

## A THEORY OF NORTH-SOUTH TRADE AND FOREIGN DIRECT INVESTMENT

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*We analyze the steady state effect of foreign direct investment (FDI) and globalization in a dynamic general equilibrium model of North-South Trade with scale invariant growth developed by Segerstrom and Dinopoulos (2007). Here FDI is defined as the movement of production bases from the North to the South by the northern firms because the incentive of FDI is the lower production cost in the South.*

*By our numerical analysis, the increase of exogenous FDI arrival rate leads to a higher imitation rate in the South, industry shift from the North to the South (the increase of the ratio of the southern imitation firms and multinational firms compared to the ratio of northern innovation firms) and lower wage inequality between the North and the South. But there is no change in the long run innovation rate and the decrease of short run innovation rate. On the other hand, globalization is defined here as the increase of South population. By my numerical analysis, globalization leads to less copying of Northern products, faster technological progress, more industry shift from the North to the South utilizing the increase in multinational firms, and greater wage gaps between the two regions.*

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## I. INTRODUCTION

Since 1990, Foreign Direct Investment (FDI) in China, India and South East Asia. This paper seeks to address the question of whether FDI increases economic growth to both developed and developing countries.

This paper uses trade theory based on endogenous economic growth to examine the role of FDI in economic growth.

There are two obvious reasons why some firms may wish to engage in FDI. First, the production cost may be reduced, as predicted Markusen (1984) and Helpman (1984). Second, firms may be able to avoid some additional costs associated with serving foreign markets (for example, transportation costs and tariffs) as in the models by Horstmann and Markusen (1992) and Brainard (1993).

Some recent empirical work incorporates endogenous growth in international trade models to study how FDI affects economic growth. Borenztein, Gregorio and Lee (1998) test the effect of FDI on economic growth in a cross country regression framework utilizing data on FDI flows from the developed countries to 69 developing countries over last two decades. According to this paper, FDI has positive effect on economic growth in developing countries. However, this effect is observed only when the host country has a minimum threshold stock of human capital.

In a theoretical paper, Glass and Saggi (1998) find that international technology transfer (ITT), depends on whether substitute channels of ITT (e.g. imitation) exist in the host country. They found that when ITT occurs through FDI alone, a faster flow of FDI to the South leads to faster aggregate rates of innovation through, imitation. This model is based on Grossman and Helpman's (1991) and has the scale effect property, which was criticized by Jones (1995).<sup>1</sup>

The pattern of product innovation in the North and imitation in the South gives rise to a product cycle in international trade. Krugman (1979)

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<sup>1</sup> Jones (1995) find that all of endogenous growth models until then have the scale effect property. In response to this critique, a variety of R&D driven endogenous growth models without the scale effect property have been developed: see for instance Jones (1995b), Segerstrom (1998), Kortum (1997), Young (1998), Dinopoulos and Thompson (1998), Howitt (1999) and Li (2002), etc.

introduces a North-South trade model with an exogenous product innovation and international technology transfer from the North to the South. Grossman and Helpman (1991) endogenized the imitation rate which was exogenous variable in Krugman's model and introduced a North-South trade model with a quality ladder product cycle. They also studied the role of imitation in transferring technology to the South in the absence of FDI. Dinopoulos and Segerstrom (2007, 2010) developed a North-South Trade model without a scale effect property. Our model extends the North-South trade model by Dinopoulos and Segerstrom (2007, 2010) by adding an FDI option for Northern firms. It assumes that Northern firms have an incentive to engage in FDI because of lower production cost in the South.

The main objective of this chapter is to study how FDI affects economic growth in the North-South trade model with Shumpeterian endogenous growth but without a scale effect property. It paper also intends to explain how FDI affects the imitation rate of the South, the short-run growth rate (innovation rate) of the North, the wage differential between the two regions, and industry shifts between two regions. Through numerical analysis, we show that an increase in the exogenous rate of FDI leads to a higher imitation rate in the South, an increase in the industry shift from the North to the South (increase in the ratio of Southern imitation firms and multinational firms), lower wage inequality between the two regions under certain conditions, and a lower short run innovation rate. However there is no predicted change in the long run innovation rate. The numerical analysis predicts that an increase in the population of the South leads to a lower imitation rate of Northern products, faster technological change, more production shifts from the North to the South by multinational firms, and higher wage inequality between the North and the South.

The rest of this chapter is organized as follows. Section II describes a dynamic general equilibrium model of North-South trade with scale invariant growth and FDI. Section III characterizes steady state equilibrium and explains how FDI and globalization affect the short-run innovation rate, the imitation rate, wage differentials and other endogenous variables. We conclude in Section IV with a few remarks.

## II. THE MODEL

There are two regions, the North and the South. Assume that workers in the North are capable of conducting both *innovative* and *imitative* R&D. But workers in the South can only conduct *imitative* R&D because of its insufficient labor skills labor. In the South, technological progress occurs through the import of product designs and production methods developed in the North.

### 2.1. The Industry Structure

There is a continuum of industries indexed by  $\theta \in [0,1]$  in both the North and the South. In each industry  $\theta$ , a firm is distinguished by a time-varying measure of quality indexed by  $j = 0, 1, 2, \dots$ . At time  $t = 0$ , all firms have the lowest quality level  $j = 0$ . At time  $t$ , a firm can achieve quality level  $j + 1$  if the highest quality of the industry at time  $t$  is level  $j$  and the firm invests on R&D activity at time  $t$ .

### 2.2. Consumers

In each region (North or South), there is a fixed number of households at each time. Each household lives forever and is endowed with one unit of labor. The population grows exponentially at a fixed rate  $n > 0$ . The initial population is  $\bar{L}_N$  in the North and  $\bar{L}_S$  in the South.<sup>2</sup> Therefore labor supply at time  $t$  is  $L_N(t) = \bar{L}_N e^{nt}$  in the North and  $L_S(t) = \bar{L}_S e^{nt}$  in the South. The total labor supply in the two regions at time  $t$  is  $L(t) \equiv L_N(t) + L_S(t)$ .

Consumers in the North and the South have the same preferences. The intertemporal preferences of each consumer is given by

$$u(t) = \left\{ \int_0^1 \left[ \sum_j \delta^j d(j, \theta, t) \right]^{(\sigma-1)/\sigma} d\theta \right\}^{\sigma/\sigma-1} \quad (1)$$

<sup>2</sup> Note that North and South have the same population growth rate. We do not consider the case with heterogeneous population growth in the two regions.

where  $d(j, \theta, t)$  denotes the quality  $j$  consumption of product  $\theta$  at time  $t$ ,  $\sigma > 1$  is the constant elasticity of substitution between products across industries, and  $\delta > 1$  is quality parameter. Because  $\delta^j$  is increasing in  $j$ , consumers prefer the higher quality product. Discounted lifetime utility is given by

$$U = \int_0^\infty e^{-(\rho-n)t} \ln u(t) dt, \quad (2)$$

where  $\rho > n$  is the constant subjective discount rate.

For each consumer, the discounted lifetime utility maximization problem can be solved in the following three steps.

**Step 1:** The first step is to solve industrywise static optimization problem. For each industry  $\theta$  and each time  $t$ ,

$$\max_{d(\cdot, \theta, t)} \sum_j \delta^j d(j, \theta, t) \quad (3)$$

$$\text{s.t.} \sum_j p(j, \theta, t) d(j, \theta, t) = c(\theta, t) \quad (4)$$

where  $p(j, \theta, t)$  is the price of  $\theta$ -good of quality  $j$  at time  $t$ , and  $c(\theta, t)$  is the consumer's expenditure on  $\theta$ -good at time  $t$ . The solution for this problem is only to buy the product with the lowest quality adjusted price  $p_j(\theta) / \delta^j$ . When the two products have the same quality adjusted price, the consumer prefers the highest quality product.

**Step 2:** The second step is to solve the cross industry static optimization problem. For each  $t$ ,

$$\max_{d(\cdot, t)} \int_0^1 [\delta^{J(\theta, t)} d(\theta, t)]^{(\sigma-1)/\sigma} d\theta$$

$$\text{s.t.} \int_0^1 p(\theta, t) d(\theta, t) d\theta = c(t),$$

where  $J(\theta, t)$  is the quality of  $\theta$ -good chosen at time  $t$  and  $d(\theta, t)$  is its consumption (quantity) ( $J(\theta, t)$  is obtained from Step 1 and will be explained below) and  $c(t)$  denotes the total expenditure at time  $t$ . Solving this optimal control problem, we obtain the following individual

consumer's demand function: the quantity of demand of  $\theta$ -good of quality  $J(\theta, t)$  is given by

$$d(\theta, t) = \frac{q(\theta, t)p(\theta, t)^{-\sigma}c(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'}, \quad (5)$$

where  $q(\theta, t) = \delta^{(\sigma-1)J(\theta, t)}$  a quality measure at time  $t$ . Thus  $c(\theta, t) = p(\theta, t) \frac{q(\theta, t)p(\theta, t)^{-\sigma}c(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'}$ . Since  $J(\theta, t)$  does not depend on  $c(\theta, t)$ , then  $J(\theta, t)$  does not depend on  $c(t)$  and so  $q(\theta, t)$  does not depend on  $c(t)$ .

**Step 3:** The third step is the intertemporal expenditure choice problem.

$$\begin{aligned} \max_{d(\cdot)} U &= \int_0^\infty e^{-(\rho-n)t} \ln u(t) dt \\ \text{s.t.} \\ &\text{Steps 1 and 2} \\ &\dot{A}(t) = w(t) + r(t)A(t) - c(t) - nA(t). \end{aligned}$$

Where  $A(t)$  is the individual's assets at time  $t$ ,  $w(t)$  is the individual's wage rate at time  $t$ , and  $r(t)$  is the market interest rate at time  $t$ .

Step 3 reduces to the following problem

$$\begin{aligned} \max_{c(\cdot)} \int_0^\infty e^{-(\rho-n)t} \ln \left\{ \int_0^1 q(\theta, t) \left[ \frac{p(\theta, t)^{-\sigma}c(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'} \right]^{(\sigma-1)/\sigma} d\theta \right\}^{\sigma/\sigma-1} dt \quad (6) \\ \text{s.t. } \dot{A}(t) = w(t) + r(t)A(t) - c(t) - nA(t). \end{aligned}$$

The solution for this optimal control problem leads to

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho. \quad (7)$$

So at the steady state,  $r(t) = \rho$  for all  $t$ , which implies that in the steady

state equilibrium, individual consumer's expenditure  $c$  is constant over time. Therefore at the steady state, market interest rate  $r$  is equal to the discount rate over time.

### 2.3. Production Technology and Market Structure

In any industry, active firms engage in Bertrand price competition. Firms can exit and enter an industry at any time. Northern firms enter an industry by discovering the next higher quality product and Southern firms enter an industry by imitating state of the art products. We assume the same technology across the two regions, across products, and across quality levels.

Output good markets are segmented in two regions. In each region, firms producing different qualities are under Bertrand price competition. Each unit of output goods is produced by a single labor input and so production technologies exhibit a constant returns to scale technology represented by  $f(l) = l$ . This means that one unit of labor produces one unit of output good independently of its quality level or geographic location.

Labor markets are segmented in the two regions and are perfectly competitive. Let  $w_N$  be the wage rate in the North and  $w_S$  the wage rate in the South. Then each firm in the North has the constant marginal cost equal to  $w_N$  and each firm in the South has the constant marginal cost equal to  $w_S$ . Let  $\zeta$  be the marginal cost for a multinational firm producing in the South. When a northern firm invests in the South, due to its lack of experience in the South, the multinational firm pays an additional learning cost. Thus we assume  $w_N > \zeta > w_S$ . We restrict our attention to the following case:

$$w_N > \zeta > w_S > w_N / \delta.$$

The first inequality,  $w_N > \zeta$ , means that each northern multinational firm has cost advantage in the South. The inequality  $w_N > w_S$  means that production shifts from the North to the South when a southern firm imitates. The inequality  $w_S > w_N / \delta$  means that the production shifts

back to the North when a northern firm innovates.

Let

$$\eta \equiv \frac{\zeta}{w_N} \quad (8)$$

and

$$\phi \equiv \frac{\zeta}{w_S}. \quad (9)$$

Clearly, by the previous assumption,  $\eta < 1$  and  $\phi > 1$ . If  $\eta$  increases, the difference between the northern wage (or northern marginal cost) and multinational firms' marginal cost increases.

### 2.3.1. Profits of Northern Firms

If a northern firm wins the innovative R&D race, its profit is given by

$$\pi_N = (p_N - w_N)(d_N L_N + d_S L_S), \quad (10)$$

where  $p_N$  is the northern firm's price,  $d_N$  is the quality demanded by the representative consumer in the North and  $d_S$  is the quantity demanded by the representative consumer in the South. Maximizing  $\pi_N$  with respect to  $p_N$  and taking into account that equation (5) determines both  $d_N$  and  $d_S$ , we obtain the unconstrained monopoly price  $p_N = [\sigma / (\sigma - 1)]w_N$  which is the standard markup pricing.

### 2.3.2. Profits of Multinational Firms

If a Northern firm becomes a multinational, then its profit is given by

$$\pi_F = (p_F - \zeta)(d_N L_N + d_S L_S), \quad (11)$$

where  $p_F = [\sigma / (\sigma - 1)]\zeta = [\sigma / (\sigma - 1)]\phi w_S = [\sigma / (\sigma - 1)]\eta w_N$  is also monopoly markup price.

### 2.3.3. Profits of Southern Firms

If a southern firm wins the imitative R&D race, its profit is given by



$$\pi_S = (p_S - w_S)(d_N L_N + d_S L_S) \quad (12)$$

where  $p_S$  denotes the price set by the southern firm which is given by  $p_S = [\sigma / (\sigma - 1)]w_S$ , the monopoly price level.

Southern firms may imitate the products produced by northern firms or by multinational firms. In the steady state equilibrium, southern firms imitate the products produced by multinational firms because multinational products are easier to copy by southern firms than northern products.

The following notations are useful. Let  $c_N(t)$  be the consumption expenditure of the representative northern consumer at time  $t$  and  $c_S(t)$  the consumption expenditure of the representative southern consumer at time  $t$ . Then the global consumption expenditure is

$$E(t) = E_N(t) + E_S(t) = c_N(t)L_N(t) + c_S(t)L_S(t) = \bar{c}(t)L(t),$$

where

$$\bar{c}(t) = \frac{c_N(t)L_N(t) + c_S(t)L_S(t)}{L_N(t) + L_S(t)} = \frac{c_N(t)\bar{L}_N + c_S(t)\bar{L}_S}{\bar{L}_N + \bar{L}_S},$$

is global per capita consumption expenditure. Let

$$Q(t) = \int_0^1 q(\theta, t) d\theta,$$

be the average quality level across industries at time  $t$ . Then per capita global demand for northern products with average quality  $Q(t)$ ,  $y_N(t)$ , is

$$y_N(t) = \frac{Q(t)p_N^{-\sigma}\bar{c}(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma} d\theta'}, \quad (13)$$

per capita global demand for a multinational product with average quality  $Q(t)$ ,<sup>3</sup>  $y_F(t)$ , is

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<sup>3</sup>  $\frac{y_F(t)}{y_N(t)} = \left(\frac{p_F}{p_N}\right)^{-\sigma} = \left(\frac{\zeta}{w_N}\right)^{-\sigma} = \eta^{-\sigma}.$

$$y_F(t) = \frac{Q(t)p_F^{-\sigma}\bar{c}(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma} d\theta'}, \quad (14)$$

per capita global demand for a southern product with average quality  $Q(t)$ ,  $y_S(t)$ , is

$$y_S(t) = \frac{Q(t)p_S^{-\sigma}\bar{c}(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma} d\theta'}. \quad (15)$$

Using (10) and (13), a northern quality leader in industry  $\theta$  at time  $t$  earns the following monopoly profit,

$$\begin{aligned} \pi_N(\theta, t) &= (p_N - w_N)(d_N L_N + d_S L_S) \\ &= (p_N - w_N) \frac{q(\theta, t)p_N^{-\sigma}E(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma} d\theta'}. \end{aligned}$$

Using the previous notation,

$$\pi_N(\theta, t) = \left( \frac{w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t). \quad (16)$$

Using (11) and (14), a multinational firm in industry  $\theta$  at time  $t$  earns the following monopoly profit,

$$\begin{aligned} \pi_F(\theta, t) &= (p_F - \zeta)(d_N L_N + d_S L_S) \\ &= (p_F - \zeta) \frac{q(\theta, t)p_F^{-\sigma}E(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma} d\theta'}. \end{aligned}$$

Using the previous notation,

$$\pi_F(\theta, t) = \left( \frac{\zeta}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t) \quad (17)$$

$$= \left( \frac{\eta w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t) \quad (18)$$

$$= \left( \frac{\phi w_S}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t). \quad (19)$$

If a southern quality leader wins the imitative R&D race, then by (12) and (15), the profit of the southern quality leader is given as follows,

$$\begin{aligned} \pi_s(\theta, t) &= (p_s - w_s)(d_N L_N + d_S L_S) \\ &= (p_s - w_s) \frac{q(\theta, t) p_s^{-\sigma} E(t)}{\int_0^1 q(\theta', t) p(\theta', t)^{1-\sigma} d\theta'}. \end{aligned}$$

This can be rewritten as follows,

$$\pi_s(\theta, t) = \left[ \frac{w_s}{\sigma - 1} \right] \frac{q(\theta, t)}{Q(t)} y_s(t) L(t). \quad (20)$$

## 2.4. Innovation R&D and Imitation R&D

Labor is the only factor of production used by firms that engage in either innovative or imitative R&D activities. When a northern firm  $i$  hires  $l_i$  labor for innovative R&D, its probability of success  $I_i$  (in discovering the next higher quality) is given by

$$I_i = \frac{l_i}{\gamma q(\theta, t)}, \quad (21)$$

where  $\gamma > 0$  indicates the innovative R&D productivity parameter. Thus, as the quality improves, the probability of successful innovation decreases.

Firms in the South also conducts the imitative R&D using labor as northern firms conducts. When a southern firm  $i$  in industry  $\theta$  hires  $l_i$  units of labor for imitative R&D, its probability of success,  $C_i$ , is given by

$$C_i = \frac{I_i}{\beta q(\theta, t)},$$

where  $\beta > 0$  is the imitative R&D productivity parameter. The imitation of a multinational's product is easier than the imitation of Northern product.<sup>4</sup>

Returns to both innovative and imitative R&D's are assumed to be independently distributed across firms, across industries and over time. Then the probability that some northern firms are successfully innovative in an industry is given by  $I = \sum_i I_i$ . Similarly, the probability that some southern firms successfully imitate in an industry is given by  $C = \sum_i C_i$ . The arrival rate of FDI opportunities is set exogenously to represent the exogenous standardization of production by Vernon (1966), for each product and at each instant, there is a given probability  $F_i$  that the production becomes sufficiently standardized so that northern firms can produce the same product in the South by making a subsidiary. The probability that some northern firms become multinational firms is given by  $F = \sum_i F_i$ .

At time  $t$ , a measure of  $m_N$  industries have northern quality leaders and a measure of  $m_S$  industries have southern quality leaders and a measure of  $m_F$  industries have multinational firms. All of state-of-the-art quality products are produced in the North by northern quality leaders or in the South by southern quality leaders or by multinational firms. Thus

$$m_N + m_S + m_F = 1 \quad (22)$$

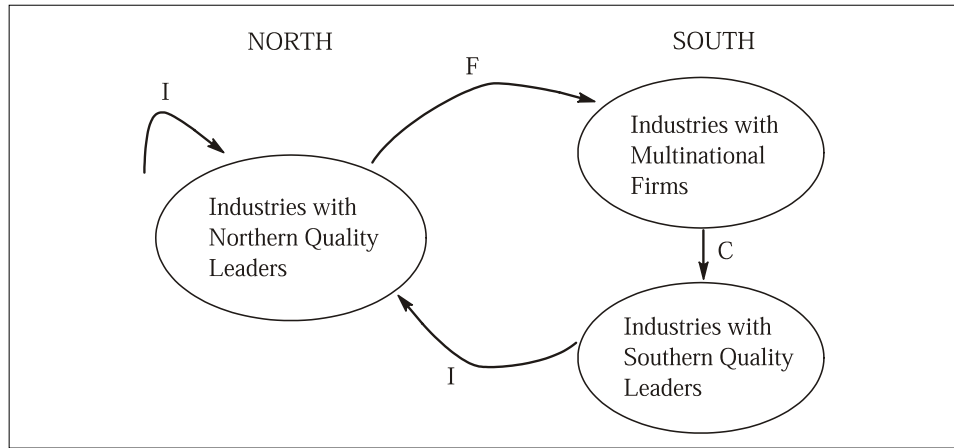
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<sup>4</sup> Suppose that  $\beta$  represents an imitaion R&D productivity parameter when southern firms imitate multinational's product and  $\beta'$  represents an imitaion R&D productivity parameter when southern firms imitate a Northern product. Suppose that  $\beta < \beta'$ . Then the success probability of imitation R&D for multinational's product is greater than the success probability of imitation R&D for Northern product. That is, this inequality implies that the imitation of multinational's product is easier than the imitation of Northern product. In this case, the southern firms do not imitate northern products in equilibrium as long as FDI occurs in this economy. It is because the expected benefit from imitating a product is same in both imitations, (the imaitons of multinational's product and imitation of Northern product). but the expected cost from the imitations of multinational's product is lower than the expected cost from the imitation of Northern product. Therefore there exist only one type of imitation (the imitation of multinational's product) in steady state equilibrium.

Since the innovation and imitation rates do not vary across industries or over time in the steady state, the flow into the  $m_N$  industries must equal the flow out of the  $m_N$  industries. Note that the objects of innovation are the products of southern firms and that a northern firm becomes a multinational firm with probability  $F$ . Hence we obtain

$$m_S I = m_N F .$$

[Figure 1] The Pattern of Innovation, Imitation and FDI



Similarly, the flow into the  $m_F$  industries must equal the flow out of the  $m_F$  industries. Hence

$$m_N F = m_F C .$$

Finally, the flow into the  $m_S$  industries must equal the flow out of the  $m_S$  industries

$$m_F C = m_S I .$$

Using the above four equations, we can derive

$$m_N = \frac{IC}{IC + (C + I)F} ,$$

$$\begin{aligned}
 m_S &= \frac{FC}{IC + (C + I)F}, \\
 m_F &= \frac{IF}{IC + (C + I)F}.
 \end{aligned}
 \tag{23}$$

## 2.5. R&D Optimization

All firms can freely enter into an innovative R&D race in the North and maximize expected discounted profits. Since they have the same innovative R&D technology, all firms other than quality leaders have an incentive to engage in an innovative R&D race. Northern quality leaders have less to gain by innovating since they already earn monopoly profits and with challengers entering innovative R&D race, until their expected discounted profits equal zero, it is not profitable for Northern quality leaders to conduct any innovative R&D. This property where only followers engage in innovative R&D is a common property of endogenous growth models.

In the steady state, the expected benefit from innovative R&D equals to the expected cost. Thus we obtain the following steady state R&D optimization condition

$$v_I(\theta, t) = w_N \gamma q(\theta, t), \tag{24}$$

where  $v_I(\theta, t)$  denotes the expected discounted profits from innovative R&D.<sup>5</sup> Entry into any imitative R&D race in the South is also free. In the steady state, the expected benefit from imitative R&D equals to the expected cost. This gives the steady state R&D optimization condition for southern firms given by

$$v_C(\theta, t) = w_S \beta q(\theta, t), \tag{25}$$

where  $v_C(\theta, t)$  denotes the expected discounted profits from imitative

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<sup>5</sup> Note that  $I_i dt$  is firm  $i$ 's probability of successful innovation during the time interval  $dt$ . Thus the expected benefit from innovative R&D is  $v_I(\theta, t) I_i dt$ . The expected cost during the same time interval is  $w_N \gamma q(\theta, t) I_i dt$ .

R&D.<sup>6</sup>

## 2.6. The Stock Market

There is a stock market that channels consumer savings to the northern and the southern firms that engage in R&D and help households to diversify the risk of holding stocks issued by these firms. Since there is a continuum of industries and returns from engaging in R&D races are independently distributed across firms and industries, each investor can completely diversify away any risk by holding a diversified portfolio of stocks.

### 2.6.1. Northern Firms

The return from holding the stock of a northern quality leader equals the return from an equal sized investment in a riskless bond via no-arbitrage conditions. The stock return is given by the dividend rate plus the capital gain minus the probability of experiencing the total capital loss due to innovation or imitation. Thus the no-arbitrage condition can be written as follows,

$$\frac{\pi_N(\theta, t) + Fv_F(\theta, t)}{v_I(\theta, t)} + \frac{\dot{v}_I(\theta, t)}{v_I(\theta, t)} - I - F = r, \quad (26)$$

where  $\frac{\pi_N(\theta, t) + Fv_F(\theta, t)}{v_I(\theta, t)}$  is the dividend rate from the stock of a Northern quality leader,  $\frac{\dot{v}_I(\theta, t)}{v_I(\theta, t)}$  is the capital gains rate. By (7), interest rate  $r$  equals the subjective discount rate  $\rho$ . Since  $v_I(\theta, t)$  is constant in the steady state, the above no-arbitrage condition (26) yields

$$v_I(\theta, t) = \frac{\pi_N(\theta, t) + Fv_F(\theta, t)}{\rho + I + F}. \quad (27)$$

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<sup>6</sup> Note that  $C_i dt$  is firm  $i$ 's probability of a successful imitation during the time interval  $dt$ . Thus the expected benefit from imitative R&D is  $v_c(\theta, t)C_i dt$  and the expected cost from imitative R&D is  $w_s \beta q(\theta, t)C_i dt$ .

### 2.6.2. Multinational Firms

The return from holding the stock of a multinational firm equals the return from an equal sized investment in a riskless bond by the no-arbitrage condition. The stock return is given by the dividend rate plus the capital gain minus the probability of experiencing total capital loss due to imitation. Thus the no-arbitrage condition for each multinational firm can be written as follows,

$$\frac{\pi_F(\theta, t)}{v_F(\theta, t)} + \frac{\dot{v}_F(\theta, t)}{v_F(\theta, t)} - C = r, \quad (28)$$

where  $\frac{\pi_F(\theta, t)}{v_F(\theta, t)}$  is the dividend rate from the stock of a multinational firm,  $\frac{\dot{v}_F(\theta, t)}{v_F(\theta, t)}$  is the capital gains rate. Since  $v_F(\theta, t)$  is constant in the steady state and  $\rho = r$ , (28) yields

$$v_F(\theta, t) = \frac{\pi_F(\theta, t)}{\rho + C}. \quad (29)$$

### 2.6.3. Southern Firms

The return from holding the stock of a southern quality leader equals the return from an equal sized investment in a riskless bond by the no-arbitrage condition. The stock return is given by the dividend rate plus the capital gain minus the probability of experiencing total capital loss due to successful innovation. Thus the no-arbitrage condition for each southern quality leader can be written as follows,

$$\frac{\pi_S(\theta, t)}{v_C(\theta, t)} + \frac{\dot{v}_C(\theta, t)}{v_C(\theta, t)} - I = r \quad (30)$$

where  $\frac{\pi_S(\theta, t)}{v_C(\theta, t)}$  is the dividend rate and  $\frac{\dot{v}_C(\theta, t)}{v_C(\theta, t)}$  is the capital gains rate. Since  $v_C(\theta, t)$  is constant in the steady state and  $\rho = r$ , (30) yields

$$v_C(\theta, t) = \frac{\pi_S(\theta, t)}{\rho + I}. \quad (31)$$



## 2.7. Steady State R&D Conditions

### 2.7.1. Northern Firms

Using (16), (17), (27) and (29), we obtain the following expression for the expected discounted profits from innovative R&D in the steady state,

$$\begin{aligned}
 v_I(\theta, t) &= \frac{\pi_N(\theta, t) + Fv_F(\theta, t)}{\rho + I + F} \\
 &= \frac{\pi_N(\theta, t) + F \frac{\pi_F(\theta, t)}{\rho + C}}{\rho + I + F} \\
 &= \frac{1}{\rho + I + F} \left[ \left( \frac{w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t) \right. \\
 &\quad \left. + \frac{F}{\rho + C} \left( \frac{\eta w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_F(t) L(t) \right] \\
 &= \frac{1}{\rho + I + F} \left[ \left( \frac{w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t) \right. \\
 &\quad \left. + \frac{F}{\rho + C} \left( \frac{\eta^{1-\sigma} w_N}{\sigma - 1} \right) \frac{q(\theta, t)}{Q(t)} y_N(t) L(t) \right] \\
 &= \frac{[1 + F\eta^{1-\sigma} / (\rho + C)] w_N}{(\rho + I + F)(\sigma - 1)} \frac{q(\theta, t)}{Q(t)} y_N(t) L(t)
 \end{aligned} \tag{32}$$

From the equation (24) and (27), we can derive the following steady state R&D condition for northern firms,

$$v_I(\theta, t) = \frac{\pi_N(\theta, t) + Fv_F(\theta, t)}{\rho + I + F} = w_N \gamma q(\theta, t), \tag{33}$$

which can be rewritten using (24) and (32) as follows:

$$\frac{\frac{1 + F\eta^{1-\sigma} / (\rho + C)}{\sigma - 1} \frac{w_N q(\theta, t)}{Q(t)} y_N(t) L(t)}{\rho + I + F} = w_N \gamma q(\theta, t)$$

Let  $x_N \equiv Q(t)/L_N(t)$  be the measure of relative R&D difficulty. Then  $L(t)/Q(t) = \frac{\bar{L}_N + \bar{L}_S}{x_N \bar{L}_N}$ . Using  $x_N$  and taking integration over  $\theta$  in both sides of the above equation, we obtain,

$$\frac{\rho + C + F\eta^{1-\sigma}}{(\rho + C)(\rho + I + F)} \frac{y_N(t)}{\sigma - 1} (\bar{L}_N + \bar{L}_S) = \gamma x_N \bar{L}_N \quad (34)$$

The left hand side of (34) is associated with the benefit from innovation. The benefit increases as  $y_N(t)$  increases (meaning consumers buy more northern products in average). Also the benefit from innovation increases as the initial population capacity,  $\bar{L}_N$  and  $\bar{L}_S$  increase. But the benefit decreases as the future discount rate  $\rho$ , imitation rate of southern firms  $C$  or innovation rate of northern firms  $I$  increase. As the exogenous arrival rate of FDI,  $F$  increases, the benefit from innovation increases. As the marginal cost of multinational firms increases, it will decrease.

The right hand side of (34) is associated with the cost of innovation. The cost increases as the level of R&D difficulty  $x_N$  increases.

### 2.7.2. Southern Firms

Using (25) and (31), we can derive the following steady state R&D condition for southern firms,

$$v_C(\theta, t) = \frac{\pi_s(\theta, t)}{\rho + I} = w_s \beta q(\theta, t). \quad (35)$$

Using (20), the condition can be rewritten as follows,

$$\frac{\left[ \frac{w_s}{\sigma - 1} \right] \frac{q(\theta, t)}{Q(t)} y_s(t) L(t)}{\rho + I} = w_s \beta q(\theta, t). \quad (36)$$

Using  $x_N$  and taking integration over  $\theta$  in both sides of the equation, we obtain,

$$\frac{\frac{y_S}{\sigma-1}(\bar{L}_N + \bar{L}_S)}{\rho+1} = \beta x_N \bar{L}_N. \quad (37)$$

The left hand side is associated with the benefit from imitation R&D. The benefit is increasing in  $y_S(t)$ ,  $\bar{L}_N$  and  $\bar{L}_S$  and is decreasing in the future discount rate  $\rho$  and innovation rate of northern firms  $I$ .

The right hand side is associated with the cost of imitation R&D. The cost increases as the level of R&D difficulty  $x_N$  and the population of the South  $\bar{L}_N$  increases.

## 2.8. Quality Dynamics

The average quality of products at time  $t$ ,  $Q(t)$  is given by

$$Q(t) = \int_0^1 q(\theta, t) d\theta = \int_0^1 \lambda^{J(\theta, t)} d\theta, \quad (38)$$

where  $\lambda = \delta^{\sigma-1} > 1$ . When innovation occurs in industry  $\theta$ , the quality improves from  $\lambda^{J(\theta, t)}$  to  $\lambda^{J(\theta, t)+1}$ . Since the innovation rate  $I$  is constant across industries and over time, the quality improvement rate during time interval  $dt$  is

$$\dot{Q}(t) = \int_0^1 [\lambda^{J(\theta, t)+1} - \lambda^{J(\theta, t)}] I d\theta = (\lambda - 1) I Q(t) \quad (39)$$

Thus,

$$\frac{\dot{Q}(t)}{Q(t)} = (\lambda - 1) I$$

Since in the steady state, the relative R&D difficulty  $x_N = Q(t) / L_N(t)$  is constant over time, the long run steady state innovation rate is given by

$$I = \frac{n}{\lambda - 1}. \quad (40)$$

Thus the long run steady state innovation rate depends on the population

growth rate  $n$  and the size of innovation  $\lambda$  as in Segerstrom (1998).

The average quality of all products can be derived from the average quality of products by northern leading firms  $Q_N(t)$ , the average quality of products by multinational firms  $Q_F(t)$  and the average quality of products by southern leading firms  $Q_S(t)$  as follows,

$$\begin{aligned} Q(t) &= \int_0^1 q(\theta, t) d\theta \\ &= Q_N(t) + Q_F(t) + Q_S(t) \\ &= \int_{m_N} q(\theta, t) d\theta + \int_{m_F} q(\theta, t) d\theta + \int_{m_S} q(\theta, t) d\theta. \end{aligned} \quad (41)$$

The average product quality for southern leading firms improves after a successful imitation and after a successful innovation by northern firms. Therefore

$$\dot{Q}_S(t) = \int_{m_F} \lambda^{J(\theta, t)} C d\theta - \int_{m_S} \lambda^{J(\theta, t)} I d\theta = CQ_F(t) - IQ_S(t) \quad (42)$$

The average product quality for multinational firms improves after emergence of new multinational firms and after successful imitation. Therefore

$$\dot{Q}_F(t) = \int_{m_N} \lambda^{J(\theta, t)} F d\theta - \int_{m_F} \lambda^{J(\theta, t)} C d\theta = FQ_N - CQ_F \quad (43)$$

The average product quality for northern leading firms after successful innovation and after production shift by multinational firms. It also after successful quality upgrade by leading northern firms. Therefore

$$\begin{aligned} \dot{Q}_N(t) &= \int_{m_S} \lambda^{J(\theta, t)+1} I d\theta - \int_{m_N} \lambda^{J(\theta, t)} F d\theta + \int_{m_N} (\lambda^{J(\theta, t)+1} - \lambda^{J(\theta, t)}) I d\theta \\ &= I\lambda Q_S(t) - FQ_N(t) + (\lambda - 1)IQ_N(t) \end{aligned} \quad (44)$$

Since the quality improvement does not occur by FDI, in the steady state,

$$\frac{\dot{Q}_F(t)}{Q_F(t)} = 0.$$

The growth rate of  $Q_N$  and  $Q_S$  in the steady state is identical. that is,

$$\frac{\dot{Q}_N}{Q_N} = \frac{\dot{Q}_S}{Q_S}.$$

Using the above equations for  $\dot{Q}_N$ ,  $\dot{Q}_F$ , and  $\dot{Q}_S$ ,

$$C \frac{Q_F}{Q_S} - I = I\lambda \frac{Q_S}{Q_N} - F + (\lambda - 1)I.$$

Therefore

$$\frac{Q_S}{Q_N} = \frac{CF}{C\lambda I},$$

$$\frac{Q_F}{Q_N} = \frac{\lambda IF}{C\lambda I}.$$

Finally, we obtain the following steady state expressions of average product qualities,

$$Q_N(t) = \frac{\lambda IC}{(\lambda I + C)F + \lambda IC} Q(t) \quad (45)$$

$$Q_S(t) = \frac{FC}{(\lambda I + C)F + \lambda IC} Q(t) \quad (46)$$

$$Q_F(t) = \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} Q(t) \quad (47)$$

The average quality of products produced in the North  $\frac{Q_N(t)}{m_N}$  is the same as the average quality of products produced by multinational firms in the south  $\frac{Q_F(t)}{m_F}$  since shifts in production from the northern firm to the multinational firm is associated with quality improvement. However the average quality of products produced in the North is somewhat higher than the average quality of products produced in the South  $\frac{Q_S(t)}{m_S}$  since

shifts in production from the South to the North are always associated with increases in product quality through innovation.

## 2.9. The Northern Labor Market

We assume that workers can move freely and instantaneously across firms and across activities (R&D activity or production) but cannot move across regions. In each region, the labor market clearing conditions (full employment) determine levels of wage rate.

**Northern Manufacturing Employment:** Since one unit of labor produces one unit of output, production employment in northern industry  $\theta$  at time  $t$  is given by

$$d(\theta, t)L(t) = \frac{q(\theta, t)p_N^{-\sigma}E(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'} = \frac{q(\theta, t)}{Q(t)}y_N(t)L(t).$$

Since there are  $m_N$  northern leading industries, the total manufacturing labor demand by northern firms is given by

$$\int_{m_N} d(\theta, t)L(t)d\theta = y_N(t)L(t)\frac{\lambda IC}{(\lambda I + C)F + \lambda IC}.$$

**Northern R&D Employment:** Since a northern firm  $i$  hires  $l_i$  labor for innovative R&D to get its probability of success  $I_i$ , the total R&D employment by northern firms is given by

$$\int_{m_N+m_S} \gamma I q(\theta, t)d\theta = \gamma I(Q_N(t) + Q_S(t)) = \gamma I \frac{\lambda IC + FC}{(\lambda I + C)F + \lambda IC} Q(t).$$

Combining the sources of labor demand, we obtain the following northern labor market clearing condition:

$$L_N(t) = y_N(t)L(t)\frac{\lambda IC}{(\lambda I + C)F + \lambda IC} + \gamma I \frac{\lambda IC + FC}{(\lambda I + C)F + \lambda IC} Q(t).$$

Dividing both sides of this equation by  $L_N(t)$  yields the steady state northern labor market condition

$$1 = y_N(t) \frac{\bar{L}_N + \bar{L}_S}{\bar{L}_N} \frac{\lambda IC}{(\lambda I + C)F + \lambda IC} + \gamma I \frac{\lambda IC + FC}{(\lambda I + C)F + \lambda IC} x_N. \quad (48)$$

The right hand side of the equation is composed of two parts. The first part is the share of manufacturing employment and the second part is the share of R&D employment. The northern manufacturing labor demand increases as  $y_N$  (average demand for northern products),  $\frac{\lambda IC}{(\lambda I + C)F + \lambda IC}$  (the ratio of northern products), or  $\frac{\bar{L}_S}{\bar{L}_N}$  (the relative size of southern consumers) increase. The northern R&D labor demand increases as  $I$  (innovation rare),  $x_N$  (innovative R&D difficulty) or the ratio of multinational products and southern products increase.

## 2.10. The Southern Labor Market

Southern labor market has three sources of labor demand, that is, southern manufacturing employment, southern R&D employment and employment by northern multinational firms.

**Manufacturing Employment by Southern Firms:** For each  $\theta$ ,

$$d(\theta, t)L(t) = \frac{q(\theta, t)p_s^{-\sigma}E(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'} = \frac{q(\theta, t)}{Q(t)}y_s(t)L(t).$$

Since there is  $m_s$  leading industries in the South, the total manufacturing labor demand by southern firms is given by

$$\int_{m_s} d(\theta, t)L(t)d\theta = y_s(t)L(t) \frac{FC}{(\lambda I + C)F + \lambda IC}.$$

**Southern R&D Employment:** For each  $\theta$ , southern R&D employment in industry  $\theta$  is

$$\sum_i l_i = \beta C q(\theta, t) d\theta.$$

Therefore the total southern R&D employment is

$$\int_{m_F} \beta C q(\theta, t) d\theta = \beta C Q_F(t) = \beta C \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} Q(t).$$

**Manufacturing Employment by Multinational Firms:** For each  $\theta$ , manufacturing employment by multinational firms in industry  $\theta$  is

$$d(\theta, t)L(t) = \frac{q(\theta, t)p_F^{-\sigma}E(t)}{\int_0^1 q(\theta', t)p(\theta', t)^{1-\sigma}d\theta'} = \frac{q(\theta, t)}{Q(t)} y_F(t)L(t).$$

Therefore, the total multinational employment is

$$\begin{aligned} \int_{m_F} d(\theta, t)L(t)d\theta &= \int_{m_F} \frac{q(\theta, t)}{Q(t)} y_F L(t) \\ &= \phi^{-\sigma} y_S L(t) \frac{\lambda IF}{(\lambda I + C)F + \lambda IC}. \end{aligned}$$

Combining these three sources of labor demand, we obtain the following southern labor market clearing condition

$$\begin{aligned} L_S(t) &= y_S(t)L(t) \frac{FC}{(\lambda I + C)F + \lambda IC} + \beta C \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} Q(t) \\ &= \phi^{-\sigma} y_S L(t) \frac{\lambda IF}{(\lambda I + C)F + \lambda IC}. \end{aligned}$$

Dividing both sides by  $L_S(t)$  yields the steady state southern labor market condition

$$1 = y_S \frac{\bar{L}_N + \bar{L}_S}{\bar{L}_S} \left( \frac{FC}{(\lambda I + C)F + \lambda IC} + \phi^{-\sigma} \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \right)$$



$$+\beta C \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \frac{Q}{L_s}.$$

If we rewrite the Steady State Southern Labor Condition using (definition 1), the steady state southern labor condition becomes

$$1 = y_s \frac{\bar{L}_N + \bar{L}_s}{\bar{L}_s} \left( \frac{FC}{(\lambda I + C)F + \lambda IC} + \phi^{-\sigma} \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \right) + \beta C \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \frac{x_N \bar{L}_N}{\bar{L}_s}. \quad (49)$$

The first part on the right-hand side is the share of manufacturing employment by southern firms, the second part is the share of multinational employment and the last part is the share of R&D employment. Manufacturing labor demand by southern firms increases as  $y_s$  (average demand for southern products),  $\frac{FC}{(\lambda I + C)F + \lambda IC}$  (the ratio of southern products) or  $\frac{\bar{L}_N}{\bar{L}_s}$  (the relative size of northern consumers) increases. The share in R&D labor demand increases as  $\frac{\lambda IF}{(\lambda I + C)F + \lambda IC}$  or  $x_N$  (the level of imitation R&D difficulty) increases. The share of multinational labor demand increases as  $y_F$  (demand for multinational products) or  $\frac{\lambda IF}{(\lambda I + C)F + \lambda IC}$  (the relative proportion of multinational firms) increases.

### III. THE STEADY STATE EQUILIBRIUM

#### 3.1. Existence of the steady state condition

Solving the innovative R&D condition (34) for  $y_N$ , we obtain

$$y_N(t) = \frac{(\rho + C)(\rho + I + F)(\sigma - 1)}{(\rho + C + F\eta^{1-\sigma})(\bar{L}_N + \bar{L}_s)} \gamma x_N \bar{L}_N. \quad (50)$$

Substituting  $y_N$  in the northern labor market condition (48), we obtain the following northern steady state condition,

$$1 = \gamma x_N \left[ (\sigma - 1) \frac{(\rho + C)(\rho + I + F)}{(\rho + C + F\eta^{1-\sigma})} \frac{\lambda IC}{(\lambda I + C)F + \lambda IC} + I \frac{\lambda IC + FC}{(\lambda I + C)F + \lambda IC} \right]. \quad (51)$$

This is a downward sloping curve in the  $(x_N, C)$  space.

We can also determine the steady state condition from the Imitative R&D condition (37) and Southern labor condition (49).

Solving the imitative R&D condition (37) for  $y_S$ ,

$$y_S(t) = \frac{(\sigma - 1)(\rho + I)}{(\bar{L}_N + \bar{L}_S)} \beta x_N(t) \bar{L}_N. \quad (52)$$

Substituting  $y_S$  in the southern labor market condition (49), we obtain the following southern steady state condition:

$$1 = \beta x_N \frac{\bar{L}_N}{\bar{L}_S} \left\{ (\sigma - 1)(\rho + I) \left[ \frac{FC}{(\lambda I + C)F + \lambda IC} + \phi^{-\sigma} \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \right] + C \frac{\lambda IF}{(\lambda I + C)F + \lambda IC} \right\}. \quad (53)$$

Given the steady state values of  $x_N$  and  $C$ , (33) determines  $y_N$  and (35) determines  $y_S$ . Given  $x_N$  and  $L_N(t) = \bar{L}_N e^{nt}$ , Definition 1 determines the time path of  $Q(t)$ . To solve for the steady state North relative wage  $w = w_N = w_N / w_S$ , we divide (33) by (35) to obtain the mutual R&D Condition

$$\frac{(\rho + C + F\eta^{1-\sigma})(\rho + I)}{(\rho + C)(\rho + I + F)} \frac{y_N}{y_S} = \frac{\gamma}{\beta}.$$

Equations (13) and (15) together with the mark-up prices  $p_N = [\sigma / (\sigma - 1)]w_N$  and  $p_S = [\sigma / (\sigma - 1)]w_S$  lead to

$$\frac{y_N}{y_S} = w^{-\sigma}.$$

Thus the mutual R&D condition can be rewritten as

$$w^\sigma \frac{\gamma}{\beta} = \frac{(\rho + C + F\eta^{1-\sigma})(\rho + I)}{(\rho + C)(\rho + I + F)}.$$

Therefore the steady state northern relative wage  $w$  is given by

$$w = \left[ \frac{\beta (\rho + C + F\eta^{1-\sigma})(\rho + I)}{\gamma (\rho + C)(\rho + I + F)} \right]^{1/\sigma}. \quad (54)$$

### 3.2. Numerical Analysis

It is now possible to analyze how the exogenous arrival rate of FDI affects innovation rate and imitation rate in the steady state equilibrium. We solve the system of two equations (51) and (53) for two unknowns  $C$  and  $x_N$  and then obtain other variables  $Q$ ,  $Q_N$ ,  $Q_F$ ,  $Q_S$ ,  $w$ ,  $m_N$ ,  $m_S$ , and  $m_F$  using (47), (45), (46), (54), and (23). This system of non-linear equations is not analytically tractable.<sup>7</sup> We will solve the system numerically under what we believe are plausible parameter values. We use the following as benchmark parameter values<sup>8</sup>:  $\gamma = 3$ ,  $\sigma = 4$ ,  $\rho = 0.05$ ,  $n = 0.01$ ,  $I = \frac{1}{24}$ ,  $\lambda = 1.24$ ,  $\bar{L}_N = 1$ ,  $\bar{L}_S = 2$ ,  $\beta = 2$ ,  $F = 0.05$ ,  $\eta = 0.6$ , and  $\phi = \frac{6}{5}$ .

The economic interpretation of these parameter choices is as follows:  $\lambda = 1.24$  means that innovation represents a 28% improvement. That is, consumers are willing to pay 28% more for each new higher quality product. Given (7),  $\rho = 0.05$  implies that the steady state market interest rate is 5%.  $\bar{L}_N = 1$ ,  $\bar{L}_S = 2$  implies that twice as much labor is employed

<sup>7</sup> The model by Dinopoulos and Segerstrom (2007) is simpler and therefore they could obtain closed form solutions for the two variables. Our model allows for FDI and so there are two kinds of northern firms, multinational or not. This makes it harder to get closed form solutions.

<sup>8</sup> These parameter values are partially based on Lundborg and Segerstrom (2002). In their paper,  $\rho = 0.05$ ,  $n = 0.01$ ,  $\bar{L}_N = 1$ , and  $\bar{L}_S = 2$ .

in the South than in the North.  $n = 0.01$  means that population growth rate is 1%:  $\gamma = 2$  and  $\beta = 3$  means that R&D productivity is higher in the South than in the North.<sup>9</sup> That is, imitation is easier than innovation.  $F = 0.05$  means that exogenous FDI arrival rate is 5%.  $\phi = \frac{\zeta}{w_S} = \frac{6}{5}$  means that a marginal cost of multinational firm is 10% higher than a marginal cost of imitation firm and  $\eta \frac{\zeta}{w_N} = 0.6$  means that a marginal cost of multinational firm is lower than marginal cost of imitation firm. Overall a marginal cost of innovation firm (northern wage,  $w_N$ ) is as twice as a marginal cost of imitation firm (southern wage,  $w_S$ ).

Column 3 of [Table 1] reports the benchmark solution. Column 4 reports the solution for a higher FDI arrival rate  $F = 0.1$ . Column 5 reports the solution for a higher level of globalization.

This table reports imitation rate ( $C$ ), short-run innovation rate ( $x_N$ ), the measure of industries with northern quality leaders ( $m_N$ ), the measure of industries with southern quality leaders ( $m_S$ ), a measure of industries with multinational firms ( $m_F$ ), the relative wage differentials ( $w$ ), the per-capita global demand for a Northern product with average quality  $Q(t)$ , ( $y_N$ ), the per-capita global demand for a Southern product with average quality  $Q(t)$ , ( $y_S$ ), the ratio of Northern production employment, the ratio of Northern R&D employment, the ratio of Southern production employment, the ratio of Southern R&D employment, the ratio of Southern multinational employment, the average quality of Northern products, the average quality of Southern products and the average quality of multinational products.

Before we analyze our FDI and Globalization experiments, it is useful to consider how we characterize the North and the South in terms of economic development. First, the South is labor abundant since we give parameter values as  $\bar{L}_N = 1$  and  $\bar{L}_S = 2$ . Second, the Northern wage is 2 times as high as the Southern wage since  $w_N / w_S = 2$ . Third, the same positive population growth rate in the North and the South. Fourth, the innovative R&D parameter in the North  $\gamma$  is higher than the imitative R&D parameter  $\beta$  in the South which means that innovation is more difficult than imitation.

<sup>9</sup> Mansfield, Schwartz, and Wagner (1981) have found that imitation costs are substantial of the order of 65% of imitation costs.

[Table 1] The result of benchmark solution  $\gamma = 3$ ,  $\sigma = 4$ ,  $\rho = 0.05$ ,  $n = 0.01$ ,  $\lambda = 1.24$ ,  $L_N = 1$ ,  $L_S = 2$ ,  $\beta = 2$ ,  $\eta = 0.6$   $\phi = \frac{6}{5}$ )

		Benchmark Solution ( $F = 0.05$ , $L_S = 2$ )	More FDI ( $F = 0.1$ , $L_S = 2$ )	Globalization ( $F = 0.1$ , $L_S = 3$ )
$C$		$2.6797 \times 10^{-2}$	0.09323	$3.9374 \times 10^{-2}$
$x_N, Q$		6.8023	5.1752	8.4753
$m_N$		0.24595	0.22358	0.16836
$m_S$		0.29514	0.5366	0.40406
$m_F$		0.45891	0.23982	0.42759
$w$		1.1471	1.0778	1.1848
$y_N$		0.72019	0.7031	0.59141
$y_S$		1.2471	0.94879	1.1654
$L_N$	Manufacturing	56.4	52.6	43.2
	Innovation R&D	43.6	47.4	56.8
$L_S$	Manufacturing	47.2	68.7	54.9
	Multinational	43.9	18.4	34.8
	Imitation R&D	8.9	12.9	10.3
$Q_N / m_N$		7.21	5.78	9.19
$Q_F / m_F$		7.21	5.78	9.19
$Q_S / m_S$		5.82	4.66	7.41

### 3.2.1. Effects of FDI

In column 4 of [Table 1], we calculate the steady state solution when  $F$  increases from 0.05 to 0.1. As in the table, the higher FDI arrival rate leads to a higher imitation rate  $C$ , a lower short-run innovation rate  $x_N$  and a lower wage differential between the two regions  $w$ . The measure of industries with northern quality leaders  $m_N$  slightly decreases from 0.24595 to 0.22358 but the measure of industries with southern quality leaders  $m_S$  increases from 0.29514 to 0.5366. Interestingly, the measure of industries with multinational firms  $m_F$  decreases from 0.45891 to 0.23981. This is because the higher FDI arrival rate brings in the more devotion to imitation R&D by southern firms. This can be seen in [Table 1]. Note that more workers are employed for imitation R&D in the South and for manufacturing in southern firms and less workers are employed for manufacturing in multinational firms. Finally, note that all three average quality levels for northern firms, for multinational firms and for

southern firms go down.

### 3.2.1. Effects of Globalization

As in Dinopoulos and Segerstrom (2007, 2010), globalization is described by an expansion in the size of the southern population.<sup>10</sup> In column 5 of [Table 1], we calculate the steady state solution when  $\bar{L}_S$  increases from 2 to 3. Let us explain effects of such globalization by comparing column 5 with column 4. As in the table, globalization leads to a lower imitation rate  $C$ , a higher short-run innovation rate  $x_N$  and a larger wage differential between the two regions  $w$ . The measure of industries with northern quality leaders  $m_N$  somewhat decreases from 0.22358 to 0.16836 and the measure of industries with southern quality leaders  $m_S$  also decreases from 0.5366 to 0.40406. Interestingly, the measure of industries with multinational firms  $m_F$  rapidly increases from 0.23981 to 0.42759. This is because globalization attracts more multinational firms due to more abundant labour supply in the South and accordingly a lower wage in the South. [Table 1] shows that less workers are employed for imitation R&D in the South and for manufacturing in southern firms and more workers are employed by multinational firms. Note that the average quality levels of northern firms, multinational firms and southern forms increase.

## IV. CONCLUDING REMARKS

Recently Dinopoulos and Segerstrom(2007) developed North-South trade model without a scale effects property that predicts economic growth from research and development in the quality of products. I extend their model by adding an FDI option for Northern firms, which can contribute to economic growth in both the North and the South.

I assumed that Northern firms of our model have an incentive to choose FDI because of lower production cost in the South.

Through a numerical analysis, I show that a higher exogenous arrival rate of FDI leads to a higher imitation rate in the South, a greater industry

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<sup>10</sup> Our globalization can be interpreted as more developing countries joining the world trade system.

shift from the North to the South (an increase in the ratio of Southern imitation firms and multinational firms) and a lower wage inequality between the North and the South. But the short-run innovation rate decreases and there is no predicted change in the long run innovation rate. In other words, FDI increases economic growth of the South and narrows wage gap between the North and the South.

Through numerical analysis, I show that an increases in the Southern population leads to less copying of Northern products, faster technological change, more production shift from the North to the South by multinational firms, and larger wage inequality between the North and the South.

## References

- Balasubramanyam, Venkataraman N., Mohammed A. Salisu, and David Sapsford (1996), "Foreign Direct Investment and Growth in EP and IS Countries," *Economic Journal*, Vol. 106, pp. 92-105.
- Barro, Robert, Xavier Sala-I-Martin (1995), *Economic Growth*, Magraw-Hill Inc.
- Borenztein, E., J. De Gregorio and J-W Lee (1998), "How does Foreign Direct Investment Affect Economic Growth?" *Journal of International Economics*, Vol. 45, pp. 115-35.
- Brainard, S. L. (1993), "A Simple theory of Multinationals Corporations and Trade with a Trade off between Proximity and Concentration," *NBER Working Paper*, No. 4269.
- Dinopoulos, E. and P., Segerstrom (1999), "The Dynamic effects of Contingent Tariffs," *Journal of International Economics*, Vol. 47, pp. 191-222.
- Dinopoulos, E. and P., Segerstrom (2007), "North-South Trade and Economic Growth," Working Paper, Stockholm School of Economics.
- Dinopoulos, E. and P., Segerstrom (2010), "Intellectual Property Rights, Multinational Firms and Economic Growth," *Journal of Development Economics*, Vol. 92, pp. 13-27.
- Dinopoulos, E. and P., Thompson (1998), "Schumpeterian Growth without Scale Effects," *Journal of Economic Growth*, Vol. 3, pp. 313-335.
- Ethier, W. J. and J. R., Markusen (1991), "Multinational Firms, Technology Difussion and Trade," *NBER Working Paper*, No. 3825.
- Glass, Amy J. and Kasmal Saggi (1998), "International Technology Transfer and Technology Gap," *Journal of Development Economics*, Vol. 55, pp. 369-98.
- Glass, Amy J. and Kasmal Saggi (1999), "Foreign Direct Investment and the Nature of R&D," *Canadian Journal of Economics*, Vol. 32, pp. 92-117.
- Glass, Amy J. and Kasmal Saggi (2002a), "Intellectual Property Rights and Foreign Direct Investment," *Journal of International Economics*, Vol. 56, pp. 387-410.
- Glass, Amy J. and Kasmal Saggi (2002b), "Licensing Versus Direct Investment: Implications for Economic Growth," *Journal of International Economics*, Vol. 56, pp. 131-53.
- Grossman, Gene M. and Elhanan Helpman (1991a), *Innovation and Growth in the Global Economy*, Cambridge, Mass: MIT Press.
- Grossman, Gene M. and Elhanan Helpman (1991b), "Quality Ladders and Product Cycles," *The Quarterly Journal of Economics*, Vol. 106, pp. 557-586.



- Helpman, E. (1984), "A Simple Theory of International Trade with Multinational Corporations," *Journal of Political Economy*, Vol. 92, pp. 451-472.
- Horstmann, I. J. and J. R. Markusen (1992), "Endogenous Market Structures in International Trade," *Journal of International Economics*, Vol. 32, pp. 109-129.
- Howitt, P. (1999), "Steady Endogenous Growth with Population and R&D Inputs Growing," *Journal of Political Economy*, Vol. 107, pp. 715-730.
- Hoekman, Bernard., Kamal Saggi (2000), "Multinational Disciplines for Investment -Related Policies?" *Gloval Governance, Regionalism, and International Economy*, Baden- Baden: Momos-Verlagsgesellschaft.
- Jones, C. (1995b), "R&D Based Models of Economic Growth," *Journal of Political Economy*, Vol. 103, pp. 759-784.
- Keller, Wolfgang (1996), "Absortive Capacity: On the Creation and Acquisition of Technology in Development," *Journal of Development Economics*, Vol. 42, pp. 75-88.
- Kortum, S. (1997), "Research, Patenting and Technological Change," *Econometrica*, Vol. 65, pp. 1389-1419.
- Krugman, P. R. (1979), "A Model of Innovation, Technology Transfer, and the World Distribution of Income," *Journal of Political Economy*, Vol. 87, pp. 253-266.
- Li, C. (2002), "Endogenous Growth without Scale Effects: Comment," University of Glasgow, *American Economic Review*.
- Lundborg, P. and Paul S. Segerstrom (2002), "The Growth and Welfare Effects of International Mass Migration," *Journal of International Economics*, Vol. 56, pp. 177-204.
- Mansfield, E., Schwartz, M. and S., Wagner (1981), "Imitation Costs and Patents: An Empirical Study," *The Economic Journal*, Vol. 91, pp. 907-918.
- Markusen, J. R. (1984), "Multinationals, Multi Plant Economies, and Gains from Trade," *Journal of International Economics*, Vol. 14, pp. 205-226.
- Markusen, J. R. (1995), "The Boundaries of Multinational Enterprises and the Theory of International Trade," *Journal of Economic Perspectives*, Vol. 9, No. 2, pp. 169-189.
- Romer, P. (1990), "Endogenous Technological Change," *Journal of Political Economy*, Vol. 98, S71-S102.
- Segerstrom, P. (1998), "Endogenous Growth without Scale Effects," *Americal Economic Review*, Vol. 88, pp. 1290-1310.
- Young, A., (1998), "Growth without Scale Effects," *Journal of Political*

*Economy*, Vol. 106, pp. 41-63.

Xu, Bin (2000), "Multinational Enterprises, Technology Diffusion, and Host Country Productivity Growth," *Journal of Development Economics*, Vol. 62, pp. 477-93.