilled laborers decreases by rectangle B, while the number of unskilled laborers increases by area A+B.
Figure 3.6: The effects of change in minimum efficiency requirement for college students.

The changes in the number of each kind of labor can be converted to skill unit as,

\[
\frac{\Delta H}{H} = -\frac{(T - T_u)}{H} f(k) \left[ \int_{j_u}^{j_u} A(T_u, I_j) dj \right] - \frac{f'(k)}{f(k)} \frac{K}{(H + L)^2} (\Delta H + \Delta L). \tag{3.11}
\]

\[
\frac{\Delta L}{L} = \frac{f(k)}{L} \int_{j_u}^{j_u} (T - \tau_j) A(\tau_j, I_j) dj - \frac{f'(k)}{f(k)} \frac{K}{(H + L)^2} (\Delta H + \Delta L). \tag{3.12}
\]

Then the change in relative endowments is given by

\[
\Delta \left( \frac{L}{H} \right) = f(k) \left( \int_{j_u}^{j_u} \frac{(T - \tau_j)}{L} A(\tau_j, I_j) + \frac{(T - T_u)}{H} A(T_u, I_j) \right) \left( \frac{L}{H} \right) > 0 \tag{3.13}
\]

The above three equations result in the following Lemma (Proof in Appendix H).
LEMMA 3.4: *When the relative wage of unskilled labor increases (decreases), the global relative endowment of unskilled labor increases (decreases).*

We can now draw the positively sloped SBS curve in the first quadrant of Figure 3.2. Then the intersection of SBS and HOS curve is the long run equilibrium of the whole model. We assume that these two curves intersect in the first quadrant of Figure 3.2.

### 3.5 Developed Country Welfare

We now explore the effect of a change in the relative endowment of unskilled labor on the welfare of the developed country. As before, child labor is available in situation $\alpha$, but is prohibited in situation $\beta$. From Lemma 3.2, a decrease in relative endowment of unskilled labor in the developing country leads to decrease in the relative price of good X, which leads to decrease in the relative wage of skilled labor. What happens to welfare? Suppose that the relative amount of unskilled labor decreased in situation $\beta$. Because trade must be balanced in situation $\beta$, we have

$$p_X^\beta (X^\beta - C_X^\beta) + (Y^\beta - C_Y^\beta) = 0.$$  

Note that term in the first parenthesis is positive, and the second is negative because the skilled labor abundant (developed) country is the exporter of good X. Also, from Lemma 3.2 the relative price of good X is higher in situation $\alpha$. Then, at the price ratio in situation $\alpha$, $p_X^\alpha (X^\alpha - C_X^\alpha) + (Y^\alpha - C_Y^\alpha) > 0$. Producer profit maximization

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35 In this section we assume that there is no factor abundance reversal, so that importer-exporter conversion is not possible. In section 3.7, however, it will be shown that importer-exporter conversion can occur without factor abundance reversal. Also, the sufficient condition for positive gains from converting will be shown.
implies $p_X^{\alpha^*}X^{\alpha^*} + Y^{\alpha^*} \geq p_X^{\beta^*}X^{\beta^*} + Y^{\beta^*}$. From these two equations and the balanced trade in situation $\alpha$,

$$p_X^{\alpha^*}C_X^{\alpha^*} + C_Y^{\alpha^*} > p_X^{\beta^*}C_X^{\beta^*} + C_Y^{\beta^*}$$

(3.14)

GDP is higher in situation $\alpha$ than in $\beta$ when evaluated at the price levels in situation $\alpha$.

In other words, the total consumption bundle in situation $\beta$ is feasible in situation $\alpha$, which reveals the preference for the bundle in $\alpha$ over that in $\beta$. Equation (3.14) is the sufficient condition for situation $\alpha$ to be lump-sum preferred to situation $\beta$, which means that the lump-sum transfer can make no person worse off in situation $\alpha$ while some will be better off.

With identical and homothetic preferences, the transfer of income among people in the developed country does not affect the total national consumption or the world price level in situation $\alpha$. Hence, equation (3.14) is the sufficient condition for the lump-sum preference of situation $\alpha$.36

**LEMMA 3.5:** A decrease in the relative endowment of unskilled labor in the developing country leads to a decrease in skilled labor wages and an increase in unskilled labor wages. The lump-sum transfer in situation $\alpha$ in the developed country can make no person worse off while some better off.

The Kaldor-Hicks criterion is used to compare the total welfare in the two situations, so that lump-sum compensation occurs only in situation $\alpha$. However, it can be shown that with any lump-sum transfer in situation $\beta$, lump-sum transfer in situation $\alpha$ can make

36 Other literature uses the assumption of a small economy to prevent lump-sum compensation from affecting the world price and the production side of the economy (Kemp 1962).
no person worse off while some better off. It is said that situation $\alpha$ is lump-sum preferred to situation $\beta$ in the Samuelson criterion (Samuelson 1950). It can also be shown that situation $\alpha$ is better than $\beta$ based on the social utility criterion. (Proof for these two criteria is shown in Appendix I.)

**Lemma 3.6:** Lemma 3.5 is true for Kaldor-Hicks, Samuelson, and the social utility criterion.

If the relative endowment of unskilled labor in the developing country increases in situation $\beta$, Lemmas 3.5 and 3.6 do not hold. Exactly the same argument used for Lemmas 3.5 and 3.6 (but in the opposite direction) leads to Lemma 3.7.

**Lemma 3.7:** An increase in the relative endowment of unskilled labor in the developing country leads to an increase in skilled labor wages and a decrease in unskilled labor wages. Situation $\beta$ is better than $\alpha$ in the three criterion of Lemma 3.6.

It seems that the government of the developed country chooses situation $\beta$ only when it leads to a higher relative unskilled labor endowment; it never chooses situation $\beta$, if it leads to a lower relative endowment of unskilled labor?

The Stolper-Samuelson theorem says that the wage of unskilled labor will increase as the relative price of the unskilled labor intensive good ($Y$) increases. In our case this results from the decrease in the relative endowment of unskilled labor in the developing country. The government of developed country may protect the welfare of domestic unskilled labor by choosing situation $\beta$.

Welfare protection of domestic unskilled labor is better achieved by choosing situation $\alpha$ with a lump sum income transfer to them. Under the assumption of identical
homothetic preferences, the level of utility is interpersonally comparable. Because social utility in situation $\alpha$ is higher (Lemma 3.6), the government can distribute that extra social utility so that both skilled and unskilled labor are better off than in situation $\alpha$. Hence, the protection of unskilled labor is better achieved by choosing $\alpha$ together with a lump-sum transfer. So, the government chooses situation $\beta$ only when the policy objective is to protect the welfare of unskilled labor and a lump sum transfer is not possible policy.$^{37}$

**LEMMA 3.8:** A decrease in the relative endowment of unskilled labor in the developing country leads to an increase in unskilled labor wages and a decrease in skilled labor wages. The developed country chooses this situation only when its policy objective is to protect the welfare of unskilled labor and lump sum transfer is technically not possible.

### 3.6 Short Run and Long Run Effects of Child Labor Prohibition

There are short run and long run effects of child labor prohibition. The former assumes that child labor prohibition in the developing country effects the international goods market (only primary effect), but not vice versa. The latter assumes that international market changes effect the skill building stage in the developing country; the resulting endowment change effects the international market and this process continues until convergence (secondly and higher effect).

Referring back to Figure 3.1, first, the change in endowment in developing country occurs in SBS, and this new endowment is transferred to HOS. Given the new endowment, HOS yields a new short run equilibrium price and wage rate. In the long

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$^{37}$ There is some literature which throws doubt on the viability of lump sum transfers. See Dixit and Norman (1986).
run, the new equilibrium wage rate is transferred back to SBS, which affects the endowment in the developing country. The long run equilibrium is achieved when this process converges.

### 3.6.1 Short Run Effect

The change in endowment occurring in SBS is transferred to HOS. The new equilibrium in HOS will be reached instantaneously, if the factor movement between industries occurs immediately as in the standard HOS model. The short run effect considers only the primary influence of child labor prohibition; the impact on HOS of the change in endowment as a result of child labor prohibition.

This endowment change will reduce the number of unskilled laborers by triangle C in Figure 3.5. The loss of unskilled labor, measured by the skill unit, is given as,

$$
\Delta L = -f(k) \int_{0}^{c} (T_{c} - \tau_{j}) A(\tau_{j}, I_{j}) \, dj,
$$

which is negative, since $T_{c} > \tau_{j}$ for $\forall j < c$.

In the short run there are no other change in endowments including that of skilled labor and other unskilled labor. The relative decrease in the endowment of unskilled labor is transferred to HOS model. From Lemma 3.2, the relative wage ratio ($w_{L}^{*} / w_{H}^{*}$) is negatively related to the relative endowment of unskilled labor in HOS model shown as HOS curve in Figure 3.7.
In the short run there is no adjustment of skill building, so that SBS curve is a vertical line in Figure 3.7. Child labor prohibition in SBS results in a lower amount of unskilled labor, which is shown as a leftward shift of SBS line to SBS’. The intersection with the negative sloped HOS curve, shifts from E to E’. This results in an increase in the relative wage of unskilled labor. Referring back to Figure 3.2, the relative price of skilled labor intensive good decreases. The total welfare of developed country also decreases (Lemma 3.8), yielding the proposition,

**PROPOSITION 3.1:** In the short run, child labor prohibition will decrease the price of the skilled labor intensive good and increase the relative wage of unskilled labor. The former deteriorates total welfare of developed country, but the latter makes the unskilled labor in the developed country better off.
3.6.2 Long Run Effect without Education Enforcement\textsuperscript{38}

The long run effect considers not only the impact of the endowment change in SBS on HOS, but also the feedback from HOS to SBS. This works as follows. First, the primary effect shown previously caused the relative wage of unskilled labor to increase. This increase in the wage rate of unskilled labor is transferred to SBS which changes the supply of each type of laborer. The change is then transferred back to HOS and continues until convergence.

Even if HOS equilibrium takes place immediately, it takes at least $T-T_u$ years to reach the new steady state equilibrium because it takes this long for all the former quasi students to leave labor market.\textsuperscript{39} The generation $T_u$ or higher includes some former quasi college students whose decision depended on the former wage rate. In this section, we assume that current child workers who are prohibited from working will not go to school. They neither work now, nor go to school, a seemingly odd situation. As shown earlier, the student who starts working before $T_c$ does so because her marginal gain is lower than cost for any given wage (equation (3.4)). Recall that equation (3.4) is satisfied even with $w_L =0$, which implies child labor prohibition because the wage rate for unskilled labor is zero. Children do not go to school when prohibited from working, unless they are forced to do so. Our assumption here is that children are not obligated to attend school, they are just prohibited from working.

\textsuperscript{38} Education enforcement implies mandatory schooling.

\textsuperscript{39} If we assume that each person finishes college education at 23 years of age and retires from her job at 65 years of age, it takes more than 40 years for the economy to reach long run equilibrium. Changing the assumption does not help much: even if workers can go back to school, they cannot reduce the education they have already completed.
From Lemma 3.4, the higher the relative wage of unskilled labor the higher the relative endowment of unskilled labor. This is shown as a positively sloped reaction curve SBS in Figure 3.7. So, the higher the wage of unskilled labor in HOS, which was caused by child labor prohibition, the higher the relative endowment of unskilled labor in SBS (feedback effect). That, in turn, leads to a lower relative wage for unskilled labor. Again, this process continues until convergence.

The shift in SBS due to child labor prohibition yields short run equilibrium $E_s^*$, where relative wage of unskilled labor has increased and the endowment decreased.
In the long run, however, convergence is reached at the long run equilibrium point $E_L$ in Figure 3.8.

PROPOSITION 3.2: *The long run effect of child labor prohibition without education enforcement has the same direction of influence as the short run, so that the relative endowment of unskilled labor decreases and its relative wage increases. The total welfare of the developed country deteriorates. The long run effects are smaller than the short run.*

The wage impact is smaller in the long run except for a perfectly inelastic HOS curve (horizontal HOS) or a perfectly elastic SBS curve (horizontal SBS). In the former case, there is no feedback from HOS because there is no wage rate change. In the latter case there is no child labor, so prohibition policy does not change rates either in short run or long run.

The endowment impact is smaller in the long run except for perfectly elastic HOS curve (vertical HOS) or perfectly inelastic SBS curve (vertical SBS). In the former case, the endowment returns to its original level immediately. However, this is not possible in SBS by the assumption. So we cannot define short run equilibrium. In the latter case, there is no feedback effect because SBS curve does not react to the wage rate.

**3.6.3 Long Run Effect with Education Enforcement**

We can use our same method to analyze the situation when all children are forced to go to school. In this case we need to investigate the direction of shift of SBS curve caused by child labor prohibition. This is the comparison of two different effects of child labor prohibition. Prohibition policy has a negative effect on the amount of unskilled labor because children are exiled from work places. But it also has a positive effect on
amount of unskilled labor because current child laborers build skill in school for later use.

If the latter effect is zero, the long run effect is the same as the shift of SBS to SBS’ in Figure 3.8. As the positive effect increases, SBS’ approaches to SBS, and SBS’ moves to the right of SBS if the positive effect more than compensates for the negative effect.

The sum of the positive and negative effect to a change in relative endowment is,

\[
\hat{L} - \hat{H} = \frac{f(k)}{L} \left[ \int_0^c \left[ \int_0^c \left( T(\tau_j, I_j) - A(\tau_j, I_j) \right) - \left( T_c A(T_c, I_j) - \tau_j A(\tau_j, I_j) \right) \right] dj \right].
\] (3.15)

The first term is positive and the second is negative because \( T_c > \tau_j \) for all \( j < c \). It can be easily shown that longer life expectancy (greater T) increases the positive effect and decreases the negative effect, likely ending up with \( \hat{L} - \hat{H} > 0 \). Actually the increase in T has both a direct and an indirect effect. It directly increases the impact of education through a longer working period, and it indirectly decreases the loss of child labor by increasing \( \tau_j \) which is the optimal level of schooling chosen voluntarily before prohibition.

Can the government increase the relative endowment of unskilled labor by extending the length of compulsory education \( T_c \)? This depends on the sign of the following function,

\[
\int_0^c \left( [T - T_c] \eta_j(T_c) - A(T_c, I_j) \right) dj.
\] (3.16)

Here \( \eta_j(T_c) \) is the rate of growth of skill for type j at the end of compulsory school year \( (T_c) \), which was defined earlier. Then, the longer compulsory education, the higher the

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40 The mismatched direction seems possible so that \( \hat{L} - \hat{H} > 0 \) but \( \hat{L}^* - \hat{H}^* < 0 \). However, this can be shown impossible by following the similar steps as Appendix H.
relative endowment of unskilled labor, given that the rate of skill growth and the life expectancy is relatively high. Higher $T_C$ decreases the endowment of unskilled labor currently available, but skill accumulates for later use. The latter more than compensates for the former as long as the skill building is effective and life expectancy is long enough. But, higher $T_C$ eventually leads to a decrease in the relative endowment of unskilled labor because the term in the square bracket in equation (3.16) is decreasing in $T_C$.

**PROPOSITION 3.3:** Long run effects of child labor prohibition with education enforcement can differ in direction from the short run effects. Longer life expectancy leads to the opposite direction. Longer compulsory education leads to the opposite direction, as long as skill building is effective and life expectancy relatively high. If it is the case, the total welfare of the developed country increases. If the long run effects have the same direction as the short run, the former are smaller.

### 3.6.4 Policy Implications and the Effectiveness of Policy

The short run effect of child labor prohibition is a reduction in the relative endowment of unskilled labor and an increase in its relative wage rate. The total welfare of the developed country will decrease. So, the developed country policy objective can be to protect the welfare of domestic unskilled labor by imposing child labor prohibition in the developing country. But, this policy is taken only when lump sum income transfers are technically impossible. The policy is more effective the more elastic the wage rate. This is shown as steeper HOS curve in Figure 3.7. This is the case in which there are higher Rybczynski and Stolper-Samuelson effects in HOS model.

The long run effects without enforcement of education have the same directional influence as in the short run, although relatively smaller. The policy is more effective as
the endowment is less elastic in SBS (steeper SBS) and the wage rate is more elastic in HOS (steeper HOS) in Figure 3.8. The former corresponds to the case in which the right hand side of the shaded triangle in Figure 3.6 has a less steep slope, which means there are much difference in optimal levels of schooling chosen by each type. On the other hand, the more elastic SBS (less steep SBS) the weaker the long run effect.

If enforcement of education is possible, the long run effect can be of opposite direction than the short run. It is more likely to be opposite as the life expectancy gets longer. Also, a longer period of compulsory education leads to the opposite direction of influence when skill building is effective and the life expectancy is long enough. If this is the case, the child labor prohibition policy will improve the total welfare of the developed country. At that time the welfare of unskilled labor in the developed country will decrease, although lump sum income transfers can compensate for the welfare loss. The policy is more effective as the endowment is less elastic in SBS (steeper SBS) and the wage rate is more elastic in HOS (steeper HOS).

Other important things to notice; it takes so long to reach the long run equilibrium, the long run effect is smaller than the short run effect if they have the same direction, and it gets smaller as SBS is more elastic (less steep SBS). Finally, economic aid can benefit the developed country. Suppose the developed country offers physical educational capital (K) to the developing country. This aid increases both factors at the same rate in the latter so that the world endowment becomes more unskilled labor abundant, which is beneficial to the donor. But, the long run effect tends to be smaller because of the feedback effect.
3.7 Increasing Returns to Scale Technology in HOS

In this section we introduce increasing returns to scale (IRS) technology in HOS. If we have IRS, unambiguous statements are not possible. However, we can show the interesting case in which child labor prohibition converts the developing country into an exporter of good X without factor abundance reversal (importer-exporter conversion). We further show, the sufficient condition for the developed country to gain from imposing child labor prohibition and becoming the importer of good X.

Suppose good Y has constant returns to scale technology as before, but now suppose that it has following Cobb-Douglas type technology

\[ Y = H^{0.5} L^{0.5}. \]

Skilled labor intensive good X has increasing returns to scale which depends on the domestic level of production (positive externality from domestic production), see Marksen and Melvin (1981), and Panagarya (1981). In this section we use the following Cobb-Douglas type production function in order to deal with factor abundance differences as well as size differences between countries.

\[ X = X^\lambda \left( H^{0.5+\theta} L^{0.5-\theta} \right), \]

where \( 1>\lambda>0 \) is the degree of increasing returns, and \( 0.5>\theta>0 \) is the degree of factor intensity difference. The greater \( \lambda \), the greater the increasing returns to domestic production of X (larger positive externality). The greater \( \theta \), the more skilled labor intensive is the production of X. Let’s assume that IRS is relatively small, say \( \lambda<2\theta \).

As before the endowments of skilled and unskilled labor in the developed country are \( H^# \) and \( L^# \) respectively. And, those in the developing country are given by \( H=sH^# \), \( L=s\sigma L^# \).

---

41 The international returns to scale assumption introduced by Ethier (1982) has less chance for this kind of drastic conversion.
Here, $s>1$ is the degree of scale difference, and $\sigma>1$ is the degree of factor abundance difference. The greater $s$, the larger is the developing country. The greater $\sigma$, the more abundant unskilled labor in the developing country.

Given these production function, let us denote the slope of the production possibilities frontier (PPF) along a straight expansion path ($Y/X$ is constant) as $P$. We can show that equation (3.17) is true between $P$ and $J$ which is defined,\(^{42}\)

\[
\frac{dP}{dJ} < 0, \tag{3.17}
\]

\[
dJ = -\frac{HH_x [(1 + w l_x) \hat{w} + (1 + w l)(- \hat{w} + wdl_x)] - (1 + w l)(1 + wk_x)HdH_x}{(1 + w l_x)^2 H_x^2}, \tag{3.18}
\]

where $w$ is relative wage rate ($w_L / w_H$), $l$ is relative endowment of unskilled labor ($L/H$).

$L_X$ and $H_X$ are each kind of labor used for production of $X$, and $l_X$ is their ratio ($L_X / H_X$).

Also, with our specific production functions $\partial J / \partial \sigma < 0$ and $\partial J / \partial s > 0$ (proof in Appendix J). These combined with equation (3.17) and (3.18) imply the following;

\[
\frac{\partial P}{\partial \sigma} > 0, \frac{\partial P}{\partial s} < 0.
\]

Of course, both countries have the same slope of PPF when $\sigma = s = 1$.

LEMMA 3.9: The slope of PPF along an expansion path becomes steeper for the developing country, as it becomes more labor abundant for a fixed level of size. The slope becomes less steep, as the developing country becomes larger for a fixed level of relative factor abundance.

\(^{42}\) We took similar procedures as Markusen and Melvin (1981).
However, the slope of the indifference curve along the expansion path is constant for both countries. Using these conditions we can conclude, if the PPF along an expansion path of one country is less steep there is at least one equilibrium in which that country is the exporter of good X and the importer of the other good Y (see Markusen and Melvin 1981 for the formal proof). So, the developing county tends to be importer of good X when it is relatively abundant in unskilled labor, while it tends to be exporter of good X when it is a relatively large country.

Suppose the developing (large) country is a current importer of good X due to the factor abundance difference. But, the unskilled labor supplied by children is so large that child labor prohibition significantly reduces the factor abundance difference between the two countries. Since the relative size difference remains, the developing country will convert to an exporter of good X. The possibility of this conversion gets higher as the size of the developing country and the child labor supply gets larger. Hence, the following

Proposition,

PROPOSITION 3.4: Child labor prohibition can cause importer-exporter conversion. Conversion can occur easier if the labor supplied by children is large, given developing country is also large.

The easiest case is that the developing country has so many children working that their prohibition results in negligible intensity difference (σ≈1). In this case the abundance difference was mainly from child labor, and its prohibition makes the size difference more significant.
Finally using this case, we present the sufficient condition for positive gain in the developed country from converting to an importer of good X. (Proof is given in Appendix K.)

**PROPOSITION 3.5:** Suppose there is factor price equalization at least in situation $\beta$. If the current production level of good X of the developing country is greater than the former production level of the same good in the developed country, and the current relative factor abundance difference is negligible, then the developed country gains in situation $\beta$.

The above proposition is intuitive. The developing country is potentially an exporter of X due to its larger size, but the factor abundance difference made it an importer of X and prevented it from pursuing this opportunity. Elimination of this restriction can enable the country to become an exporter of good X. If its scale economy (positive externality from good X) is larger than the former exporter, the former exporter can gain from converting to an importer.

The condition used in proposition 3.5 ($\sigma \approx 1$) is strong, and we can have the weaker version of positive gain. Proposition 3.5 is the sufficient condition for proposition 3.5’.

**PROPOSITION 3.5’:** (weak version of positive gain) Suppose there is factor price equalization at least in situation $\beta$. If the current production level of good X in the developing country is greater than the former production level of good X in the developed country, and the GDP share of the latter gets larger, then there is gain for the developed country.

This increase in the GDP share of the developed country in situation $\beta$ is very likely, because there is no change in its factor endowment while the developing country has
lower unskilled labor and the same skilled labor. Also, note that the above propositions do not require the developing (larger) country to increase its production of X, but it just requires that its current production of X is greater than the previous production of X by the developed (smaller) country.

In the two goods case, it may look peculiar that child labor prohibition converts the exporter-importer position. But, suppose the real world situation in which there are many goods with increasing returns to scale. Then it is more likely for the conversion to occur for some of these goods.

There are several points to note. First, this importer-exporter conversion can easily take place in short run. In the real world, it would not happen immediately because factor shifts among industries takes time. But, this conversion does not require an adjustment in the skill building stage. Second, this result tends to prevail in the long run when there is no education enforcement. In that case, the long run effect can be larger in the same direction as the short run. This would happen when either (but not both) the opposite of the Rybczynski theorem or the opposite of the Samuelson-Stolper theorem is true. In this case, HOS curve has a positive slope in Figure 3.8. Third, the education enforcement can re-convert the importer-exporter position. It would happen when the positive education effect on children in the long run is more than enough to compensate for the loss of child labor in the short run. The relative size of these effects follows from Proposition 3.2.

3.8 Conclusions and Implications

We develop a general equilibrium trade model with human capital accumulation to examine the impact of child labor prohibition on the welfare of a developed country. It
was shown that the long run equilibrium indeed takes a long time to reach, and has smaller effects than those in the short run, given the same direction of influence.

Without education enforcement, the relative endowment of unskilled labor decreases and its relative wage increases in both the short run and the long run. In this situation the policy of the developed country government will be to protect the welfare of domestic unskilled labor by insisting upon child labor prohibition by the developing country. However, the long run effects of the policy are smaller than the short run.

Can we reaffirm the claim by Fisher and Serra (2000) that “child labor prohibition can be used as standard to protect the domestic firm”? First, it is true that prohibition policy can be used as protective measure, but the objective is not to protect the profit of the domestic firm, but rather welfare of domestic unskilled labor. This difference stems from the fact that we employ a general equilibrium model while the Fisher and Serra model is partial. Second, this policy is taken only if a lump-sum transfer of income is not possible. If transfers are possible, everyone can be made better off by not prohibiting child labor. Third, the long run effect with enforcement of education can be of opposite direction to that short run. This can occur as life expectancy gets longer and skill building becomes more effective. Accordingly, the objective of child labor prohibition policy is to improve the total welfare of the developed country, although it can take a long time. The welfare of domestic unskilled labor deteriorates, but lump sum income transfers can compensate for their welfare loss. If the long run effects are in the same direction as the short run, the magnitude must be smaller.

We extend our work by introducing increasing returns in HOS model. Then, the relative country size as well as the relative labor endowments becomes important. It was
shown that prohibition of child labor can reverse the country position from an exporter to an importer. This can more easily result as the size of the developing country gets larger and the percent of children laborers in the labor force gets larger. This conversion happens in the short run, and the long run effect can be larger even if they both have the same direction of influence. Other kinds of imperfect competition are tractable taking advantage of the decomposition of F-K model into HOS and SBS. This methodology can be applied to many analyses of policy changes, especially those which immediately change the factor endowments and entail the human capital accumulation process. Immigration policy and birth control are examples.
CHAPTER 4
ECONOMIC INTEGRATION, PRODUCTION STABILITY AND ECONOMIC GROWTH

4.1 Introduction

This essay introduces an alternative path for economic growth and welfare improvement through economic integration among LDCs. I develop a simple endogenous growth model with two sources of production shocks (agriculture and manufacturing). It is shown that economic integration is most likely to lead to less production volatility (more production stability) in both sectors, which can raise the steady state economic growth rate. I have even stronger welfare implication: economic integration is always welfare improving if it reduces production volatilities of both sectors, regardless if growth rates increase or not.

The economic growth literature reveals a strong interest in the relationship between economic growth and savings (investment). Most endogenous growth models incorporate consumer savings decisions used to finance product innovation (Romer 1990, Grossman and Helpman 1991a, Aghion and Howitt 1992) and factor accumulation (Romer 1987, Grossman and Helpman 1991b). Empirical studies support the positive relationship between savings and economic growth (Levine and Renelt 1992, Temple 1999). In their seminal empirical study, Levine and Renelt found the only robust empirically significant cross-country relationship is a positive relationship between saving and the growth rate.
The macroeconomic literature has modeled the relationship of consumer saving decisions to income uncertainty (Sandmo 1970, Caballero 1991, Carroll 1992). To a much lesser extent, some economic growth models incorporate income uncertainty due to production shocks and investigate the effects of production volatility change on growth rates (Newbery and Stiglitz 1981, Smith 1996, Canton 1996). These models support the causal relationship: higher volatility in production leads to higher precautionary savings, which leads to higher investment and ultimately, higher economic growth rate.

While some empirical studies strongly support the positive relationship between production volatility and average growth rates in developed countries (Kormendi and Meguire 1985, and Grier and Tullock 1989), one frequently cited study (of production shock, precautionary savings and economic growth), does not (Smith 1996). In his simulation study based on his own theoretical model with reasonable parameters, Smith found that the precautionary saving motive raises average growth rates by only 0.1% from the case without it. Similarly, increasing the standard deviation of the production shock by 50% raises the average growth rate by only 0.1%. Smith’s (1996) work suggests that the link between cyclical uncertainty and precautionary savings is of little usefulness to the understanding of economic growth.

The positive relationship between production shock volatility and growth rates in developed countries could neither be confirmed empirically. An ARCH-M model was

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43 Also see King, Plosser and Rebelo (1988) for the effect of current temporary productivity shock on the long-run growth path and rate of growth.

44 This result is conditional on a relatively high (higher than 10) coefficient of relative risk aversion in (Smith, and Newbery and Stiglitz). But, Smith referred to some empirical studies and concluded that the coefficient of relative risk aversion is much greater than 1.0.
estimated using time series data for three developed countries (US, UK and Japan) to test the production volatility-growth relationship. Of the three, only Japan had a strong positive result; the US had insignificant estimate and UK had a negative sign. Again, this result sheds doubt on the impact of production shocks on the economic growth of developed countries.

On the other hand, the claim for developing countries is that production stability is essential for economic growth (Hayami 1995, Bloom, Sachs, Collier and Udry 1998). This claim is particularly relevant for production agriculture where supply fluctuations can be severe. Instability of agricultural production can adversely affect investment, production growth, and consumption, which in turn can damage the economic growth of the country (Eicher and Staatz 1998, Abler, Tolley and Kripalani 1994). Additionally, Ramey and Ramey (1995) found that countries with higher production volatility have lower growth rates in contrast to the positive relationship of Kormendi and Meguire (1985) and Grier and Tullock (1989).^{45}

Production volatility can have particularly important implications for economic growth in a less developed countries (LDC). However, no endogenous growth model has been developed to illustrate the possible link between production volatility and economic growth in LDC. Application of existing growth theory to an LDC, suggests that higher production volatility would grow the economy. This essay explores the possibility of a negative volatility effect on economic growth and welfare.

Another inadequacy of existing models is that none provide the specific source of production volatility change; it is assumed exogenous. In this respect, the current essay

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^{45} Ramey and Ramey point out possible biasness in the parameters estimated by the counterparts.
illustrates the case in which government policy can affect volatility. Economic integration among LDCs can result in off-setting fluctuations, which in turn lowers volatility for the entire region. Also, economic integration gives manufacturers more freedom to choose production sites; they can choose less risky locations and/or diversify operations. This diversification of operations may reduce the volatility of production shocks for manufacturers. Besides, as often observed, economic integration may require stricter enforcement of property right laws, which can result in lower volatility (shown later). These are all possible sources for volatility reduction owing to economic integration among LDCs.

Some theoretical work addresses the effect of economic integration on economic growth. Economic integration between countries of similar sizes and resource endowments can lead to higher growth rates for a couple of reasons. One is through increased information flows of general scientific knowledge (Rivera-Batiz and Romer 1990). For instance, R&D activities develop new product designs using general scientific knowledge. At the same time, the stock of general scientific knowledge accumulates as a by-product of R&D (spillover effect), and this stock is increasing proportionally to the total number of differentiated products. Higher information flows across borders, due to economic integration, leads to higher stock of scientific knowledge, which in turn makes R&D activities more productive and profitable. In their “Knowledge Driven Model” higher rates of economic growth cannot be reached solely through the trade of goods; a higher flow of general scientific knowledge resulting from economic integration is essential.
However, it is not clear whether the spread of scientific knowledge is possible only inside economically integrated countries. It may occur among non integrated countries which simply trade goods. Still more, given rapid advances in communication technologies information flows may occur even without the trade of goods. If economic integration does not induce higher information flows, the rationale for higher economic growth is not apparent.

The second path of higher growth due to economic integration is through increased entrepreneurial competition (Grossman and Helpman 1991b). International competition encourages entrepreneurs in each country to pursue new and distinctive products. Economic integration alleviates duplication of R&D activities, which leads to higher spillover to stock of general scientific knowledge, and higher growth rate. This effect can be more serious than the previous one, because economic integration can increase the competition among manufacturers producing differentiated products. However, the spillover effect of R&D on general scientific knowledge is not easily tested, and it is not clear if greater competition actually results in higher stocks of general scientific knowledge.

On the other hand, the change in production volatility, therefore change in income uncertainty, is caused by market integration effects including change in rules on direct investment and property rights. All of these are clearly shown in terms of treaty. Besides, the end result of policy change is reflected in lower income volatility and higher expected interest rates (shown later), both which are clearly measurable. Therefore, in our benchmark model we concentrate on the effect of production volatility on economic growth, and extend our analysis to information flows and competition effect in Appendix 90.
M. In our benchmark model, we assume that information flows are achieved before and after economic integration, and there is no duplication in differentiated products before and after economic integration.

Our intent is to provide an alternative path for economic growth through economic integration among LDCs. In particular, economic integration reduces production volatility, which facilitates both higher economic growth rates (through lower income uncertainty) and higher expected returns on investment. The model also shows very strong and general welfare implications: economic integration is welfare improving if it reduces production volatility, no matter whether growth rate increases or not. Besides, decrease in production volatility help the government reduce the level of subsidy to achieve optimal growth rate.

The structure of the essay is as follows. In section 2 the basic features of the endogenous growth model are described together with an illustration of how economic integration lowers production volatility. In section 3 the steady state equilibrium of the model and the effect of economic integration are presented. In the 4th section we present a welfare analysis of economic integration, and evaluate resource allocation efficiency at the steady state equilibrium. In the final section a summary of the results and conclusions are provided.

4.2 Description of the Model

This section has two parts. Firstly, the market structure is described. Then we explain how economic integration decreases production volatilities.
4.2.1 Market Structure

We characterize our model as follows. There are m (m>1) countries in the region all of which have the same size and resource allocations.\textsuperscript{46} All m countries are endowed with two types of labor in fixed amount, skilled (H) and unskilled (L). There are two industries: manufacturing and agriculture. Skilled labor is used for manufacturing activities. There are two types of manufacturing activities: production of horizontally differentiated goods ($x_i$) and research and development (R&D) which designs new differentiated goods. Both of these use skilled labor as inputs. Because all intermediate goods are differentiated, each manufacturer is a monopoly and earns monopoly profit. Differentiated manufactured goods are used as intermediate inputs together with unskilled labor in the agriculture sector, and more intermediate variety increases productivity of agriculture.

We further assume that the economy is underdeveloped (LDC) where all final goods are agricultural.\textsuperscript{47} Consumers earn wages in either the agriculture sector (unskilled) or the manufacturing sector (skilled); the income can either be saved or used to purchase food. Savings are invested in manufacturing sector and used to finance R&D activities. Returns to R&D activities come in the form of monopoly profit in intermediate goods market. Figure 1 illustrates the basic concepts of this LDC economy.

\textsuperscript{46} This simplification is made only for expository reasons. The conclusions of the model are not affected, as long as all the countries have same proportion of resource allocation.

\textsuperscript{47} This does not mean that agriculture’s share of GNP is 100%, because the manufacturing sector also creates value added. GNP share for each sector is provided later.
4.2.2 Production Shocks

Both agriculture and manufacturing are exposed to production shocks but in different ways. Agriculture experiences cyclical production shocks that are generally country specific. The main source of agricultural shock is biological in nature. The realization of the shock is assumed once per period, reflecting the harvest period. Specifically suppose the production shock for country \( i \) in period \( t \) is \( \theta_i \) where total production is \( X\theta_i \). Given the production shock has mean=1 and variance=\( \sigma_i^2 \), the variance of production is,

\[
\text{var}(X\theta_i) = X^2\sigma_i^2.
\]

Suppose production diversification between two countries or crop insurance is available. If farmers are risk averse, they can insure output through diversification or an
insurance contract without changing expected income. The variance of total production after insurance for countries i and j is,

\[
\text{var}\left(\frac{X\theta_i}{2} + \frac{X\theta_j}{2}\right) = \frac{X^2\sigma_i^2}{4} + \frac{X^2\sigma_j^2}{4} + \frac{X^2\text{cov}(\theta_u, \theta_{\mu})}{2}
\]

Postulating homoskedasticity, \((\sigma_i^2 = \sigma_j^2)\)

\[
\text{var}\left(\frac{X\theta_i}{2} + \frac{X\theta_j}{2}\right) = X^2\sigma_i^2\left(\frac{1}{2} + \frac{\text{cov}(\theta_u, \theta_{\mu})}{\sigma_i^2}\right) = X^2\sigma_i^2\left(\frac{1}{2} + \frac{\text{cor}(\theta_u, \theta_{\mu})}{2}\right).
\]

 Except for the case of perfect correlation \((\text{cor}(\theta_i, \theta_j)=1)\), the variance with diversification is strictly less than without diversification. With independent production shocks in each country, the variance is \(\frac{X^2\sigma_i^2}{2}\). In the same manner, if the production in m countries can be diversified (or insured), the variance of the total production \(X\sum_{i=1}^{m}\theta_i\) is \(\frac{X^2\sigma_i^2}{m}\), which is \(1/m\) times lower than before.

Because agriculture is the economy’s final good, the profit of manufacturers and their return on investment fluctuate according to the aggregate production shock \(\sum_{i=1}^{m}\theta_i = \theta_i\).

In addition to this production shock, which is transferred from agriculture, each manufacturer is exposed to firm specific Poisson shock. The Poisson shock reflects occurrences such as natural disaster, war, epidemic and property right violations all of which force the firm into shutdown.

Due to the Poisson shock, the probability of shutdown for firm k in time interval dt is given by \(\lambda_k dt\) where \(\lambda_k\) is the firm specific expected rate (also equal to variance) of
shutdown. Hence, is a contentious time frame shock in contrast to the single period agricultural harvest shock. This distinction is made because it better reflects the real world, however, we will present the alternative case in which shutdown can occur only once per period.

The expected rate of shutdown can decrease for two major reasons. First, firm $k$ can diversify operations in the integrated economy. This diversification clearly helps avoid shutdown, because it can continue operation in other sites in the event of a natural disaster, war, or epidemic at a specific site. In the special case where the firm can shift production to other operating sites with negligible cost, the probability of shutdown in interval $dt$ decreases from $\lambda_x dt$ to $(\lambda_x dt)^m$. Second, if the participation in the customs union requires stricter property rights, this effect can occur whether a firm diversifies operations or not.

In summary, economic integration lowers production volatility for each sector: lower cyclical shock in agriculture and lower Poisson shock in manufacturing. As elaborated in the next section, this lower production volatility reduces volatility in wages and investment returns. Further, as shown later, lower production volatility increases the expected return from investment due to a lower default rate.

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48 This is more likely as the number of production sites increases, because production adjustments at other sites can easily compensate for an accident at one site. The assumption of no setup cost helps the firm to diversify operations.
4.3 Steady State Equilibrium

This section has two parts. We first derive the economic growth rate of an autarkic country. Second, we evaluate the impact of economic integration on the growth rate of LDCs.

4.3.1 Autarky Equilibrium

Firstly we investigate producer’s optimization problem, and then consumer’s problem follows. Finally, the economic growth rate of an autarkic country is derived.

4.3.1.1 Producer Problem

We define the agricultural production function in country i with Cobb-Douglass technology as,

\[ D_i = AX_i^\beta L_i^{1-\beta} \theta_i, \quad (4.1) \]

where \( X_i \) is an indicator of productivity of differentiated intermediate inputs, \( L_i \) is the quantity of unskilled labor, \( A \) is a constant reflecting the choice of units, and \( \theta_i \) is the production shock. We use an indicator of productivity reflecting the variety of horizontally differentiated inputs (Dixit and Stiglitz 1977).

\[ X_i = \left[ \int_{j=1}^{n_i} x_{iij}^\alpha dj \right]^{1/\alpha}, \quad (4.2) \]

where \( x_{ij} \) is intermediate input j available in country i. The elasticity of substitution between any two intermediate goods is given by \( \frac{1}{1-\alpha} \), where \( 0<\alpha<1 \).

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49 To be precise Dixit and Stiglitz used this form for a utility function, and Ethier (1982) applied the form to production of intermediate goods.
Given (4.1) and (4.2) (assuming a normalized agricultural product price), the optimization problem for the risk adverse farmer with utility function \((U)\) is,

\[
\begin{align*}
\text{Max}_{x_i, L_i} & \quad EU \left[ AX_i^\beta L_i^{1-\beta} \theta_i - \sum_{j=1}^{n_i} p_{ij} x_{ij} d j - w_L L_i \right] \\
\text{s.t.} & \quad X_i = \left[ \int x_{ij}^\alpha d j \right]^{1/\alpha},
\end{align*}
\]

where \(p_{ij}\) is price of intermediate good \(x_{ij}\), and \(w_L\) is a wage rate for unskilled labor. The solution to this optimization problem results in optimum input levels \((x_{ij}^*, L_i^*)\) and target output level \(D_i^* = D(x_{ij}^*, L_i^*)\). Since we assumed that all \(m\) countries have the identical input endowments and that the farmer in each country faces the country specific production shock which is identically and independently distributed of other countries, we can eliminate the country subscript.

The specific value of \(D^*\) is not important for equilibrium analysis, if only we can derive the property of total demand for each variety by farmers. We can derive the input demand from cost minimization problem for the target output level \(D^*\).

\[
\begin{align*}
\text{Min}_{x_i, L} & \quad \sum_{j=1}^{n} p_j x_j d j + w_L L \\
\text{s.t.} & \quad D^* = AX^\beta L^{1-\beta}.
\end{align*}
\]

Using equation (4.2) in this cost minimization problem, we have the following first order conditions,

\[
\begin{align*}
w_L L &= \zeta (1 - \beta) D^* , \quad (4.3) \\
p_j &= \zeta / D^* \left[ \int \sum_{j=1}^{n_i} x_{ij}^\alpha d j \right]^{-1} x_{ij}^{\alpha-1} , \quad (4.4)
\end{align*}
\]
where $\zeta$ is the Lagrangian multiplier of the constraint. The market for the final good is assumed to be perfectly competitive, so that price equals marginal cost. This condition means $\zeta = 1$. Then we have the following condition from (4.3),

$$\beta D^* = \int_{j=1}^{n} p_j x_j dj. \quad (4.5)$$

Substituting (4.4) into (4.5), and solving for $\beta D^*$,

$$\beta D^* = \left( \int_{j=1}^{n} x_j^{\alpha} dj \right)^{\frac{1}{\alpha}} \left( \int_{j=1}^{n} p_j x_j^{\alpha-1} dj \right)^{\frac{\alpha-1}{\alpha}}.$$

Substituting the above equation back to equation (4.4),

$$\left( \int_{j=1}^{n} x_j^{\alpha} dj \right)^{\frac{1}{\alpha}} \left( \int_{j=1}^{n} p_j x_j^{\alpha-1} dj \right)^{\frac{\alpha-1}{\alpha}} \left[ \int_{j=1}^{n} x_j^{\alpha-1} dj \right]^{-1} x_j^{\alpha-1} = p_j.$$

Solving this for the $x_j$ yields the demand function for intermediate good $j$,

$$x_j = \left( \int_{j=1}^{n} x_j^{\alpha} dj \right)^{\frac{1}{\alpha}} \left( \int_{j=1}^{n} p_j x_j^{\alpha-1} dj \right)^{\frac{1}{\alpha}} \frac{1}{p_j^{\frac{1}{1-\alpha}}} \frac{1}{\int_{j=1}^{n} p_j x_j^{\alpha-1} dj} \beta D^*. \quad (4.6)$$

Farmer’s demand elasticity for each intermediate is $\frac{1}{1-\alpha}$.

From equation (4.3) the demand function for labor is $L^* = \frac{(1 - \beta) D^*}{w_L}$.

Denoting the total supply of unskilled labor in the country as $\bar{L}$, we can define the total output of final goods (GNP) of the country in period $t$ as,

$$D(\bar{L}, X_\theta) = D_\theta .$$
Here $\bar{D}_t$ is the time variant expected output of the final good, and $\theta_t$ is the cyclical shock. As a result, equation (4.3) and (4.5) can be converted to the economy-wide relation, $w_t L = (1 - \beta) \bar{D}_t \theta_t$, and $\int_{j=1}^{n} p_j x_j dj = \beta \bar{D}_t \theta_t$, which means that of total output of agricultural production, $\beta (0 < \beta < 1)$ belongs to unskilled labor and $(1 - \beta)$ belongs to differentiated intermediate goods in each period.

Now we turn to the profit maximization of manufacturers of intermediate goods. Manufacturers undertake two different activities. First, their research and development activities create blueprints for new varieties of differentiated intermediates, and then second they produce the intermediates. The cost of R&D can be regarded as an initial cost for the manufacturing, which is financed by investor shareholders.

Each manufacturing firm is a monopolist in the sense that a single firm produces and sells the specific intermediate good variety, protected by patent. So, each manufacturer enjoys monopoly profit by selling its unique variety. However, once the patent right is violated or accidents such as wars, epidemics and natural disasters cause the operation to shutdown, the profit goes to zero and remains unrecoverable.

We assume the production of intermediate goods follows constant returns to scale technology as in agriculture. We also assume that all the varieties have the same production function, using skilled labor input. By appropriately choosing units, we can assume the input-output coefficient to be one ($H_j= x_j$) where $H_j$ is quantity of skilled labor for good $j$. 
Given the demand for each variety of intermediate good in equation (4.6), the owner
(investor=consumer=wage earner) mandates the firm to choose the supply of the good to
maximize operating profit each period,

$$\max_{x_{jt}} \pi_{jt} = p_{jt} x_{jt} - w_{jt} H_{jt} = p_{jt} x_{jt} - w_{jt} x_{jt}.$$ 

The first order condition is,

$$p_{jt} \left( 1 + \frac{\partial p_{jt}}{\partial x_{jt}} \frac{x_{jt}}{p_{jt}} \right) = w_{jt} \Rightarrow p_{jt} \left( 1 - \frac{1}{\text{Elastity}_{jt}} \right) = w_{jt}.$$ 

Substituting the demand elasticity from (4.6),

$$p_{jt} \left( 1 - \frac{1}{1/(1-\alpha)} \right) = w_{jt} \Rightarrow p_{jt} = w_{jt} / \alpha.$$ 

The profit for manufacturer j becomes,

$$\pi_{jt} = (1-\alpha)p_{jt} x_{jt}.$$ 

Assuming symmetric equilibrium (all varieties are equally demanded), profit is

$$\pi_t = (1-\alpha) \beta \overline{D}_t \theta_t \overline{n}_t.$$ (4.7) 

Manufacturer profit varies annually as $\overline{D}_t = D(\overline{L}, X_t)$ changes as the productivity
of intermediate goods ($X_t$) changes; the cyclical production shock $\theta_t$ changes, and; the
total number of differentiated products ($n_t$) changes.

Next we consider the stock market valuation of the intermediate firms. A shareholder
receives dividends $\pi_t dt$ at interval $dt$. She also enjoys capital gains of $\nu dt$ unless
accidents results in the shutdown of operations. On the other hand, if accidents occur
during the interval $dt$, the shareholders will suffer total capital loss $v_t$. The probability of
this happening is $\lambda dt$, where $\lambda$ is the expected number of Poisson shocks within a unit interval.

Conventional in other endogenous growth models, we assume that the risk adverse investor (consumer) owns a perfectly diversified portfolio (Agwion and Howitt 1992, Grossman and Helpman 1991b). The law of large numbers implies that a constant fraction $\lambda dt$ of all intermediate firms shutdown operations during interval $dt$. Given the current stock value $v_t$, the expected return $\tilde{r}_t$ from the portfolio is,

$$\tilde{r}_t v_t dt = \bar{r}_t dt - (\lambda dt)v_t + (1 - \lambda dt)\tilde{v}_t dt,$$

where $\tilde{v}_t = d\tilde{v}_t / dt$. Ignoring $(dt)^2$ term,

$$\tilde{r}_t \approx \frac{\bar{r}_t}{v_t} + \frac{\tilde{v}_t}{v_t} - \lambda.$$  \hspace{1cm} (4.8)

This means that expected return from investment is the sum of the expected profit ratio and the stock value growth rate less the expected number of Poisson shocks in the unit interval. The important thing is that $r_t, \pi_t, v_t$ change according to the innovation in the cyclical shock. This means that the investor cannot avoid the aggregate cyclical shock even if she owns a perfectly diversified portfolio. Another implication is that the expected investment return is a decreasing function of expected number of Poisson shocks $\lambda$. Remember $\lambda$ is the expected rate of Poisson shock for all individual firms, and the law of large number yields a fixed rate for the entire manufacturing industry. So, the owners of a firm will attempt to minimize $\lambda$ through diversification or stricter enforcement of property right rules.

---

50 If the shock on manufacturers also occurs only once a period with probability $\lambda$, we have

$$\tilde{r}_t v_t = \bar{r}_t - v_t \lambda + (1 - \lambda) \Delta \tilde{v}_t.$$ This leads to the same form as equation (4.8), if the probability and the stock value change are small so that $\lambda \Delta \tilde{v}_t / v_t$ is negligible.
We now turn to the R&D activities of manufacturers. We assume that a manufacturer can invent a new intermediate variety by hiring a finite amount of skilled labor for R&D.\(^5\) After invention it enjoys the monopoly rent from the production and sale of the new variety, until an accident either shuts down the firm due to perhaps a property right violation or a natural disaster.

The instantaneous invention velocity function is,\(^5\)

\[
\frac{dn_t}{dt} = amn_t H_{R_t},
\]

(4.9)

where \(H_{R_t}\) is number of skilled labor hired for R&D, and \(a\) is a skilled labor productivity parameter. Another implication is that the invention velocity increases as the number of varieties \((mn_t)\) increases in the region. This reflects the spillover effect of R&D activities on the stock of basic scientific knowledge. Assuming perfect information flows and no duplication (even under autarky), more varieties in the region means greater contributions of the R&D sector to the stock of scientific knowledge. This increases the velocity of invention of a country.\(^5\)

Newly developed firms or existing firms finance R&D cost by issuing equity. The cost of R&D is \(w_{R_t} H_{R_t} dt\). The value of the firm is \(v_t\), so that R&D activities create \(amn_t H_{R_t} v_t dt\) in interval \(dt\). Then the manufacturer’s (entrepreneur’s) profit maximization problem becomes,

\[
\max_{H_{R_t}} \quad amn_t H_{R_t} v_t - w_{R_t} H_{R_t}.
\]

\(^5\) We can assume the firm is either newly founded or that it is an existing firm engaged in R&D.

\(^5\) If inventions also occur only once a period, (4.9) becomes \(\Delta n_t = amn_t H_{R_t}\) without any other change.

\(^5\) The case of imperfect information flows and duplication of varieties is investigated in Appendix M.
If \( amn, \nu_i > w_{lh} \), there would be unbounded demand for skilled labor in the market and an equilibrium cannot be attained. If \( amn, \nu_i < w_{lh} \), there is zero invention and therefore, no economic growth. Initially, assuming positive growth of the economy, we eliminate this latter possibility. Later we will show the sufficient condition for this. The following condition emits positive R&D activity and economic growth,

\[
\text{4.10}
\]

4.3.1.2 Consumer Problem

We turn now to the consumers’ utility maximization problem. Consumers earn wages in the agricultural or manufacturing sectors, purchase food and save money, which is used to finance R&D activity. Another source of income is the return from saving (investment) that can be either consumed or saved.

Each period, consumers make consumption and saving (investment) decisions so as to maximize utility over an infinite horizon. Their optimization problem is,

\[
\text{4.11}
\]

where \( Y \) is for skilled labor and \( Y \) for unskilled labor. \( C \) is consumption, and \( A \) is wealth at the beginning of period \( t+i \).

The first order condition is,

\[
\text{FOC} \quad E_i \left\{ \frac{U'(C_i)}{1 + \rho} \right\} = 1.
\]

Assuming a constant relative risk aversion utility function, so that \( U(C) = \frac{C^{1-\eta}}{1-\eta} \),

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\[
E_t \left\{ \frac{C_t}{C_{t+1}} \right\}^{\eta} \frac{1 + r_{t+1}}{1 + \rho} = 1,
\]

where \( \eta (\eta > 1) \) is the coefficient of relative risk aversion, and \( \rho (\rho > 0) \) is the subjective discount factor.

Now we set forth some assumptions regarding the stochastic process of cyclical shocks. Suppose that this process follows the AR(1) process,

\[
\ln \theta_{t+1} = \phi \ln \theta_t + \epsilon_{t+1}, \text{ where } \epsilon_{t+1} \sim N(0, \sigma).
\]

If \( \phi \) is less than 1.0, \( \ln \theta \) follows stationary process. But, if \( \phi = 1.0 \), \( \ln \theta \) follows random walk. We assume that \( \phi = 1 \) for three reasons. First, Prescott (1986) has found that the production shock process is well described by an AR(1) process with \( \phi \) close to one. Second, as derived below, the random walk assumption for the shock process leads to steady state equilibrium in which logarithm of GNP follows random walk with drift. Indeed many empirical studies support this conclusion. Nelson and Plosser (1982) found evidence that GNP and other macroeconomic time series behave like random walk rather than stationary processes. Other researchers have reached similar conclusions (Campbell and Mankiw 1987, Gardner and Kimbrough 1989). The third reason is theoretical tractability. As shown in Appendix N very specific form of AR(1) process must be assumed to achieve a steady state equilibrium with rational expectations in which the logarithm of GNP follows a trend reverting process rather than random walk with drift. Thus, we assume the logarithm of the error term follows the random walk process,\(^{54}\)

\(^{54}\)On this respect, Smith allows more freedom choosing the value of \( \phi \): any value between -1 and 1. But, this freedom heavily depends on assumption of 100% capital depreciation each period. However, this has not been verified by empirical work.
\[ \ln \theta_{r+1} = \ln \theta_r + \epsilon_{r+1}, \text{ where } \epsilon_{r+1} \sim N(0, \sigma). \]

The logarithm of final good production (GNP) in period t+1 becomes,
\[ \ln D_{t+1} = \ln \overline{D}_{t+1} + \ln \theta_{t+1}. \]

This enables the stochastic process of GNP to follow random walk with drift.\(^{55}\)
\[ \ln D_{t+1} - \ln D_t = \ln \overline{D}_{t+1} - \ln \overline{D}_t + \epsilon_{t+1} = g + \epsilon_{t+1}. \]  

(4.13)

where g is drift term or expected growth rate of economy (derived below).

In steady state equilibrium the allocation of resources to each sector (agriculture, R&D and intermediary production) is fixed. Due to constant returns to scale technology in all the sections, and fixed monopoly profit rates, the final good outputs are claimed by each factor in fixed proportions. Of total GNP, unskilled labors take \((1 - \beta)\) as payment, skilled labors in the production of intermediates take \(\alpha \beta\) and owners of intermediates take \((1 - \alpha)\beta\) as profit.\(^{56}\) The savings (investment) of each person finance R&D activities, which then becomes income of skilled labor employed in R&D sector. That is
\[ \frac{\alpha^2 \beta g}{am(1 - \alpha)\beta H - \alpha g} \text{ of GNP, which is equal to the saving (investment) rate of the economy.}^{57}\]

It follows then that GNP in period t+1 (\(\overline{D}_{t+1} \theta_{t+1}\)) is distributed to each factor according to the above proportions. Hence, the innovation in period

\(^{55}\) With this setup, we should call the volatility \(\sigma\) “innovation volatility”. However, the same mechanism by which economic integration reduces the volatility inside the region can be applied to this case as before, because \(\epsilon_{t+1}\) is a stationary process (white noise).

\(^{56}\) The wages of skilled labor in R&D and production sector is equalized at \(\frac{am(1 - \alpha)\alpha \beta^2}{am(1 - \alpha)\beta H - \alpha g}\) of GNP.

\(^{57}\) This saving rate is positive as long as economic growth rate is positive. The specific condition for positive economic growth is given in Appendix N.
\( t+1(\ln \theta_{t+1} - \ln \theta_t = \varepsilon_{t+1}) \) revises the growth rate of income of all factors by the same rate \( (\varepsilon_{t+1}) \) without changing relative proportions, so that incomes of all factors grow by \( g + \varepsilon_{t+1} \).

Fixed relative wages means that the innovation in period \( t+1 \) does not change the factor allocation. So, the innovation in \( t+1 \) does not change the expected return in \( t+2 \) and afterwards. Without a change in factor allocation there is no change in the growth rate in \( t+2 \) and afterwards. Changing the growth rate requires a shift of factors to the R&D sector which is the source of economic growth.

The savings rate shown above is a constant, so that a fixed portion of individual income is consumed. As a result, consumption follows the innovation of production shock in period \( t+1 \).

\[
\begin{align*}
&\left(\ln C_{t+1} - \ln C_t\right) - E_t(\ln C_{t+1} - \ln C_t) = r_{t+1} - E_t r_{t+1} = \varepsilon_{t+1}, \\
\Rightarrow & g_{t+1} - E_t g_{t+1} = r_{t+1} - E_t r_{t+1} = \varepsilon_{t+1}.
\end{align*}
\]

This means that both innovations in consumption growth rate and investment return follows the innovation in production shock.

Using these results we transform the first order condition for a consumer,

\[
(1 + g)^{-\frac{1}{\eta}} \frac{1}{1 + \rho} E_t \left[ \exp \left( (1 - \eta) \varepsilon_{t+1} \right) \right] = 1.
\]

Using the moment generating function for a normal distribution and taking log of both sides, we have,

\[
g = \frac{\bar{r} - \rho}{\eta} + \frac{(1 - \eta)^2}{2\eta} \sigma^2. \quad \text{(4.14)}
\]
One more condition is needed: factor market clearing for skilled labor. From equation (4.9) the quantity of skilled labor demanded for R&D activities is \( \frac{\hat{n}_i}{am} \), where \( \hat{n}_i \) is the (variety) invention rate. As we have assumed an input-output coefficient of 1, skilled labor demanded in the production of intermediate goods is \( \int_{j=1}^{n} x_j dj \). The market clearing condition is given as,

\[
\frac{\hat{n}_i}{am} + \int_{j=1}^{n} x_j dj = H ,
\]

where H is the total number of high skilled labors available. For symmetrical equilibrium in which all inputs are equally demanded,

\[
\frac{\hat{n}_i}{am} + n_i x_i = H , \quad (4.15)
\]

where \( x_i \) is output of each variety in period t. From equations (4.1) to (4.15), the stochastic process of logarithm of GNP follows a random walk with drift g, which is,

\[
\ln D_{t+1} = \ln D_t + g + \epsilon_{t+1} , \quad (4.16)
\]

where drift term g is given by,

\[
g = \beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \left[ \frac{1}{\alpha - 1} amH - (\rho + \lambda) + \frac{(\eta - 1)^2}{2} \sigma^2 \right] . \quad (4.17)
\]

The stochastic process in equation (4.17) applies to the consumption and wage rates of all people (derivation in Appendix L).

This expected growth rate (g) of the economy is increasing in skilled labor productivity in R&D (a), increasing in cost share of intermediates in agricultural
production ($\beta$), increasing in monopoly rent ($1-\alpha$), and decreasing in subjective discount factor ($\rho$). Many endogenous growth models have the same properties (Grossman and Helpman 1991b). It is also increasing in total number of available skilled labors in the region ($m_H$). This is because the knowledge spillover effect of R&D is fully realized even under autarky.

The saving rate for all consumers is
\[
s = \frac{\alpha \beta g}{(1-\alpha)m_H - \alpha g}.
\]
This is equal to the income share of GNP for skilled labor in R&D. Savings (investment) in this economy is used to finance the cost of R&D which invents new intermediate good varieties. The cost for R&D equals the income of workers, so these three are equalized in the steady state equilibrium. We can see that the saving rate increases with the economic growth rate ($g$). So, our model is consistent with observations showing a positive relation between saving and economic growth (Levine and Renelt (1992)).

Also from equation (4.17), necessary and sufficient condition for positive growth is,
\[
(\frac{1}{\alpha} - 1)m_H > \rho + \lambda - \frac{(\eta - 1)^2}{2}\sigma^2.
\]
Thus, for the country to grow, it must have sufficient quantities and productivity of skilled labor, as well as a low subjective discount rate. Otherwise, the economy eventually moves to zero growth.\(^{58}\) In the next section, we investigate the effect of economic integration on economic growth.

\(^{58}\) If $\rho + \lambda - \frac{(\eta - 1)^2}{2}\sigma^2 < 0$, even zero endowment of skilled labor enables positive growth. However, this does not make sense because there is no innovation without skilled labor. In order for the model to
4.3.2 Effect of Economic Integration

The effect of economic integration in the less developed economy is given only by the change in production shock volatilities\(^{59}\); namely, the Poisson arrival rate of accidents (\(\lambda\)) and the variance of cyclical shocks (\(\sigma^2\)). From equation (4.17) \(\frac{\partial G}{\partial \lambda} < 0\), which means the growth rate is decreasing in Poisson arrival rates. However, equation (4.17) also implies \(\frac{\partial G}{\partial \sigma^2} > 0\), which means that the growth rate increases in volatility of cyclical shocks. So, the growth rate decreases in volatility in manufacturing (Poisson shocks), but increases in volatility in agriculture (cyclical shocks). If the relative effect of the former is bigger, the model shows the negative relation between production shock and economic growth. If this is the case, we can conclude that production stability due to economic integration increases the rate of economic growth, a finding not evident in the existing literature.

Decreasing Poisson arrival rate increases the expected rate of return from investment, which, in steady state equilibrium, increases the expected rate of interest. This is the positive effect on economic growth. However, decreasing volatility provides consumers (wage earners) an incentive to reduce precautionary savings due to greater income stability. This is the negative effect on economic growth. Which effect is bigger depends on the impact of economic growth on the two shocks and the coefficient of relative risk

\[
\rho + \lambda - \frac{(\eta - 1)^2}{2} \sigma^2 > 0.
\]

\(^{59}\) Also, economic integration increases available types of intermediate goods for farmers from \(n\) to \(mn\), and this must increase GNP temporarily. However, this is only level effect, and does not affect the growth rate in steady state equilibrium (comment: saving up leads to temporary consumption down).
aversion ($\eta$). If the reduction of the Poisson shock is larger than the reduction of the
cyclical shock, economic integration tends to lead to a higher growth rate. Also, the less
risk averse the consumer, the more likely economic integration will result in higher
growth rates. Lower risk aversion ($\eta$ approaching one) means that consumers are less
motivated for stability and precautionary savings; therefore, less sensitive to income
volatility. If this is the case, a change in volatility of income does not affect the
precautionary savings decision, leaving the interest rate effect more important.

PROPOSITION 4.1

The steady state equilibrium growth rate increases with lower volatility of the production
of intermediates, but decreases with lower volatility of agricultural cyclical shock. The
former effect tends to be higher as consumers become less risk averse.

This result has important implications which test the relation between production
shocks and economic growth. Most of these studies omit interest rates from set of
explanatory variables (Smith 1996, Ramey and Ramey 1992). However, our model
shows that average interest rates reflect production stability in the manufacturing section
(which enjoys monopoly profit). The more stable manufacturing production, the higher
the expected return on investment, which in turn attracts more investment.

Perfect diversification (or insurance) may not occur in the agricultural sector due to
non-perfect economic integration or lack of preferences for stability. The former case is
possible when there are special provisions for agricultural market exemptions from the
customs union. The latter is possible if we assume farmers are risk neutral. If either of
these occurs, the earnings of unskilled labor remain as volatile as before economic
integration. Then, precautionary savings effect disappears for unskilled labor, leaving only the higher expected return effect. So, economic integration has a stronger pro-growth effect.

4.4 Welfare Analysis

In this section, we analyze the long run welfare effect of economic integration. Firstly, we derive the change in expected present discounted lifetime utility with economic integration. Next, we investigate whether market equilibrium leads to an efficient allocation of resources as well as government policy options designed to facilitate optimal resource allocation.

4.4.1 Welfare Impact of Economic Integration

For computational ease, we convert the discrete time stochastic process of consumption of equation (4.17) into a continuous time process. Continuous time characterization is consistent with the endogenous growth model literature. The random walk with drift of (4.17) is converted to a geometric Brownian motion with drift (Dixit and Pindyck 1994).

\[ dC_t = gC_t dt + \varepsilon_t \sqrt{d\tau}, \]

where \( \varepsilon_t \sim N(0,\sigma) \) for \( \forall \), and \( E(\varepsilon_t, \varepsilon_s) = 0 \) for \( \tau \neq \sigma \), and \( g \) is the expected instantaneous drift rate of geometric Brownian motion (the same as the expected growth rate of consumption in our model), and \( \varepsilon_t \sqrt{d\tau} \) is the process innovation.

Expected utility (denoted \( W \)), assuming continuous time, is,

60 In any event, the earnings of skilled labor and investment returns become less volatile after integration. Because differentiated intermediate goods are sold to all farmers the integrated market results in reduced volatility for each firm, irrespective of diversification of individual farmers.
\[ W = E_t \int_t^\infty e^{-\rho(\tau-t)} \frac{C_{\tau}^{1-\eta}}{1-\eta} d\tau, \]

where, \( C_\tau \) follows a geometric Brownian motion with drift \((4.18)\).

Applying Ito’s Lemma (Ito 1991) to equation \((4.18)\),

\[ dC_\tau^{1-\eta} = (1-\eta) \left[ g - \frac{1}{2} \eta \sigma^2 \right] C_\tau^{1-\eta} d\tau + (1-\eta) C_\tau^{1-\eta} \epsilon_\tau \sqrt{d\tau}. \]

We can find this also follows geometric Brownian motion. Hence, we can apply Ito’s Lemma again,

\[ d \ln C_\tau^{1-\eta} = (1-\eta) \left( g - \frac{1}{2} \sigma^2 \right) d\tau + (1-\eta) \epsilon_\tau \sqrt{d\tau}. \]

So, over a finite interval \( d\tau \), the change in logarithm of \( C_\tau^{1-\eta} \) is normally distributed with mean \((1-\eta) \left( g - \frac{1}{2} \sigma^2 \right) d\tau \), and variance \((1-\eta)^2 \sigma^2 d\tau \). Given the initial consumption at \( t \), the expected value of \( C_\tau^{1-\eta} \) is given by,

\[ E_t C_\tau^{1-\eta} = C_t^{1-\eta} \exp \left( (1-\eta) \left( g - \frac{1}{2} \eta \sigma^2 \right) (\tau - t) \right). \]

We derive the present discounted lifetime utility of consumption \( W \) as,

\[ W = E_t \int_t^\infty e^{-\rho(\tau-t)} \frac{C_{\tau}^{1-\eta}}{1-\eta} d\tau = \frac{C_t^{1-\eta}}{\eta - 1} \left. \frac{-1}{\rho + (\eta - 1) \left( g - \frac{1}{2} \eta \sigma^2 \right)} \right|_{\tau=t}, \]  

where \( \eta > 1 \). \((4.19)\)

---

\(^{61}\) Note that cardinal value of utility is negative given \( \eta > 1 \). So, utility with higher level of consumption asymptotically approaches zero. Hence, present discounted lifetime utility converge to a finite value.

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Of course, this is an increasing function of growth rate \( g \) and a decreasing function of the volatility of income \( \sigma^2 \). The sufficient condition for welfare improving economic integration is \( dg - \frac{1}{2} \eta d \sigma^2 > 0 \).

Assuming that economic integration weakly decreases \( \sigma^2 \left( d \sigma^2 \leq 0 \right) \), increasing \( g \left( dg > 0 \right) \) is a sufficient condition for welfare improvement. Even if \( g \) decreases or remains the same \( \left( dg \leq 0 \right) \), economic integration results in higher lifetime utility if the reduction in \( g \) is sufficiently small so that \( dg - \frac{1}{2} \eta d \sigma^2 > 0 \). In the following argument we show this is true if cyclical shock volatility is strictly decreasing \( \left( d \sigma^2 < 0 \right) \) given the Poisson shock is not increasing \( \left( d \lambda \leq 0 \right) \). Using drift term given as equation (4.17),

\[
\text{sign}(dW) = \text{sign} \left( dg - \frac{\eta}{2} d \sigma^2 \right) \\
= \text{sign} \left[ -\beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} d \lambda \right. \\
\left. - \left\{ \frac{\eta}{2} - \beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \left( \frac{\eta - 1}{2} \right) \right\} d \sigma^2 \right]. \\
\text{(4.20)}
\]

Because \( 0 < \beta < 1, \ 0 < \alpha < 1, \eta > 1 \) we have \( 0 \leq \beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \leq \frac{1}{\eta} \).

Then we have \( -\beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} < 0, -\left\{ \frac{\eta}{2} - \beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \left( \frac{\eta - 1}{2} \right) \right\} < 0 \).

Hence, equation (4.20) is not negative if \( d \sigma^2 \leq 0 \) and \( d \lambda \leq 0 \), and is strictly positive if one of these has a strict negative sign. From these results, we have the following powerful Proposition.
PROPOSITION 4.2

If economic integration weakly decreases production volatility in both sectors
\( (d\sigma^2 \leq 0 \text{ and } d\lambda \leq 0) \), it is weakly welfare improving \( (dW \geq 0) \). It is strictly welfare improving \( (dW>0) \), if one of these has a strict inequality.

Note that Proposition 4.2 is very general conclusion about the welfare impact of production stability, because it does not depend on parameter values or the change in the economic growth rate. As in Proposition 4.1, the effect of production stability on economic growth rate was ambiguous: stability in manufacturing sector has a positive effect but stability in agriculture sector has a negative effect. The total effect depends on parameter values and which effect is stronger. However, from Proposition 4.2 if economic integration leads to production stability in both sectors, an improvement in welfare occurs, whether or not \( g \) increases.

Production stability has a direct effect and two indirect effects on consumer welfare: a decrease in \( \sigma^2 \) directly increases the utility of a risk averse consumer and indirectly decreases it through lower growth rates, and a decrease in \( \lambda \) indirectly increases it through higher growth rates. The two positive effects are at least as large as the negative effect, ending up with welfare improving integration. Recall, production stability is the most likely result of economic integration.

4.4.2 Optimal Growth Rate

Still, we do not know whether market equilibrium in each regime brings about the optimal rate of economic growth. We know that choosing the economic growth rate is equivalent to choosing the level of investment and choosing resource allocation. Hence,
our task here is to investigate whether market equilibrium realizes the welfare maximizing growth rate (investment and resource allocation).

The social planner’s constrained optimization problem is to maximize the discounted present value of utility,

$$
\max_{n_t, x_t} \int_{t}^{\infty} e^{-\rho(t-\tau)} \left( \frac{\left( \frac{n_{t-1}}{n_t} \right) (n_t x_t)^{\eta} L^{1-\beta}}{1-\eta} \right)^{1-\eta} d\tau
$$

s.t. \( \frac{\dot{n}_t}{amn_t} + n_t x_t = H. \)

Assuming that the social planner can immediately achieve the steady state in period t,

using \( g_r = \frac{(1-\alpha)\beta}{\alpha} \dot{n}_t / n_t \) the planner’s optimization is to choose the steady state growth rate so that,

$$
\max_{g} \left[ \frac{\left( \frac{n_{t-1}}{n_t} \right) (n_t x_t)^{\eta} L^{1-\beta}}{1-\eta} \right]^{1-\eta}
$$

s.t. \( \frac{\alpha}{(1-\alpha)\beta am} g + n_t x_t = H. \)

The solution yields the optimal level of growth rate (\( g^* \)),

$$
g^* = \beta \left[ 1 + \beta (\eta-1) \right] \left[ \frac{1}{\alpha} - 1 \right] amH - \rho + \frac{(\eta-1)\eta}{2} \sigma^2 \right] \right]^{1-\eta}
$$

That market equilibrium growth rate (g) is smaller than optimal growth rate (\( g^* \)). This means that market equilibrium allocates less than optimal skilled labor to R&D, because
the level of investment is lower than optimal level. The important implication is that the difference between the optimal growth rate and market equilibrium rate increases, as the rate of Poisson shock ($\lambda$) increases. The higher the rate of Poisson shock, the higher the portion of manufacturing firms that shut down (fraction $\lambda dt$ of all firms shutdown during interval $dt$). This raises the possibility of default, as a result the expected return from investment decreases and fewer resources are directed to investment. The same conclusion is true for cyclical agricultural production shocks: the difference between optimal growth rate and market equilibrium rate increases, as the production volatility ($\sigma^2$) increases.

The equally important implication is that the equilibrium growth rate is lower than the optimal rate even when production shock effects are ignored. This is parallel to the popular three effects of R&D result: consumer surplus effect, profit destruction effect and intertemporal spillover effect (Grossman and Helpman 1992a, Romer 1996). In our model as well as others, the first two effects cancel out and the intertemporal spillover effect remains. This positive R&D externality cannot be fully captured in market equilibrium.

The next question is how the government can achieve the optimal level of investment? There are potentially three policy options. The first is to reduce the volatility in Poisson shock through stricter enforcement of property rules or by allowing more freedom of choosing operation sites. However, as we can see from equation (4.21), the optimal level of growth rate cannot be reached even if the government succeeds in virtually eliminating Poisson shock ($\lambda=0$). Therefore, the government cannot realize the optimal level of R&D with this policy alone.
The second policy option is to intentionally increase the volatility of cyclical production shock \( \sigma^2 \). In this way, the government can force consumers to save more by motivating precautionary savings. However, increasing volatility raises the optimal level of growth rate \( g^* \) more than it raises the equilibrium rate \( g \), widening their difference. So, this policy cannot lead to the optimal investment rate. This can be explained by the fact that a higher \( \sigma^2 \) increases \( g \), but it is welfare deteriorating. From equation (4.19) and (4.20) we can show that increasing \( \sigma^2 \) given fixed level of \( \lambda \) decreases \( W \). Higher savings from precautionary motivation is not enough to compensate for the welfare loss due to higher volatility.

Instead, the government can make the equilibrium growth rate closer to optimal growth rate by decreasing \( \sigma^2 \). However, from equation (4.21), the former never reaches the latter even when \( \sigma^2 = 0 \). In conclusion, the government cannot realize the optimal growth rate and the efficient allocation only by production stabilization policy.

PROPOSITION 4.3

The optimal growth rate is higher than the market equilibrium growth rate. Production stabilization policy alone cannot realize the optimal growth rate.

The final policy option is subsidy to R&D activity in which government pays a fraction \( s^* \) of R&D costs.\(^{62}\) This R&D subsidy reduces the entrepreneur’s cost from \( w_{Ht}H_{Rt} \) to \( (1 - s^*)w_{Ht}H_{Rt} \).

Then entrepreneur’s profit maximization problem with positive R&D activity, as in equation (4.10), becomes,

---

\(^{62}\) It is easy to show that a subsidy to goods production cannot increase the growth rate.
Replacing equation (4.10) by (4.10') we can solve for the subsidy as a function of optimal growth rate \(g^*\) and equilibrium growth rate \(g\) as (derivation is given in Appendix O),

\[
s^* = \frac{(k + l + 1)(g^* - g)}{(k + l)g^* + \left( \rho + \lambda - \frac{(\eta - 1)^2}{2\sigma^2} \right)},
\]

(4.22)

where \(k = \beta(\eta - 1) > 0, l = \frac{\alpha}{1 - \alpha} > 0\).

This is increasing in optimal growth rate and decreasing in equilibrium growth rate, and increasing in difference between them. If we substitute \(g\) and \(g^*\) into equation (4.22) (to see property of subsidy in more detail), \(s^*\) is given as,

\[
s^* = \frac{amH - lp + (k + 1)\lambda + [l\eta + k + 1]\left(\frac{\eta - 1}{2}\right)\sigma^2}{\left[\frac{k}{l} + 1\right]amH + (1 - l)p + (k + 1)\lambda + [(l - 1)\eta + k + 1]\left(\frac{\eta - 1}{2}\right)\sigma^2}.
\]

(4.23)

Note that \(s^*\) does not have to be less than one (see Appendix P). This means that a 100% cost reduction subsidy to R&D may not be enough to realize the optimal growth rate.

This happens when production volatilities are so large (\(s^*\) is shown always increasing in \(\Phi^2\), and increasing in 8 for \(s^* < 1\)). However, the government can always reach the optimal growth rate by combining the R&D subsidy with a production stability policy (see Appendix P). Actually, the level of subsidy is minimized by decreasing both production volatilities, and the minimum level is given by,
Note this is strictly less than one. The optimal growth rate is always possible by a combined policy even if an isolated policy is not effective. Even when optimal growth rate is possible only by a subsidy to R&D, the level of subsidy is decreased by the combined policy. These results are summarized as the following proposition.

PROPOSITION 4.4

A subsidy to R&D alone may or may not lead to the optimal growth rate. A combined policy of R&D subsidy with production stabilization will always achieve the optimal rate of growth. The level of subsidy is decreased with a policy of production stabilization, even when the subsidy alone will lead to the optimal growth rate.

4.5 Conclusion

In this essay we have developed an endogenous growth model with two sources of production volatility to investigate the effect of economic integration on the economic growth and welfare of less developed countries.

First, economic integration is most likely to reduce production volatility of both the agricultural and manufacturing sectors, but the volatility effect on steady state equilibrium growth rate is ambiguous: lower volatility in the production of intermediates increases the growth rate, while lower volatility in agricultural cyclical shocks decreases it. The total effect on the growth rate depends on the relative size of the changes in production volatilities, but the positive effect (from intermediates production) tends to be relatively higher as the consumer becomes less risk averse.
Our model has the very general and strong welfare implications: if economic integration weakly decreases production volatility in both sectors, it is weakly welfare improving. It is strictly welfare improving, if one sector strictly decreases.

The optimal growth rate is always higher than the market equilibrium growth rate, and the government policy of production stabilization alone will not lead to the optimal growth rate. On the other hand, an R&D subsidy by itself may or may not lead to optimal growth. However, the combined policy of production stabilization and subsidy will always lead to the optimal growth rate, even if the latter alone cannot achieve it. The level of subsidy is decreased with a policy of production stabilization, even if the subsidy policy alone is sufficient.
APPENDIX A

PROPERTIES OF OPTIMAL PROFIT FUNCTION

Proof that the optimal profit is non-decreasing in \( P \).

Suppose \( x_1(P), s_1(P), x_2(P), s_2(P) \) was chosen for a value \( P \). Also, \( x_1'(P'), s_1'(P') \), \( x_2'(P'), s_2'(P') \) was chosen for a value \( P' \leq P \). Then,

\[
P[x_1 - s_1] + (1 - P)[x_2 - s_2] \geq P[x_1' - s_1'] + (1 - P)[x_2' - s_2'] \geq P'[x_1' - s_1'] + (1 - P')[x_2' - s_2']
\]

\[
\Rightarrow \Pi(P, F) \geq \Pi(P', F).
\]

The first inequality is from the optimization at \( P \) and the second is from \( P' \leq P \) and

\[x_1' - s_1' \geq x_2' - s_2'.\]

Proof that the optimal profit is convex in \( P \).

For any value \( P, P' \), and \( P^* = \lambda P + (1 - \lambda)P' \) such that \( 0 \leq \lambda \leq 1 \), \{ \( x_1(P), s_1(P), x_2(P), s_2(P) \) \}, \{ \( x_1'(P'), s_1'(P'), x_2'(P'), s_2'(P') \) \}, \{ \( x_1^*(P^*), s_1^*(P^*), x_2^*(P^*), s_2^*(P^*) \) \}, were chosen respectively. Then, we have the following relationships from optimization,

\[
\lambda\left[P(x_1 - s_1) + (1 - P)(x_2 - s_2)\right] \geq \lambda\left[P(x_1^* - s_1^*) + (1 - P)(x_2^* - s_2^*)\right]
\]

\[
(1 - \lambda)\left[P'(x_1 - s_1') + (1 - P')(x_2 - s_2')\right] \geq (1 - \lambda)\left[P'(x_1^* - s_1^*) + (1 - P')(x_2^* - s_2^*)\right]
\]

Summing up each side of the inequalities,

\[
\lambda\left[P(x_1 - s_1) + (1 - P)(x_2 - s_2)\right] + (1 - \lambda)\left[P'(x_1 - s_1') + (1 - P')(x_2 - s_2')\right] \geq \left[P'(x_1^* - s_1^*) + (1 - P')(x_2^* - s_2^*)\right]
\]

\[
\therefore \lambda \Pi(P, F) + (1 - \lambda)\Pi(P', F) \geq \Pi\left[\lambda P + (1 - \lambda)P', F\right]
\]

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APPENDIX B

PROPERTIES OF INFORMATION RENT

Here we prove the information rent increases on any level of $P$ larger than $\bar{P}$, as the expected (target) value $\bar{P}$ decreases. The effect of decrease in $\bar{P}$ on information rent is given by,

$$\frac{\partial R(P, \bar{P})}{\partial \bar{P}} = -\frac{\partial \left[ \Pi^* (P, F) - \Pi(P, \bar{P}, F) \right]}{\partial \bar{P}} = -\frac{\partial \Pi(P, \bar{P}, F)}{\partial \bar{P}}$$

$$= -PS_1(\bar{P}) + (1 - P)(x_1^*(\bar{P}) - s_1^*(\bar{P})).$$

Here we used the first order condition given by equation (2.3). Using other first order conditions given by equation (2.1) and (2.2), the above equation is transformed as follows,

$$= -P[c_1^*(x) - c_1^*(x)] \frac{dx_2}{dP} + (1 - P)[1 - c_1^*(x)] \frac{dx_2}{dP}.$$

Substituting equation (2.4),

$$= P[c_1^*(x) - c_1^*(x)] \frac{dx_2}{dP} + (1 - P) \left[ 1 - 1 - \frac{\bar{P}}{1 - \bar{P}} \left[ c_1^*(x) - c_2^*(x) \right] \right] \frac{dx_2}{dP}$$

$$= \left[ P - \frac{\bar{P}}{1 - \bar{P}} (1 - P) \right] \left[ c_1^*(x) - c_2^*(x) \right] \frac{dx_2}{dP} > 0, \quad \text{for} \quad P > \bar{P}.$$

The first term is positive for any value of $P > \bar{P}$. The second term is negative because the marginal disutility is higher for the unskilled labor for any given value of $x$. The third term is negative and is derived by taking total derivative of the equation (2.4) as follows,
\[
\begin{align*}
&\quad c_2^\ast(x_2) \frac{dx_2}{dP} = \left[ \frac{1}{1-P} + \frac{\bar{P}}{(1-P)^2} \right] [c_1^\ast(x_2) - c_2^\ast(x_2)] + \frac{\bar{P}}{1-P} [c_1^\ast(x_2) - c_2^\ast(x_2)] \frac{dx_2}{dP} \\
&\quad \frac{dx_2}{dP} = \left[ c_2^\ast(x_2) - \bar{P}c_1^\ast(x_2) \right] \left[ \frac{1}{1-P} \right] [c_1^\ast(x_2) - c_2^\ast(x_2)] < 0.
\end{align*}
\]
APPENDIX C

COMPETITIVE AND NOT COMPETITIVE MNC

Here we introduce two types of MNC (competitive and not competitive firm), and investigate whether the local government invests in education to attract a competitive MNC.

C.1 Visible Efficiency in Setup Cost

Suppose that the competitiveness of the MNC is measured only by the fixed setup cost of the foreign operation. Also, suppose that the local government knows the type of the MNC (high cost or low cost) or can infer this from the brand name, reputation, nationality, stock price and so on.

The information rent, which eventually becomes the revenue of the local government, is unaffected by the setup cost. So, the government is indifferent between hosting either a high or low cost firm. The chosen level of education, tax revenue are the same regardless of type, although the tax rate does depend on whether the MNC is high or low-cost.

C.2 Visible Efficiency in Setup Cost and Production

Continuing to assume that the type of the firm is visible, competitiveness is measured by both productivity as well as setup cost. Suppose that the non-competitive firm produces \( \phi (\phi<1) \) times as much output as the competitive firm can from local inputs. The both types of MNCs use the same strategy set in their principal agent contract with local labor.
But, the surplus from the contract with each labor type is $\phi$ times lower than for the non-competitive firm, which leads to $\phi$ times lower information rent. Accordingly, the local government always chooses to host the competitive firm, and the chosen level of education is at least as high as that chosen when hosting a non-competitive firm.

**C.3 Invisible Type**

We now assume that the type of the firm is invisible, and the non-competitive firm’s productivity is $\phi$ ($\phi<1$) times lower and its setup cost is $\eta$ ($\eta>1$) times higher than the competitive firm. The local government offers the single level of education ($P$) simply because multiple levels of $P$ cannot coexist. For the given level of $P$, all the MNCs must choose the lower tax rate. Hence, the standard hidden type program collapses, and the best it can do is to use the tax rate and education level to screen out the non-competitive firm.

The sufficient condition for the successful screen-out is that the local government can make the profit of non-competitive firm negative (equation (C.1)), but still satisfy the incentive compatibility of the competitive firm (equation (C.2)), and its own budget for education (equation (C.3)) as follows,

\[
(1-t)[\phi P(x_1(P) - s_1(P)) + \phi(1-P)(x_2(P) - s_2(P)) - \eta F] \leq 0, \quad (C.1)
\]

\[
(1-t)[P(x_1(P) - s_1(P)) + (1-P)(x_2(P) - s_2(P)) - F] \geq P(x_1(\overline{P}) - s_1(\overline{P})) + (1-P)(x_2(\overline{P}) - s_2(\overline{P})) - F, \quad (C.2)
\]

\[
l[P(x_1(P) - s_1(P)) + (1-P)(x_2(P) - s_2(P)) - F] \geq \int_{P_\phi}^P C(P) dP. \quad (C.3)
\]

These are arranged to
\[
\left[1 - (1-t)\phi\right]\left[P(x_1(P) - s_1(P)) + (1 - P)(x_2(P) - s_2(P))\right] \\
\geq P(x_1(\bar{P}) - s_1(\bar{P})) + (1 - P)(x_2(\bar{P}) - s_2(\bar{P})) + (P - P_0)C - (1-t)\eta F.
\]

This tends to happen as the non-competitive firm’s relative productivity (\(\phi\)) gets lower, its relative setup cost (\(\eta\)) gets higher. These two make the distinction between the two kinds of firms easier. Also, lower marginal costs (\(C\)), higher current levels of education (\(P_0\)), and higher setup cost (\(F\)) tend to satisfy the conditions. The first two make EDI more profitable, and the third enlarges the difference in profitability between two types of MNC. Besides, the left hand side of the above equation is an increasing and convex function and the right hand side is linear function of \(P\), so a higher \(P\) tends to satisfy the conditions. Then, the local government invests in education to invite in (screen out) the competitive (non-competitive) firm. On the other hand, a higher tax rate helps screen out the non-competitive firm (equation (C.1)) and helps satisfy the education budget (equation (C.3)), but makes the incentive compatibility harder (equation (C.2)). The local government sets the tax rate that would guarantee the reservation profit for the competitive firm, so that the incentive compatibility for the entering MNE remains binding.

**C.4 Welfare Cost from Hidden Type of MNCs**

A welfare cost from hidden type of MNC is possible in the following case. The local government may have positive EDI just to screen out non-competitive firms even if its current level of education is lower than the *take-off point*. In that case, it incurs a welfare cost from EDI since the current level of education is the optimum and there is no incentive for additional education.
This tends to happen as the non-competitive firm’s relative productivity ($\phi$) gets higher, its relative setup cost is ($\eta$) lower, and marginal cost and expected level of education gets higher. The first two make the difference in profitability between the two types of firms smaller, and the latter two higher the \textit{take-off point}. Then, it is more likely to have EDI before the \textit{take-off point} just to screen out non-competitive type.
APPENDIX D

PROPERTY OF TAX RATE

Here we show the property of tax rate in case of $P_0 < P_i$. From equation (2.12), tax rate
is given by,

$$t = 1 - \frac{\Pi(P, \bar{P}, F)}{\Pi^*(P, F)} = 1 - \frac{\Pi(P_0, \bar{P}, F)}{\Pi^*(P_0, F)}$$

Given $P_0 < P_i$.

At $P_0=0$,

$$t = 1 - \frac{\Pi(0, \bar{P}, F)}{\Pi^*(0, F)} > 0.$$

This is because optimal profit is always higher than reservation profit except for the case
in which $P_0 = \bar{P}$. So, tax rate is positive at $P_0=0$.

Next, at $P_0 = \bar{P}$,

$$t = 1 - \frac{\Pi(\bar{P}, \bar{P}, F)}{\Pi^*(\bar{P}, F)} = 1 - \frac{\Pi^*(\bar{P}, F)}{\Pi^*(\bar{P}, F)} = 1 - 1 = 0.$$

Then we can conclude that tax rate is zero at $P_0 = \bar{P}$. Change in the tax rate at $P_0=0$ is
given by,

$$\left. \frac{dt}{dP_0} \right|_{P_0=0} = -\frac{\frac{\partial \Pi(0, \bar{P}, F)}{\partial P_0}}{\Pi^*(0, F)} - \frac{\partial \Pi^*(0, F)}{\partial P_0} \frac{\Pi(0, \bar{P}, F)}{[\Pi^*(0, F)]^2}.$$

Using equation (2.5),

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\[
\frac{dt}{dP_0} \bigg|_{P_0 = 0} = \frac{\partial \Pi^*(0, F)}{\partial P_0} \Pi(0, \bar{P}, F) - b \Pi^*(0, F) \frac{\Pi^*(0, F)}{[\Pi^*(0, F)]^2}.
\]

We know \( \Pi(0, \bar{P}, F) < \Pi^*(0, F) \) from property of optimal profit and \( \frac{\partial \Pi^*(0, F)}{\partial P_0} < b \) because of the convexity of \( \Pi^*(P, F) \) and \( \frac{\partial \Pi^*(P, F)}{\partial P} \bigg|_{P = \bar{P}} = b \). Then we can conclude,

\[
\frac{dt}{dP_0} \bigg|_{P_0 = 0} = \frac{\partial \Pi^*(0, F)}{\partial P_0} \Pi(0, \bar{P}, F) - b \Pi^*(0, F) \frac{\Pi^*(0, F)}{[\Pi^*(0, F)]^2} < 0.
\]

With the similar argument \( \frac{dt}{dP_0} \bigg|_{P_0 = \bar{P}} > 0 \) can be derived. Then we can draw the tax ratio as the function of \( P_0 \) in Figure 2.7 and Figure 2.8.
APPENDIX E

CONDITION FOR MATCHING EFFECT

We derive the range of $F$ and $\overline{P}$ for the matching effect to be realized, which is shown in Figure 2.9. Firstly, note that $a(\overline{P}) + b(\overline{P})\overline{P}$ is non-decreasing and convex in $\overline{P}$, and is smaller than or equal to $a(\overline{P}) + b(\overline{P})$. The allowable range of $F$ gets greater, as the difference between these $\{a(\overline{P}) + b(\overline{P})\} - \{a(\overline{P}) + b(\overline{P})\overline{P}\} = b(\overline{P}) - b(\overline{P})\overline{P}$ gets greater.

If we evaluate $b(\overline{P}) - \overline{P}b(\overline{P})$ at $\overline{P} = 0$, $b(0) = 0$. In order to evaluate

$$\frac{d}{d\overline{P}} [b(\overline{P}) - \overline{P}b(\overline{P})] \text{at } \overline{P} = 0,$$

we have to know the sign of $b'(0) - b(0) = b'(0)$.

By the definition $b(\overline{P}) = x_1(\overline{P}) - s_1(\overline{P}) - \left(x_2(\overline{P}) - s_2(\overline{P}) \right)$. Using the first order conditions, $b(\overline{P}) = x_1(\overline{P}) - x_2(\overline{P}) - c_1(x_1(\overline{P})) + c_1(x_2(\overline{P}))$. 

\[
\therefore b'(\overline{P}) = \left(1 - c'_1(x_1)\right)\frac{dx_1}{d\overline{P}} - \left(1 - c'_1(x_2)\right)\frac{dx_2}{d\overline{P}} = -\left(1 - c'_1(x_2)\right)\frac{dx_2}{d\overline{P}}.
\]

$1 - c'_1(x_2)$ is positive from equation (2.3), and $\frac{dx_2}{d\overline{P}}$ is negative from Appendix B. Hence, $b'(\overline{P})$ is positive, and $b(\overline{P}) - \overline{P}b(\overline{P})$ is increasing in $\overline{P}$ at $\overline{P} = 0$.

If we evaluate $b(\overline{P}) - \overline{P}b(\overline{P})$ at $0 < \overline{P} < 1$, $b(\overline{P})[1 - \overline{P}] > 0$. If we evaluate

$$b(\overline{P}) - \overline{P}b(\overline{P}) \text{ at } \overline{P} = 1, \ b(1) - b(1) = 0.$$

If we evaluate $\frac{d}{d\overline{P}} [b(\overline{P}) - \overline{P}b(\overline{P})] \text{ at } \overline{P} \approx 1,

$$b'(\overline{P}) - b'(\overline{P}) - b(\overline{P}) = -b(\overline{P}) < 0.$$
In summary \( h(P) - Pb(P) \) is zero at \( P = 0 \) and \( P = 1 \), and is positive everywhere \( 0 < P < 1 \), but increasing in \( P \) near \( P = 0 \) and decreasing in \( P \) near \( P = 1 \).
APPENDIX F

LOCAL LABOR WELFARE

We derive the change in welfare of local labor with value of $P$. That is given by,

$$
\frac{d}{dP} \left[ P(s_1 - c_1(x_1)) + (1 - P)(s_2 - c_2(x_2)) \right] = s_1 - c_1(x_1) + P \left[ \frac{ds_1}{dP} - \frac{\partial c_1(x_1)}{\partial x_1} \frac{dx_1}{dP} \right] - (s_2 - c_2(x_2)) + (1 - P) \left[ \frac{ds_2}{dP} - \frac{\partial c_2(x_2)}{\partial x_2} \frac{dx_2}{dP} \right].
$$

From equation (2.3) $\frac{dx_1}{dP} = 0$. Then the above equation becomes,

$$
= s_1 - c_1(x_1) - (s_2 - c_2(x_2)) + P \left[ \frac{ds_1}{dP} \right] + (1 - P) \left[ \frac{ds_2}{dP} - \frac{\partial c_2(x_2)}{\partial x_2} \frac{dx_2}{dP} \right].
$$

Substituting equation (2.1) and (2.2),

$$
= \left[ c_1(x_1) + c_2(x_2) - c_1(x_1) - c_1(x_1) - (c_2(x_2) - c_2(x_2)) \right] + P \frac{d}{dP} \left[ c_1(x_1) + c_2(x_2) - c_1(x_1) - c_1(x_1) \right] + (1 - P) \left[ c_2(x_2) \frac{dx_2}{dP} - c_2(x_2) \frac{dx_2}{dP} \right]
$$

$$
= \left[ c_2(x_2) - c_1(x_2) \right] + P \frac{d}{dP} \left[ c_2(x_2) - c_1(x_2) \right] + \frac{dx_2}{dP} \left[ c_2(x_2) - c_1(x_2) \right].
$$

Finally substituting the result of $\frac{dx_2}{dP}$ from Appendix B, we have equation (2.12),

$$
\frac{d}{dP} \left[ P(s_1 - c_1(x_1)) + (1 - P)(s_2 - c_2(x_2)) \right] = [c_2(x_2) - c_1(x_2)] - \frac{P}{1 - P} \left[ \frac{c_2(x_2) - c_1(x_2)}{c_2(x_2) - Pc_1(x_2)} \right].
$$
When \( P=0 \) the above equation is positive because \( c_2'(x_2) > c_1'(x_2) \). When \( P \approx 1 \) the above equation is negative because \( \frac{[c_2'(x_2) - c_1'(x_2)]^2}{c_2(x_2) - Pc_i(x_2)} > 0 \). Both disutility functions are continuous and twice differentiable, so the above equation is continuous. Then, the above equation must be zero at least one point between 0 and 1. The maximum point of surplus is given as one of these.

It can be also derived that the marginal effect of education on the welfare of local labor is decreasing at \( P=0 \) and increasing at \( P \approx 1 \). This is derived by taking the derivative of equation (2.12),

\[
\frac{d^2}{dP^2} \left[ P(s_1 - c_1(x_1)) + (1 - P)(s_2 - c_2(x_2)) \right] \\
= \left[ c_2'(x_2) - c_1'(x_2) \right] \frac{dx_2}{dP} - \left[ \frac{1}{1 - P} + \frac{P}{(1 - P)^2} \right] \frac{[c_2'(x_2) - c_1'(x_2)]^2}{c_2(x_2) - Pc_1'(x_2)} \\
+ \frac{P}{1 - P} \left[ \frac{2[c_2'(x_2) - c_1'(x_2)] [c_2^''(x_2) - c_1^''(x_2)]}{Pc_1''(x_2) - c_2'(x_2)} \right] \frac{dx_2}{dP}.
\]

Substituting \( \frac{dx_2}{dP} \) from Appendix B and arranging,

\[
= - \frac{[c_2'(x_2) - c_1'(x_2)]^2}{(1 - P)^2 [c_2'(x_2) - Pc_1'(x_2)]^3} \\
\left\{ (2 - P)[c_2''(x_2) - Pc_1''(x_2)]^2 - P[c_2''(x_2) - c_1''(x_2)] [c_2''(x_2) + Pc_1''(x_2) - c_2''(x_2)] \right\} \\
- 2P[c_2''(x_2) - Pc_1''(x_2)] [c_2''(x_2) - c_1''(x_2)].
\]

It is clear that the above equation is negative at \( P=0 \) without any additional condition. It is positive at \( P \approx 1 \) if the third derivative is small so that \( c_1''(x_2) + c_1''(x_2) > c_2''(x_2) \).

Actually, this sufficient condition is not so restrictive.
Then we can say marginal labor surplus has negative slope at $P=0$, and positive slope at $P \approx 1$. Again, both disutility functions are continuous and twice differentiable, so the above equation is continuous. Then, the above equation (the slope of marginal surplus) must be zero at least one point between 0 and 1. The minimum point of marginal surplus is given as one of these.

The following figures show labor surplus and marginal labor surplus for quadratic and cubic disutility function respectively ($c_1(x) = \frac{x^2}{2}, c_2(x) = \frac{a \cdot x^2}{2}$ and $c_1(x) = \frac{x^3}{3}, c_2(x) = \frac{a \cdot x^3}{3}$, where $a$ is the indicator of relative disutility for unskilled labor, and $a=3$ is used for figures below).
Figure F.1: Labor surplus for quadratic and cubic disutility function.
Figure F.2: Marginal labor surplus for quadratic and cubic disutility function.
APPENDIX G

PROOF OF LEMMA 3.3

Proof of Lemma 3.3 is presented. Suppose equation (3.6) is true for type $j_u$ person,

$$(e^{-r_{j_u}} - e^{-r_T})A(T_{j_u}, I_{j_u}) = (e^{-r_{j_u}} - e^{-r_T})A(\tau_{j_u}, I_{j_u})w,$$

where $w$ is the relative wage rate for unskilled labor ($w_L / w_H$). Differentiating both sides by $w$, we have,

$$\left(e^{-r_{j_u}} - e^{-r_T}\right)\frac{\partial A(T_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{dI_{j_u}}{dw}$$

$$= \left(e^{-r_{j_u}} - e^{-r_T}\right)\left[\frac{A(\tau_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{dI_{j_u}}{dw} w + A(\tau_{j_u}, I_{j_u})\right]$$

$$+ \left(-re^{-r_{j_u}} A(\tau_{j_u}, I_{j_u}) + (e^{-r_{j_u}} - e^{-r_T})\frac{\partial A(\tau_{j_u}, I_{j_u})}{\partial \tau_{j_u}}\right) \frac{d\tau_{j_u}}{d\tau_{j_u}} \frac{dI_{j_u}}{dI_{j_u}}.$$

Using equation (3.4),

$$\left(e^{-r_{j_u}} - e^{-r_T}\right)\frac{\partial A(T_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{dI_{j_u}}{dw} = \left(e^{-r_{j_u}} - e^{-r_T}\right)\left[\frac{A(\tau_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{dI_{j_u}}{dw} w + A(\tau_{j_u}, I_{j_u})\right].$$

Using \(e^{-r_{j_u}} - e^{-r_T})A(T_{j_u}, I_{j_u}) = (e^{-r_{j_u}} - e^{-r_T})A(\tau_{j_u}, I_{j_u})w,$

$$\left[\frac{\partial A(T_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{1}{A(T_{j_u}, I_{j_u})} - \frac{\partial A(\tau_{j_u}, I_{j_u})}{\partial I_{j_u}} \frac{1}{A(\tau_{j_u}, I_{j_u})}\right] \frac{dI_{j_u}}{dw} = \frac{1}{w}$$

(G.1)

Assuming equation (3.5) is satisfied with strict inequality,
\[
\frac{\partial A(T, I_j)}{\partial I_j} \frac{1}{A(T, I_j)} \geq \frac{\partial A(T, I_j)}{\partial T} \frac{\partial A(T, I_j)}{\partial I_j} \frac{1}{A(T, I_j)^2}.
\]

This means \( \frac{\partial A(T, I_j)}{\partial I_j} \frac{1}{A(T, I_j)} \) is increasing in T, and is the sufficient condition for the expression in the square bracket in (A1) is positive, because \( T_u > \tau_{j_u} \).

Then we can conclude \( \frac{dI_{j_u}}{dw} > 0 \), which means \( \frac{d_j}{dw} > 0 \).
APPENDIX H

PROOF OF LEMMA 3.4

Proof of Lemma 3.4 is presented. Suppose both $\Delta H$ and $\Delta L$ are negative. Then, both the first and the second term of equation (3.12) become positive so that $\Delta L$ is positive. This is a contradiction. So, at least one of $\Delta H$ and $\Delta L$ must be positive. Also, equation (3.13) is positive because $T > T_v > \tau_j$.

Change in the global relative endowment of unskilled labor is given by the following equation,

$$\frac{L + L^H + \Delta L}{H + H^H + \Delta H} - \frac{L + L^H}{H + H^H} = \frac{L}{H} \left[ \frac{1 + L^H / L + \Delta L / L}{1 + H^H / H + \Delta H / H} - \frac{1 + L^H / L}{1 + H^H / H} \right].$$

i) When $\Delta H < 0, \Delta L > 0$, above equation is positive.

ii) When $\Delta H > 0, \Delta L > 0$, above equation is positive because $\Delta L / L - \Delta H / H > 0$.

Hence, the global relative endowment of unskilled labor increases when the relative wage of it increases.
APPENDIX I

PROOF OF LEMMA 3.6

Proof of Lemma 3.6 is presented. I firstly prove the utility function criterion, and then prove Samuelson criterion.

When all the consumers have an identical and homothetic preference, we can define the social utility function \( u(C^X, C^Y) \) where \( C^X, C^Y \) are the total consumption of each good in the developed country and \( u \) has the same functional form as the individual utility function (Wong 1995).

From the property of expenditure function,
\[
p^\alpha_X C^\alpha_X + C^\alpha_Y = e(p^\alpha_X, u^\alpha)
\]
\[
p^\beta_X C^\beta_X + C^\beta_Y \geq e(p^\beta_X, u^\beta)
\]

Using these conditions and equation (3.14),
\[
u(C^\alpha_X, C^\alpha_Y) > u(C^\beta_X, C^\beta_Y)
\]

Now let us move on to the proof of Samuelson criterion. Because of identical and homothetic preference, lump-sum transfer in each situation does not change the total consumption in the country. Because there is an increase in the social utility level in situation \( \alpha \) shown above, the total consumption in situation \( \alpha \) can be distributed to make everyone better off than in \( \beta \). For example, the following distribution \( \tilde{C}^\alpha_{X,j}, \tilde{C}^\alpha_{Y,j} \) for person \( j \) after lump-sum transfer can make everyone better off than any \( (C^\beta_{X,j}, C^\beta_{Y,j}) \).
\[ u(\tilde{C}_{X,j}^{\alpha#}, \tilde{C}_{Y,j}^{\alpha#}) = u(C_{X,j}^{\beta#}, C_{Y,j}^{\beta#}) + \frac{u(C_{X}^{\alpha#}, C_{Y}^{\alpha#}) - u(C_{X}^{\beta#}, C_{Y}^{\beta#})}{H^{#} + L^{#}} \]

This means that for any lump-sum transfer in situation \( \alpha \), lump-sum transfer in situation \( \beta \) can make everyone better off. This is Samuelson criterion.
APPENDIX J

PROPERTIES OF FUNCTION J

Firstly we prove that $J$ is decreasing function of $\sigma$ for any given value of $s$ ($\frac{\partial J}{\partial \sigma} < 0$).

Suppose the situation in which the country becomes more unskilled labor abundant ($\sigma$ increases), but both relative level of outputs ($X/Y$) and relative size of the country ($s$) are fixed. This situation is shown can be explained by using the figure in the next page. The original production point was $E$ in which $H_X$ and $L_X$ were devoted to production of $X$, and $(H-H_X)$ and $(L-L_X)$ were devoted to production of $Y$. 
Figure J.1: The effects of increase in unskilled labor endowment.

The increase in unskilled labor endowment shifts up the contract curve, because both goods have Cobb-Douglas type technology. Also, this technology means that both goods have unit elasticity of substitution, so that the rate of change in factor ratio is the same for each production no matter what change wage rate has.

\[
\left( \frac{L_x}{H_x} \right) = \hat{L}_x - \hat{H}_x = \hat{L}_y - \hat{H}_y = \varphi > 0. \tag{J.1}
\]

Then, the rate of change in production for each good is given by,

\[
\hat{Y} = 0.5\hat{L}_y + 0.5\hat{H}_y,
\]

\[
\hat{X} = (1 - \lambda)(0.5 - \theta)\hat{L}_x + (0.5 + \theta)\hat{H}_x \}
\]

On the straight expansion path \( \hat{Y} = \hat{X} \). Then,

\[
0.5\hat{L}_y + 0.5\hat{H}_y = (1 - \lambda)^{-1}\{0.5 - \theta)\hat{L}_x + (0.5 + \theta)\hat{H}_x \}.
\]
Substituting (A2),
\[ \varphi \left[ 0.5 - (0.5 - \theta)(1 - \lambda)^{-1} \right] + \hat{H}_Y = (1 - \lambda)^{-1} \hat{H}_X. \]
\[ \therefore \hat{H}_Y < (1 - \lambda)^{-1} \hat{H}_X. \]

The final two inequalities used \( 0 < \theta < 0.5, 0 < \lambda < 1, \) and \( \lambda < 2\theta. \)

But, it is impossible for \( \hat{H}_Y \) to have the same sign as \( \hat{H}_X \), because the total amount of H is fixed in the country. Then \( \hat{H}_X > 0, \hat{H}_Y < 0. \) This means the actual E’ on the new contract curve has to be in the north east of E’ in Figure J.1 to retain relative level of outputs \((X/Y)\) fixed.

Comparing E and the actual E’, we have \( dl_X > 0, dH_X > 0, \hat{w} < 0. \) Using these conditions and \( l_X < l \) from factor intensity, we have,

\[ dJ = \frac{-HH_x \left[ (1 + w l_x)\hat{w} + (1 + w) (\hat{w} + wl_x) \right] - (1 + w l)(1 + w l_x)HdH_x}{(1 + w l_x)^2 H_x^2} < 0. \]
\[ \therefore \frac{\partial J}{\partial \sigma} < 0. \]

In the same way, \( \frac{\partial J}{\partial S} > 0 \) can be proved. But, it does not need a condition \( \lambda < 2\theta. \)
APPENDIX K

PROOF OF PROPOSITION 3.5

Proof of Proposition 3.5 is presented. $X^{\alpha} < X^{\beta}$ means $c_X(\omega^{\beta}, X^{\beta}) < c_X(\omega^{\beta}, X^{\alpha})$ because of Cobb-Douglas type technology with increasing returns to scale. Where $c_i$ is the cost function for good $i$, and $\omega^\beta$ is factor price vector in situation $\beta$. Multiplying both sides by $C_X^{\alpha}$ and adding $c_Y(\omega^{\beta})C_Y^{\alpha}$. Note that the cost function of good Y does not depend on the total production.

$$c_X(\omega^{\beta}, X^{\beta})C_X^{\alpha} + c_Y(\omega^{\beta})C_Y^{\alpha} < c_X(\omega^{\beta}, X^{\alpha})C_X^{\alpha} + c_Y(\omega^{\beta})C_Y^{\alpha}.$$ 

Because there is no increasing returns to scale for an individual producer,

$$p_X^{\beta}C_X^{\alpha} + C_Y^{\alpha} < c_X(\omega^{\beta}, X^{\alpha})C_X^{\alpha} + c_Y(\omega^{\beta})C_Y^{\alpha}.$$ (K.1)

We also have the following result,

$$c_X(\omega^{\beta}, X^{\alpha})C_X^{\alpha} + c_Y(\omega^{\beta})C_Y^{\alpha} \leq \omega^\beta a_X(\omega^\alpha, X^{\alpha})C_X^{\alpha} + \omega^\beta a_Y(\omega^\alpha)C_Y^{\alpha}$$

$$= \omega^\beta \left( H_c^{\alpha} + \frac{L_c^{\alpha}}{L^\alpha + L} \right) = \phi^\alpha \omega^\beta \left( \frac{H^\alpha + H}{L^\alpha + L} \right) \leq \phi^\beta \omega^\beta \left( \frac{H^\alpha + H}{L^\alpha + L} \right) = p_X^\beta X^{\beta\alpha} + Y^{\beta\alpha}$$

$$= p_X^\beta C_X^{\beta\alpha} + C_Y^{\beta\alpha}.$$ (K.2)

where $H_c^{\alpha}$ and $L_c^{\alpha}$ are total amount of skilled and unskilled labor needed to produce the consumption bundle of the developing country in situation $\alpha$. $\phi^{\alpha\beta}$ is GDP share of the
developed country in the global economy in situation $\alpha$, and $\phi^\beta$ is that in situation $\beta$.

The former cannot be larger because there was child labor in the developing country in situation $\alpha$ in addition to the relative scale difference (Note that there is only scale difference in situation $\beta$). The first inequality is from cost minimization, the second equality is from identical homothetic preference for both countries, the third equality is from non satiation, and the final equality is from balance of trade in situation $\beta$. From (K.1) and (K.2),

$$p^\beta_X C^\alpha_X + C^\alpha_Y < p^\beta_X C^\beta_X + C^\beta_Y$$

This means that the consumption bundle chosen in situation $\alpha$ is feasible in situation $\beta$. Under the assumption of identical and homothetic preference, this is the sufficient condition for the positive gain for the developed country.
APPENDIX L

DERIVATION OF EQUILIBRIUM GROWTH RATE

Here we derive the steady state equilibrium growth rate \( g \). Index of productivity of intermediate inputs can be transformed as,

\[
X_t = n_t^{\alpha - 1} (n_t x_t) = \text{(average productivity)} \cdot \text{(total amount of inputs)}.
\]  

(L.1)

Define hypothetical price \( P_{xt} \) for index of productivity of intermediate inputs such that,

\[
P_{xt} X_t = p_t n_t x_t.
\]  

(L.2)

From Cobb Douglass technology and normalized price for agricultural product,

\[
1 = w_{\omega}^{1-\beta} P_w^\beta.
\]

Then \( P_{xt} \) is,

\[
P_{xt} = w_{\omega}^{(\beta-1)/\beta} = (AX_t^\beta (1 - \beta)L^{-\beta})^{(\beta-1)/\beta} = K X_t^{\beta-1}.
\]  

(L.3)

where \( K = (A(1 - \beta)L^{-\beta})^{(\beta-1)/\beta} = \text{constant} \).

From (L.1), (L.2) and (L.3), price of each intermediate is,

\[
p_t = n_t^{\alpha - 1} P_{xt} = n_t^{\alpha - 1} K X_t^{\beta-1} = Kn_t^{\alpha - 1} \left( \frac{1}{n_t^{\alpha}} x_t \right)^{\beta-1} = K (n_t x_t)^{\beta-1} n_t^{(\beta-1)\beta}.
\]  

(L.4)

Substituting equation (4.14) and expectation of (4.7) to (4.8),

\[
(1 - \alpha) \frac{P_{xt} X_t}{n_t V_t} + \frac{\dot{V}_t}{V_t} = \rho + \eta g - \frac{(1 - \eta)^2}{2} \sigma^2 + \lambda.
\]

Defining \( V_t = 1 / n_t V_t \), and using (L.3),

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\[(1-\alpha)KX_{t}^{\beta}V_{t}-(\hat{V}_{t}+\hat{n}_{t}) = \rho + \eta g_{t} - \frac{(1-\eta)^{2}}{2}\sigma^{2} + \lambda.\]

Using the relation of \(g_{t}\) and \(n_{t}\), \(g_{t} = (\frac{1}{\alpha} - 1)\beta\hat{n}_{t},\)

\[(1-\alpha)KX_{t}^{\beta}V_{t}-(\hat{V}_{t}+\hat{n}_{t}) = \rho + \eta(\frac{1}{\alpha} - 1)\beta\hat{n}_{t} - \frac{(1-\eta)^{2}}{2}\sigma^{2} + \lambda.\]  \(\text{(L.5)}\)

Using equation (4.10) and \(p_{t} = \frac{w}{m}/\alpha,\)

\[V_{t} = \frac{am}{\alpha p_{t}}.\]  \(\text{(L.6)}\)

Form this and (L.4) we have \(\hat{V}_{t} = -\hat{p}_{t} = -(\frac{1}{\alpha} - 1)\beta\hat{n}_{t}.\) Substituting this into (L.5),

\[(1-\alpha)KX_{t}^{\beta}V_{t} = \beta(\frac{1}{\alpha} - 1)(\eta - 1) \hat{n}_{t} = \rho + \lambda - \frac{(1-\eta)^{2}}{2}\sigma^{2}.\]

From (L.4) and (L.6), \(V_{t} = \frac{am}{\alpha} n_{t}^{-\frac{1}{\alpha}} K^{-\beta} X_{t}^{1-\beta}.\) Substituting this into the above,

\[\frac{(1-\alpha)am}{\alpha} n_{t}^{-\frac{1}{\alpha}} X_{t}^{-\beta} = \beta(\frac{1}{\alpha} - 1)(\eta - 1) + 1 \hat{n}_{t} = \rho + \lambda - \frac{(1-\eta)^{2}}{2}\sigma^{2}.\]  \(\text{(L.7)}\)

Substituting resource constraint for skilled labor (equation (4.15)) into this, we have the following time invariant invention rate,

\[\hat{n} = \left[\left(\frac{1}{\alpha} - 1\right)\beta(\eta - 1) + 1\right]^{-1}\left(\frac{1}{\alpha} - 1\right)amH - (\rho + \lambda) + \frac{(\eta - 1)^{2}}{2}\sigma^{2}\right].\]

This can be converted to expected growth rate which is also drift term of logarithm of GNP,

\[g = \beta \left(\beta(\eta - 1) + \frac{1}{1-\alpha}\right)^{-1}\left(\frac{1}{\alpha} - 1\right)amH - (\rho + \lambda) + \frac{(\eta - 1)^{2}}{2}\sigma^{2}\right].\]  \(\text{(L.8)}\)
APPENDIX M

INFORMATION FLOW AND COMPETITION EFFECT

Here we show information flow and competition effect of economic integration on growth rate. The steady state equilibrium growth rate with these effects is same as equation (4.21). However, if we assume that these effects do not exist in autarky, the autarky equilibrium growth rate will become lower than equation (4.21).

Firstly, we derive the autarky equilibrium growth rate without any of these effects ($g_0$).

Then, we will derive the autarky equilibrium growth rate ($g_1$) in the hypothetical situation in which only information flow effect exist.

Firstly, suppose each country is in autarky in which spillover to general scientific knowledge comes only from domestic R&D activity. Invention velocity function, which was given by equation (4.9), now becomes,

$$\frac{dn_t}{dt} = an_tH_{it}.$$

(4.9')

Then equation (4.10) and (L.6) also change to the following equations,

$$an_tv_t = w_{it}.$$

(4.10')

$$V_t = \frac{a}{\alpha p_t}.$$

(L.6')

Substituting this into equation (L.5) and solving for growth rate,

$$g_0 = \beta \left[ \beta (\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \left[ \frac{1}{\alpha - 1} aH - (\rho + \lambda) + \frac{(\eta - 1)^2}{2} - \sigma^2 \right].$$

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This is autarky steady state equilibrium growth rate without information flow or competition.

Next, suppose each country is still in autarky, but information flows across borders. Spillover to general scientific knowledge also comes from R&D activity in other countries, but there are some varieties of intermediates which are overlapped. For simplicity we suppose that, of all intermediates produced in the region only \((1 - \delta)mn_i\) is the genuine variety, where \(\delta\) is rate of overlapping.

Invention velocity function, which was given by equation (4.9), now becomes,

\[
\frac{dn_t}{dt} = am(1 - \delta)n_tH_{nt}.
\] (4.9’’)

Following the same step above, we have growth rate as,

\[
g_1 = \beta \left[ \beta(\eta - 1) + \frac{1}{1 - \alpha} \right]^{-1} \left[ \left( \frac{1}{\alpha} - 1 \right) am(1 - \delta) H - (\rho + \lambda) + \frac{(\eta - 1)^2}{2} \right].
\]

Note \(g_0 < g_1 < g\). \(g_1 - g_0\) is information flow effect, and \(g - g_1\) is competition effect of economic integration.
APPENDIX N

CYCLICAL SHOCK LEADING TO STATIONARY PROCESS

Here we derive the stochastic process of cyclical shock which leads to stationary process of logarithm of GNP.

Suppose logarithm of GNP follows the AR(1) trend reverting stationary process,

\[ \ln D_{t+1} = \phi \ln D_t + \xi + \kappa t + \epsilon_{t+1}, \text{ where } \epsilon_{t+1} \sim N(0, \sigma). \]  \hspace{1cm} (N.1)

Note that long run trend is given by \( \frac{\kappa}{1-\phi} \). Suppose cyclical shock has the following stochastic process,

\[ \ln \theta_{t+1} = h(\ln \theta_t) + \epsilon_{t+1}, \]

where \( h \) is some function of shock in previous period. Then,

\[ \frac{\theta_{t+1}}{\theta_t} = \exp \left\{ h(\ln \theta_t) - \ln \theta_t + \epsilon_{t+1} \right\}, \]

\[ E_t \left( \frac{\theta_{t+1}}{\theta_t} \right)^{1-\eta} = \exp \left\{ h(\ln \theta_t) - \ln \theta_t \right\} (1-\eta) \cdot \exp \left( \frac{(1-\eta)^2 \sigma^2}{2} \right). \]  \hspace{1cm} (N.2)

In order to have steady state equilibrium with a fixed resource allocation, error term of interest rate must be the same as that of GNP. Then the first order condition of consumer’s lifetime utility maximization must satisfy the following,

\[ \left( 1 + \frac{\kappa}{1-\phi} \right)^{-\eta} \frac{1+\bar{r}}{1+\rho} E_t \left( \frac{\theta_{t+1}}{\theta_t} \right)^{1-\eta} = 1. \]

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Substituting (N.2) into the above equation, taking log of both sides, we have the following specific form for $h$.

$$h(\ln \theta_i) = \ln \theta_i - \frac{\kappa \eta}{(1 - \phi) \eta - 1} + \frac{\bar{r} - \rho}{\eta - 1} + \frac{\eta - 1}{2} \sigma^2.$$
APPENDIX O

SUBSIDY TO ACHIEVE OPTIMAL GROWTH RATE

Here we derive subsidy to R&D to achieve optimal growth rate.

Replacing equation (4.10) by (4.10’), equation (L.7) becomes,

\[ \frac{(1-\alpha)am}{\alpha(1-s^*)} n_i x_i = \left[ \beta \left( \frac{1}{\alpha} - 1 \right) (\eta - 1) + 1 \right] \hat{n}_i = \rho + \lambda - \frac{(1-\eta)^2}{2} \sigma^2. \]

Converting invention rate to growth rate and substituting resource constraint (equation (4.12)),

\[ \frac{(1-\alpha)am}{\alpha(1-s^*)} \left[ H - \frac{\alpha}{\beta(1-\alpha)} g \right] = \left[ \beta \left( \frac{1-\alpha}{\alpha} \right) (\eta - 1) + 1 \right] \frac{\alpha}{\beta(1-\alpha)} g = \rho + \lambda - \frac{(1-\eta)^2}{2} \sigma^2. \]

To have optimal growth rate \( g^* \), we must substitute \( g = g^* \). Arranging,

\[ \frac{1-\alpha}{\alpha} amH = (1-s) \left[ (\eta - 1) + \frac{\alpha}{\beta(1-\alpha)} g^* + \left( \rho + \lambda - \frac{(1-\eta)^2}{2} \sigma^2 \right) \right] g^* / \beta. \quad (O.1) \]

From equation (4.18), \( \frac{1-\alpha}{\alpha} amH \) can be made function of market equilibrium growth rate as,

\[ \frac{1-\alpha}{\alpha} amH = \beta^{-1} \left[ \beta (\eta - 1) + \frac{1}{(1-\alpha)} \right] g + \rho + \lambda - \frac{(1-\eta)^2}{2} \sigma^2. \]

Then we substitute this into (O.1), and solve for subsidy \( (s^*) \). It is given by function of optimal growth rate \( (g^*) \) and equilibrium growth rate \( (g) \).
Using $k = \beta(\eta - 1) > 0$ and $l = \frac{\alpha}{1 - \alpha} > 0,$

\[
s^* = \frac{(k + l + 1)(g^* - g)}{(k + l)g^* + \left(\rho + \lambda - \frac{(\eta - 1)^2}{2}\sigma^2\right)}.
\]
APPENDIX P

PROPERTIES OF SUBSIDY

Here we derive some properties of subsidy \( s^* \). Substituting equation (4.21) into (O.2), \( s^* \) can be function of parameters as,

\[
s^* = \frac{amH - l\rho + (k + 1)\lambda + (l\eta + k + 1)(\eta - 1)\sigma^2}{\left(\frac{k}{l} + 1\right)amH + (1 - l)\rho + (k + 1)\lambda + [(l - 1)\eta + k + 1](\eta - 1)\sigma^2}.
\]

This is larger than one if the following condition is satisfied,

\[
\frac{(\eta - 1)\eta}{2}\sigma^2 > \frac{kamH}{l} + \rho.
\]

Also, it can be shown that \( s^* \) is increasing in \( \sigma^2 \) as

\[
\text{sign}\left[\frac{\partial s^*}{\partial \sigma^2}\right] = \text{sign}\left[\left[l\eta + k + 1\frac{k}{l} + \eta\right]amH + (k + 1)\rho + (k + 1)\lambda \eta \right] > 0.
\]

In the same way, \( s^* \) is increasing in \( \lambda \), given \( s^* < 1 \). This is by the following function.

\[
\text{sign}\left[\frac{\partial s^*}{\partial \lambda}\right] = \left[k + 1\right]\{amH - l\rho + (k + 1)\lambda + (l\eta + k + 1)(\eta - 1)\sigma^2\}.
\]

This is positive if \( s^* < 1 \).
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