# 1 Introduction

Together with the rise of the BRICs (Brazil, Russia, India, and China) in the world economy, North-South trade has gained increasingly attentions. Empirics suggests that North-South trade accounts for a significant share of the total world trade and its pattern depends critically on technological innovations in developed countries and technology transfers to developing countries. Meanwhile, the theretical literature that describes prominently stylized facts about innovations and technology transfers between Northern developed economies (henceforth the North) and the Southern industrializing economies (henceforth the South) is Vernon's celebrated *product cycle.* In particular, Vernon (1966) argues that there is usually a life-cycle in a typical manufactured product. Inventions and initial manufacturing of a new advanced product happens in the North because of its R&D capabilities, human resources, and the need to locate production of a new product close to markets in the early stages of a product's life-time. When the product has become standard and popular, the technology is transferred and manufacturing of the old product shifts to the low-wage South. International trade features the exchange of the latest innovative goods produced by the North for older established goods produced predominantly in the South.

In present global international trading world, production and technology transfer through Foreign Direct Investment (FDI) of Multinational Corporations (MNCs) have also obtained considerably attentions. The underlying reason is that the production outscoring of MNCs is thought as an very important source of technology transfer to the Southern developing countries. By producing close to Southern firms and by employing Southern labor, MNCs introduce the new technology, educate local labor, and therefore directly and indirectly transfer technology. In literature, there is, however, very few work that considers roles of MNCs in Product Cycle mechanism.

Also, under Globalization, emerging Southern countries such as the BRICs with large labor force are integrating in to the world economy through international trade, which leads to changes in the relative labor supply of North-South partners. People in developed countries facing a decreasing and aging labor force often question whether an increase in Southern low wage labor attracts Foreign Direct Investment (FDI) of MNCs, hence takes away their jobs and pushes down their wage rate. At the same time, although there are limitations on labor movement from the South to the North,

high-skilled labor often concentrates to work in the North to take advantage of high wages and opportunities to improve their skills, which causes brain drain in less-developed countries. This paper, therefore, also attempts to address these questions.

With aforementioned motivations, this paper builds a dynamic general equilibrium model of an international product cycle originally characterized by an endogenous production transfer rate of MNCs, but still keep innovation and imitation rates endogenous. This model will help us to understand the Product Cycle Mechanism with FDI, and hence provide more insights about technology transfer, world trade patterns, and the distribution of income under a global environment with FDI.

We find that: (1) An increase in the labor force of the South does not affect the production transfer rate but raises the North-South relative wage rate. (2) A decrease in general labor force of the North facilitates production transfer to the South and reduce the relative wage and (3)An increase in high-skilled workers of the North also accelerates the North-South production transfers but improve the relative wage. These findings mainly result from optimal production transfer decision of MNCs. It is the entrance and exit action of MNCs to the Southern economies and the shifting of Southern labor between sectors that endogenously change the rates of production transfer, imitation, and the fraction of products manufactured by each country and sector, causing relatively different demands for labor and North-South relative wage rate.

This paper is related to other works that were developed from the seminal work of Vernon. In particular, Krugman (1979) built a product cycle model with an exogenous rate of innovation and imitation; there is continuous introduction of new products in the North while the South imitates in each period to produce some of the goods formerly produced only in the North at an *exogenous* imitation rate. As a result, at the steady state, a constant fraction of the goods are produced solely by the North and the rest are produced solely by the South after they have been imitated. More interesting, there is no fixed pattern of trade; each good is exported by the North when first introduced but eventually becomes an export of the South, i.e., there exists a *moving equilibrium* where the North exports new products and imports old ones. By assuming goods and labor markets are competitive and that each good has a downward sloping demand curve, Krugman also found out a typical inverse

relationship between the relative size of labor supply and relative wage.

Grossman and Helpman (1991) followed Krugman by modeling another type of Product Cycle. They assume labor is needed for both manufacturing and R&D, then the innovation rate, imitation rate, and the fraction of goods produced by the North are *endogenized* in their model. As results, in addition to Krugman's effects that an increase of the supply of labor in a region lowers its relative wage of labor, an increase in the supply of labor has an additional effect of increasing the fraction of goods produced by that region, hence raising the demand for labor in the manufacturing sector. In their specific model, the latter dominates the former so they conclude that a rise in a country's labor supply improves the relative wage of that country, which contradicts Krugman's results. However, in their research Grossman and Helpman did not mention in detail the route of technology transfer in the Product Cycle model, i.e., while the North and South labor markets are completely separated, the Southern firms can directly learn or imitate technology from the Northern firms.

The structure of this paper is as follows: Section 2 describes the model and Section 3 solves it. In Section 4, we analyze the effects of demographic changes. Conclusions and discussion about further extension possibilities are in Section 5.

# 2 The model

We consider a world economy comprising two free trade regions, denoted by the North and the South with symmetrically differentiated products. The production of these symmetrically differentiated products consists of two different activities: learning and manufacturing. Before a firm can begin to manufacture any variety, it has to learn the production technology or the *blueprints* specific to that variety. If the variety is a new one, then this learning represents an *innovation.* Otherwise, when the variety already exists on the market, then the learning activity is an *imitation.*

In this model, there are 2 kind of labor: general labor and high-tech labor. The high-tech labor can be understood as the well educated human capital or the talented people who have ability to develop (innovate) products. The North differs from the South in the facts that: the North has both high-tech labor and general labor while the South possesses only the general labor, which makes North have executive

advantageous ability to innovate or develop new products and distinguishes this model with other product cycle models. General labor, as usual, can be used for both manufacturing and imitation. However, we assume that the Intellectual Property Rights Protection in the North is perfect so there is no imitation in the North. Here, $L_S, L_N$ are exogenous supply of (general) labors in the South and North respectively. $H_N$ is an exogenous supply of high-tech labor in the North and $H_S = 0$.

There is no difference in productivity of general labor in North and South. That is after the blueprint of certain variety has been obtained, the manufacturing of that variety in either country requires one unit of general labor.

The main idea of our model is that the North uses high-tech labor to develop new varieties and bringing them to the market. Since the wage rate is lower in South, Northern firms will transfer production to the South through FDI, a process called *multi-nationalization*. Then the local Southern firms use general labor to imitate the blueprints of these multinationlized products and manufacture them. In this paper, following Edwin. Lai (1997)[1], we assume the multinationalization means the setting up a multinational corporation (MNC) by a Northern firm, therefore we do not differentiate between multinationalization through wholly owned subsidiary, partly subsidiary or technology licensing. Northern firms transfer production to the South to take advantage of the lower wage, which they equalize the probability that they will lose their monopoly of manufacturing to Southern imitators. Since Southern wage is lower, the Northern firm will stop production in the North once it has multinationalized production. We also assume that multinationalization (prior to imitation) is the only form of production transfer to South and therefore, a product can not be imitated until it has been multinationalized by the innovator.

## 2.1 Demands for Goods

At any time, there exists a continuum of potential goods that are all desirable to the consumers, but only a subset of these goods are available at. Households worldwide have identical preferences for differentiated products and choose instantaneous

[1]Lai Edwin use Product Cycle with MNCs to study the effects of International Intellectual Property Rights Protection to the production transfer to the South, Edwin, however assumes the imitation is costless and exogenous.

expenditure to maximize intertemporal utility function

$$U_t = \int_t^{\infty} e^{-\rho(\tau-t)} log[u(\tau)] d\tau, \tag{1}$$

where $\rho$ is the subjective discount rate and $u(.)$ is the instantaneous sub-utility function given by

$$u(\tau) = [\int_0^n x(j)^{\alpha} dj]^{1/\alpha}, \quad 0 < \alpha < 1. \tag{2}$$

In (2), $x(j)$ denotes consumption of differentiated product $j$, and $n$ is the most recent number of varieties available on the market, therefore is a function of time $\tau$.

The representative consumer maximizes (1) subject to an intertemporal budget constraint

$$\int_t^{\infty} e^{-r(\tau-t)} E(\tau) d\tau \leq \int_t^{\infty} e^{-r(\tau-t)} I(\tau) d\tau + A(t), \tag{3}$$

[2] where $r$ is the nominal interest rate; $E(\tau), I(\tau)$ are his instantaneous expenditure and factor of income at time $\tau$, respectively; and A(t) is the current value of his asset holding at t.

The solution of intertemporal maximization problem requires [3]

$$\frac{\dot{E}}{E} = r - \rho, \tag{4}$$

Maximization of utility $u(t)$ (2) subject to budget constraint

$$\int_0^n p(j)x(j)dj = E$$

in each period leads to the demand function [4]

$$x(j) = \frac{p(j)^{-\epsilon}}{\int_0^n p(j')^{1-\epsilon} dj'} E, \tag{5}$$

where $p(j)$ is the price of product $j$ and the (constant) elasticity of substitution between every pair of products is $\epsilon \equiv 1/(1-\alpha) > 1$. Due to symmetry of all goods in the preference funtion (2), $x(j)$ is the same for all goods produced in the same country.

[2](3) can be presented in flow equation form as $I(t) - E(t) + rA(t) = \dot{A(t)}$

[3]see Appendix A for a detailed derivation

[4]see Appendix B

## 2.2 Innovation, Multinationalization, and Imitation

At any time $t$, $n$ differentiated products have been developed by North, $n_N$ goods are manufactured only by the North firms while $n_S$ goods have been multinationalized, $n = n_S + n_N$. Furthermore, $n_S = n_M + n_L$, where $n_M$ is the number of goods manufactured by Northern MNCs and $n_L$ is the number of goods which have been imitated by local Southern firms and hence are being produced by them, $n = n_N + n_M + n_L$. From the symmetry of all goods in the demand function, $x_N, x_M, x_L$ stands respectively for the demand for any good produced by a Northern firm, Northern MNC, and Southern firm.

We are at the moment concerned only with the steady state or the long run equilibrium with *balanced growth path*, i.e, the steady state in which growth rate of the economy is constant over time. On this balanced growth path, the growth rates are such that:

$$\frac{\dot{n_S}}{n_S} = \frac{\dot{n_N}}{n_N} = \frac{\dot{n_M}}{n_M} = \frac{\dot{n_L}}{n_L} = \frac{\dot{n}}{n} = \frac{\dot{n_S + n_N}}{n_S + n_N} \equiv g. \tag{6}$$

Firms behave as Bertrand competitors, thereby taking the prices of other firms products and the level of aggregate spending as given. A firm with the unique ability to produce some variety facing a demand curve (5) with elasticity equal to $-\epsilon$ will set a price of the product it produces in order to maximize its own instantaneous profit

$$\pi(j) = x(j)[p(j) - c(j)],$$

where $c(j)$ is the per unit production cost of good $j$, and in this model is equal to the wage rate in the country where the production of good $j$ takes place.

Thus, we obtain from the first order condition the mark-up pricing rule for a Northern firm, MNC or a Southern firm as (Dixit-Stiglitz, 1977)

$$p(j) = \frac{w_i}{\alpha}, \quad i = North, South \tag{7}$$

We further, assume that MNCs will stop producing when their products has been imitated by Southern firms. If not, as Bertrand competitors MNCs and their Southern imitator would each set price equal to marginal cost and earn zero profit either. And, it may be thought that Southern government would carry out certain non-tariff policies or implicit regulations to MNCs to barrier or disturb their productions when their local Southern firms can produce such goods.

For simplicity, we follow Grossman-Helpman (1991) to set nominal expenditure constant through time, i.e., E(t) = 1, for all time t. Then,

$$(4) \Rightarrow r = \rho \tag{8}$$

We define here the *rate of imitation* by Southern firms from MNCs as $i \equiv \frac{\dot{n_L}}{n_S}$, which is is the probability that a multinationalized product will be copied at the next instant and the rate of multinationalization or the production transfer rate as $m \equiv \frac{\dot{n_M}}{n_N}$, which is the probability that a Northern produced product will be multinationalized in the next moment.

The multinationalization rate $m$ is endogenized based on optimization of Northern firms: knowing imitation rate $i$, a Northern firm will decide whether or not to multinationalize at each date. Since, there is symmetry among all Northern firms, at any date, the equilibrium value of $m$ is the one that leaves all Northern firms indifferent in Present Discounted Value (PDV) of profits between multinationalizing and continuing production in the North.

### 2.2.1 Innovation

Only high-tech labor in the North can develop new varieties. The development of a new variety requires $\frac{a_d}{K_N}$ unit of high-tech labor, where $K_N$ is the level of scientific knowhow that is useful for innovation in the North, and $a_d$ is the productivity parameter in innovation sector. I assume that only those varieties which the North temporarily maintains exclusively produce, contributes to $K_N$, i.e., $K_N \sim (n_N + n_M)$. Unit are chosen such that $K_N = (n_N + n_M)$, therefore the the cost of development of a new variety is

$$c_d = {w_N}^d \frac{a_d}{n_N + n_M} \tag{9}$$

where ${w_N}^d$ is the wage of high-tech labor and

$$\dot{n_N} + \dot{n_M} = \frac{H_N}{a_d}(n_N + n_M) \Rightarrow g = \frac{H_N}{a_d}. \tag{10}$$

which implies that in this model, at steady state, the innovation rate or the rate of new development of varieties is exclusively determined by the quantity of high-tech labor $H_N$ and the productivity of innovation sector $a_d$.

### 2.2.2 Multinationalization

After developing *blueprints*, i.e., the technique to manufacture particular products, North firms consider whether to manufacture in the North or setting an MNC i.e., conducting multinationlization.

If continuing to produce in the North; Northern firms have to hire general labor in the North with high wage rate $w_N$ but faces no risk of being imitated by the Southern firms so the PDV of profits of a Northern firm that never multinationzlized is $\Pi_N$:

$$\Pi_N = \frac{\pi_N}{r}, \quad \pi_N = x_N w_N(\frac{1-\alpha}{\alpha}) = \frac{{L_N}^d}{n_N} w_N(\frac{1-\alpha}{\alpha}) \tag{11}$$

where $\pi_N$ is the Northern firm's instantaneous profit, and ${L_N}^d$ is Northern genaral labor employed by Northern manufacturing.

Otherwise, if conducting multinationalization, MNCs can exploit low wage rate in the South but faces the risk of being imitated so the expected present discounted value of profits of a MNC with arrival imitation rate $i$ can be calculated as

$$\Pi_M = \frac{\pi_M}{r+i}, \quad \pi_M = x_M w_S(\frac{1-\alpha}{\alpha}) = \frac{L_M}{n_M} w_S(\frac{1-\alpha}{\alpha}) \tag{12}$$

where $i \equiv \frac{\dot{n_L}}{n_S}$ is the imitated hazard rate, $w_S$ is the wage rate in the South, and $L_M$ is Southern general labor employed by all MNCs. [5]

Since in steady state equilibrium the typical firm is indifferent between multinationalizingand continuing production in North, the PDV of profits of the two typical firms must be equal[6], that is

$$\Pi_N = \Pi_M \iff \frac{r}{r+i} = \frac{\pi_N}{\pi_M} = \frac{{L_N}^d}{L_M}\frac{n_M}{n_N}\frac{w_N}{w_S} \tag{13}$$

From (5), (7), (11), (12)

$$\frac{\pi_N}{\pi_M} = (\frac{w_N}{w_S})^{1-\epsilon} \Rightarrow \frac{w_S}{w_N} = (\frac{\pi_N}{\pi_M})^{\frac{1}{\epsilon-1}} = (\frac{r}{r+i})^{\frac{1}{\epsilon-1}} \tag{14}$$

From (13), (14) we get:

$$\frac{r}{r+i} = (\frac{{L_N}^d}{L_M}\frac{n_M}{n_N})^{\alpha} \tag{15}$$

[5]For detailed derivation and interpretation of the equation (12), see Appendix C

[6]Since we are concerned only to the balanced growth path, we don't consider the uninteresting corner solution, in which the PDV of profit of one typical firm is always greater than the other' one.

Free entry and the profit maximization of the Northern firms imply that the expected PDV of profits should be equal to the cost of innovation in the steady state equilibrium, hence

$$\Pi_N = c_d \iff {L_N}^d(1 + \frac{n_M}{n_N}) = (\frac{{w_N}^d}{w_N})\frac{\alpha a_d}{1-\alpha}r \tag{16}$$

*Assumption* ${w_N}^d = (1+\tau)w_N, \quad \tau \geq 0$

As high-tech labor only exists in small ratio of the Northern labor population but possess unique ability to innovate and develop new variety, they can negotiate for their wage rate with rate of $\tau$ higher than general labor's wage rate. $\tau$ is an exogenously negotiable power parameter, and is nonnegative, which implies the fact that high-tech labor have ability to work like general labor while the adverse is not true, the larger the $\tau$ is the more negotiable power the high-tech labors have.

Then,

$$(16) \Rightarrow {L_N}^d(1 + \frac{n_M}{n_N}) = (1+\tau)\frac{\alpha a_d}{1-\alpha}r \tag{17}$$

### 2.2.3 Imitation

Consider now the imitation activity in the South. Unlike the development of new variety in the North, general labor in the South can be employed both to imitate any multinationalized product that are being manufactured by the MNCs and to manufacture imitated products.

A Southern firm selects at random one of the existing, not previously imitated MNC products to copy. An imitation of a blueprint of one product from MNCs requires $\frac{a_I}{K_S}$ unit of general labor, where $a_I$ is a fixed productivity parameter in Southern imitation sector and $K_s$ is the stock of disembodied knowledge capital in the South. Like what have been done in the North, I assume the stock of knowledge to be proportional to the cumulative experience in the learning sector in the South and units are chosen so that $K_S = n_S$, where $n_s$ is the number of products that have been being manufactured in the entire South, which consists of those manufactured by the MNCs and those manufactured by the local Southern firms. Then, the cost of imitation is

$$c_I = w_S\frac{a_I}{n_S}$$

and the set of varieties produced by Southern firms grows according to

$$\dot{n_L} = \frac{{L_S}^I}{a_I} n_S \tag{18}$$

${L_S}^I$ is the Southern labor employed by imitation sector in the South, and $w_S$ is the Southern wage rate.

In the equilibrium and under free entry of imitation in the South, it follows that the PDV of profits from manufacturing must be equal to the cost of imitation, therefore

$$\Pi_S = \frac{\pi_S}{r} = \frac{1}{r}\frac{L_S^p}{n_L} w_S \frac{1-\alpha}{\alpha} = c_I = w_S \frac{a_I}{n_S} \tag{19}$$

$$\Rightarrow {L_S}^p = a_I \frac{n_L}{n_S}\frac{\alpha}{1-\alpha} r \tag{20}$$

${L_S}^p$ is labor employed by Southern firms to manufacture imitated products in the South. Finally, we complete the description of the model by showing 2 labor-market clearing conditions.

$${L_N}^d = L_N \tag{21}$$

$$L_M + {L_S}^I + {L_S}^p = L_S \tag{22}$$

# 3 Solution

We define the imitation rate and production transfer rate as $i \equiv \frac{\dot{n_L}}{n_S}$, $m \equiv \frac{\dot{n_M}}{n_N}$ hence in the steady state the ratio between multinationalized products and products manufactured in the North and the ratio of products produced by local Southern firms and products manufactured in entire South are respectively:

$$\frac{n_M}{n_N} = \frac{n_M}{\dot{n_M}}\frac{\dot{n_M}}{n_N} = \frac{m}{g}; \quad \frac{n_L}{n_S} = \frac{n_L}{\dot{n_L}}\frac{\dot{n_L}}{n_S} = \frac{i}{g} \tag{23}$$

From (8),(20), (21), (22), and (23), we obtain the Southern general labor employed by the MNCs:

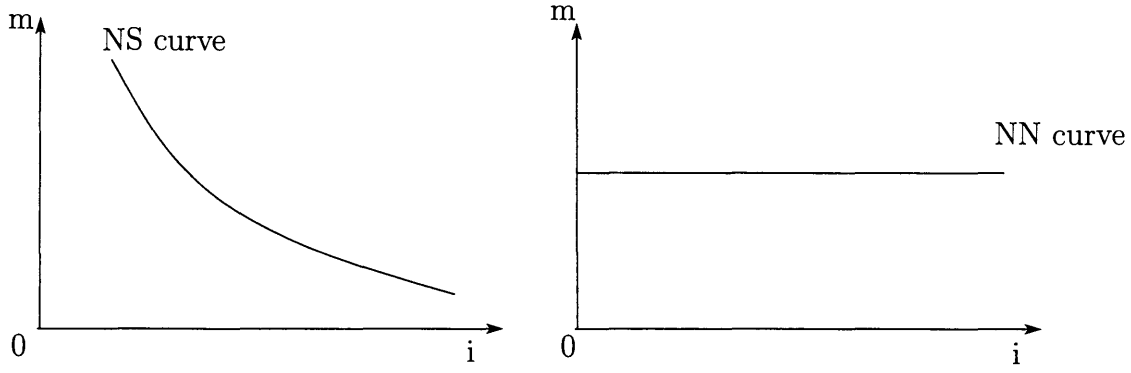
$$L_M = L_S - a_I i - \frac{a_I \alpha}{1-\alpha}\frac{i}{g}\rho \tag{24}$$

**NS curve**

From (8), (15), (21),(23), (24) i.e., from multinationalization equilibrium, labor-market clearing in the North and South, and the steady state conditions we obtain the NS curve, which represents the steady state relationship between imitation rate $i$ and multinationalization rate $m$.

$$(\frac{L_S - a_I i - \frac{a_I \alpha}{1-\alpha}\frac{i}{g}\rho}{L_N \frac{m}{g}})^{\alpha} \frac{\rho}{\rho + i} = 1 \tag{25}$$

The NS curve is negative sloping. The intuitive reasons are that the higher the imitated hazard rate the higher the risk that MNCs may lose their monopoly power of manufacturing products and therefore their future profits, hence the less attractive to carry out manufacturing new products in the South. In other point of view, the more MNCs appear in the South the more Southern general labors are demanded or the Southern labor would be drawn from the imitation sector to FDI sector, which makes imitation rate in the South decrease.




**NN curve**

From (8), (17), (21) and (23) i.e., free entry condition in the North, the Northern labor market clearing, and steady state conditions we get the other relationship between imitation rate and multinationalization rate , denoted by NN curve

$$L_N(1 + \frac{m}{g}) = (1 + \tau)\frac{\alpha a_d}{1 - \alpha}\rho \tag{26}$$

In the steady state equilibrium, the multinationalization rate is proximately determined by the economic forces in the North.

Our model is the North leading model. In steady state, the leading North take advantage of high-tech labor to develop new products, then use all Northern general labor to manufacture and determine the ratio of North-manufactured products and multinationalized products ($\frac{n_M}{n_N} = \frac{m}{g}$). The South can not affect the innovation and the multinationalization of the North.

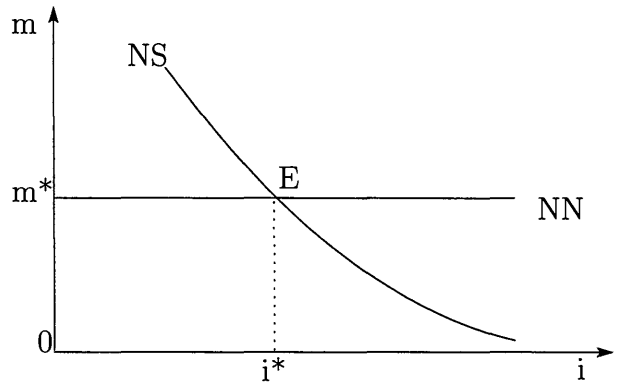
Combine (22) and (23) we have solutions of the multinationalization rate $m^*$(the rate of production transfer) and the imitation rate $i^*$ for the steady state of the model.

$$m^* = [(1+\tau)\frac{\alpha a_d}{(1-\alpha)L_N}\rho - 1]g \tag{27}$$

$$(\frac{L_S - a_I i^* - \frac{a_I \alpha}{1-\alpha}\frac{i^*}{g}\rho}{(1+\tau)\frac{\alpha a_d}{1-\alpha}\rho - L_N})^{\alpha}\frac{\rho}{\rho + i^*} = 1 \tag{28}$$

and the relative wage rate between South and North is:

$$\frac{\pi_N}{\pi_M} = (\frac{w_N}{w_S})^{1-\epsilon} \Rightarrow \frac{w_S}{w_N} = (\frac{\pi_N}{\pi_M})^{\frac{1}{\epsilon-1}} = (\frac{\rho}{\rho + i^*})^{\frac{1}{\epsilon-1}} \tag{29}$$



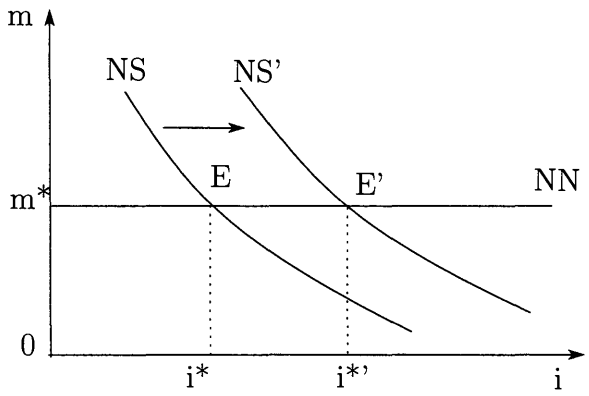

# 4 Comparative Steady States Analysis

In the steady state, the numbers of varieties grows at the constant innovation rate $g$, Northern MNCs transfer production from North to South at constant multinationalization rate or production transfer rate $m$, and Southern firms imitate at the constant imitation rate $i$. We are concerned with determinants of these steady state rates of

production transfer and imitation and the relative North-South wage rate. At the same time, we are also interested in the growth of instantaneous utility in the model.

## 4.1 Increase of general labor force of the South

First, we consider the effects of an increase in Southern general labor. The NS curve shifts to the right while the NN curve does not move. As results, imitation rate increases while production transfer rate remains unchanged. According to (29) the North-South relative steady state wage rate $\frac{w_N}{w_S}$ increases or the South-North relative steady state wage rate $\frac{w_S}{w_N}$ decreses. Furthermore, the ratio between the numbers of products manufactured by the Northern firms and multinationalized products $\frac{n_M}{n_N} = \frac{m}{g}$ keeps constant but the ratio between the numbers of products manufactured by the Southern local firms and those manufactured in the entire South $\frac{n_L}{n_S} = \frac{i}{g}$ increases.




The intuitive mechanism is as follows. When there are more general labor supply in the South or $L_S$ increases, $w_S$ decreases, so the cost to imitate and manufacture in the South fall, and it is more attractive for Northern firms to conduct FDI. In Southern imitation sector and manufacturing sector, more Southern general labors can be employed to imitation sector, which hence, leads to higher imitation rate $i$ and higher ratio of products manufactured by the local South. In FDI sector, things are different; Northern firms transfer production to South to take advantage of the lower wage rate, which they balance against the probability or the imitation hazard rate $i$ that they may lose their future profits to the Southern imitators. An increase in Southern general labor supply leads to a lower Southern wage rate $w_S$ but at the same time a higher hazard imitation rate $i$, which have opposite effects to the profits

of MNCs. In our model, since the change in the Southern labor supply does not have any effect to the innovation and production transfer rate, the increase in Southern labor are drawn to imitation and local manufacturing sector. In the steady state equilibrium imitation rate $i$ will rise to the level so that the production transfer rate $m$ is the same as before the increase in Southern labor supply. We summarize all these findings in the following proposition.

**Proposition 1**: *An increase in Southern (general) labor supply leads to a higher North-South relative wage rate, does not affect the rate of production transfer (FDI) from North to South , and fosters the imitation and manufacturing activities of the South.*

Return to the question posed at the beginning about the effects of the integrating in the international trade of Southern large population countries, we can conclude from this model that: it lower the Southern relative wage rate, has no effects on the rate of FDI flow from developed countries to developing countries but foster the localization process, i.e., increase the ratio between the numbers of products manufactured by developing countries' local firms and those manufactured in the Southern world. The increasing in Southern population itself does not affect the rate of production transfer of MNCs or take Northern jobs away, it even raise the North-South relative wage rate.

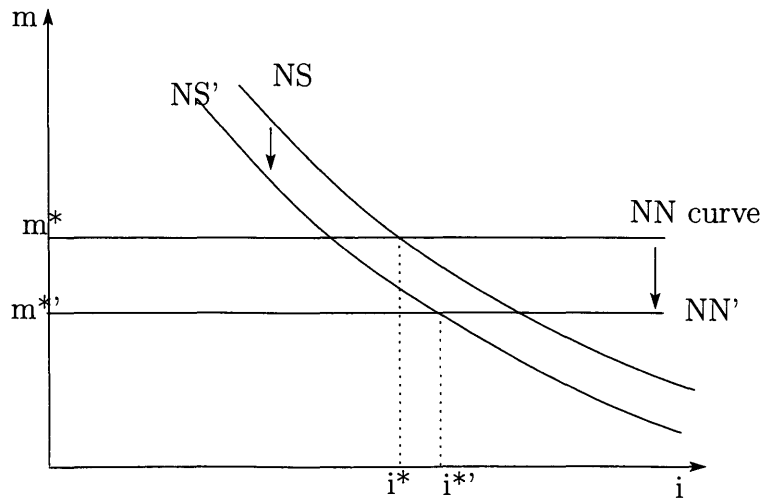
## 4.2 Increase in General Labor Force of the North

We then consider the effects of an increase in Northern general labor. The NS curve shifts to the left while NN curve shifts downward. It is clear that multinationalization rate $m$ must decrease but unclear from the graph that whether imitation rate $i$ increases or decreases. But we know from (28) that $i$ must increase. Therefore, from (29) we obtain a higher North-South relative steady state wage rate $\frac{w_N}{w_S}$, which is the same with Grossman-Helpman's result when Northern labor supply increase.

In Grossman-Helpman model, the North-South labor markets are separated. When labor supply in the North increases, more labor is put in to innovation sector, there are more products developed and manufactured in the North so the fraction of goods

produced by the country rises and the demand for labor bounce back. Therefore, the North-South relative wage rate rise when Northern labor supply increases. In our model, because there exists FDI or optimal MNCs that move between North and South, there is a *connection* between two labor market. In other words, the North and South general labor are alternative for the MNCs in manufacturing products. Our model shows that when the Northern general labor supply increase, it is the drawing of optimal MNCs from the South leads to higher fraction of products manufactured in the North. This changes raises the demand for labor in the North and at the same time lower demand for labor in the South, therefore results a higher North-South relative wage rate.

When there is an increase in Northern general labor supply $L_N$, the wage rate $w_N$ or the cost to manufacture in the North fall, which implies that manufacturing in the North becomes more profitable attractive for Northern firms, hence there will be the drawing the of MNCs from the South. Therefore, the general labor that are demanded by MNCs in the South decreases or there wil be excess labor supply at the moment. As results, the Southern wage rate $w_S$ fall, and those excess labor supply are drawn to imitation sector so the imitation rate $i$ increases. This will by its turn accelerate the drawing MNCs from the South and lower the rate of production transfer. At the same time, as there are more firms returning back to manufacture in the




North ($\frac{n_M}{n_N} = \frac{m}{g}$ decreases), the fraction of products manufactured by the North increases and the demand for labor there will bounce back so the relative wage rate $\frac{w_N}{w_S}$ increases at the steady state. At a glance, it seems contradictory that an exit

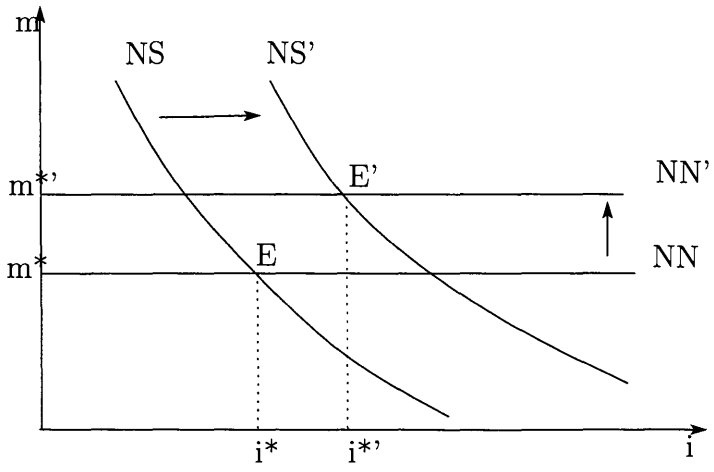
of MNCs from the South happens at the same time of an increase in the North-South relative wage rate but it is the increase in imitation rate $i$ that explains for this results. In considering whether or not setting a MNCs, Northern firms not only concern relative wage rates but also the hazard imitation rate $i$ that their future profit may be lost.

We summarize the results in this section in the proposition:

**Proposition 2**: *An increase in Northern labor supply leads to a higher North-South relative wage rate, higher imitation rate, and lower rate of production transfer from North to South.*

Now, return to the question about the effects of decreasing labor population in developed countries in the international trading world. We can conclude from this model that there would be more FDI ( MNCs), more production transfer from the developed countries to the developing countries, and the North-South relative wage rate would drop.

## 4.3 Increase in High-Skilled Workers of the North




It is straightforward to show that $\frac{[dlogu(t)]}{dt} = (1-\alpha)g/\alpha$. Therefore, in our model, the quantity of high-tech labor $H_N$ and the productivity in innovation sector $a_d$ in the North, which affect the steady state rate of innovation $g$ will determine the growth in utility at steady state.

Next, we consider the effects of an increase in innovation rate $g$ ( which may due to an increase in high-tech labor quantity or an improvement in productivity of innovation sector ) to production transfer rate, imitation rate, and the relative North-South wage rate. The NN curve shifts upward while the NS curve shifts to the right. As results, both production transfer rate and imitation rate increase, hence, the North-South relative wage rate $\frac{w_N}{w_S}$ rise.

As $g$ increases, there are more products being developed in the North, which implies a higher labor demand to manufacture them and push the Northern wage rate $w_N$ to increase. Therefore, Northern firms have more motivation to conducts FDI in the South and the production transfer rate rises. However, according to (27), ratio $\frac{n_M}{n_N} = \frac{m}{g}$ still keeps constant at steady state, which means that the ratio between numbers of products manufactured by the Northern firms and multinationalized products remains unchanged. In steady state, the production transfer rate is proportional to the innovation rate. Following an increase in MNCs, there is more stock of dissembled knowledge capital $K_S = n_S$ in the South, which make it cheaper $(\frac{a_I}{n_S})$ to imitate, hence promote imitation activities in the South. As results, there are also more demand for Southern labor and imitation rate $i$ rises. At the same time, from (28) we have that $\frac{n_L}{n_S} = \frac{i}{g}$ must fall or the ratio between the numbers of products manufactured by the local Southern firms and those manufactured in the entire South drops, which implies there is a move of Southern general labor to the FDI sector. Finally, although there is an increase in Southern wage rate $w_S$, the increase in imitation rate $i$ and $w_S$ themselves discourage the setting MNCs to the South at the equilibrium so that there are relatively more demand in labor in the North or the North-South relative wage rate $\frac{w_N}{w_S}$ will increase at the steady state.

We can summarize the findings as follows:

**Proposition 3**: *An increase in Northern high-tech labor g raises the whole world's growth in utility and the North-South relative wage rate, promotes production transfer (FDI) to the South and the imitation activities of the South, and draws Southern general labor to FDI sector.*

# 5 Conclusion

This paper incorporates production transfer of MNCs into the Vernon's celebrated product cycle theory to analyze effects of demographic changes on the North-South production and technology transfers, the pattern of world trade, and the relative wage rate. We find that the integration of Southern developing economies into the world trade system increases the relative wage rate but does not affect production transfer. While decreasing and aging population of the North facilitates production transfer and reduces the relative wage, the Northern developed economies benefit from an increase in skilled worker via immigration and investment in human capital.

There are several possible extensions of this paper for further studies. First, we can include the innovation rate to the dynamic model and consider the relationship between innovation rates and production rates and imitation rates. One way to do that is to set a connection between general labor and high-tech labor; in order to become a high-tech labor, a general labor supplier needs to invest some costly education. Second, besides technology transfers through production transfers of MNCs, we can also consider technology transfers through the direct imitation between Northern firms and Southern local firms. Third, we just consider effects of changes in labor supplies separately, it may be more clearly and interesting if we can analyze them simultaneously.

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# A Derivation of equation (4)

From the symmetry of all varieties and equation (3),

$$U = (nx^{\alpha})^{\frac{1}{\alpha}} = n^{\frac{1}{\alpha}}x = n^{\frac{1}{\alpha}}\frac{E}{np} = n^{\frac{1-\alpha}{\alpha}}\frac{E}{p} \Rightarrow \frac{\partial U}{\partial E} = \frac{n^{\frac{1-\alpha}{\alpha}}}{p} \tag{30}$$

The current value Hamiltonian of the dynamic optimization problem (1) s.t. (3) is

$$H = logU + \lambda[I(t) - E(t) + rA(t)] \tag{31}$$

where $\lambda$ is the current value Lagrangian multilpier.

The first FOC is

$$H_E = \frac{1}{U}\frac{\partial U}{\partial E} - \lambda = 0$$

Subtitute $\frac{\partial U}{\partial E}$ from above to this equation we obtain

$$\lambda = \frac{1}{U}\frac{n^{\frac{1-\alpha}{\alpha}}}{p} \Rightarrow \frac{\dot{\lambda}}{\lambda} = -\frac{\dot{U}}{U} + (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} - \frac{\dot{p}}{p} \tag{32}$$

Another FOC is

$$\lambda = \rho\lambda - H_A = (\rho - r)\lambda \Rightarrow \frac{\dot{\lambda}}{\lambda} = \rho - r \tag{33}$$

(30) implies

$$-\frac{\dot{E}}{E} = -\frac{\dot{U}}{U} + (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} - \frac{\dot{p}}{p} \tag{34}$$

From (32), (33), (34) we obtain

$$\frac{\dot{E}}{E} = -\frac{\dot{m}}{m} = r - \rho \tag{35}$$

# B Derivation of Equation (5)

We have Lagrangian for this maximimum problem as:

$$L = [\int_0^n x(j)^{\alpha}dj]^{1/\alpha} + \beta[E - \int_0^n p(j)x(j)dj]$$

where $\beta$ is the Lagrangian multilpier. The FOC is:

$$\frac{1}{\alpha}[\int_0^n x(j)^\alpha dj]^{1/\alpha-1}\alpha x(j)^{\alpha-1} = \beta p(j)$$
$$\{x(j)^{\alpha-1}U^{1-\alpha}\}^{\frac{1}{1-\alpha}} = [\beta p(j)]^{\frac{1}{1-\alpha}}$$
$$x(j)p(j)^\epsilon = U\beta^{-\epsilon} \quad (\epsilon \equiv \frac{1}{1-\alpha})$$

Therefore, $x(j) = U\beta^{-\epsilon}p(j)^{-\epsilon}$. Subtitute (B) to budget contraint

$$\int_0^n p(j)x(j)dj = E$$

we obtain,

$$E = \int_0^n p(j)x(j)dj = U\beta^{-\epsilon}\int_0^n p(j)^{1-\epsilon}dj \tag{36}$$

Subtitute $U\beta^{-\epsilon}$ from (36) to (B) we get the demand function (5)

$$x(j) = \frac{p(j)^{-\epsilon}}{\int_0^n p(j')^{1-\epsilon}dj'}E,$$

# C Discounted Expected Profits of an MNC

Assume that the duration $\tau$ between the date of multinationalization and date of imitation $t$is a random variable with exponential distribution, having a Poisson arrival rate $i$, then the probability that monopoly power will be lost to a Southern imitator before $t$ is:

$$Pr(\tau \leq t) = f(t) = 1 - e^{-it}$$

Therefore, $Pr(\tau = t) = f'(t) = ie^{-it}$

The expected PDV of profit of an MNC at the time of multinationalization is

$$\Pi_m = \int_0^\infty (\int_0^t \pi_m e^{-rj}dj)Pr(\tau = t)dt$$
$$= \pi_m \int_0^\infty (\int_0^t e^{-rj}dj)ie^{-it}dt = \frac{\pi_m}{r+i}$$