Economic Openness and Labor Allocation between Skilled and Unskilled Sectors

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Abstract

This paper introduces an endogenous growth model which is based on Romer(1990) but modifies the original model by incorporating worker's skill heterogeneity. With the heterogeneity, the model has a labor allocation mechanism that divides all the workers between research and production sectors. Different with Romer(1990), this labor allocation is determined by both demand and supply conditions of skilled labor in the economy. This model can be extended to an open economy. The extended model explains how economic openness affects on the labor allocation through specialization and knowledge spillover channels.

JEL Classification: E24, F15, F41, F43, O30, O40

Keywords: Endogenous Growth, Heterogeneity, Labor Allocation, Wage Structure, Specialization, Knowledge Spillover, Economic Openness

Ⅰ. Introduction

This paper is aimed at analyzing the effect of economic openness on the employment structure(i.e. the ratio of employment between skilled and unskilled sectors). To this end, this paper modifies the endogenous growth model of Romer(1990) by incorporating workers skill heterogeneity. With the heterogeneity, the model explains the labor allocation mechanism between skilled(research) and unskilled(production) sector and show how this labor allocation is affected by economic openness. The reason why I use the endogenous growth framework for this purpose is that I think the feature of the endogenous growth frame in dealing with the process of technological change is helpful to understand current Korean economy which is experiencing drastic structural change.

In Romer(1990) model, the technological level of an economy is represented by the number of varieties of intermediate goods, which means if a economy has greater number of varieties, the economy can produce and consume more final good under given amount of labor. The economy employs workers for two types of jobs; researcher and final good producer. The researchers invent new designs of intermediate goods. The final good producers produce final good by inputting labor and intermediate goods.

As aforementioned, since Romer(1990) model is based on homogeneity of agents, although all the jobs are categorized by two types(research and final good production), the workers in the two different sectors are not differentiated. Thus, the model does not provide any intuition about the relationship between individual worker's characteristic and his working sector. In other words, it remains unexplained that who works in the research sector and who works in the production sector.

This paper makes a modification to Romer(1990) by incorporating workers skill heterogeneity to explain how employment structure of an economy is determined by the characteristics of individual workers. The employment structure is determined by labor allocation between research and production sectors, and the labor allocation is decided by skill supply and demand conditions of the economy based on the individual characteristics of the workers. That is, the model in this paper uses the Romer-type endogenous growth model as a basic frame but the agents are heterogenous(i.e. each worker has different level of skill) rather than homogenous and choose their working sectors(research and production) according to their heterogeneous skill levels. In the process, the choice of the workers is affected by the supply and demand conditions of skilled labor in the economy because wages in each sector are endogenously determined by these conditions. In this sense, employment structure of an economy is endogenously determined by supply and demand conditions of skilled labor. The heterogeneous model also has an interesting feature that the long-run growth rate of an economy is expressed as a function of such an employment structure.

Followings are some implications drawn from the modified endogenous growth model with workers skill heterogeneity.

First, the supply of skilled workers may increase or decrease in accordance with changes of college enrollment rates, and by combining with the demand condition of skilled workers, this change affects on the employment structure, hence the long-run growth rate of the economy.

Second, the model implies that not only the supply of skilled labor but also its distribution play an important role in determining the labor allocation. This feature provides an implication on income distribution. For example, if the demand of skilled labor is the same while the supply of skilled labor goes up (mostly due to enhanced educational attainment), the income distribution will be further deteriorated because the barriers to entry into skilled sector become higher and the income gap between skilled and unskilled workers will become bigger. In other words, if the supply of skilled labor increases with the same demand condition, then some marginal skilled workers in the skilled sector exit to the unskilled sector, which leads to depreciation of real income of these medium level earners, thereby further aggravating income polarization. However, if the supply of skilled labor increases along with an increase of skilled labor demand, the overall wage levels will go up and such an aggravation would not be caused.

Third, some comparative static analyses can be carried out based on the model. According to the analyses, for instance, skill biased technological progress has a strong positive effect on the long-run growth rate of the economy but its effect on the labor allocation appears to be relatively negligible. Meanwhile, the effect of an increase of skilled labor supply on the long-run growth rate of the economy is ambiguous, only causes more severe competition in entering the skilled sector.

Last but not least, the modified growth model can be extended to an open economy. When an economy is opened form its autarky state, two kinds of new aspects can be considered; trade of goods and knowledge spillover between countries. As Rivera-Batiz & Romer(1991) analyzes based on Romer(1990), the economic openness may affect on the long-run growth rate of an economy through the trade and knowledge spillover channels. Since the model in this paper extends Romer(1990) with workers skill heterogeneity to see the labor allocation mechanism more specifically, the extended model to an open economy can provide an interesting implication on the effect of economic openness on the labor allocation. The following example shows how an economic openness affects employment structure(relative size of employment between skilled and unskilled sectors). When trade takes place after an economy is open, final goods production sector of each country will be able to use more variety of intermediate goods through import, hence the license payments on each design of intermediate good also increases. Accordingly, labor productivity increases in every sector(research and final good production) when an economy is open, but the relative size of such increase may differ in accordance with countries' total amount of accumulated knowledge stock and types of trade. For instance, advanced countries with lots of accumulated knowledge stock has a comparative advantage in research(skilled) sector, hence the labor demand of research sector will increase in advanced countries when they open. On the contrary, in the case of less advance countries with comparative advantages in final good production(unskilled) sector, the labor demand of research sector will decrease when they open. Therefore, this asymmetric effect can cause the asymmetric effect of economic openness on the employment structure between skilled and unskilled sectors.

The above mentioned examples is about the effect of economic openness through *specialization channel*. Likewise, one can also take a look at how economic openness affects the employment structure through *knowledge spillover channel*. Once an economy is opened, active transfer of knowledge enables the country to tap into the knowledge accumulated in other countries not to mention of the country, thereby enhancing the overall productivity of its research sector. Positive effect of this knowledge spillover may be particularly strong in less advanced country which has relatively small amount of accumulated knowledge. Therefore, the employment size of research sector may increase even in the less advanced country if the knowledge spillover effect outweighs the specialization effect.

This paper also tries to check whether the above-mentioned channels of the model work in reality by using actual cross country data. The empirical analysis on the panel data of 21 OECD countries for the period of 1970-2000 confirms that economic openness affects the relative size of employment between skilled and unskilled sectors as already predicted by the model. That is, as the model shows through the specialization channel, countries that have lot of accumulated knowledge stock have relatively more employment in the skilled sector. It is also appeared that such an effect on employment structure appears to be greater for countries that actively export knowledge-intensive products. Moreover, as explained in the model through the knowledge spillover channel, the more knowledge spillover a country experiences, the more employment a country has in the skilled sector.

This paper comprises as follows. Chapter Ⅱ introduces a basic autarky model. Chapter Ⅲ extends the model to an open economy and examines some implications drawn from the model. Chapter Ⅳ presents the method and results of the empirical analysis. Chapter Ⅴ contains concluding remarks.

Ⅱ. Basic Model

This chapter introduces a model designed to explain endogenous labor allocation process in each employment sector(skilled and unskilled). The endogenous growth model of this paper follows Romer(1990) model but incorporates workers' skill heterogeneity into the model. In this chapter, I will provide a brief explanation on the basic structure of the model and show how the long-run growth rate of the economy is derived. I will also present several implications derived from the model related to the labor allocation and the long-run growth rate.

Before making more detailed explanation on the model, I briefly mention the basic assumptions of the model. First, the labor market is largely categorized by research(skilled) and final good production(unskilled) sectors, as in the existing endogenous growth models such as Romer(1990). Second, all the agents are employed and participate in one of the aforementioned labor sectors. Third, individual agents are considered as a kind of continuum and allocated to the sectors according to their skill levels. These skill levels are exogenously given when born and the distribution of the workers in terms of the skill levels is assumed to be an exponential function as follows.

$$h(z) = \lambda e^{-\lambda z} \quad z \in [0, \infty) \quad (\lambda > 0) \tag{1}$$

(where z is a variable for individual skill level, λ refers to the parameter which decides the shape of the distribution)

Fourth, the population size of the economy is normalized to one. Fifth, the basic setting for individual agent's optimization is based on the perpetual youth model introduced by Yaari(1965) and Blanchard (1985). To be more specific, every agent passes away by the probability of "p" in each point of time and the number of deaths and births are the same so the total population of the economy is fixed(the total population size is normalized to one). Sixth, although agents have heterogeneous skill levels but their preferences are the same each other. That is, each agent maximizes his life time utility as follows.

$$Max \int_{t_0}^{\infty} \log c_t \cdot e^{-(\rho+p)(t-t_0)} dt \tag{2}$$

$$s.t. \quad \frac{da_t}{dt} = ra_t + w_t - c_t$$

(where t_0 refers to time at birth, ρ means time preference, p is the instantaneous probability of death, r is the rate of return of the asset in the economy(real interest rate), c is the amount of consumption, a is the amount of asset holdings, w is wage)

1. Structure of the Model

Following Romer(1990), the modified model in this paper consists of three sectors; final good production, intermediate goods production and research sectors. The role of each sector is the same as Romer(1990). Further details on the sectors, as follows.

(1) Final Goods Production Sector

Final good is the only consumable commodity which is produced by labor and intermediate goods input. Following is the production function of the final good.

$$Y(t) = A(t) \cdot [L_Y(t)]^{1-\alpha} \cdot \int_0^{N(t)} [x_j(t)]^{\alpha} \, dj \qquad (0 < \alpha < 1) \tag{3}$$

(where A is overall technology level of the economy, L_Y is the number of workers in the final good sector, N indicates the number of variety of intermediate goods, x_j is the amount of j-th intermediate good input, t refers to time)

Wage(w_Y) of the workers in the final good sector is determined by their marginal productivity from equation (3) as follows.

$$w_Y(z) = w_Y = MP_{L_Y} = \frac{\partial Y}{\partial L_Y} = (1-\alpha)\frac{Y}{L_Y} \quad \text{for } all\ z \in [0, \infty) \tag{4}$$

Note that the wage(w_Y) of the final good production workers are the same each other regardless of their heterogeneous skill levels(z) because of the assumption that all the workers' productivities are the same in the production sector. This assumption is necessary in order to guarantee "assortive marching" which refers to the paring of each worker to his working place for maximizing his utility under given level of skill. In other words, under the assumption, workers with relatively higher skill level have comparative advantage in the skilled(research) sector while those with relatively lower skill level have comparative advantage in the unskilled(final good production) sector, thereby all the workers are allocated to respective working sectors in accordance with their skill levels, which is so called "self-sorting process".

The amount of demand for each intermediate good for producing final good is also determined by its marginal productivity as follows.

$$MP_{x_j} = \frac{\partial Y}{\partial x_j} = A\alpha L_Y^{1-\alpha} x_j^{\alpha-1} = p_j \quad \Rightarrow \quad x_j = L_Y \left(\frac{A\alpha}{p_j}\right)^{\frac{1}{1-\alpha}} \tag{5}$$

(where x_j is demand of the j-th intermediate good, p_j is price of the j-th intermediate good)

(2) Intermediate Good Sector

One unit of intermediate good is produced by one-to-one transferring of one unit of final good (labor input is not necessary for this). To do this, intermediate good producers need to buy a patent license from the research sector. Unlike the final good production sector, which is a perfectly competitive market, each intermediate good producing firm is a monopoly and set its selling price to maximize its profit. Since the price of final good is normalized to one, p_j refers to the price of the intermediate good.

Each intermediate good producing firm decides its price to maximize the monopolistic profit. Under the symmetric assumption that applies to all types of intermediate goods, the equilibrium price(p_j) of each intermediate good is the same each other and consequently the demand of each intermediate good is the same each other.

$$Max\ [p_j - 1]x_j \ \Rightarrow\ p_j^* = \frac{1}{\alpha} \quad \text{for } all\ j \in N(t) \tag{6}$$

Therefore, the instantaneous profit of each intermediate good producing firm can be derived as follows.

$$\pi_j(t) = \left(\frac{1-\alpha}{\alpha}\right) A^{\frac{1}{1-\alpha}} \alpha^{\frac{2}{1-\alpha}} L_Y(t) \quad \text{for } all\ j \in N(t) \tag{7}$$

Note that free entry condition is satisfied since all the profit of intermediate good producing firms are spent for patent license,

(3) Research Sector

The research sector hires research workers who invent new designs of intermediate goods. The money obtained by selling the patent rights are paid to the research workers as salary. If there is an equilibrium threshold skill level(z_1) in which all the workers are allocated to either research or final good production sector (i.e. the workers with relatively high skill level participate in the research sector while th e workers with relatively low skill level work in the final good production sector. More details will be provided in the next section), the number of newly invented intermediate goods at time t can be expressed as follows.

$$\frac{dN(t)}{dt} = \int_{z_1}^{\infty} \delta(z)\, h(z)\, dz \bullet N(t) \tag{8}$$

(where, *N(t)* is the number of types of intermediate goods, z_1 refers to equilibrium threshold skill level, $\delta(z)$ means each research worker's productivity, $h(z)$ indicates the distribution of workers according to their skill levels)

The labor productivity of worker in the research sector with z skill level is expressed as $\delta(z)=e^{\gamma z}$, which means that the worker produces new designs of intermediate good as much as "$\delta(z)N(t)=e^{\gamma z}N(t)$" at every point of time (γ indicates a degree of skill bias technology. That is, the parameter value will go up when there is skill biased technological progress in the economy). Equation (9) is derived from equation (3) and (8), and shows that the growth rate of the number of variety of intermediate goods which indicates the speed of technological progress of the economy is a function the parameter values of λ and γ, and the equilibrium threshold level(z_1).

$$\frac{\dot{N}}{N}=\frac{\lambda}{\lambda-\gamma}e^{(\gamma-\lambda)z_1} \qquad (\lambda>\gamma) \tag{9}$$

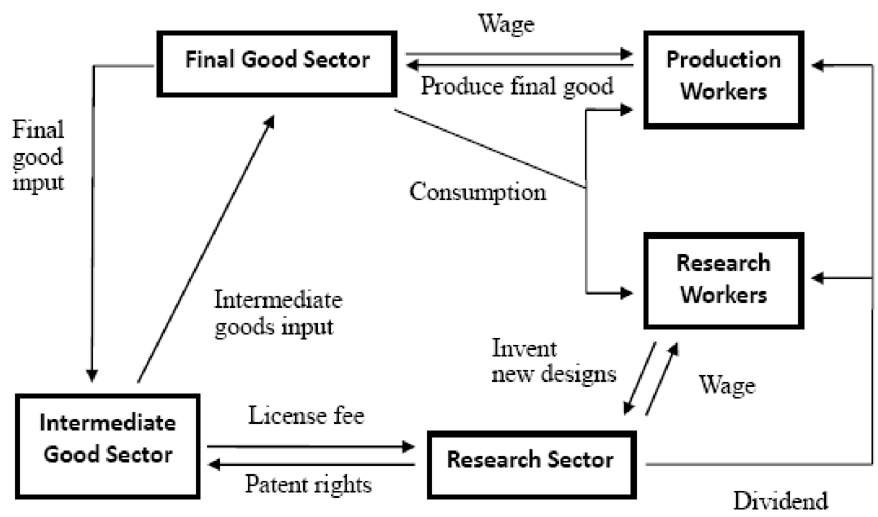
Each research worker gets his wage according to the market value of the designs of the intermediate good that he invented. Accordingly, the instantaneous wage of a research worker whose skill level is z, $w_R(z)$, can be expressed as follows.

$$w_R(z)=P_A^j(t)\cdot e^{\gamma z}\cdot N(t) \quad \text{for } all \ j\in N(t),\ z\in[z_1,\infty) \tag{10}$$

(where, $P_A^j(t)$ is the present value of the design of j-th intermediate good, *N(t)* is the number designs of intermediate good that the economy has at time *t*)

In the research sector, the only cost for inventing new intermediate goods is the wage for the researchers. All the money for paying the wages are raised by selling the patent license for intermediate good designs. The patent rights for all the existing intermediate goods held by the research sector can be regarded as the asset of the economy, which are owned by the agents of the economy. [Figure 1] shows the basic structure of the model.

<Figure 1> Structure of the model



2. Balanced Growth Path Equilibrium

One of the interesting feature of the model in this paper is that it has unique equilibrium threshold skill level which divides all the workers between research and final good production sectors according to the skill supply and skill demand conditions of the economy. The model is also characterized by that the long-run growth rate of the economy is expressed as a function of this equilibrium threshold skill level.

Under the assumption that the distribution of workers in terms of their skill levels is an exponential function($h(z) = \lambda e^{-\lambda z}$) as aforementioned, the number of workers allocated to each working sector can be expressed as follows. Note that the total number of workers is normalized to one.

$$L_Y = \int_0^{z_1} \lambda e^{-\lambda z}\, dz = 1 - e^{-\lambda z_1} \tag{11}$$

$$L_R = \int_{z_1}^{\infty} \lambda e^{-\lambda z}\, dz = e^{-\lambda z_1} \tag{12}$$

(where L_Y is the number of workers in the final good production sector, L_R is the number of workers in the research sector, z_1 refers to the equilibrium threshold skill level)

Since the demand of all kinds of intermediate goods are the same each other, the total amount of final good production can be solved as equation (13) from equation (3) and (5). Moreover, the wage of workers in the final good production sector can be expressed as equation (14) from equation (4).

$$Y = AL_Y^{1-\alpha} N x_j^{\alpha} = A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} L_Y^{1-\alpha} N \tag{13}$$

$$w_Y(z) = w_Y = (1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} N \quad \text{for } all\ z \in [0, \infty) \tag{14}$$

From equation (7) and (11), the profit generated from each intermediate good at every point of time can be expressed as follows.

$$\pi_j(t) = \left(\frac{1-\alpha}{\alpha}\right) A^{\frac{1}{1-\alpha}} \alpha^{\frac{2}{1-\alpha}} \left(1 - e^{-\lambda z_1}\right) \quad \text{for } all\ j \in N(t) \tag{15}$$

The rate of return(r) of the economy should be the constant on the balanced growth path(BGP) and the price of each patent right of intermediate good design should be the same as the present value of all the future profits generated by the patent right. Thus, the price of each patent right of the design is obtained as follows.

$$P_A^j = \int_t^{\infty} \pi_j(s) \bullet e^{-r(s-t)}\ ds = \frac{\pi_j}{r} \tag{16}$$

As aforementioned, the distinguishing feature of the model in this paper compared with Romer(1990) and Acemoglu(1998) is that the long-run equilibrium growth rate of the economy is determined by both supply and demand conditions of skilled labor. The supply and demand conditions for skilled labor can be derived as follows.

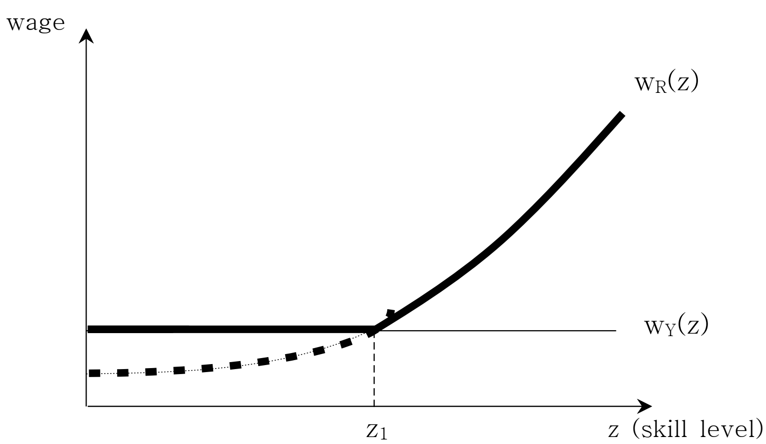
Above all, on the equilibrium, the worker whose skill level is exactly the same as the equilibrium threshold level should receive the same wage either he works in the research sector or production sector. In consideration of this condition, the equilibrium price of each patent right can be determined as follows.

$$w_Y(z_1) = w_Y = (1-\alpha)A^{\frac{1}{1-\alpha}}\alpha^{\frac{2\alpha}{1-\alpha}}N \tag{17}$$
$$= w_R(z_1) = P_A^j \bullet e^{\gamma z_1} \bullet N$$

$$\Rightarrow\ P_A^j = \frac{(1-\alpha)A^{\frac{1}{1-\alpha}}\alpha^{\frac{2\alpha}{1-\alpha}}}{e^{\gamma z_1}} \tag{18}$$

[Figure 2] shows a wage profile of the economy in accordance with the skill level of the workers.

<Figure 2> wage profile of the economy



Thus, skill supply of the economy is derived from the labor market equilibrium condition from equation (15), (16) and (18) as follows.

$$r = \frac{\pi_j}{P_A^j} = \alpha e^{\gamma z_1}\left(1 - e^{-\lambda z_1}\right) \qquad \text{(skill supply)} \tag{19}$$

Meanwhile, skill demand curve is derived from the preference side of the agents as Romer(1990). As mentioned above, each agent has different skill level(z) but assumed to have the same preference. The basic setting for the agent's life-time utility optimization is based on "Perpetual Youth" model introduced by Yaari (1965) and Blanchard(1985). That is, all the agents die with the probability of p at every instant of time, and the number of deaths and births is always the same so the population size of the economy fixed as constant number one. The optimization problem of the representative agent is expressed as follows.

$$Max \int_{t_0}^{\infty} \log c_t \bullet e^{-(\rho+p)(t-t_0)}\, dt \tag{20}$$
$$s.t. \quad \frac{da_t}{dt} = ra_t + w_t - c_t$$

(where t_0 is time at birth, ρ is time preference, p is instantaneous probability of death, r is rate of return of the economy, c is consumption, a is amount of asset holding, w is wage)

The solution of the above dynamic optimization problem is shown in the equation (21). As we can see from the equation (21), on the balanced growth path, the optimal quantity of consumption and asset holding are different according to individual skill levels but the growth rates are the same for every agent.

$$c_t(z_i) = c_{t_0}(z_i) \bullet e^{g(t-t_0)} \tag{21}$$
$$w_t(z_i) = w_{t_0}(z_i) \bullet e^{g(t-t_0)}$$
$$a_t(z_i) = a_{t_0}(z_i) \bullet e^{g(t-t_0)} \quad \text{for } all \;\; z_i \in [0, \infty)$$

(where g is long-run growth rate of the economy ($g = r - \rho - p$))

Therefore, the growth rate of the total consumption is determined by the preference of the representative agent who achieves inter-temporal optimization as follows.

$$\frac{\dot{C}}{C} = r - \rho - p \tag{22}$$

And the equilibrium growth rate of the number of variety of intermediate goods can be expressed as follows.

$$\frac{dN(t)}{dt} = \int_{z_1}^{\infty} \delta(z)\, dH(z) \bullet N(t) \tag{23}$$
$$\Rightarrow \quad \frac{\dot{N}}{N} = \frac{\lambda}{\lambda - \gamma} e^{(\gamma-\lambda)z_1} \qquad (\lambda > \gamma)$$

In sum, the skill demand of the economy is expressed as follows.

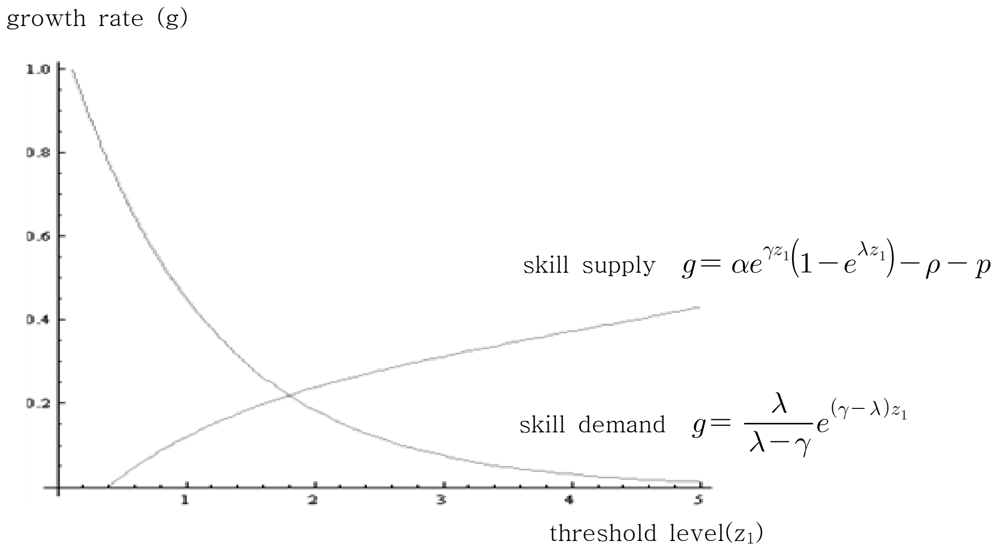
$$g = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{N}}{N} = r - \rho - p = \frac{\lambda}{\lambda - \gamma} e^{(\gamma - \lambda) z_1} \quad \text{(skill demand)} \tag{24}$$

[Figure 3] shows how the equilibrium growth rate(g) and the equilibrium threshold skill level(z_1) are determined by the skill demand and supply conditions.

The reason why the skill supply curve has upward slope can be explained as below. As mentioned above, the skill supply curve is derived from the labor market equilibrium condition in which the threshold divides all the workers between research and production sectors according to the their heterogeneous skill levels. As equation (24), the long-run growth rate(g) of the economy is the same as the growth rate of the number of varieties of intermediate goods(N). The higher growth rate of the number of varieties (or, the higher rate of return of the economy(r)) corresponds to the lower present value of patent right for each intermediate good, hence the relatively lower wage of skilled sector. Thus, labor supply to the skilled sector will decrease, meaning that the equilibrium threshold level(z_1) should be higher with higher economic growth rate.

Meanwhile, the reason why skill supply curve has downward slope can be explained as below. As aforementioned, the skill demand is decided by the preference side. As equation (24) shows, the rate of return of the economy goes up when growth rate of the economy become higher. Under the higher rate of return, agents are willing to save more. This means that the economy would like to allocate more labor on the research sector, hence the higher economic growth rate corresponds to the lower equilibrium threshold level.

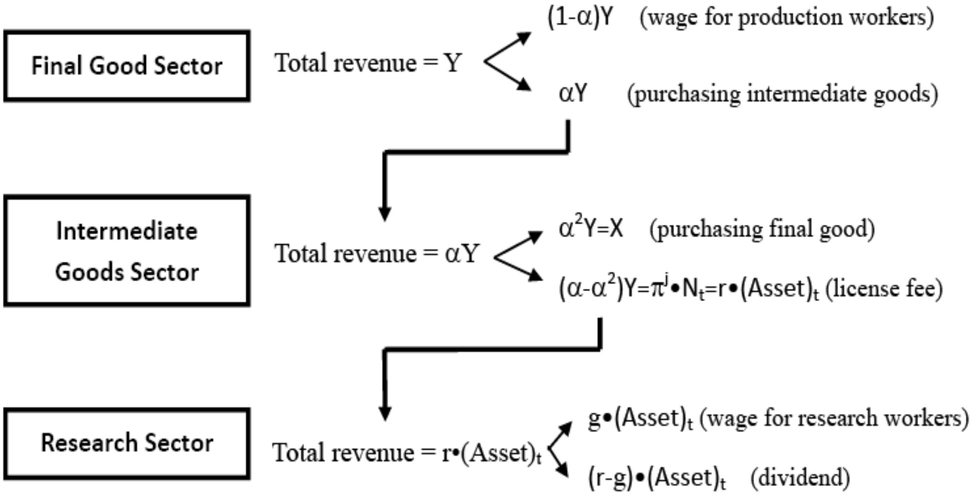
<Figure 3> Equilibrium of the economy



Note: The following parameter values are used for this simulation. A=1, α=1/3, λ=1, γ=0.1, ρ=0.01, p=0.1

[Figure 4] shows the resource flow of the economy. We can see from the [Figure 4] that the market clearing condition of the economy is satisfied.

<Figure 4> Summary of resource flow of the economy



3. Comparative Static Analysis

Several comparative static analyses can be carried out based on the skill supply and demand curves. This section presents comparative analyses for two cases; skill biased technological change and enhancement on educational attainment.

(1) Case 1: skill biased technological change (when γ increases)

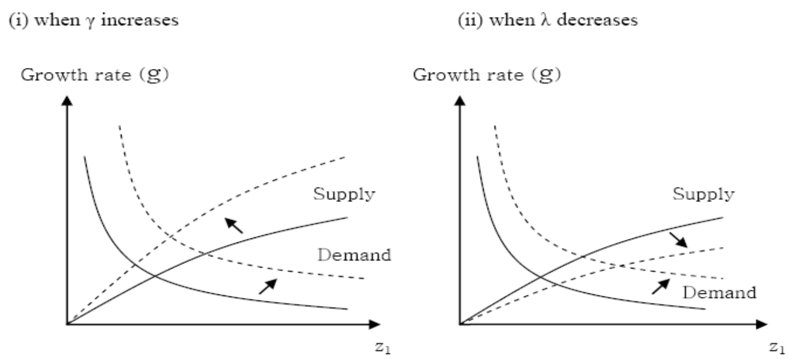
In this model, skill biased technological change(SBTC) is represented by increasing "γ" because under the higher value of γ, the productivity of research workers will be relatively more higher. Therefore, under the higher value of γ, *ceteris paribus*, the more number of workers prefer to work in the research sector, which makes the equilibrium threshold level(z_1) decreases (i.e. the skill supply curve shifts to the leftward).

On the contrary, regarding to the skill demand, when the γ value goes up, the number of variety of intermediate good designs produced in the research sector would increases even with the same number of research workers due to the increase of the research worker's productivity. This causes a surplus of research workers. So, under the given skill demand condition from preference side, an increase of γ value correspond to an increase of the equilibrium threshold level. In other words, the skill demand curve shifts to the rightward when the γ value increases.

(2) Case 2: enhancement of educational attainment (when λ decreases)

When the skilled labor supply increases(λ decreases) due to an exogenous enhancement of educational attainment, the workers' distribution($h(z) = \lambda e^{-\lambda z}$) becomes flatter. This causes more severe competition for entering the research sector, hence causes an increase of the equilibrium threshold level. That is, when the λ value decreases, the skill supply curve shifts to the rightward. Meanwhile, the decline of λ value indicates that the more workers are located on the right-hand side of the equilibrium threshold. Thus, the skill demand curve shifts to the rightward when λ decreases.

<Figure 5> Comparative static analysis



Ⅲ. Extension to an Open Economy

In this chapter, the autarky model in the previous chapter is extended to an open economy. To this end, this paper adopts the idea of Rivera-Batiz & Romer(1991) which extends Romer(1991) model to an open economy by modifying some functional forms of the original model. The main idea of the modification is presented as follows.

Rivera-Batiz & Romer(1991) recognizes that endogenous growth model has some advantage in analyzing macro-economic effect of economic openness on economic growth compared with neo-classical model in that the endogenous growth model considers not only the effect of flows of goods(trade) but also the effect of flows of ideas(knowledge spillover). According to the extended model of Rivera-Batiz & Romer(1991), once the economy is opened, the amount of final good production is increased because the productivity of the final good sector increases due to the availability of import new kinds of intermediate goods from other countries (trade effect). Moreover, economic openness enables the opened country to use other countries' accumulated knowledge, and this makes the productivity of research sector increases, hence increases the long-run growth rate of the economy (knowledge spillover effect).

In this chapter, the basic autarky model in the previous chapter is extended to an open economy by exploiting the idea of Rivera-Batiz & Romer(1991). The extended model presented in this chapter has some distinguishing features compared with Rivera-Batiz & Romer(1991).

First, Rivera-Batiz & Romer(1991) analyzes only the effect of economic openness on economic growth with the homeogenous setting as Romer(1990), whereas the proposed model in this chapter analyzes the effect on employment structure(i.e. relative size of employment between skilled and unskilled sectors) as well based on workers' skill heterogeneity.

Second, while Rivera-Batiz & Romer(1991) takes into account only the symmetric case in which two identical countries trade each other, the proposed model in this chapter considers an asymmetric countries case as well. That is the case that two countries with different characteristics(one with high level of accumulated knowledge stock, and the other with relatively low level of accumulated knowledge stock) trade each other. Both the symmetric and asymmetric cases above are separated to situations with and without knowledge spillover in order to differentiate the effect of economic openness through specialization and knowledge spillover channel. To sum it up, we will consider the following four different cases in total; (1) Two identical countries(N=N*) without knowledge spillover, (2) Two identical countries(N=N*) with knowledge spillover, (3) Two different countries(N>N*) without knowledge spillover, (4) Two different countries(N>N*) with knowledge spillover

1. Extension of the Model

To extend the autarky model to an open economy, some functions need to be modified. First, the final good production function (3) in the previous chapter is modified as equation (25) to reflect that the intermediate goods produced in the other country become available when an economy is open[1].

$$Y = AL_Y^{1-\alpha}\int_0^{N+N^*} x_j^{\alpha}\ dj \qquad (0<\alpha<1) \tag{25}$$

(where, all the variables refer to the same as those in the aforementioned function (3). N means the number of varieties of a country, N^* refers to the number of varieties of the other country, the time subscript t is dropped here)

The equation (23) also needs to be modified as follows to reflect the possibility of utilizing accumulated knowledge stock of the other country when the economy is open. The modified functions are as follows. In particular, I separate two cases; the case without knowledge spillover and the case with knowledge spillover as below.

(i) without knowledge spillover

$$\frac{dN}{dt} = \int_{z_1}^{\infty} \delta(z)\, dH(z) \bullet\ N \tag{26}$$

(ii) with knowledge spillover

$$\frac{dN}{dt} = \int_{z_1}^{\infty} \delta(z)\, dH(z) \bullet\ (N+N^*) \tag{27}$$

Except these modification, all the other steps for solving balanced growth path equilibrium is the same as the previous autarky case. So, here I skip the process for solving the equilibrium and directly show the results.

2. Case by case analysis

Comparison and analysis are made among the four cases with respect to the effect of economic openness on the employment structure and economic growth based on the previously mentioned extended growth model.

1) For simplicity, it is assume that each country invents totally different set of intermediate goods (i.e. $N \cap N^* = \varnothing$)

(Case 1) Two identical countries(N=N*) without knowledge spillover

The final goods production function, wage in the final good production sector, and the demand for intermediate goods are modified as below in this case.

$$Y \equiv A \cdot L_Y^{1-\alpha} \cdot \int_0^{N+N^*} x_j^{\alpha} \cdot dj \qquad (0<\alpha<1) \tag{28}$$

$$W^Y = W^{Y*} = MP_{L_Y} = \frac{\partial Y}{\partial L_Y} = (1-\alpha)\frac{Y}{L_Y} \tag{29}$$

$$MP_{x_j} = \frac{\partial Y}{\partial x_j} = AL_Y^{1-\alpha}\alpha \cdot x_j^{\alpha-1} = p_j \quad \Rightarrow \quad x_j = L_Y\left(\frac{A\alpha}{p_j}\right)^{\frac{1}{1-\alpha}} \tag{30}$$

As explained in the previous chapter, the profit of each intermediate good producing firm is derived as follows.

$$\begin{aligned}\pi^j &= (p_j-1)(x_j+x_j^*) \\ &= \left(\frac{1-\alpha}{\alpha}\right) \cdot A^{\frac{1}{1-\alpha}}\alpha^{\frac{2}{1-\alpha}} \cdot (L_Y+L_Y^*) \ \ \text{for}\, all\ \ j \in N \cup N^*\end{aligned} \tag{31}$$

Since the two countries are identical, the equilibrium threshold levels of the two countries are the same (z_1=z_1*). The number of newly developed intermediate good designs in the research sector are the same in this without knowledge spillover case, as shown below.

$$\begin{aligned}\dot{N} &= \int_{Z1}^{\infty}\delta(z)dH(z) \cdot N = \left[\frac{\lambda}{\lambda-\gamma}e^{(\gamma-\lambda)z_1}\right] \cdot N \qquad (\lambda>\gamma) \\ &= \dot{N}^* = \int_{Z1}^{\infty}\delta(z)dH(z) \cdot N^* = \left[\frac{\lambda}{\lambda-\gamma}e^{(\gamma-\lambda)z_1}\right] \cdot N^* \\ &\quad where\ \ \delta(z)=e^{\gamma z}\ \text{and}\ dH(z)=h(z)=\lambda e^{-\lambda z},\ \ z\in[z_1,\infty)\end{aligned} \tag{32}$$

As mentioned before, the wage of each research worker is the same as the value of the total intermediate good designs invented by the worker.

$$W^R(z) = p_A^j \cdot e^{\gamma z} \cdot N \tag{33}$$

$$W^R(z)^* = p_A^j \cdot e^{\gamma z} \cdot N^* \tag{34}$$

The quantity of final good production can be obtained as follows from equation (28) and (30).

$$Y = Y^* = A^{\frac{1}{1-\alpha}}\alpha^{\frac{2}{1-\alpha}} \cdot L_Y \cdot [N+N^*] \tag{35}$$

Since the two countries are identical, the wage and the number of employment is also the same for each sector. Thus,

$$L_Y = L_Y{}^* \text{ and } L_Y + L_Y{}^* = 2L_Y \tag{36}$$

Accordingly, the wages in each sector of the countries are determined as follows.

$$W^Y(z) = W^Y(z)^* = (1-\alpha)A^{\frac{1}{1-\alpha}}\alpha^{\frac{2}{1-\alpha}} \cdot \left[N + N^*\right] \tag{37}$$

$$W^R(z) = W^R(z)^* = p_A^j \cdot e^{\gamma z} \cdot N \tag{38}$$

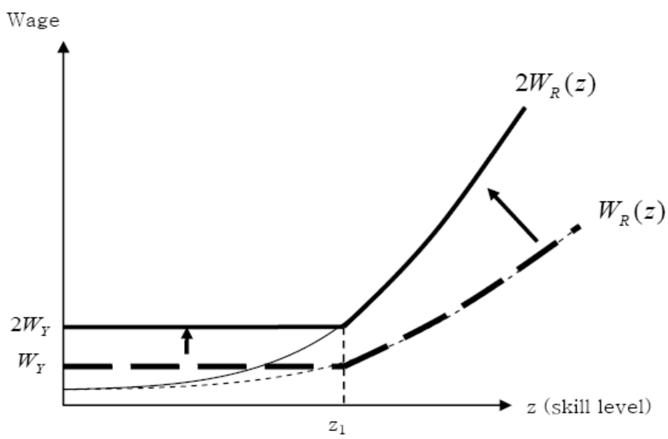
$$where \;\; p_A^j = \frac{\pi_j}{r} = \left(\frac{1-\alpha}{\alpha}\right)A^{\frac{1}{1-\alpha}}\alpha^{\frac{2}{1-\alpha}}\left(L_Y + L_Y^*\right) \cdot \left(\frac{1}{r}\right)$$

As we can see from equation (37) and (38), when the economy is open, the wages in both final good production(unskilled) and research(skilled) sectors are doubled and the equilibrium threshold skill level remains the same. The reason why the production workers' wages are doubled is that the labor productivity of the final good sector increases at twice due to import of new kinds of intermediate goods from the other country. The reason why the research workers' wages are doubled is that the price of patent right increases at twice due to market size effect caused by export of intermediate goods to the other country. However, it is important to notice that this is "*level effect*" that immediately appears after economic openness. As shown in [Figure 6], wages increase in the same proportion in all sectors, so economic openness accompanies no changes in equilibrium threshold skill level(z_1), which means no change in the employment structure, hence no change in the long-run growth rate of the economy.

Implication 1

If two countries are identical and there is no knowledge spillover,
then economic openness has positive "level effect" but no "growth effect"

<Figure 6> Wage profile (Case 1)



(Case 2) Two identical countries(N=N*) with knowledge spillover

On the other hand, for this "*with knowledge spillover case*", the equation (32) should be modified as equation (39) since in this case each country's research sector can use the other country's accumulated knowledge stock as well. So N should be replaced by "N+N*" to take in the feature of knowledge spillover between countries.

$$\dot{N} = \int_{Z1}^{\infty} \delta(z) dH(z) \bullet (N+N^*) = \left[\frac{\lambda}{\lambda - \gamma} e^{(\gamma - \lambda) z_1} \right] \bullet (N+N^*) \qquad (\lambda > \gamma) \tag{39}$$

$$= \dot{N}^* = \int_{Z1}^{\infty} \delta(z) dH(z) \bullet (N+N^*) = \left[\frac{\lambda}{\lambda - \gamma} e^{(\gamma - \lambda) z_1} \right] \bullet (N+N^*)$$

$$where \;\; \delta(z) = e^{\gamma z} \;\; \text{and} \;\; dH(z) = h(z) = \lambda e^{-\lambda z}, \;\; z \in [z_1, \infty)$$

Therefore, the wages of production and research workers of each country can be summarized as follows. The present value of patent right of each intermediate good design is twice greater than the autarky since the intermediate goods are traded.

$$W^Y(z) = W^Y(z)^* = (1-\alpha) A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} \bullet [N+N^*] \tag{40}$$

$$W^R(z) = W^R(z)^* = p_A^j \bullet e^{\gamma z} \bullet (N+N^*) \tag{41}$$

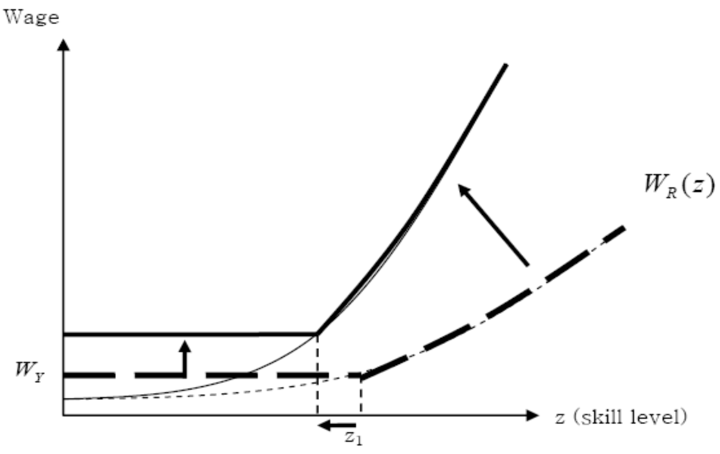
$$where \;\; p_A^j = \frac{\pi_j}{r} = \left(\frac{1-\alpha}{\alpha} \right) A^{\frac{1}{1-\alpha}} \alpha^{\frac{2\alpha}{1-\alpha}} (L_Y + L_Y^*) \bullet \left(\frac{1}{r} \right)$$

Note that equation (40) is the same as equation (37) which is for the "*without knowledge spillover case*", but equation (41) is not the same as equation (38). This difference leads different equilibrium threshold level(z_1). This difference is because, in this knowledge spillover case, the economy has another source of increasing productivity of research workers in addition to the effect of increasing present value of patent right, so called knowledge spillover effect, due to the availability of the other country's knowledge stock. Therefore, the economy will hire more researchers when open, hence the equilibrium threshold level will be placed at the further left-hand side than that of autarky case. Thus, the balanced growth path growth rate of the economies will be greater than those of autarky case. In conclusion, when we consider knowledge spillover between countries, we may think that not only the income level but also the equilibrium growth rate of the economy is higher than the autarky case. Thus, we may conclude the effect of economic openness in this case as follows.

Implication 2

If two countries are identical and there is knowledge spillover,
then economic openness has both positive "level effect" and positive "growth effect"

<Figure 7> Wage profile (Case 2)



(Case 3) Two different countries(N>N*) without knowledge spillover

The equilibrium wages for this asymmetric case can be derived as the same way in the previous symmetric case. That is, the equation from (28) to (38) in the previous case can be applied to this case too. However, it is important to notice that the actual values of the variables are quite different from those of the previous symmetric case. That is, the quantity of each country's final good production, the number of intermediate good varieties, employment size of each sector and income levels are different each other (i.e., $Y \neq Y^*$, $\dot{N} \neq \dot{N}^*$, $L_Y \neq L_Y^*$, $L_R \neq L_R^*$, $W_Y(z) \neq W_Y(z)^*$, $W_R(z) \neq W_R(z)^*$). Accordingly, the effect of economic openness on the economies also should be different by countries in this case.

Note that N is larger than N^* in equation (28). Since N is larger than N^*, the labor productivity of production workers will be increased relatively more in the less advanced country(N^*) than in the advanced country(N) when the economies are open. Accordingly, wages of the final good production(unskilled) workers will be increased and this effect will be relatively greater in the less advanced country. Meanwhile, when the economies are open, the wages of research(skilled) workers will be increased due to the increase of the price of patent right(p_A^j). Note that the profit from each type of intermediate good in the autarky is expressed as equation (7), but the profit is expressed as equation (31) for the open economy case. Since the size of employment of production sector will be greater in the less advanced country than the advanced country due to the greater increase of labor productivity in the less advanced country, the increase of patent right price should be greater in the advanced country. This causes relatively more increase of research worker's wage in the advanced country. Thus, the size of employment of the skilled sector will be increased more in the advanced country than the less advanced country.

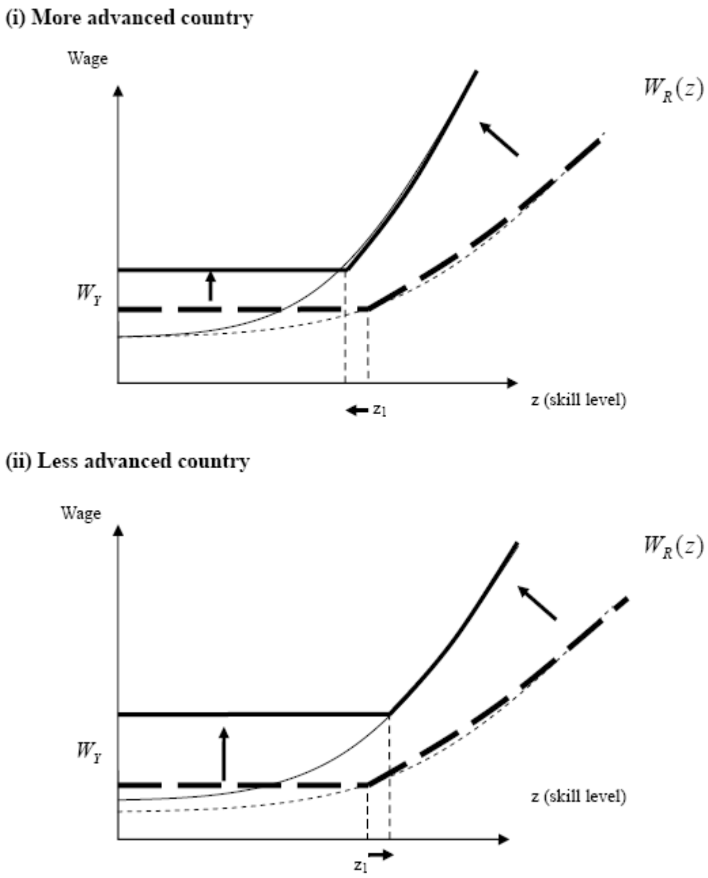
Considering this feature, when the less advanced country and the advanced country trade each other, they experience different changes in wage profile after economic openness. As shown in [Figure 8], the equilibrium threshold level of the advanced country, in which skilled sector wage increase is relatively greater, moves to the leftward, whereas the equilibrium threshold level of the less advanced country, in which unskilled sector wage increase is relatively greater, moves to the rightward. In sum, when the two asymmetric countries are integrated, the skilled sector employment increases in the advanced country, whereas unskilled sector employment increases in less advanced country.

Implication 3

If two countries are not identical (i.e. one is more advanced and the other is less advanced) and there is no knowledge spillover,

then economic openness has positive "level effect" in both countries and each country will specialize in either production or research (i.e. the more advanced country will specialize in research and the less advanced country will specialize in production)

<Figure 8> Wage profile (Case 3)



(Case 4) Two different countries($N>N^*$) with knowledge spillover

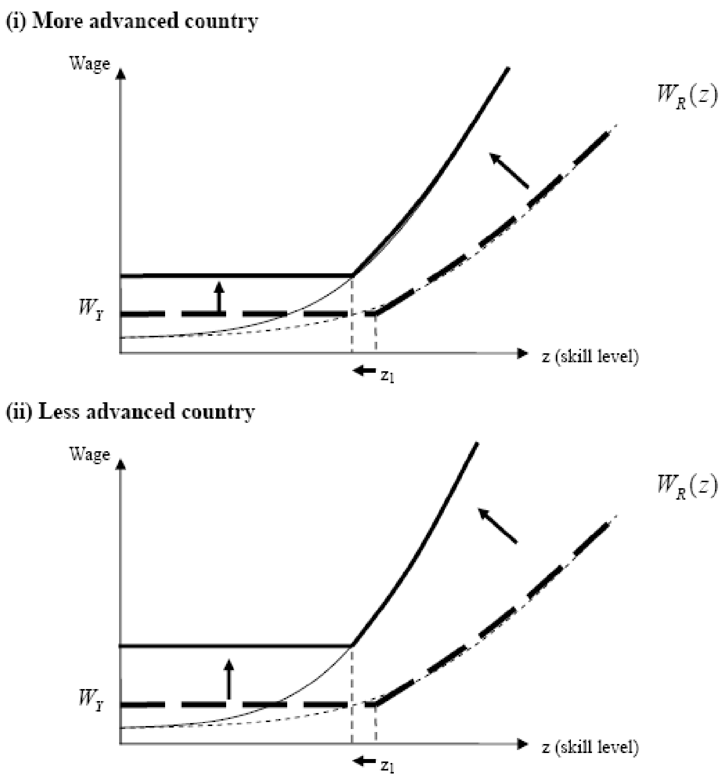
Contrary to the previous case of asymmetric countries without knowledge spillover, if we assume knowledge spillover between countries, wages should be the same in both countries for both production and research sectors. Similarly to the case of symmetric countries with knowledge spillover, when the economies are open, both countries will hire more researchers, so the equilibrium threshold level(z_1) will move to the leftward in both countries. Therefore, the economic openness has not only level effect but also growth effect in this case. Since $N>N^*$, the degree of the growth effect of economic openness will be greater in the less advanced country. This means that all the production and research workers in both countries can get gains of trade, but the workers in the less advanced country get relatively more gains from the economic openness. Thus, we can get an intuition as follows for this case of asymmetric countries with knowledge spillover.

Implication 4

If two countries are not identical (i.e. one is more advanced and the other is less advanced) and there is knowledge spillover,

then economic openness has both positive “level effect” and positive “growth effect” in both countries, and the degree of the level effect is greater in the less advanced country

<Figure 9> Wage profile (Case 4)



Ⅳ. Empirics

This chapter presents empirical results based on the extended model to an open economy. According to the model, there are two kinds of channels that the economic openness affects employment structure(relative size of employment between skilled and unskilled sectors). One is the specialization channel in which each country specializes in its more competitive sector once the economy is open. That is, advanced country specializes in research sector since the country has comparative advantage in the research(skilled) sector, and the country hires more research workers when the economy is open. On the contrary, less advanced country has comparative advantage in the production(unskilled) sector, so the country hires more workers in the production sector. The other is the knowledge spillover channel in which the productivity of each country's research sector is enhanced once the economies are open since the countries can use knowledge stock accumulated by other country. Thus, through the knowledge spillover channel, the economic openness causes an increase of research sector employment in both countries when the economies are open.

These effects can be captured by the movement of the equilibrium threshold level(z1). By analyzing the relation between equilibrium threshold level and the other variables, it can be checked whether the two kinds of channels are working or not. This chapter presents how to check these effect empirically.

The explanation for the variables as follows. First, to measure the amount of knowledge stock inflows from other countries, Foreign R&D stock is used as Coe and Helpman(1995) and Coe et al(2009). Foreign R&D stock is estimated by averaging its trading partners' Domestic R&D stock weighted by import shares. Each country's Domestic R&D stock is estimated by perpetual inventory method using time series of its R&D investment data. I get the cross-sectional Foreign R&D stock data from Helpman's homepage. It is assumed that the more Foreign R&D stock a country has, the more knowledge spillover inflow to the country.

Two kinds of variables are used for estimating the effect of economic openness on the employment structure through specialization channel. They are R&D dependency and Domestic R&D gap. The R&D dependency is measured by R&D weighted import penetration which is defined as a country's degree of R&D dependence. Meanwhile, the Domestic R&D gap is measured as follows.

$$Domestic\,R\&D\,Gap^{i} \text{ (domestic R\&D gap of country i)}$$
$$= \frac{Domestic\ R\&D\ Stock^{Max}}{Domestic\ R\&D\ Stock^{i}} \text{ for } all\ country\ i \in I$$

To estimate parameter value of λ, I use cross country panel data of educational attainment from Barro & Lee. The data contains each country's employment share by educational level for 146 countries from 1950 to 2010. The parameter value of λ for each country for each year is calculated to fit closest to the distribution of employers by education levels. For this, I normalize 12 years of education to skill level one. ILO provides yearly data of cross country employment by occupational categories from 1970. The occupational categories are as shown [Table 1]. The equilibrium threshold level(z_1) can be calculated by combining the estimated value of λ and the occupational employment data with the assumption that the skilled(research) sector prefers to hire more skilled worker.

<Table 1> Occupational Category (ILO)

Skilled Sector	- Professional, Technical and related workers - Administrative and Managerial workers
Unskilled Sector	- Clerical and related workers - Sales workers - Service workers - Agricultural workers, Fisherman and Hunters, etc - Production and related workers, Transport equipment operators, etc

Apart from the variables mentioned above, there would be some other variables that could affect the employment structure. For example, the size of land of a country may affect the country's industrial structure, hence the employment structure. Religious and cultural characteristics could affect the country's employment structure too. To control this kinds of factors, I use fixed effect panel model. 21 OECD countries data from 1970 to 2000 with 10 years interval are used. The sources of the data are as follows.

· OECD STAN Database / UNIDO
· ILO Occupational Employment Database
· Coe, Helpman, and Hoffmaisner(2009)
· Barro & Lee Educational Attainment Database
· NBER Industrial bilateral Trading Data
· Feenstra, "UCD Statistics Canada Trade Data"
· Feenstra et al(1997), Feenstra(2000)
· Ginarte & park(1997), Park & Lippoldt(2005), Park(2008)

The estimation equation of the fixed effect model is as follows.

$$\begin{aligned}\triangle \ln(z_{1it}) = {} & \alpha_i + \alpha_t + \beta_0 \triangle \ln(\lambda_{it}) + \beta_1 \triangle \ln(DRD_{it}) \\ & + \beta_2 \triangle \ln(FRD_{it}) + \beta_3 IM_{i,t-1} \triangle \ln(FRD_{it}) \\ & + \beta_4 \ln(Dgap_{i,t-1}) + \beta_5 \triangle IM_{it} \ln(Dgap_{i,t-1}) \\ & + \beta_6 \triangle WIP_{it} + \beta_7 \triangle PP_{it} + \beta_8 \triangle Ggap_{it} + \beta_9 \ln(z_{1i,t-1}) + \epsilon_t\end{aligned}$$

(where i indicates country, t refers to time, z_1 is the equilibrium threshold level, λ is parameter for the distribution of workers in terms of their skill levels, *IM* is import share(Import/GDP), *DRD* and *FRD* are Doemstic and Foreign R&D Stock respectively, *Dgap* is Doemstic R&D gap, *WIP* is R&D weighted import penetration, *PP* is the index of strength of patent protection, *Ggap* is gender gap in employment of skilled sector(share of employment in the skilled sector among women/share of employment in the skilled sector among man), △ refers to first difference)

According to the extended model in the previous chapter, the signs of the equation are predicted as follows.

First, the sign of β_0 will be negative since the lower value of λ means the more skill supply, thus it should correspond to the higher threshold level(z_1). The sign of β_1 will be negative since the greater Domestic R&D Stock menas the higher labor productivity in the research sector, hence more demand of the skilled sector. Therefore, the greater Domestic R&D Stock should correspond to the higher threshold level(z_1).

The signs of β_2 and β_3 will be both negative. It is because the greater Foreign R&D Stock means more knowledge spillover from the other countries, and this fact will be greater if the country is more opened (i.e. greater import share). Since the more knowledge spillover causes the higher productivity of research sector, the greater Foreign R&D Stock and import share should correspond to the lower threshold level(z_1).

The signs of β_4 and β_5 will be both positive. It is because of the effect though the specialization channel. The country with greater R&D gap will have relatively lower productivity in the research(skilled) sector and have comparative advantage in the production(unskilled) sector. Thus the country will have higher threshold level(z_1) and this effect will be greater if the country is more opened.

The sigh of β_6 will be positive since the greater R&D weighted import penetration means the greater dependency of skilled labor from the other countries, thus the country with greater R&D weighted import penetration should have the higher threshold level(z_1).

The sign of β_7 will be negative since the country with better patent protection has relatively bigger research sector. And the sign of β_8 will be negative because the country with less gender gap in employment of the skilled sector has greater employment in the skilled sector.

The empirical results are shown at [Table 2]. As we can see from the table, the empirical results support the model's prediction.

<Table 2> Regression results

Dependent variable: $\triangle\log(z_{1t})$						
	(1)	(2)	(3)	(4)	(5)	(6)
$\log(z_{1t-1})$	-0.586***	-0.586***	-0.593***	-0.592***	-0.021	-0.003
	(0.182)	(0.199)	(0.191)	(0.211)	(0.066)	(0.069)
$\triangle\log(\lambda_t)$	-0.556***	-0.525**	-0.543**	-0.497**	-1.155***	-1.126***
	(0.193)	(0.221)	(0.201)	(0.236)	(0.112)	(0.099)
$\triangle\log(DRD_t)$	-0.332***	-0.221*	-0.318**	-0.164	0.021	0.027
	(0.088)	(0.122)	(0.117)	(0.169)	(0.041)	(0.043)
$\triangle\log(FRD_t)$	-0.164	-0.113	-0.164	-0.108	-0.138	-0.064
	(0.098)	(0.101)	(0.103)	(0.104)	(0.085)	(0.074)
$IM_{t-1}\cdot\triangle\log(FRD_t)$	-0.188***	-0.193**	-0.185***	-0.190**	-0.140**	-0.110
	(0.060)	(0.082)	(0.065)	(0.081)	(0.063)	(0.067)
$\log(Dgap_{t-1})$	0.148***	0.083	0.144**	0.057	-0.018*	-0.019*
	(0.044)	(0.069)	(0.054)	(0.087)	(0.010)	(0.011)
$\triangle\log(IM_t)$	0.267**	0.268*	0.269**	0.268*	0.228*	0.159
$\cdot\log(Dgap_{t-1})$	(0.117)	(0.137)	(0.125)	(0.137)	(0.115)	(0.115)
$\triangle\log(WIP_t)$	0.049***	0.050**	0.049***	0.052**	0.011*	0.014*
	(0.014)	(0.018)	(0.015)	(0.019)	(0.006)	(0.007)
$\triangle\log(PP_t)$			-0.011	-0.028	-0.074**	-0.039
			(0.034)	(0.038)	(0.031)	(0.032)
$\triangle\log(Ggap_t)$			-0.256	-0.249	-0.167	-0.178
			(0.341)	(0.342)	(0.314)	(0.346)
$Quality_t$					-0.071	-0.186
					(0.621)	(0.654)
Constant	-0.578***	-0.327	-0.559***	-0.221	-0.044	-0.134
	(0.164)	(0.292)	(0.196)	(0.352)	(0.065)	(0.089)
Total elasticity of $\triangle z_1$ with respect to[1] :						
$\triangle$FRD $(\beta_2+\beta_3\overline{IM})$	-0.227**	-0.178*	-0.226**	-0.172	-0.185**	-0.102
	(0.102)	(0.098)	(0.108)	(0.105)	(0.087)	(0.076)
Dgap $(\beta_4+\beta_5\overline{\triangle IM})$	0.161***	0.096	0.157***	0.070	-0.007	-0.012
	(0.043)	(0.068)	(0.054)	(0.087)	(0.011)	(0.011)
Fixed Effect	Yes	Yes	Yes	Yes	No	No
Time Effect	No	Yes	No	Yes	No	Yes
# Obs	63	63	63	63	63	63
R^2 adjusted	0.753	0.764	0.756	0.769	0.652	0.698

Robust standard errors are in parentheses (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$).
Time dummies are not reported.

1) Total elasticity is evaluated at their sample means ($\overline{IM}=0.3355, \overline{\triangle IM}=0.048$).
Standard errors for the total elasticity is calculated by delta method.

V. Concluding Remarks

This paper introduces a simple endogenous growth model. The main contribution of the model is showing a labor allocation mechanism which divides workers between research(skilled) and production(unskilled) sectors, and explains how this labor allocation is determined by the supply and demand condition of the skilled labor in the economy. In the model, this labor allocation is closely related to the long-run growth rate of the economy. That is, the long-run growth rate of the economy can be expressed as a function of the labor allocation. The model also shows comparative analyses that explain the effect of skill biased technological change and increasing supply of skilled workers on the labor allocation, hence on the long-run growth rate of the economy.

Followings are some implications drawn from the modified endogenous growth model with heterogeneous workers.

First, the supply of skilled workers may increase or decrease in accordance with changes of college enrollment rates, and by combining with the demand condition of skilled workers in the economy, this change affects on the employment structure, hence the long-run growth rate of the economy.

Second, in the model, not only the supply of skilled labor but also its distribution plays an important role in determining the labor allocation. This feature of the model provides an implication on income distribution. For example, if the demand of skilled labor is the same while the supply of skilled labor goes up (mostly due to enhanced educational attainment), the income distribution will be further deteriorated because the barriers to entry into skilled sector become higher and the income gap between skilled and unskilled workers will become bigger. In other words, if the supply of skilled labor increases with the same demand condition, then some marginal skilled workers in the skilled sector exit to the unskilled sector, which leads to depreciation of real income of these medium level earners, thereby further aggravating income polarization. However, if the supply of skilled labor increases along with the demand of skilled labor, the overall wage levels will go up and such an aggravation would not be caused.

Third, some comparative static analyses can be carried out based upon the model. For instance, skill biased technological progress under ceteris paribus condition has strong positive effect on the long-run growth rate of the economy but its effect on the labor allocation appears to be relatively negligible. Meanwhile, an increase of the supply of skilled labor causes more severe competition in entering the skilled sector but itse ffect on the long-run growth rate is relatively negligible.

Last but not least, the proposed model can be extended to an open economy. When an economy is opened form its autarky state, two kinds of new aspects can be considered;

trade of goods and knowledge spillover between countries. The extended model in this paper captures these features by adopting the idea introduced by Rivera-Batiz & Romer(1991). Rivera-Batiz & Romer(1991) extends Romer(1990) model to an open economy case and shows that the long-run growth rate of economies are effected by economic openness through the specialization and knowledge spillover channels. Note that the proposed model in this paper extends Romer(1990) model by incorporating workers skill heterogeneity to explain the labor allocation mechanism more specifically. By extending the heterogeneous model to an open economy, it can be shown that how economic openness affects on the labor allocation between skilled and unskilled sectors. Following examples explain how the economic openness affects employment structure through trade and knowledge spillover channels.

When trade takes place after an economy is open, final goods production sector of each country will be able to use more variety of intermediate goods through import hence both the productivity of final good sector and the license payment on each design of intermediate good increases. Accordingly, wages increase in both research and final goods production sector and the relative size of such increase differs in accordance with the total amount of a country’s accumulated knowledge stock. For instance, advanced countries with lots of accumulated knowledge have relative comparative advantage in research(skilled) sector. Thus, the labor demand of research sector will goes up in advanced countries when they open. On the contrary, in the case of less advanced countries with comparative advantages in final good production, the labor demand will relatively more increase in the final goods production(unskilled) sector when they open. Therefore, when the economies are open, employment in the research sector will be enlarged for the advanced country and, at the same time, employment in the production sector will be enlarged for the less advanced country.

The above mentioned examples are about the effect of economic openness through specialization channel. Likewise, one can also take a look at how economic openness affects the employment structure in consideration of knowledge spillover channel. Active transfer of knowledge enables countries to tap into the accumulated knowledge of other countries not to mention of theirs, thereby enhances the overall productivity in their research sector. This positive effect of the knowledge spillover may be particularly strong in less advanced countries which has relatively small amount of accumulated knowledge. Accordingly, the employment increases in research sector caused by increased productivity outweighs the employment decrease in the sector caused due to the aforementioned trade specialization factor when such a knowledge spillover effect is quite strong, which can be translated into the possibility of more employment in the research sector of less advanced country.

< reference >

Acemoglu, D. (1998), “Why do new technologies complement skills? Directed technical changes and wage inequality”, *Quarterly Journal of Economics*

Acemoglu, D. (2002), “Directed Technical Change”, *Review of Economic Studies*

Acemoglu, D. and J. Ventura (2002), “The World Income Distribution”, *Quarterly Journal of Economics*

Barro, R. J. and J. H. Lee (2000), “International Data on Educational Attainment: Updates and Implications”, *CID Working Paper No.42*

Bartel, A. P. and N. Sicherman (1997), “Technological Change and Wages: An Inter-Industry Analysis”, *NBER Working Paper No.5941*

Blanchard, O. J. (1985), “Debt, Deficits, and Finite Horizons”, *Journal of Political Economy*

Blanchard, O. J. and S. Fischer (1989), *Lectures on Macroeconomics*, The MIT Press

Blanchard, E. and G. Willmann (2008), “Trade, Education, and the Shrinking Middle Class”, *Mimeo*

Bottazzi, L. and G. Peri (2005), “The International Dynamics of R&D and Innovation in the Short Run and in the Long Run”, *Mimeo*

Card, D. and J. E. Dinardo (2002), “Skill Biased Technological Change and Rising Wage Inequality: Some Problems and Puzzles”, *NBER Working Paper No.8769*

Ciccone, A. and G. Peri (2005), “Long-Run Substitutability between More and Less Educated Workers: Evidence from U.S. States, 1950-1990”, *Economics and Statistics*

Coe, D. T. and E. Helpman (1995), “International R&D Spillovers”, *European Economic Review*

Coe, D. T., E. Helpman and A. W. Hoffmaister (2009), “International R&D Spillovers and Institutions”, *European Economic Review*

Dinopoulos, E. and P. S. Segerstrom (1999), “A Shumpeterian Model of Protection and Relative Wages”, *The American Economic Review*

Feenstra, R. C., R. E. Lipsey and H. P. Bowen (1997), “World Trade Flows, 1970-1992, with production and tariff data", *NBER Working Paper No.5910*

Feenstra, R. C. (1996), “Trade and Uneven Growth", J*ournal of Development Economics*

Feenstra, R. C. (2000), “World Trade Flows, 1980-1997", *Center for International Data*

Feenstra, R. C. (2004), *Advanced International Trade*, Princeton University Press

Frantzen, D. (2000), “R&D, Human Capital and International Technology Spillovers: A Cross-country Analysis”, *Scandinavian Journal of Economics*

Ginarte, J. C. and W.G. Park (1997), "Determinants of patent rights: a cross national study" *Research Policy*

Grossman, G. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, MIT Press

Ingram, B. F. and G. R. Neumann (2000), “The Returns to Skill”, *Labour Economics, Vol13*

Iranzo, S. and G. Peri (2006), “Schooling Externalities, Technology and Productivity: Theory and Evidence from U.S. States”, *Review of Economics and Statistics*

Katz, L. F. and K. M. Murphy (1992), “Changes in Relative Wages, 1963-1987: Supply and Demand Factors”, *Quarterly Journal of Economics*

Keller, W. (1998), “Are international R&D spillovers trade-related? Analyzing spillovers among randomly matched trade partners”, *European Economic Review*

Lee, G. (2006), “The effectiveness of international knowledge spillover channels”, *European Economic Review*

Mello, M. (2008), “Skilled Labor, Unskilled Labor, and Economic Growth”, *Economics Letters*

Mendes de Oliveria, M., M. C. Santos and B. F. Kiker (2000), “The role of Human Capital and Technological Change in Overeducation”, *Economics of Education Review*

Park, W.G. and D. Lippoldt (2005), "International licensing and the strengthening of intellectual property rights in developing countries during the 1990s" *OECD Economic Studies*

Park, W. G. (2008), “International Patent Protection:1960-2005”, Research Policy
Rivera-Batiz, L. A. and P. M. Romer (1991), “Economic Integration and Endogenous Growth”, *Quarterly Journal of Economics*

Romer, P. M. (1990), “Endogenous Technological Change”, *Journal of Political Economy*

Sattinger, M. (1980), *Capital and the Distribution of Labor Earnings*, North-Holland

Yaari, M. E. (1965), “Uncertain Lifetime, Life Insurance, and the Theory of the Consumer”, *Review of Economic Studies*

Yeaple, S. R. (2006), “A Simple Model of Firm Heterogeneity, International Trade, and Wages”, *Journal of International Economics*