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Technological Transfer through Foreign Direct Investment and Endogenous Growth

Kenichiro Ikeshita

1 Introduction

Dynamics of national economies are much related to the patterns of trade. Conversely, we can often see that the change of trade is characterized by dynamics of economy. Vernon (1966) provided his famous product-cycle hypothesis in his celebrated article. He argued new products are invented by R&D activities in developed countries and firms in developed countries have a large comparative advantage to produce new goods. But as the technologies of production become formulated, less developed countries attempt to imitate them and the gap of wage determines the comparative advantage. Eventually the goods are produced in less developed countries.

This hypothesis was first modeled by Krugman (1979). He analyzed technological transfer had negative effects on economic welfare. But he assumed the growth and imitation rates are given exogenously. After ten years in which growth theory made rapid progress, Grossman and Helpman (1991a, 1991b) succeeded to integrate growth theory and product-cycle hypothesis. In other words, they succeeded to determine growth rate and imitation rate simultaneously. Grossman and Helpman (1991a) concluded that technological transfer by imitation is positively related to economic growth with a variety expansion endogenous growth model.

On the other hand, in the field of international economics, foreign direct investment is regarded as one of the possibilities to which technology is transferred. But the relation between foreign direct investment and economic growth has not been researched enough.

The purpose of this paper is to investigate the relationship between foreign direct investment and economic growth by using that variety expansion endogenous growth model. The crucial point of this model is that labors in developed countries are employed and they educate how to produce the goods when foreign direct investment is carried out and the location of production is transferred. It is natural to consider that these activities are costly.

In section 2, we construct the product-cycle model that shows the technologies are transferred by foreign direct investment. In section 3, we concentrate our analysis on the steady state of the model. The model is reduced to two curves for growth rate and the rate of technological transfer. We can see that growth and technological transfer can have negative correlation each other if cost of technological transfer is high enough. In section 4, we investigate the effects of industrial policies that promote research or foreign direct investment. Finally in section 5, we mention our conclusions.

2 The Model

In this section, we set up the model that is considered in this paper. In all of this paper, we call developed countries and less developed countries "north" and "south" respectively. Both countries have final good sectors and production functions are identical. Real number t describes time and $Y^i(t)$ is the quantity of final output in country i at time t. the production function is represented by

$$Y^i(t)=A(K^i(t))^{\beta}(D^i(t))^{1-\beta}. \tag{2.1}$$

$D^i(t)$ is an index constructed by differentiated intermediate goods and expressed as

$$D^i(t)=\left[\int_0^{n(t)} x_j^i(t)^{\alpha}dj\right]^{\frac{1}{\alpha}}. \tag{2.2}$$

$K^i(t)$ is capital stock in country i at time t, $n(t)$ denotes the number of available intermediate goods at time t. For simplicity, we suppose $n(t)$ takes a real number. A is the parameter of productivity and $x_j^i(t)$ is the quantity of j-th intermediate goods used for the production of final good in country i at time t. j is an index of deferentiated intermediate goods and takes the value between 0 and $n(t)$. α and β are parameters and $0<\alpha,\beta<1$.

Here we clarify the markets of final and intermediate goods. Final goods cannot move internationally and be produced under the perfect competitive condition in each country. Intermediate goods are traded across the countries. The firm which produces each kind of intermediate good is located in north or south but the market is opened to the world. So one kind of intermediate good has one price. We regard the final good in north as numeraire and demote $q(t)$ as the price of final output in south. $R^N(t)$ and $p^j(t)$ denote the rental rate of capital in north and the price of j-th intermediate goods respectively. From the profit maximization, we derive

$$K^N(t)=\beta\frac{Y^N(t)}{R^N(t)}, \tag{2.3}$$

$$x_j^N(t)=\frac{(1-\beta)Y^N(t)}{\int_0^{n(t)} p_j(t)^{\frac{\alpha}{1-\alpha}}dj}p_j(t)^{\frac{1}{\alpha-1}}. \tag{2.4}$$

Similarly, for the final good sector in south, we derive

$$K^S(t)=\beta\frac{q(t)Y^S(t)}{R^S(t)}, \tag{2.5}$$

$$x_j^S(t)=\frac{(1-\beta)q(t)Y^S(t)}{\int_0^{n(t)} p_j(t)^{\frac{\alpha}{1-\alpha}}dj}p_j(t)^{\frac{1}{\alpha-1}}. \tag{2.6}$$

where $R^S(t)$ is the rental rate of capital in south. From (2.4) and (2.6), the world demand of j-th intermediate goods is expressed as

$$x_j(t)=x_j^N(t)+x_j^S(t)=\frac{(1-\beta)(Y^N(t)+q(t)Y^S(t))}{\int_0^{n(t)} p_j(t)^{\frac{\alpha}{1-\alpha}}dj}p_j(t)^{\frac{1}{\alpha-1}}. \tag{2.7}$$

The firms that are located in the north or south supply the kinds of goods monopolistically and earn the profit $\pi_j(t)$. Then each firm determines the price and the quantity of the goods that maximized the firm's profit. We suppose that one unit of labor is necessary to produce one unit of intermediate good.

First we consider the case in which the j-th intermediate goods is produced in the north. This means that the marginal cost which firm confronts is wage rate in north $w^N(t)$. Then the price, output and profit of intermediate goods produced in north are given as

$$p_j(t)=p^N(t)=\frac{w^N(t)}{\alpha}, \tag{2.8}$$

$$x_j(t)=x^N(t)=\frac{(1-\beta)(Y^N(t)+q(t)Y^S(t))}{\int_0^{n(t)} p_j(t)^{\frac{\alpha}{1-\alpha}}dj}p^N(t)^{\frac{1}{\alpha-1}}, \tag{2.9}$$

$$\pi_j(t)=\pi^N(t)=(1-\alpha)p^N(t)x^N(t). \tag{2.10}$$

Second we consider that the firm of j-th intermediate good has changed its location and produce the goods in south. In this case, the firm maximizes the profit under the condition that marginal cost is wage rate in south and the following relations are derived.

$$p_j(t)=p^S(t)=\frac{w^S(t)}{\alpha}, \tag{2.11}$$

$$x_j(t)=x^S(t)=\frac{(1-\beta)(Y^N(t)+q(t)Y^S(t))}{\int_0^{n(t)} p_j(t)^{\frac{\alpha}{1-\alpha}}dj}p^S(t)^{\frac{1}{\alpha-1}}, \tag{2.12}$$

$$\pi_j(t)=\pi^S(t)=(1-\alpha)p^S(t)x^S(t). \tag{2.13}$$

Here, as the incentive condition that there really exists foreign direct investment, we assume that the wage in south is lower than that of north.

$$w^S(t)<w^N(t). \tag{2.14}$$

If this condition is satisfied, the firm that changed its location to the south sets its price lower than when it is in the north and its profit increases because the price elasticity of demand is larger than 1. Then we can call (2.14) the incentive condition for foreign direct investment. Of course, the wages are determined endogenously. We must consider whether this condition is plausible or not. But we will confirm that this condition is satisfied in any value of parameters in section 3.

Then, consider R&D activity and foreign direct investment in north. The innovation in north takes the form that the number of differenciated intermediate goods increases. The number of available intermediate goods is $n(t)$. We assume that the employed workers in R&D sector and the level of knowledge in the whole economy provides the increase of $n(t)$. then the increase of number of goods is expressed as[1)]

$$\dot{n}(t)=\frac{H(t)}{a}L^{I}(t). \tag{2.15}$$

where $L^{I}(t)$ is labor input to R&D sector and $H(t)$ is the level of knowledge in the economy. The change of location is realized by the activity of the firm that produce intermediate goods in the north. When we imagine the technological diffusions in the real world, it seems implausible to assume that the technologies are transferred as soon as those are invented in developed countries. Technology and organization to produce goods must be formulated and educated for south labors. The important view is these technological transformation or education are highly labor intensive activities. Then we formulate these costly activities as the following stochastic structure. u denotes the time when technology is transferred to south by foreign direct investment. The probability that $u<\tau$ is expressed as

$$Prob(u<\tau)=1-e^{-\int_t^\tau \mu(s)ds}. \tag{2.16}$$

Precisely this means the conditional probability that technology has not been transferred to south until the time t. $\mu(t)$ depends on the level of effort by the firm. To cause some value of $\mu(t)$, the firm must employ the northern labor to formulate the technology or educate the know-how to labor in south. Moreover we consider the level of knowledge in the north helps to transfer the technology. Then $\mu(t)$ is specified as

$$\mu(t)=\frac{H(t)}{a^{T}}L^{T}(t) \tag{2.17}$$

where a^{T} is a parameter that shows the cost of technological transfer and L^{T} is the labor employed for transfer activities. Let $G(t,u)=1-\exp\left(-\int_t^u \mu(s)ds\right)$ to be its conditional distribution function of (2.16). We can interpret $\mu(t)$ as the flow of probability that technology is transferred and the density function is given by

$$g(t,u)=\mu(u)e^{-\int_t^u \mu(s)ds}. \tag{2.18}$$

Let $V^{N}(t)$ and $V^{S}(t)$ denote the stock market value of firm located in north and south respectively. $V^{N}(t,u)$ denotes the sum of present value profit when foreign direct investment succeeded at the time u. Then by using (2.18), $V^{N}(t)$ is given by

$$V^{N}(t)=\int_t^\infty g(t,u)V^{N}(t,u)du. \tag{2.19}$$

Consider the components of $V^{N}(t)$. The firm in the north invests in technology transfer by using

1) A dot on variable represents derivative for time. Then $\dot{n}\equiv\frac{dn}{dt}$

a part of its profit. To cause some value of intensity $\mu(t)$, $a^T\mu(t)/H(t)$ units of labor are necessary and paid wage to them is $w^N(t)a^T\mu(t)/H(t)$. When technology is transferred at the time u, the sum of present value profit after the time u, evaluated at t, is equal to exp $\left(-\int_t^u r^N(s)ds\right)V^S(u)$. Then

$$V^N(t, u)=\int_t^u e^{-\int_t^\tau r^N(s)ds}\left[\pi^N(\tau)-\frac{w^N(\tau)a^T}{H(t)}\mu(\tau)\right]d\tau+e^{-\int_t^u r^N(s)ds}V^S(u). \tag{2.20}$$

By differentiating $V^N(t)$ with time t, we derive the following relation.

$$r^N(t)V^N(t)=\left[\pi^N(t)-\frac{w^N(t)a^T}{H(t)}\mu(t)\right]+\mu(t)(V^S(t)-V^N(t))+\dot{V}^N(t) \tag{2.21}$$

Next, we would like to show the relation between $V^N(t)$ and (2.15) which expresses R&D technology. If $L^I(t)$ units of labor is employed in R&D, $H(t)L^I(t)/a$ kinds of new goods are developed. Development of new good provides the value $V^N(t)$ to the firm. Then firms earn the value $V^N(t)H(t)L^I(t)/a$ with employing $L^I(t)$ units of labor in R&D sector. On the other hand, the firms must pay the wage $w^N(t)L^I(t)$. If $V^N(t)H(t)L^I(t)/\mathrm{a}>w^N(t)L^I(t)$, $L^I(t)$ is not determined as finite value. Conversely, $V^N(t)H(t)L^I(t)/a<w^N(t)L^I(t)$, $L^I(t)$ must be zero and the resources are not invested in R&D activities, then, as the condition that finite quantity of labor is employed, we derive

$$\frac{w^N(t)a}{H(t)}=V^N(t). \tag{2.22}$$

Similarly, we can show the relation between among $V^N(t)$, $V^S(t)$ and (2.17) which represents technology transfer. When firm in north cause the intensity $\mu(t)$, the paid wage is $w^N(t)a^T\mu(t)/H(t)$. Then the expected return is equal to $\mu(t)[V^S(t)-V^N(t)]$. Moreover we derive $V^S(t)>V^N(t)$ from the incentive condition for foreign direct investment. A firm in north choose its intensity to maximize the expected net profit $\mu(t)[V^N(t)-V^S(t)]-w^N(t)a^T\mu(t)/H(t)$. In the case where $V^N(t)-V^S(t)>w^N(t)a^T\mu(t)$, the intensity is not determined as finite value. On the other hand, in the case where $V^N(t)-V^S(t)<w^N(t)a^TH(t)$, the expected net profit is below the cost for any intensity. Therefore $\mu(t)=0$ and technology transfer does not happen. All the way, the intensity is determined as a finite positive value, the following condition must be satisfied.

$$\frac{w^N(t)a^T}{H(t)}=V^S(t)-V^N(t). \tag{2.23}$$

(2.21) and (2.23) imply

$$r^N(t)V^N(t)=\pi^N(t)+\dot{V}^N(t). \tag{2.24}$$

From (2.22) and (2.23), we can derive $V^S(t)$ as follow.

$$V^S(t)=\frac{w^N(t)(a+a^T)}{H(t)}. \tag{2.25}$$

We will now mention the knowledge level in the economy. R&D activity provides not only the blueprints of intermediate goods but also the increase of the knowledge level in the whole economy. We assume that $H(t)$ is proportionate to the number of goods invented until time t. Using appropriate measure of knowledge level, $H(t)$ is given by

$$H(t)=n(t). \tag{2.26}$$

Let $n^N(t)$ and $n^S(t)$ be respectively the number of variety produced in north and south. Obviously $n(t)=n^N(t)+n^S(t)$. Then a demand of good produced in north or south is derived as follow (For a moment, we omit t which represents time).

$$x^N=\frac{(1-\beta)(Y^N+qY^S)}{n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}}(p^N)^{\frac{1}{\alpha-1}}, \tag{2.27}$$

$$x^S=\frac{(1-\beta)(Y^N+qY^S)}{n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}}(p^S)^{\frac{1}{\alpha-1}}. \tag{2.28}$$

Moreover define x^i_j as the country j's demand of good produced in country i. Then x^i_N is given by

$$x^N_N=\frac{(1-\beta)Y^N}{n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}}(p^N)^{\frac{1}{\alpha-1}}, \tag{2.29}$$

$$x^S_N=\frac{(1-\beta)Y^N}{n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}}(p^S)^{\frac{1}{\alpha-1}}. \tag{2.30}$$

From (2.2), (2.29) and (2.30), we can confirm this equation.

$$D^N=[n^N(x^N_N)^\alpha+n^S(x^S_N)^\alpha]^{\frac{1}{\alpha}}=\frac{(1-\beta)Y^N}{[n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}]^{\frac{\alpha-1}{\alpha}}}. \tag{2.31}$$

We introduce a new price index $P(t)=[n^N(p^N)^{\frac{\alpha}{\alpha-1}}+n^S(p^S)^{\frac{\alpha}{\alpha-1}}]^{\frac{\alpha-1}{\alpha}}$ and (2.31) is rewritten as

$$D(t)=\frac{(1-\beta)Y^N(t)}{P(t)}. \tag{2.32}$$

Substituting (2.3) and (2.33) to (2.1), we derive

$$R^N(t)^\beta P(t)^{1-\beta}=A\beta^\beta(1-\beta)^{1-\beta}. \tag{2.33}$$

From similar procedure for south, we derive

$$R^S(t)^\beta P(t)^{1-\beta}=Aq(t)\beta^\beta(1-\beta)^{1-\beta}. \tag{2.34}$$

From (2.33) and (2.34), the relation between each country's rental rate of capital and the price of final good in south must satisfy the following relation.

$$\left(\frac{R^S(t)}{R^N(t)}\right)^\beta=q(t). \tag{2.35}$$

Then we consider the behavior of consumption. Households earn wage by supplying their labor force and receive the interest from their assets. They decide how much to consume and save. We assume that each household has one unit of labor and the total number of household is L^i. Each household also has the same utility function. Let $c^i(t)$ be the consumption per capita in each country. Then they distribute their income to consumption or saving to maximize their total utility that is given by

$$U^i=\int_0^\infty e^{-\rho\tau}\log c^i(\tau)d\tau \tag{2.36}$$

where ρ is subjective discount rate and $\log c^i(t)$ is flow of utility when a household in country i consume the quantity $c^i(t)$. We define $f^N(t)$ as the asset held by a household in north. Then the intertemporal budget constraint is expressed by

$$\dot{f}^N(t)=w^N(t)+r^N(t)f^N(t)-c^N(t). \tag{2.37}$$

Each household in north chooses the path of consumption to maximize (2.36) subject to (2.37) and the initial asset condition. By using Maximum Principal, we derive the first order condition as

$$\frac{\dot{c}^N(t)}{c^N(t)}=r^N(t)-\rho. \tag{2.38}$$

We assume $C^N(t)$ is the total consumption in north and L^N is the total number of household in north. Obviously $C^N(t)=c^N(t)L^N$. If L^N is constant over time, the growth rate of $C^N(t)$ is same as the growth rate of consumption per capita that is given by

$$\frac{\dot{C}^N(t)}{C^N(t)}=r^N(t)-\rho. \tag{2.39}$$

Similarly the intertemporal budget constraint in south is

$$\dot{f}^S(t)=w^S(t)+r^S(t)f^S(t)-q(t)c^S(t). \tag{2.40}$$

Then the growth rate of total consumption in south is given by

$$\frac{\dot{C}^S(t)}{C^S(t)}=r^N(t)-\rho-\frac{\dot{q}(t)}{q(t)}. \tag{2.41}$$

Next we consider about the market equilibria of final good and labor. In each country, final good is used to domestic consumption or domestic capital accumulation.

$$Y^i(t)=C^i(t)+\dot{K}^i(t). \tag{2.42}$$

For simplicity, we assume that capital does not depreciate in this paper[2]. Then the rental rate of capital is equal to the interest rate.

$$R^i(t)=r^i(t). \tag{2.43}$$

For the labor market in north, $a\dot{n}(t)/n(t)$ units of labor are employed to R&D activity because of (2.15) and (2.26). At time t the number of firm which is located in north is $n^N(t)$ and we consider the case in which all the firm in north choose same value of $\mu(t)$[3]. From (2.17) and (2.26), $a^T\mu(t)n^N(t)/n(t)$ units of labor is employed for technological transfer. Finally the quantity of intermediate goods produced in north is $n^N(t)x^N(t)$, which is equal to the labor employed for production of intermediate goods. Then we can derive

$$a\frac{\dot{n}(t)}{n(t)}+a^T\mu(t)\frac{n^N(t)}{n(t)}+n^N(t)x^N(t)=L^N. \tag{2.44}$$

On the other hand, the southern labor is used for only the production of intermediate good. Then

2) We here assume capital does not move across the regions. But this assumption does not much limit the follow analysis because interest rates in both countries become identical in the steady state.

3) The economic environment that northern firm confronts is indifferent to the variety of intermediate goods.

$$n^S(t)x^S(t)=L^S. \tag{2.45}$$

Finally, we already mentioned that $\mu(t)$ is regarded as the flow of probability to which technology is transferred. For large $n(t)$, $\mu(t)$ will be same as the ratio of northern products that are transferred to south per unit of time.

$$\mu(t)=\frac{\dot{n}^S(t)}{n^N(t)}. \tag{2.46}$$

3 Steady State Equilibrium

In this section, we will investigate the model that is specified above. First we define the steady state as the state in which all the growth rates of variable are constant. But this statement does not mean the growth rates of all variables are identical. Here we would like to define some new variables. Let $\xi^i(t)$ be the share of country i in the total number of differentiated products. $g(t)$ is the growth rate of total number of goods and $g^i(t)$ is the growth rates of the number of goods manufactured in each country. From $n(t)=n^N(t)+n^S(t)$,

$$g(t)=\xi^N(t)g^N(t)+\xi^S(t)g^S(t). \tag{3.1}$$

In the steady state, $\xi^i(t)$ become constant and $g=g^N=g^S$. Also (2.46) means that the intensity $\mu(t)$ is the rate of technological transfer. From its definition, $\mu(t)=g^S(t)\xi^S(t)/(1-\xi^S(t))$. In the steady state, because $g^S(t)=g$ and the share is constant, $\mu(t)$ is constant and given by

$$\xi^S=\frac{\mu}{\mu+g}. \tag{3.2}$$

From (2.35), (2.38), (2.41) and (2.43), $r^i(t)$ and $q(t)$ become constant. Moreover (2.44) is rewritten with g, μ and ξ^N as

$$ag+a^T\mu\xi^N+n^N(t)x^N(t)=L^N \tag{3.3}$$

which implies the quantity of labor employed in manufacturing is constant. From (2.27) and (2.28), we can derive

$$\left(\frac{L^S}{L^N-ag-a^T\mu\xi^N}\frac{g}{\mu}\right)^{\alpha-1}=\frac{w^S}{w^N}. \tag{3.4}$$

Then $w^N(t)$ and $w^S(t)$ have same growth rate in the steady state. $P(t)$ is constant over time from (2.33) and we derive $\dot{w}^i/w^i=(1-\alpha)g/\alpha$ from $\dot{P}(t)=0$. The constancy of q and equilibrium condition of the final goods market imply that $Y^N(t)$, $Y^S(t)$, $C^N(t)$, $C^S(t)$, $K^N(t)$ and $K^S(t)$ have the same growth rates. Moreover, because of the constancy of $n^N(t)x^N(t)$, all growth rate of them are equal to those of wages, which means $q=1$.

From (3.3), (2.8) and (2.10), the profit earned by the firm in the north is expressed by

$$\pi^N(t)=\frac{1-\alpha}{\alpha}w^N(t)(L^N-ag-a^T\mu\xi^N)\frac{1}{n^N(t)}. \tag{3.5}$$

From (3.5), (2.22), (2.24) and (2.26), the steady state interest rate in north is

$$r^N = \frac{1-\alpha}{\alpha}\frac{1}{a}(L^N - ag - a^T\mu\xi^N)\frac{1}{\xi^N} + \frac{\dot{w}^N}{w^N} - g. \tag{3.6}$$

Because C^N and w^N have the same growth rate, we derive

$$\frac{1-\alpha}{\alpha}\left(\frac{L^N}{a} - g - \frac{a^T}{a}\mu\xi^N\right)\frac{1}{\xi^N} = g + \rho. \tag{3.7}$$

By differentiating $V^S(t)$ with t, we obtain $\dot{V}^S(t) = r^N(t)V^S(t) - \pi^S(t)$. From (2.11), (2.25), (2.26), (2.28) and (2.45),

$$r^N = \frac{1-\alpha}{\alpha}\left(\frac{L^S}{a+a^T}\right)\frac{w^S}{w^N}\frac{1}{\xi^S} + \frac{\dot{w}^N}{w^N} - g. \tag{3.8}$$

Using (3.4), (3.6) and (3.8), we can obtain

$$\frac{w^S}{w^N} = \left(\frac{a}{a+a^T}\right)^{\frac{1-\alpha}{\alpha}} < 1. \tag{3.9}$$

Then we can conclude that the incentive condition for foreign direct investment (2.14) is satisfied in the steady state. By substituting (3.10) to (3.8) and using the fact that C^N and w^N have the same growth rates, we derive

$$\frac{1-\alpha}{\alpha}\left(\frac{L^S}{a+a^T}\right)\left(\frac{a}{a+a^T}\right)^{\frac{1-\alpha}{\alpha}}\frac{1}{\xi^S} = g + \rho. \tag{3.10}$$

(3.7) and (3.11) express the relation between g and μ that must be satisfied in the steady state and depicted by *NN*-curve and *SS*-curve respectively in figure 1 and 2. The intersection point E represents the steady state equilibrium growth rate and technological transfer[4]. To investigate the shapes of these curves is critical to the following analysis. First we consider the *NN*-curve. In conclusion, its slope can be upward or downward. To discuss it, we have to mention that (3.7) represents

$$\frac{\pi^N}{V^N} = g + \rho. \tag{3.11}$$

In other words, the profit rate is equal to the sum of the growth rate g and the subjective discount rate ρ. $g+\rho$ expresses the capital cost. Then larger g corresponds to higher real cost of capital. At the same time, a rise in g increases the employment of R&D activity. And it means larger share of the goods in north. The rise in the share conversely decreases the profit per brand. Then to keep equality of (3.7), μ must effect on increase in the profit rate in the case g increases. A rise in μ directly increases the employment in technology transfer activity and indirectly decreases the share of northern products. Then if the rise in μ does not decrease the labor in manufacturing and this effect does not decrease the profit rate largely, we can conclude that the rise in μ increases the profit rate, which means the *NN*-curve is upward. In other words, if a^T which represents the cost of technology transfer is small enough and α which represents the share

4) $L^N/(a+a^T) > \frac{1-\alpha}{\alpha}\left(\frac{L^S}{a+a^T}\right)\left(\frac{a}{a+a^T}\right)^{\frac{1-\alpha}{\alpha}}$ is necessary and sufficient condition for two curves to intersect uniquely and we assume this condition is satisfied.

of wage in the whole sale is large enough, the slope of the NN-curve is positive. This case is illustrated in figure 1. Conversely, if a^T is large and α is small, NN-curve is illustrated as a downward in figure 2. As a condition of parameters, the slope of NN-curve depends on the relation between $\bar{g}=(1-\alpha)L^N/a-\alpha\rho$ and $L^N(a+a^T)$ 5).

In general, we easily imagine the transfer of specific technology is less difficult than the development of that. Also we often observe the share of wage in the sale is more than 50%. Then we can conclude that upward slope is representative case. Here, as a sufficient condition, we mention NN-curve become upward if

$$\frac{a^T}{a+a^T}<\alpha. \tag{3.12}$$

Next we consider the shape of SS-curve. For simplicity, a new variable γ is defined as

$$\gamma\equiv\frac{1-\alpha}{\alpha}\left(\frac{L^S}{a+a^T}\right)\left(\frac{a}{a+a^T}\right)^{\frac{1-\alpha}{\alpha}}. \tag{3.13}$$

And (3.11) is represented by

$$g=\gamma-\rho+\frac{\gamma(\gamma-\rho)}{\mu-\gamma}. \tag{3.14}$$

which is a hyperbola that has $g=\gamma-\rho$ and $\mu=\gamma$ as its asymptotes. Similarly to (3.7), (3.11) means

$$\frac{\pi^S}{V^S}=g+\rho. \tag{3.15}$$

A rise in g increases the capital cost and decreases the share of southern products. This implies the increase in profit rate expressed by LHS of (3.16). But this effect is less large as the effect to capital cost. Then to keep the equality of (3.16), μ must decrease to the share of southern brands and SS-curve is illustrated as a downward schedule.

5) From Grossman and Helpman (1991c), $\bar{g}=(1-\alpha)L^N/a-\alpha\rho$ is the growth rate when trade does not exist. Here we assume $\bar{g}$ is positive, which means the north is able to grow without trade.

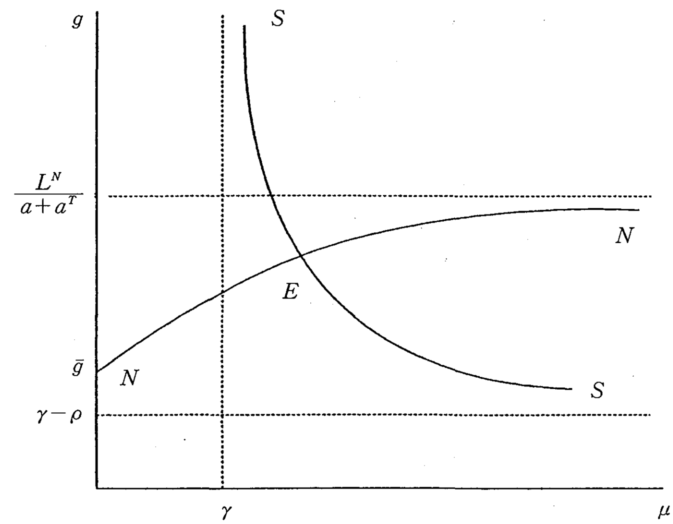

figure 1 the determination of g and μ (a) NN-curve slopes upward

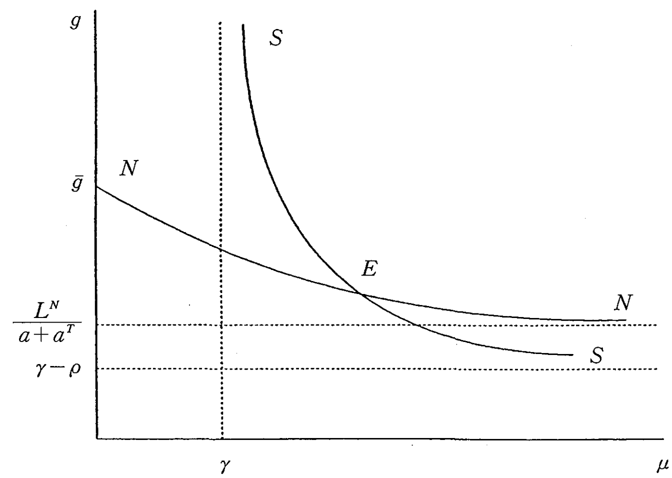

figure 2 the determination of g and μ (b) NN-curve slopes downward

4 Industrial Policy

In this section, we analyze how some policies used by government effect the growth rate or technological transfer. First, we consider the case in which government subsidizes the cost of R&D activity in order to promote it. We use ϕ^N to denote the fraction of development cost borne by the government. Then the private cost to develop a new product is $w^N(t)(1-\phi^N)a/n(t)$. Using it, (3.7) is replaced by

$$\frac{1-\alpha}{\alpha}\frac{1}{1-\phi^N}\left(\frac{L^N}{a}-g-\frac{a^T}{a}\mu\xi^N\right)\frac{1}{\xi^N}=g+\rho. \tag{4.1}$$

We see that the subsidy in research shifts the *NN*-curve upward from (4.1). Moreover, this subsidy also shifts *SS*-curve because $V^S(t)$ is modified as

$$V^S(t)=\frac{w^N(t)[(1-\phi^N)a+a^T]}{H(t)}. \tag{4.2}$$

From (4.2), (3.8) which represents the wage difference, becomes

$$\frac{w^S(t)}{w^N(t)}=\left[\frac{(1-\phi^N)a}{(1-\phi^N)a+a^T}\right]^{\frac{1-\alpha}{\alpha}}. \tag{4.3}$$

We can see the subsidy to research expands the wage difference. In general, the subsidy to R&D activity promotes the demand of labor for the research sector. This effect increases the wage in north relatively. (3.11) is replaced by

$$\frac{1-\alpha}{\alpha}\left[\frac{L^S}{(1-\phi^N)a+a^T}\right]\left[\frac{(1-\phi^N)a}{(1-\phi^N)a+a^T}\right]^{\frac{1-\alpha}{\alpha}}\frac{1}{\xi^S}=g+\rho. \tag{4.4}$$

The shift of *SS*-curve by the subsidy for the research is not unique. This subsidy decreases the relative wage that is expressed by the term in the second blanket of (4.4) and increases the term in first blanket. If the former effect is smaller than the latter, the profit rate represented by RHS of (4.4) increases by the subsidy. Then we see *SS*-curve shifts upward. Conversely, if the effect of the wage difference is large enough, the subsidy decreases the profit rate and makes the *SS*-curve shift downward.

The determinants of the shift are a^T, which represents the cost of technological transfer, and α, which is the fraction of paid wage in the sale. When $(1-\alpha)/\alpha a<1$, the subsidy to R&D activity shifts *SS*-curve upward. On the other hand, when $(1-\alpha)/\alpha a>1$, *SS*-curve shifts downward.

First we consider the case in which *NN*-curve is increasing and $(1-\alpha)/\alpha a<1$. This case is illustrated by figure 3. The subsidy for research makes both *NN*-curve and *SS*-curve shift upward and g increases. But the change of μ is not unique. If the *SS*-curve responds largely to the subsidy, μ may also increases. Note that (3.13) which is the sufficient condition for the *NN*-curve to have positive slope is equivalent to $(1-\alpha)/\alpha a<1$. Then if (3.13) is satisfied, the *NN*-curve has positive slope and the *SS*-curve shifts upward.

Next we analyze the case in which the *NN*-curve is increasing and $(1-\alpha)/\alpha a>1$. In this case, the *NN*-curve shifts upward and the *SS*-curve downward. Then we easily see that the subsidy to research decreases μ and the change of g depends on the shifts of two curves. If the shift of *NN*-curve is enough large, g may increase by the subsidy. This case is in figure 4.

Finally, let us consider the case in which the *NN*-curve is decreasing. In this case, the *SS*-curve never shifts upward because the condition $(1-\alpha)/\alpha a>1$ is not satisfied if the *NN*-curve is not decreasing. Then the subsidy for R&D activity makes the *NN*-curve shift upward and the *SS*-curve downward. Eventually we easily see that g increases and μ decreases. This case is

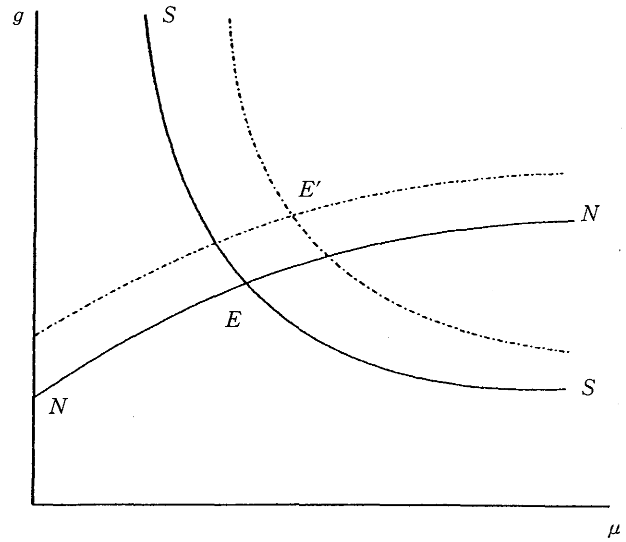

figure 3 the effect of subsidy to R&D activity (*a*) *NN*-curve slopes upward and *SS*-curve shifts upward

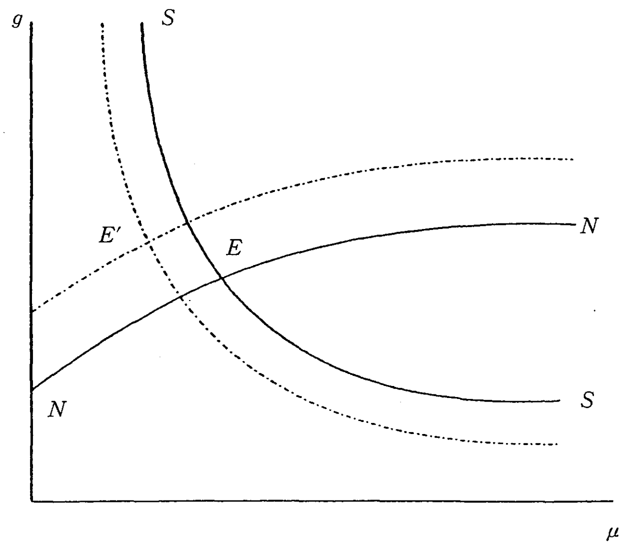

figure 4 the effect of subsidy to R&D activity (*b*) *NN*-curve slopes upward and *SS*-curve shifts downward

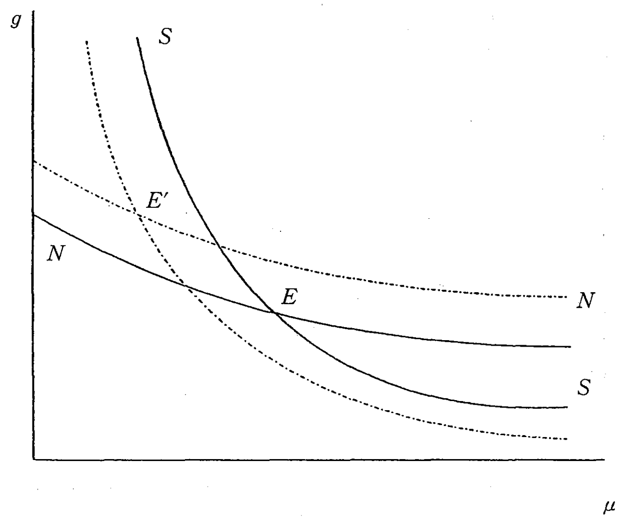

figure 5 the effect of subsidy to R&D activity (*c*) *NN*-curve slopes downward and *SS*-curve shifts downward

illustrated in figure 5.

Here we analyze the policies that promote technological transfer. We suppose that policy reduces the private cost of technological transfer by the fraction ϕ^S. In this case, the private cost of transfer is rewritten as $w^N(t)(1-\phi^S)a^T/n(t)$. Then $V^S(t)$ is modified as

$$V^S(t)=\frac{w^N(t)[a+(1-\phi^S)a^T]}{n(t)}. \tag{4.5}$$

Because of this subsidy, (3.8), which represents the wage difference, becomes

$$\frac{w^S(t)}{w^N(t)}=\left[\frac{a}{a+(1-\phi^S)a^T}\right]^{\frac{1-\alpha}{\alpha}}. \tag{4.6}$$

Then the subsidy to technological transfer reduces the wage difference. In general, these policies reduce the labor demand of north manufacturing. This effect makes the wage difference small.

Because of this subsidy, (3.11) that expresses the *SS*-curve is replaced by

$$\frac{1-\alpha}{\alpha}\left[\frac{L^S}{a+(1-\phi^S)a^T}\right]\left[\frac{a}{a+(1-\phi^S)a^T}\right]^{\frac{1-\alpha}{\alpha}}\frac{1}{\xi^S}=g+\rho. \tag{4.7}$$

In this case, the shift of the *SS*-curve by this subsidy is unique. the *SS*-curve shifts upward and the *NN*-curve do not move. Then in the case in which the *NN*-curve is increasing, this subsidy increases both g and μ. This case is in figure 6. On the other hand, when the *NN*-curve is decreasing, this policy promotes technological transfer but the economic growth is undermined. This case is illustrated in figure 7.

We have considered the effect of subsidy that promotes technology transfer. But we often observe that deregulation to multinational firms or construction of infrastructure to promote the

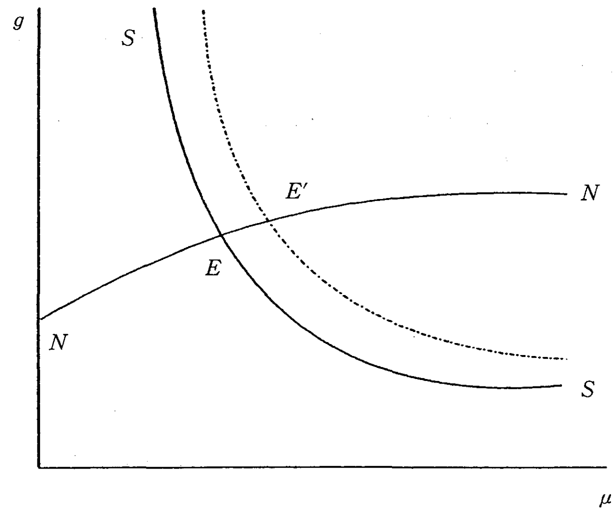

figure 6 the effect of subsidy to technological transfer (*a*) *NN*-curve slopes upward

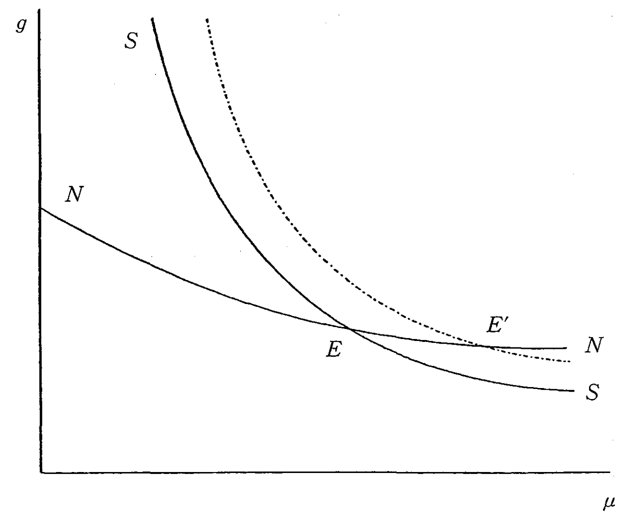

figure 7 the effect of subsidy to technological transfer (*b*) *NN*-curve slopes downward

entry of foreign firms rather than subsidy. These policies seem to decrease a^T rather than reducing the private cost of transfer by subsidizing. We finally analyze the policy that decreases a^T.

The important point is these policies have an effect that is different from the subsidy. The subsidy for technological transfer shifts only the SS-curve. On the other hand, the decrease of a^T shifts the NN-curve through the equilibrium of labor market (2.41). This case is in figure 8. When the NN-curve is increasing, the decrease in a^T provides a rise in g. but the effect to μ is not clear. If the shift of the SS-curve is not large, μ may decrease by the decline of a^T.

Moreover, by the decrease of a^T, the relation of $(1-\alpha)L^N/a-\alpha\rho$ and $L^N/(a+a^T)$ may converse. See the figure 9 in which the NN-curve is initially decreasing. In this case, $L^N/(a+a^T)$ is smaller than $(1-\alpha)L^N/a-\alpha\rho$. If the government takes the policy that decrease a^T enough, $L^N/(a+a^T)$ may become larger than $(1-\alpha)L^N/a-\alpha\rho$ and the slope of the NN-curve may become positive.

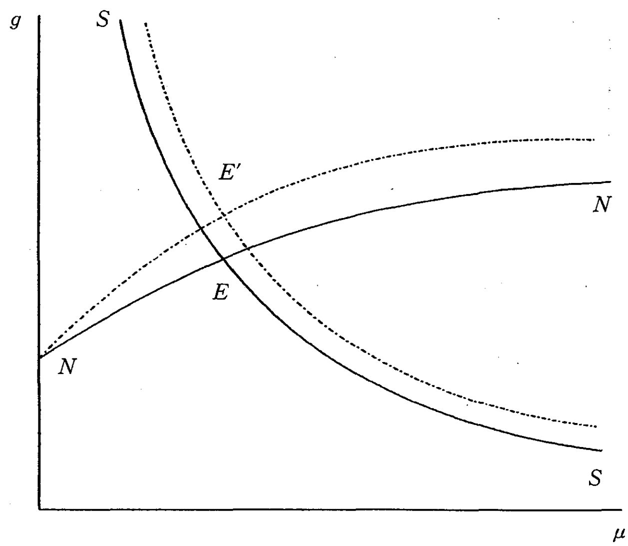

figure 8　the effect of policies that decrease a^T

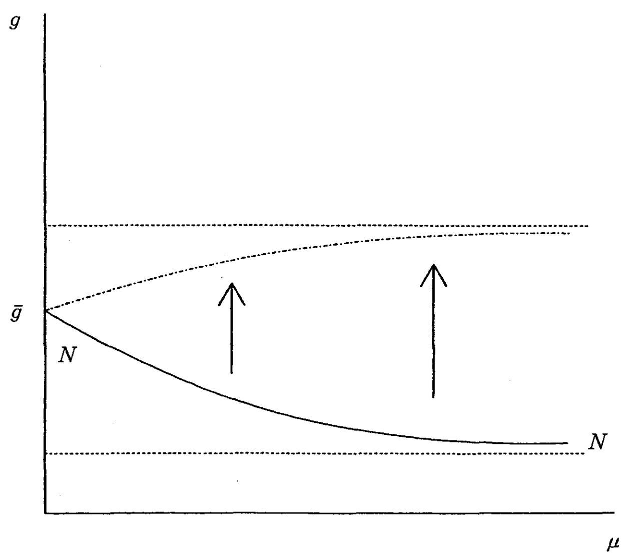

figure 9　the effect of policies that decrease a^T　(b) the change of the slope of NN-curve

5 Conclusion

In this paper, we have constructed the product-cycle model that technology is transferred through foreign direct investment and analyzed how the policies that promote research or foreign direct investment effects economic growth and technological transfer. We here mention two characteristic conclusions in our model. First we obtain the SS-curve as a declining curve. This result is different from Grossman and Helpman (1991a) that derives the SS-curve as a horizontal line. Second the slope of the NN-curve may be negative if the cost of transfer is high enough.

These results imply that the positive relation between the growth rate g and the rate of technological transfer μ is limited. And this fact makes the effects of policies more complicated. Even in the most general case that the NN-curve and the SS-curve shifts upward, whether or not the subsidy for research increases μ is not clear. Moreover this subsidy decreases μ clearly when NN-curve is decreasing.

On the other hand, the subsidy in technological transfer has relatively clear effects because this subsidy does not shift the NN-curve. Then both g and μ increase by the subsidy to transfer activity when the slope of the NN-curve is positive. Moreover the policies that reduce a^T itself may change the slope of the NN-curve from negative to positive. This means the initially negative relationship between g and μ is changed by the policies that reduce the cost of transfer.

Of course in this paper there remains some extensions for future research. First we have assumed that the northern labor is employed in transfer activity. We here ignore that the southern labor is also necessary for the technological transfer. We will investigate the case where the southern labor is used for transfer. Second, we have assumed there is one kind of labor in both countries. But when we consider the technological transfer of foreign direct investment, the discrimination between skilled and unskilled labor may be necessary. Hence introducing two kinds of labor, human capital and unskilled labor, to our model may be an interesting extension.

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