Title: Competition for FDI in the Product Cycle

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Abstract

The paper develops a dynamic model of the North-South product cycle, in which Northern firms continuously transfer production to two Southern countries through foreign direct investment (FDI). The technologies of Northern multinationals are eventually imitated by Southern firms. The competition among Southern countries for FDI through R&D, trade, FDI and intellectual property rights policies are examined. A Southern country's subsidy to attract inward FDI benefits its production workers at the expense of those in other Southern countries. However, a Southern country's import tariffs against the North benefit the production workers of all Southern countries.

Keywords: product cycle, North-South trade, foreign direct investment

1 Introduction

The 1990s have been an era of liberalization in international trade and investment for less developed countries. A major reason developing countries (hereinafter LDCs or the South) want to attract direct investment from more advanced countries (hereinafter DCs or the North) is the potential technological spillovers (see for example, Findlay, 1978). Borensztein, De Gregorio and Lee (1998) conclude that "... it appears that the main channel through which FDI [foreign direct investment] contributes to economic growth is by stimulating technological progress, rather than by increasing total capital accumulation in the host country". In order to acquire the technology or know-how from more advanced countries, LDCs provide incentives to attract firms from the more advanced countries to locate on their soil, hoping that they can learn how to produce the goods themselves. Therefore, we see export-processing zones being established in developing countries, such as *maquiladoras* in Mexico[1] and special economic zones in southern China. Export processing zones usually provide subsidized infrastructure and tax holidays to foreign firms. We also see that Singapore has adopted the policy of providing incentives to attract FDI from advanced countries as a major development strategy. Recently, Hong Kong decided to build a "cyberport" that provides subsidies to attract international high-tech companies to set up design facilities there, hoping that it can facilitate the city's evolution into a high-tech design center.[2]

Northern firms hire Southern workers to work for their subsidiaries in the South. These workers learn the skills and the operation of the firms, and may eventually leave and set up their own companies. However, since the parent firm would usually hold the most crucial part of the technology as a trade secret, imitators in the LDCs have to invest in research in order to fully imitate the technology. Therefore, although imitation is made possible by the presence of MNCs, it is also costly to the imitator.

Because of the positive externality of the presence of Northern MNCs in a Southern country, Southern governments all have the incentive to subsidize Northern FDI. Since the number of Northern firms whose production operations are transferable to the South is limited, Southern firms might have to compete with each other for Northern FDI through subsidization of the activity, trade policy, intellectual property rights policy, etc.

[1] These are assembly plants located in northern Mexico controlled by multinational firms that process imported materials and components for export, mostly to the United States.

[2] See website http://www.cyber-port.com/ for the "cyberport".

In this paper, I shall capture the above phenomenon using a dynamic general equilibrium model of the international product cycle (Vernon 1966) with one Northern country and two Southern countries. The product cycle model assumes that only the Northern firms can innovate, and Southern firms can acquire technology only through imitation from MNCs. I use the model to study how a Southern country's trade policy, FDI policy and technology policy affect the rate of technology diffusion from the North to the Southern countries, the rate of imitation by the Southern countries and the distribution of workers' income among all countries. I emphasize how policies in one Southern country affect the other Southern countries.

There exists a literature on tax competition between countries for foreign direct investment. All of them are partial equilibrium analyses of strategic interaction between two countries for a firm to be located on their soil. See, for example, Bond and Samuelson (1989) and Janeba (1998). Typically, in equilibrium, the firm would locate in only one of the countries. Moreover, because of the partial equilibrium nature of the model, wages are exogenous. My model, on the other hand, captures the continuous innovation and production transfer by Northern firms and continuous imitation by the South. It examines the world with two or more Southern countries competing for the FDI from many firms in the North. The model can also determine how wages are affected by policies.

The key results of this paper are as follows. First, a Southern country's subsidy policies aimed at attracting Northern FDI can be "beggar-thy-neighbor" in nature, in the sense that, a Southern country's subsidy to inward FDI from the North would lead to higher real wage of production labor in that country, at the expense of production labor in other Southern countries. Therefore, a Southern country's subsidy policy can have a negative externality on other Southern countries. Second, Southern tariffs on imports from the North can be used as an incentive to attract FDI, since Northern firms would want to "jump" the tariffs. However, unlike other policies that attract FDI, a Southern country's tariffs on Northern goods benefit the production workers of other Southern countries too. Therefore, the policy can have a positive externality on other Southern countries. Finally, an increase in the number of Southern countries participating in the product cycle lowers the real wage of production workers in all Southern countries. The entry of a giant LDC, such as China, into the WTO would increase the size of the Southern region tremendously. According to this model, it would lower the real wage of production workers in Southern countries that compete with China for Northern FDI.

Section 2 lays out the dynamic general equilibrium model with innovation in the North and gradual diffusion of technology to the South. Section 3 solves for the steady state equilibrium of the model. Section 4 evaluates the effects of various policies on the steady state equilibrium and on factor returns. Section 5 concludes.

2 The Model

This is a dynamic general equilibrium model with two regions and three countries: one in the North and two in the South. Each country is endowed with unskilled and skilled labor. The variables L_N^r, L_s^r and L_s^{r*} denote the supply of skilled labor in the North, Southern country S1 and Southern country S2 respectively. (The superscript r stands for research.) The variables L_N^p, L_s^p and L_s^{p*} denote the supply of unskilled labor in the North, Southern country S1 and Southern country S2 respectively. (The superscript p stands for production.) All workers can perform production tasks, but only skilled workers can undertake R&D (i.e. innovation or imitation).[3]

In equilibrium, I assume that the North has such an absolute advantage in innovation that only Northern firms have the incentive to undertake product innovation. Moreover, I assume that parameters are such that, in equilibrium, only Southern firms have the incentive to imitate. This would be true when the Northern wage is sufficiently higher than that of the South in equilibrium, and the labor requirement for innovation is not much higher than that for imitation. Product innovation is the development of a new variety of product. Consumers have love-of-variety of the kind specified by Dixit and Stiglitz (1977). In equilibrium, the Southern wage is lower than the Northern wage, so Northern firms have the incentive to locate production in the South. However, this incentive is tempered by the risk of the product being imitated by Southern firms. There is a constant probability with which a Northern MNC's product is imitated, given that it has not been imitated yet.

In this paper, I are only concerned with the steady state, i.e. the long run equilibrium. For the present purpose, I shall not undertake welfare analysis, but focus on the income

[3] We assume that parameters are such that, in equilibrium, wages are higher in the R&D sector than in the production sector in both the North and the South. Consequently, workers who can perform R&D and production will always work in the R&D sector. Therefore, I implicitly assume that R&D workers command a higher wage than production workers in each country due to their additional skills. A condition for this to be true is derived in an appendix available from the author upon request.

distribution among production workers in different countries. The steady state is defined as a state at which the growth rate of the economy is constant over time.

When a Northern firm develops a product, it incurs an upfront innovation cost. It then earns the opportunity to make a stream of future profits. In equilibrium, there is no imitation by Northern firms, and imitation only occurs in South. However, imitation is costly.

At any date, a number of differentiated products have been developed by the North. Each innovation takes the form of the introduction of a new differentiated product in the economy by a firm. In equilibrium, since the unit cost of production is lower in the South, some Northern firms will transfer production to the South by setting up a wholly-owned subsidiary (MNC), a process I call "multinationalization". Since the Southern unit cost of production is lower, the Northern firm will stop production in the North once it has multinationalized production.[4]

I assume that a product developed by the North cannot be imitated by the South until its production has been multinationalized by the innovator. Moreover, I assume that the Northern firm's unit labor requirement for production is greater in the South than in the North. Despite this, the unit cost of production in the South is still lower because of its lower wage. The only motivation for production transfer by a Northern firm is the lower production cost in the South.

2.1 Consumers' Optimization

Assume there is a representative agent in each country who chooses a time path of instantaneous expenditure $E(\tau)$ to maximize overall utility at time t:

$$W = \int_t^\infty e^{-\rho(\tau-t)} \frac{U(\tau)^{1-\sigma} - 1}{1-\sigma} d\tau \tag{1}$$

subject to the intertemporal budget constraint

$$\int_t^\infty e^{-r(\tau-t)} E(\tau) d\tau = \int_t^\infty e^{-r(\tau-t)} I(\tau) d\tau + A(t) \qquad \text{for all } t \tag{2}$$

where ρ is the time rate of preference; r is the nominal interest rate ; $0 \le \sigma \le 1$ and σ is intertemporal elasticity of substitution; $U(\tau)$ is instantaneous utility at time τ ; $E(\tau)$ is

[4] I do not differentiate between multinationalization through a wholly-owned subsidiary, partly-owned subsidiary or technology licensing. I assume that there is no information asymmetry to prevent the efficient buying and selling of technology. So, the three modes of technology transfer would yield the same result.

instantaneous expenditure at τ ; $I(\tau)$ is instantaneous income at τ ; $A(t)$ is the current value of assets at t. The agent has perfect foresight and takes the time path of $A(\tau)$, $I(\tau)$, r and prices of goods as given.

At any date t, the instantaneous utility is assumed to be

$$U(t) = \{\int_0^{n(t)} [x(z)]^\alpha dz\}^{\frac{1}{\alpha}} \tag{3}$$

where $0 < \alpha < 1$; $x(z)$ = quantity of good z consumed and $n = n(t)$ also stands for the index of the most recently developed good existing in the world at time t.

The optimization problem specified by the last three equations can be reduced to a two-stage budgeting problem, where the agent solves a dynamic optimization problem of allocating $E(t)$ over time, then solves a static optimization problem of choosing the various $x(z)$ subject to a budget constraint of $E(t) = \int_0^{n(t)} p(z)x(z)dz$ at time t.

It can be shown that the first order conditions of the dynamic optimization problem can be reduced to the equation:

$$r = \rho - (1-\sigma) \cdot \frac{1-\alpha}{\alpha} \cdot \frac{\dot{n}}{n} + \frac{\dot{E}}{E} \tag{4}$$

where $\dot{E}/E$ is the growth rate of total expenditure on goods.[5] Equation (4) implies that the higher the interest rate the more people are willing to postpone consumption to the future, so that $\dot{E}/E$ is higher. Also, define the steady state value of $\dot{n}/n$ as g. The time argument t will be dropped hereinafter for convenience, unless otherwise stated.

The solution to the static maximization problem yields

$$x(z) = \frac{p(z)^{-\epsilon}}{\int_0^n p(u)^{1-\epsilon} du} E \tag{5}$$

where $\epsilon = 1/(1-\alpha)$ is the elasticity of substitution between any two goods, and $\epsilon > 1$.

The production technology is assumed to exhibit constant returns to scale, and the unit labor requirement for production is the same for all goods produced in the same country. Due to the symmetry of all goods in the preference function (3), $x(z)$ is the same for all goods produced in the same country.

[5] A derivation of (4) can be found in, for example, Lai (1998).

2.2 The Steady State

At any given date, there are n goods existing in the world, among which the production of n_s goods has been transferred to the first Southern country (S1), the production of n_s^* has been transferred to the second Southern country (S2) and n_N goods continue to be produced in the North. Therefore, $n = n_s + n_s^* + n_N$.[6] Hereinafter, all Southern variables with an asterisk are those associated with country S2. *Since the conditions in S1 and S2 are similar, I shall only focus on the description of S1 when I refer to a Southern country.* Moreover, $n_s = n_i + n_m$ where n_i = number of products that have been imitated by S1; n_m = number of products that have not been imitated and so are produced only by Northern MNCs in S1. Because of symmetry of all goods in the demand function, x_N, x_m and x_i stand for the demand for any good produced only by a Northern firm, only by a Northern MNC in S1, and by both a Northern MNC and Southern firm in S1, respectively. Goods that have been imitated are produced by both the MNC and the imitator in S1. I assume that the two firms collude and split a monopoly profit between them. It follows that $x_i = x_m$. The values of x_N, x_m and x_i are determined by demand function (5) when the prices of the n goods are known. Because transportation cost is zero and there are no prohibitive trade barriers, the producer of a good always sells to the world market. Let π_N be the instantaneous profit of a Northern firm, and π_m be that of a MNC whose product has not been imitated by a firm in S1 at that date, and π_i be that of a firm in S1 that has imitated from an MNC. (π_i is also the instantaneous profit of an MNC whose product has been imitated. Therefore, $\pi_i = \pi_m/2$.) Wages of (unskilled) production workers in the North and S1 are denoted by w_N and w_s respectively. Wages of (skilled) research workers in the North and S1 are denoted by w_N^r and w_s^r respectively.

2.3 Innovation and Technology Diffusion

We assume constant returns to scale in the production of each good. There are no fixed costs of production per period, nor are there transportation costs.

[6] For simplicity, assume that the same Northern firm would either stay in the North or move its production completely to the South, and it only sets up an MNC in either S1 or S2 but not both. But this assumption is not essential for the validity of the derivation that follows. More generally, Northern firms can choose to locate some fraction of their production in each of the South, S1 and S2 respectively. In that case, n_s/n is the fraction of the aggregate profit of all Northern firms derived from MNCs in S1, n_s^*/n is that derived from MNCs in S2 and n_N/n is that derived from Northern plants that stay in the North.

Assume for simplicity that each product is developed and produced by a different firm.[7] Firms compete with each other by setting prices. At each date, because of time separability of the intertemporal profits function, a Northern innovator or an MNC producing good z chooses price $p(z)$, given the prices of other goods, to maximize instantaneous profit $\pi(z)$, subject to the demand function (5). Therefore, a Northern firm or its subsidiary in the South chooses $p(z)$ to maximize $\pi(z) = x(z)[p(z) - c(z)]$ subject to the demand function (5), where $c(z)$ is the unit production cost of good z.

Thus, I obtain from the first order condition the mark-up pricing rule for a Northern innovator or an MNC whose product has not been imitated (Dixit and Stiglitz, 1977)

$$p(z) = \frac{c(z)}{\alpha} \tag{6}$$

I assume that the Northern firms have such comparative advantage in innovation (vs. imitation of Northern goods) that Northern-innovated goods will not be imitated in the North, but will only be imitated in the South (after multinationalization). Once a product is imitated in a Southern country, I assume, for simplicity, that the Southern imitator colludes with the MNC.[8] Therefore,

$$\pi_i = \frac{\pi_m}{2} \tag{7}$$

Without loss of generality, I assume that the unit labor requirement for production is one in North, so that

$$c_N(z) = w_N \tag{8}$$

where $c_N(z)$ is the unit cost of production of a good z that is produced in North, w_N = wage rate of production workers in North.

On the other hand,

$$c_s(z) = w_s \eta \tag{9}$$

where $c_s(z)$ is the unit cost of production of a good z that is produced in S1, $\eta > 1$ is the unit labor requirement for all goods produced in S1. A similar equation exists for S2.

[7] It is not necessary to have all products developed by different firms, but it is necessary to have a sufficiently large number of firms so that we can ignore the effects of any single producer's action on the denominator of the demand function (5).

[8] We do not lose much generality by making this assumption. An alternative assumption is that the two firms split a profit that is less than the monopolistic one. But this change of assumption would not affect the qualitative aspects of any of our results. Moreover, the assumption that the imitator and the innovator split the monopoly profit is also used in, for example, Segerstrom (1991).

In the steady state, $\dot{n}_s/n_s = \dot{n}_i/n_i = \dot{n}_m/n_m = \dot{n}/n = g$, and g, n_s/n, n_i/n and n_m/n are constant over time. It can be deduced from (5) to (8) and symmetry of all $x(z)$ in the utility function that in the steady state, π_N and π_m are constant over time. All the above descriptions about S1 also apply to S2.

Define the (Poisson arrival) rate of imitation from MNCs by firms in S1 as $\dot{n}_i/n_m$, denoted by δ; and the (Poisson arrival) rate of multinationalization from the North to S1 as $\dot{n}_s/n_N$, denoted by ω. The rate δ can be regarded as a "hazard rate", i.e. the probability that a multinationalized product will be imitated at the next instant. Similarly, ω is the "hazard rate" at which a North-produced product will be multinationalized to become an MNC in S1 in the next instant.[9] The rate of multinationalization ω is endogenous, being determined by optimization decisions of Northern firms, as shown below. All firms that have not been imitated have an equal chance of being imitated at any date. Therefore, all unimitated products of MNCs in S1 face the same δ. The variables δ and ω are both constant over time in the steady state.

Knowing δ, a Northern firm will decide whether or not to multinationalize at each date. There is symmetry among all Northern firms. At any date, the equilibrium values of ω and ω^* are the ones that leave all Northern firms indifferent between transferring production to the South and continuing production in the North. If ω (or ω^*, respectively) is below the equilibrium value, the PDV of profits from transferring production to S1 (or S2, respectively) is higher than that from continuing production in the North for each firm. Thus, more Northern firms transfer their production to S1 (S2), leading to an increase of ω (ω^*). If ω (ω^*) is above the equilibrium value, there are gains from moving production back to the North. As some firms move back to the North to seek higher profits, ω (ω^*) decreases. Therefore, ω (ω^*) is a stable equilibrium.[10]

[9] If we assume the duration τ between the time of multinationalization and time of imitation to have an exponential distribution with cumulative density $Pr(\tau \leq t) = 1 - e^{-\delta t}$, then δ is the "hazard rate" or Poisson arrival rate at which a good will be imitated in the next instant provided that it has not been imitated. See Lee and Wilde (1980). See also Helpman (1993) for a discussion of "hazard rate".

[10] There are other reasons for Northern firms to stay in the North, despite the higher production cost. However, I only focus on the factor that is affected by trade and investment policies.

2.3.1 Innovation

Following Romer (1990) and Grossman and Helpman (1991), the number of new products developed by a firm is assumed to be

$$\frac{1}{a} \cdot l_N^r \cdot n,$$

where a is a cost parameter of innovation, l_N^r is amount of skilled labor devoted to product development in the firm. The term n captures the positive externalities of knowledge on productivity of innovation, since n is a proxy for knowledge, as in Romer (1990).

Therefore, in equilibrium, the total number of new products developed in North at date t is given by

$$\dot{n} = \frac{1}{a} \cdot L_N^r \cdot n. \tag{10}$$

Recall that L_N^r is the aggregate quantity of skilled labor devoted to R&D in the North. The rate of innovation is therefore given by $g \equiv \dot{n}/n = (1/a) \cdot L_N^r$, which is constant, given that L_N^r is constant.

The Northern labor productivity in innovation is $\dot{n}/L_N^r = n/a$. The steady state growth rate of Northern labor productivity in innovation is therefore $\dot{n}/n = g$, the same as the rate of innovation.

Following the above modification to Romer (1990) and Grossman and Helpman (1991, ch.3), we obtain the cost of innovation by a Northern firm as:

$$C_d = a\frac{w_N^r}{n}.$$

As implied from the above discussion, a/n is the labor requirement for developing a new product.

2.3.2 Imitation

Assuming perfect knowledge spillovers from North to South, the labor productivity in imitation in S1 is directly proportional to knowledge stock in the North:

$$\dot{n}_i = \frac{1}{b} \cdot L_s^r \cdot n \tag{11}$$

where b is the cost parameter of imitation. Recall that L_s^r is the total amount of labor that can undertake imitation in the South. A corresponding equation exists for S2.

It can be shown that in the steady state $\dot{n}_i/n_i = \dot{n}/n \equiv g$.[11] Southern labor productivity in imitation is $\dot{n}_i/L_s^r$. Hence, I obtain the cost of imitation in S1 as

$$C_i = b\frac{w_s^r}{n}.$$

We normalize by setting $w_N^r = n/a$ so that the value of each Northern firm is one at any time. This also implies that E/n is constant over time in steady state, or $\dot{n}/n = \dot{E}/E$. Hence, equation (4) becomes $r = \rho + \psi g$, where $\psi = 1 - (1-\sigma)[(1-\alpha)/\alpha] \leq 1$. We assume that $\alpha \geq 1-\sigma$ (which will include the case of logarithmic utility in the intertemporal utility function stated in equation (1)) so that $0 \leq \psi \leq 1$. This will ensure the stability of the general equilibrium.[12]

2.3.3 Pricing Strategy of Northern Firms and MNCs

When production location is in the North, a Northern innovator-cum-producer firm prices at the monopoly level according to (6) and (8), so that the price of a Northern good is

$$p_N = \frac{w_N}{\alpha}. \tag{12}$$

After production has been transferred through multinationalization to S1, the MNC sets its price at the monopoly level:

$$p_m = \frac{w_s \eta}{\alpha} \tag{13}$$

The demand function (5), production cost function (8), and mark-up pricing rules (12) & (13) show that the profit of the MNC, π_m, and that of a Northern firm, π_N, are related by

$$\frac{\pi_m}{\pi_N} = (\frac{w_s \eta}{w_N})^{1-\epsilon} \tag{14}$$

It must be true that $\pi_m > \pi_N$ in equilibrium; otherwise there is no incentive to shift production location to the South. Since $\epsilon > 1$, we need the condition that $(w_s/w_N) \cdot \eta < 1$. It is shown below that this must be true in equilibrium.

[11] Define $K_1 \equiv L_N^r/a$ and $K_2 \equiv L_s^r/b$. Equation (10) implies $n = n(0)e^{K_1 t}$ and (11) implies $\dot{n}_i = K_2 n(0)e^{K_1 t}$ which implies $n_i = [K_2 n(0)/K_1]e^{K_1 t} + n_i(0) - [K_2 n(0)/K_1]$. Therefore, $n_i \to [K_2 n(0)/K_1]e^{K_1 t}$ as $t \to \infty$, which implies $\dot{n}_i/n_i = \dot{n}/n$ in the steady state.

[12] If $\psi < 0$, then more entry into innovation activity lowers the interest rate, which can increase the profit rate of innovations, leading to even more entry. This would cause instability of the steady state equilibrium.

2.3.4 Multinationalization Equilibrium

The expected present discounted value (PDV) of profits of a Northern MNC *with* Poisson arrival imitation rate δ is

$$\Pi_m = \frac{\pi_m}{r+\delta} + \frac{\delta \pi_m}{2r(r+\delta)} = \frac{\pi_m(2r+\delta)}{2r(r+\delta)} \tag{15}$$

For more detailed derivation and interpretation of the equation, refer to Appendix A and Lee and Wilde (1980). Note that $\partial \Pi_m / \partial \delta < 0$, i.e. an increase in the probability of imitation lowers the PDV of profits of a MNC.

Let Π_N be the PDV of profits for a Northern firm if the innovator never multinationalizes. It is clear that $\Pi_N = \pi_N / r$. Since in steady state equilibrium a Northern firm is indifferent between multinationalization and continuing production in North, it must be true that the PDV of a Northern firm's profits is Π_N regardless of whether it eventually multinationalizes. Therefore $\Pi_N = \Pi_m$ in steady state equilibrium. Hence,

$$\frac{\pi_N}{\pi_m} = \frac{2r+\delta}{2(\delta+r)} \tag{16}$$

The above equation shows that because of the risk of being imitated, the instantaneous profit of a Southern MNC must be larger than that from Northern production in equilibrium.

2.3.5 Imitation Equilibrium

Equations (10) and (11) and the fact that $\dot{n}_i/n_i = \dot{n}/n$ in the steady state (see footnote 11) implies that

$$\frac{n}{n_i} = \frac{\dot{n}}{\dot{n}_i} = \frac{b}{a} \cdot \frac{L_N^r}{L_s^r} \qquad \text{in steady state.} \tag{17}$$

The above equation shows that n_i/n, the steady state fraction of Northern products imitated by S1, is constant over time, being determined by the exogenous variables L_N^r and L_s^r.

2.3.6 Zero Profit Conditions

Finally, it has to be emphasized that I assume free entry into the innovation business in the North and imitation business in the South. In the steady state, therefore, PDVs of the profits of all firms are zero. From these conditions, I can derive the wage of Southern research workers relative to other wages. I can also derive the condition for the wage of research workers to be higher than the wage of production workers, which I have assumed. The conditions are derived in an appendix, which is available from the author upon request.

3 Solution of the Model

3.1 Steady State Equilibrium

In this section, I want to find the reduced form of the following four equations: (i) One multinationalization equilibrium condition for each of S1 and S2; and (ii) On imitation equilibrium condition for each of S1 and S2. All these equations are in terms of the variables δ, ω, δ^* and ω^*. Then I shall be able to find the effects of changes in the parameters on the endogenous variables. However, since the equations for S1 and S2 are similar, I only need to present the equations for S1 for simplicity of exposition. Hereinafter, therefore, I shall only deal with two equations instead of four. Because the unit labor requirement for all goods produced in the South is η, as shown in (9), and price is constant mark-up over cost as shown in (12) and (13), we have $\pi_m = x_m(p_m - w_s\eta) = x_m w_s \eta[(1-\alpha)/\alpha]$ where $x_m = (L_s^p/n_s) \cdot \eta$. Similarly, $\pi_N = x_N w_N[(1-\alpha)/\alpha]$ where $x_N = L_N^p/n_N$, since the unit labor requirement for all goods produced in the North is one.

Hence, we have

$$\pi_m = (L_s^p/n_s) \cdot w_s \cdot [(1-\alpha)/\alpha]$$

$$\pi_N = (L_N^p/n_N) \cdot w_N \cdot [(1-\alpha)/\alpha]$$

Moreover, it can be shown that, in steady state,

$$\frac{n_s}{n_i} = \frac{g+\delta}{\delta} \quad ; \quad \frac{n_N}{n_s} = \frac{g}{\omega} \quad \text{and} \quad \frac{n}{n_N} = \frac{\omega + \omega^* + g}{g} \tag{18}$$

Using the previous three equations and (14), equation (16) can be re-written as

$$\left[\frac{2r+\delta}{2(\delta+r)}\right]^{\frac{1}{\alpha}} = \eta \cdot \frac{\omega}{g} \cdot \frac{L_N^p}{L_s^p} \tag{19}$$

The equation is represented in the (δ, ω) space as the MM curve in Figure 1A. We can interpret the above equation as one that describes how ω adjusts for given δ. When the left hand side (LHS) is greater than the right hand side (RHS) of (19), $\Pi_N > \Pi_m$, which induces more Northern firms to transfer production to S1, increasing ω, until equality is reached.[13] When the LHS is less than the RHS of (19), $\Pi_N < \Pi_M$, implying that the value of ω is too high to justify Northern firms transferring production to S1. Hence, fewer firms will transfer, thus lowering ω. Mathematically, we have $\dot{\omega}$ expressed as a function of $\Pi_M - \Pi_N$:

$$\dot{\omega} = f(\Pi_N - \Pi_M), \qquad \text{where } f(0) = 0 \text{ and } f'(.) \geq 0$$

$$\Rightarrow \qquad sgn(\dot{\omega}) = sgn(LHS_{19} - RHS_{19})$$

The corresponding equation for S2 is represented in the (δ^*, ω^*) space as the MM^* curve in Figure 2.

Using (18), equation (17) becomes

$$\left[\frac{(\omega + \omega^* + g)(\delta + g)}{\delta\omega}\right] \cdot \frac{a}{b} = L^{r\,r}_{Ns} \tag{20}$$

The equation is represented by the DI curve in the (δ, ω) space in Figure 1A. We can interpret the above equation as one that yields the steady state value of δ for given ω and ω^*. The steady state ratio n_i/n is determined by L^r_s and L^r_N as given in (17). Given some existing values of δ, ω^* and ω, suppose there is some exogenous change that leads to $LHS_{20} > RHS_{20}$ (such as an exogenous decrease in b). Then the existing value of n/n_i is higher than the steady state value, that is, $n/n_i > (b/a) \cdot (L^r_N/L^r_s) = \dot{n}/\dot{n}_i$. Therefore, $\dot{n}/n < \dot{n}_i/n_i$, leading to a gradual decrease of n/n_i. This is reflected in a gradual increase of δ until $n/n_i = (b/a) \cdot (L^r_N/L^r_s)$ as given by (17). Hence, we have

$$sgn(\dot{\delta}) = sgn(LHS_{20} - RHS_{20}).$$

Intuitively, whenever $LHS_{20} > RHS_{20}$, more Southern firms find it profitable to enter the imitation business than before, increasing the steady state rate of imitation δ and steady state value of n_i/n. The corresponding equation for S2 is represented by the DI^* curve in the (δ^*, ω^*) space in Figure 2.

Now, it can be seen that both (19) and (20) can be represented in the (δ, ω) space by downward sloping curves MM and DI respectively in Figure 1A. In an appendix available upon request, I prove that, as shown in Figure 1A, the MM curve is flatter than the DI curve as long as $\alpha L^r_N/a > 1$. In fact, the steady state equilibrium is stable and unique when MM

[13] This is implicitly assuming myopic behavior of Northern firms (i.e. they do not consider the future movement of δ).

is flatter than DI, as discussed in the appendix. I assume that this condition is satisfied in the rest of the paper. It is also shown in the appendix that, for changes in parameters of S1 that shift the DI^* curve but not the MM^* curve in Figure 2 (e.g. $a, b, L_s^r, \eta, L_s^p, L_s^{r*}, b^*$), any upward adjustment of ω is accompanied by a downward adjustment of ω^* when $\alpha L_N^r/a > 1$. Therefore, any increase in ω due to changes in these parameters leads to a decrease in the LHS of (20). We can therefore treat ω^* as negatively related to ω whenever changes in these parameters occur. The DI' curve in Figure 3 and 4 has already taken into account the fact that ω^* is a function of ω and other variables that shifts the DI^* curve but not the MM^* curve in Figure 2.

Therefore, I have obtained two equations (19) and (20) (with ω^* expressed as a function of ω and other variables) in two unknowns δ and ω, with a stable and unique steady state equilibrium.

3.2 Trade and FDI Policies

First consider tariffs imposed on exports from the North to S1. An ad valorem tariff would have no effect at all since the elasticity of demand faced by all firms remains the same. A specific tariff, however, can have an effect on the steady state equilibrium. Assume for simplicity that there is no trade barrier between S1 and S2, but there are trade barriers between the Southern countries and the North.[14] Define $\lambda(\theta, \theta^*) \equiv (1+\theta)^{1-\epsilon} e_s + (1+\theta^*)^{1-\epsilon} e_s^* + e_N$, where $\theta \equiv t/c_N$; $\theta^* \equiv t^*/c_N$; $e_N \equiv E_N/E$; $e_s \equiv E_s/E$; $e_s^* \equiv E_s^*/E$; t is the specific tariff imposed on S1's imports from North; E_s, E_s^* and E_N are the total consumption expenditure in S1, S2 and the North, respectively; c_N is the unit cost of production in the North, which is equal to w_N since the unit labor requirement is equal to one. Note that $e_N + e_s + e_s^* = 1$. Therefore, $\lambda(\theta, \theta^*) \leq 1$ for $\theta, \theta^* \geq 0$; $\lambda(0,0) = 1$, $\partial\lambda/\partial\theta < 0$ and $\partial\lambda/\partial\theta^* < 0$. Define also $\phi(\theta, \theta^*) \equiv \left[(1+\theta)^{1-\epsilon} e_s + (1+\theta^*)^{1-\epsilon} e_s^* + e_N\right] / \left[(1+\theta)^{-\epsilon} e_s + (1+\theta^*)^{-\epsilon} e_s^* + e_N\right] \geq 1$ for $\theta, \theta^* \geq 0$. Note that $\phi(0,0) = 1$. In Appendix B, it is shown that $\pi_N \propto \lambda$ and $\pi_N/x_N \propto \phi$.

Similarly, define $\lambda_s(\theta_s) \equiv e_s + e_s^* + (1+\theta_s)^{1-\epsilon} e_N$ where $\theta_s \equiv t_s/c_s$; t_s is the specific tariff imposed on the North's imports from S1; c_s is the unit cost of production in S1, which is equal to $w_s\eta$ since the unit labor requirement in S1 is equal to η. Note that $\lambda_s(\theta_s) \leq 1$ for $\theta_s \geq 0$, $\lambda_s(0) = 1$, $\partial\lambda_s/\partial\theta_s < 0$. Define $\phi_s(\theta_s) \equiv \left[e_s + e_s^* + (1+\theta_s)^{1-\epsilon} e_N\right] / \left[e_s + e_s^* + (1+\theta_s)^{-\epsilon} e_N\right] \geq 1$ for $\theta_s \geq 0$, and note that $\phi_s(0) = 1$.

[14] The existence of trade barriers between the Southern countries would not affect the results in this section.

To examine the effects of an FDI incentive given by S1, define μ as S1's ad valorem sales subsidy to Northern MNCs in S1. In Appendix B, it is shown that $\pi_m \propto \lambda_s(1+\mu)$ and $\pi_m/x_m \propto \phi_s(1+\mu)$.

With the above trade and investment policies in place, I show in the appendix that the MM curve now becomes

$$\frac{\phi_s(1+\mu)}{\phi} \cdot \left[\frac{(1+\mu)\lambda_s}{\lambda}\right]^{\frac{1-\alpha}{\alpha}} \left[\frac{2r+\delta}{2(\delta+r)}\right]^{\frac{1}{\alpha}} = \eta \cdot \frac{\omega}{g} \cdot \frac{L_N^p}{L_s^p} \tag{21}$$

As discussed in the last section, I can treat ω^* as a function of ω for comparative steady states analysis with respect to changes in certain parameters in S1. Therefore, the DI curve remains the same as before, as given in equation (20).

Again, I have obtained two equations (21) and (20) (with ω^* expressed as a function of ω and other variables), in two unknowns δ and ω. In Appendix B, I derive the relative wage of production workers in S1 to that of the North

$$\frac{w_s}{w_N} = \left[\frac{(2r+\delta)(1+\mu)\lambda_s}{2(r+\delta)\lambda}\right]^{\frac{1-\alpha}{\alpha}} \cdot \frac{1}{\eta} \tag{22}$$

(Recall that $r = \rho + \psi g$.) We are now ready to carry out our comparative steady states analysis.

4 Comparative Steady States Analysis

The comparative steady states analysis can most easily be undertaken graphically. The results are shown in Figures 3, 4 and 5. A summary of the results is given in Table 1 at the end of Section 4. In the following subsections and propositions, we only highlight and discuss the most interesting results.

First, Figure 4 shows that an increase in L_s^p/η, the effective supply of production labor in the South, shifts MM upward. It leads to an increase in ω and w_s/w_N and a decrease in δ.

Proposition 1 *An increase in the effective supply of production labor in S1 leads to higher rate of production transfer to S1, lower rate of production transfer to S2, and higher w_s/w_N.*

It seems counter-intuitive that an increase in the supply of production labor in a Southern country would raise its wage relative to that of Northern production labor. This result contrasts sharply with those in Krugman (1979) and Lai (1995), who assume that, in the product cycle, the South can only directly imitate from the North and there is no FDI from the North. But this result agrees with that of Lai (1998), who emphasizes FDI as the major channel of production transfer to the South. The economic intuition is that an increase in production labor supply in a Southern country enables the scale of operation of each MNC to increase, which increases the profitability of MNCs there, thus encouraging more multinationalization (and lowering the rate of imitation). Hence, the demand for Southern workers rises, leading to an increase in the relative wage of production workers.

Next, Figure 3 shows that an increase in L_s^r/b, the effective supply of skilled labor in the South, shifts DI' to the right, leading to a decrease in ω, increase in δ and decrease in w_s/w_N according to (22). The decrease in b can be interpreted as an increase in general knowledge of research workers, an R&D subsidy or a relaxing of the enforcement of intellectual property rights (IPR) protection in S1.

Proposition 2 *An increase in the effective supply of labor that can perform imitation in S1 leads to a decrease in the rate of production transfer to S1, an increase in production transfer to S2, and a decrease in* w_s/w_N.

Therefore, a relaxation of intellectual property rights protection in a Southern country, which would lead to a decrease in b, hurts the real income of its production workers (and terms of trade) because Northern firms are less willing to transfer production to the Southern country due to increased probability of the product being imitated. This benefits the production workers in other Southern countries, who now enjoy a higher real wage due to higher rate of production transfer from the North that increases the demand for production workers. However, this result has to be treated with caution because I have assumed that the South cannot imitate prior to multinationalization of a technology. In a more general model, some Southern firms can imitate Northern products by reverse engineering even prior to multinationalization. Thus, an increase in imitation capability should increase the rate of reverse engineering. Also, the real wage of skilled workers can increase. Therefore, the welfare effect on S1 is not clear, and there may well be an optimal level of intellectual property rights protection.

Next, Figure 4 shows that an increase in FDI subsidy μ leads to an increase in ω, a decrease in δ and hence an increase in w_s/w_N. These subsidies, as observed in many countries in Southeast and East Asia, include subsidy to infrastructure, tax holidays, and even an improved living environment for executives.

Therefore, we have

Proposition 3 *An FDI subsidy μ given by S1 leads to higher rate of production transfer to S1, lower rate of production transfer to S2, and higher w_s/w_N.*

Note that, from (21), for given L_N^p and L_s^p, the relative wage of unskilled workers w_s/w_N is positively related to the rate of production transfer ω, since a higher rate of transfer increases the demand for labor in S1. Since an FDI subsidy increases ω, it leads to a decrease in ω^* according to Figure 2. Therefore, it increases the real wage of production workers in S1 (and its terms of trade) at the expense of production workers in S2. Again, the welfare consequence of an FDI subsidy is not clear since there is a cost to the subsidy. There may be an optimal level of subsidy, given the fact that there is a tradeoff between the cost and benefit.

To the extent that an increase in real wages of production workers is a welfare gain, tightening IPR or subsidizing inward FDI from the North are beggar-thy-neighbor policies. In this case, these policies create negative externalities on other Southern countries. This is a prisoners' dilemma, and it implies that there would be over-subsidy of inward FDI or over-protection of IPR.

Next, I evaluate the effects of tariffs on imports from the North to S1. The result is shown in Figure 5A and 5B.

Proposition 4 *A specific tariff t imposed on imports from the North to S1 leads to a higher rate of production transfer to S1 and S2, as well as higher w_s/w_N and w_s^*/w_N, provided that S1 and S2 are not too dissimilar in the values of $\eta, L_s^p, L_s^r, b,\ \theta_s$ and μ.*

If S1 and S2 are symmetrical, in the sense that $\eta, L_s^p, L_s^r, b, \theta_s$ and μ are the same in S1 and S2, an increase in t affects S1 and S2 in exactly the same way and the magnitude of changes are the same. Therefore, the equilibrium outcome must be that both ω and ω^* increase, as shown in Figure 5A and 5B. (For the proof, see Appendix C). It follows that as long as S1 and S2 are sufficiently similar in these fundamental parameters, the same qualitative result should obtain. The intuition: A Southern country's trade barriers against Northern imports lower the profits of all Northern firms relative to those of MNCs in the Southern countries (both S1 and S2), thus prompting more production transfer from the North to both S1 and S2. This increase in tariff-jumping FDI raises the demand for Southern labor and improves the terms of trade of both S1 and S2. The interesting thing about this result is that S1's trade barriers lead to increased FDI in both S1 and S2. Thus, it does not only benefit S1's production workers, but also those of S2. S1, however, must balance the gains to production workers against the costs of price distortions caused by the tariffs. There may well be an optimal level of import tariffs imposed by S1.

To the extent that an increase in the real wages of production workers is welfare-improving, S1's import tariffs create positive externalities on S2, and the latter can get a free-ride from the former. This implies that there would be under-use of such a policy tool if there is no coordination among Southern countries.

Finally, as large LDCs like China and India integrate more and more with the world, the effect is equivalent to a large increase in the number of Southern countries participating in the international product cycle. The consequences are stated below.

Proposition 5 *Suppose all Southern countries are identical, and there are N of them. Then an increase in N leads to a decrease in w_s/w_N and ω in each Southern country, but an increase in the total rate of production transfer to all Southern countries.*

For a proof, see Appendix D. The intuition is as follows. Since the Northern firms now find more cheap labor available in the South, the aggregate rate of production transfer should increase. However, each Southern country now has a smaller fraction of Northern production transferred to it. This is reflected in lower ω and higher δ in each country. Also, because of the lower rate of production transfer, demand for labor in a Southern country is lower, leading to a decrease in w_s/w_N in each country. The increased integration of a large country like China with the world is similar to a large increase in N. Therefore, we would expect an event such as China's entry into the WTO to cause a decrease in the real wage of production workers in other Southern countries.

A summary of all the comparative steady states analyses are given in Table 1.

5 Conclusion

I have constructed a simple dynamic general equilibrium model to analyze how Southern trade- and investment-related policies interact with each other in a North-South product cycle. It turns out that there is a rich array of results generated from this simple model.

I find that when Southern countries have to rely mostly on Northern MNCs to transfer production to their countries before they can imitate the technology, a faster rate of production transfer to a Southern country would sustain a higher real wage of production workers as well as a better terms of trade. However, a Southern country's policies that benefit its production workers, such as a FDI subsidy, are often at the expense of those in other Southern countries. To the extent that increases in real wages for their production workers are perceived as welfare-improving by Southern governments, this creates a prisoners' dilemma. In such an environment, Southern countries can over-subsidize inward FDI from the North.

However, when a Southern country increases trade barriers against the North, they benefit its own production workers as well as those of other Southern countries due to an increase in tariff-jumping FDI. Therefore, they have a positive spillover effect on other Southern countries. To the extent that an increase in real wages of production workers is welfare-improving, there is incentive to free-ride. In that case, there could well be under-use of such a policy tool to attract inward FDI.

Finally, our model of FDI competition also implies that an increase in the number of Southern countries participating in the product cycle lowers the relative wage of all existing Southern production workers. Therefore, the increased integration of large LDCs into world trade would likely have an adverse effect on the real wage of production workers of other LDCs. This agrees with the predictions of other models.

It may be argued that with the establishment of the WTO and the emergence of other trade agreements in the world, countries cannot erect import tariffs so easily nowadays. However, there are still many non-tariff trade barriers such as administrative measures, product standards and anti-dumping lawsuits. Moreover, subsidies to industries can be hidden, especially in developing countries. Therefore, the analysis of trade and investment policies is still not out of fashion, even in this era of trade liberalization.

One possible extension of the present paper is to analyze the welfare implications of FDI subsidies, tariffs and intellectual property rights policies. Because of the existence of tradeoffs between costs and benefits, there can well be an optimal level for each policy variable.

Another extension would be to assume that a Southern firm can also imitate directly from a Northern firm located in the North through reverse-engineering. Changes in FDI would therefore change the percentage of imitation done through reverse-engineering rather than from MNCs.

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Appendixes

A Discounted Expected Profits of an MNC

We assume that the duration τ between the date of multinationalization and date of imitation is a random variable with exponential distribution, having a Poisson arrival rate δ:

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

Therefore,

$$Pr(\tau = t) = f'(t) = \delta e^{-\delta t}$$

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

$$\Pi_m = \int_0^\infty (\int_0^t \pi_m e^{-rs} ds + \int_t^\infty \frac{\pi_m}{2} e^{-rs} ds) Pr(\tau = t) dt$$

It is straightforward to show that the RHS is equal to $[\pi_m/(r+\delta)] + [\delta\pi_m]/[2r(r+\delta)] = [(2r+\delta)\pi_m]/[2r(r+\delta)]$.

See Lee and Wilde (1980) for a similar calculation.

B Trade and FDI Policy

Define $A \equiv 1/[\int_0^n p(u)^{1-\epsilon}du]$. When $t > 0$, the Northern firm treats the unit production cost of exports to S1 as equal to $c_N(1+\theta)$. When $t^* > 0$, the Northern firm treats the unit production cost of exports to S2 as equal to $c_N(1+\theta^*)$. Therefore,

$$x_N = AE\frac{c_N^{-\epsilon}}{\alpha^{-\epsilon}}[(1+\theta)^{-\epsilon}e_s + (1+\theta^*)^{-\epsilon}e_s^* + e_N]$$

So,

$$\begin{aligned}\pi_N &= (\frac{1-\alpha}{\alpha})AE\frac{c_N^{1-\epsilon}}{\alpha^{-\epsilon}}[(1+\theta)^{1-\epsilon}e_s + (1+\theta^*)^{1-\epsilon}e_s^* + e_N] \\ &= (1-\alpha)AE(\frac{w_N}{\alpha})^{1-\epsilon}\lambda(\theta,\theta^*) \end{aligned} \tag{23}$$

Similarly,

$$x_m = AE\frac{c_s^{-\epsilon}}{\alpha^{-\epsilon}}[(1+\theta_s)^{-\epsilon}e_N + e_s^* + e_s]$$

Therefore,

$$\begin{aligned}\pi_m &= (\frac{1-\alpha}{\alpha})AE\frac{c_s^{1-\epsilon}}{\alpha^{-\epsilon}}\lambda_s(\theta_s)(1+\mu) \\ &= (1-\alpha)AE(\frac{w_s\eta}{\alpha})^{1-\epsilon}(1+\mu)\lambda_s(\theta_s) \end{aligned} \tag{24}$$

From (23) and (24) as well as (16), I obtain

$$\frac{2r+\delta}{2(\delta+r)} = \frac{\pi_N}{\pi_m} = (\frac{w_s}{w_N}\eta)^{\epsilon-1}\left[\frac{\lambda}{(1+\mu)\lambda_s}\right]$$

Hence, we get (22).

Since

$$\pi_N = \phi\cdot(\frac{1-\alpha}{\alpha})\cdot c_N x_N \qquad \text{where } c_N = w_N \text{ and } x_N = \tfrac{L_N^p}{n_N}$$

$$\pi_m = \phi_s(1+\mu)\cdot(\frac{1-\alpha}{\alpha})\cdot c_s x_m \qquad \text{where } c_s = w_s\eta \text{ and } x_m = \tfrac{L_s^p}{n_s\eta}$$

we have

$$\frac{w_s}{w_N}\cdot\eta\cdot\frac{\phi}{\phi_s(1+\mu)}\cdot\frac{L_N^p}{L_s^p}\cdot\frac{\omega}{g} = \frac{\pi_N}{\pi_m} = \frac{2r+\delta}{2(\delta+r)}$$

which, together with (22), leads to (21).

In order to find the effect of θ on the RHS of (21), I evaluate

$$\frac{\partial[\phi\lambda^{\frac{1-\alpha}{\alpha}}]}{\partial\theta} = \frac{[e_s(1+\theta)^{1-\epsilon}+B_1]^{\frac{1-\alpha}{\alpha}}(1+\theta)^{-\epsilon-1}}{[e_s(1+\theta)^{-\epsilon}+B_2]^2(1-\alpha)}\cdot(-\theta e_N) < 0.$$

where $B_1 \equiv (1+\theta^*)^{1-\epsilon} e_s^* + e_N$ and $B_2 \equiv (1+\theta^*)^{-\epsilon} e_s^* + e_N$. Therefore, an increase in t leads to an increase in the RHS of (21) and shifts the MM curve to the right. Similarly, an increase in t_s leads to a decrease in the RHS of the equation and shifts the MM curve to the left.

C Proof of Proposition 4

Suppose S1 and S2 are identical in the sense that $\eta = \eta^*, L_s^p = L_s^{p*}, L_s^r = L_s^{r*}, b = b^*, \theta_s = \theta_s^*, \mu = \mu^*$ so that $\phi_s = \phi_s^*$ and $\lambda_s^* = \lambda_s$. (ϕ and λ are common for both S1 and S2.) Therefore, the MM curves are the same in both S1 and S2. In equilibrium, $\omega = \omega^*$. Therefore, in equilibrium, the equation for the DI curve for both S1 and S2 can be written as

$$\left[\frac{(2\omega + g)(\delta + g)}{\delta\omega}\right] \cdot \frac{a}{b} = \frac{L_N^r}{L_s^r}$$

We can call this curve DI'', which is downward sloping and has to be steeper than the MM curve for stability.

Therefore, as t increases, the MM curve shifts up, leading to an increase in ω and a decrease in δ. This implies an increase in w_s/w_N for both Southern countries.

D Proof of Proposition 5

Suppose all Southern countries are identical, and there are N of them. Suppose for simplicity that $\theta = \theta_s = \theta^* = \mu = 0$ for all countries. For a typical Southern country, the MM curve is given by (19). In equilibrium, ω is the same for all Southern countries. Therefore, in equilibrium, the equation for the DI curve for all Southern countries can be written as

$$\left[\frac{(N\omega + g)(\delta + g)}{\delta\omega}\right] \cdot \frac{a}{b} = \frac{L_N^r}{L_s^r}$$

We can call this curve DI'', which is downward sloping and has to be steeper than the MM curve for stability.

Therefore, as N increases, the DI'' curve shifts to the right, leading to a decrease in ω and an increase in δ. This implies a decrease in w_s/w_N for all incumbent Southern countries.

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Table 1: Comparative Steady States Analysis						
	δ	δ^*	ω	ω^*	w_s/w_N	w_s^*/w_N
L_s^p/η increases	D	I	I	D	I	D
L_s^r/b increases	I	D	D	I	D	I
μ increases	D	I	I	D	I	D
t increases	D	D	I	I	I	I
N increases	I	I	D	D	D	D

I = Increase; D = Decrease.

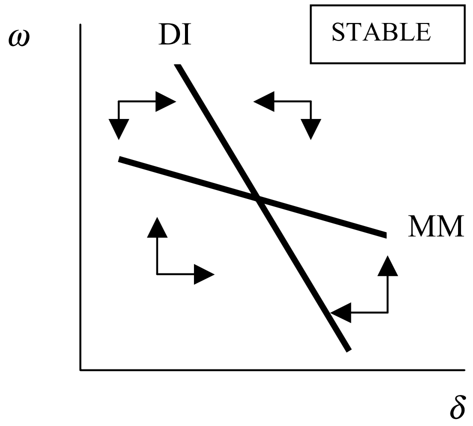

Figure 1A

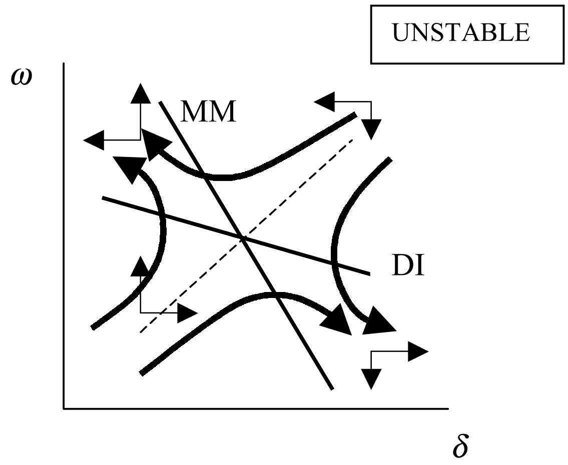

Figure 1B

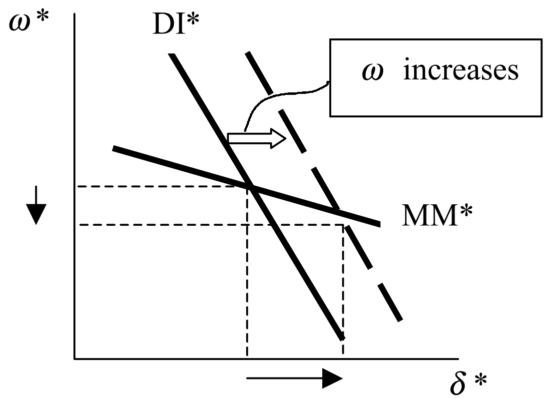

Figure 2

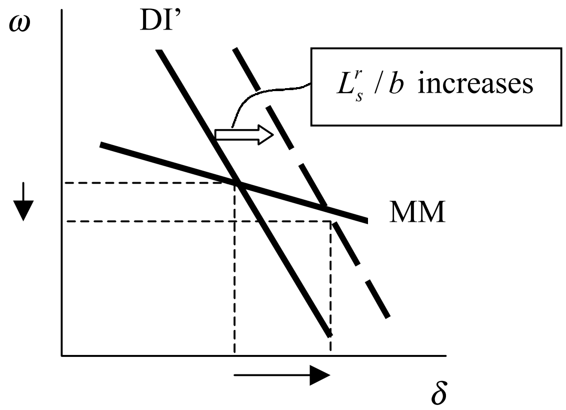

Figure 3

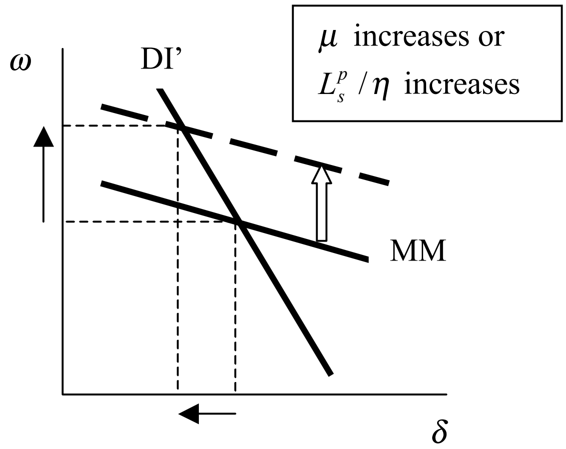

Figure 4

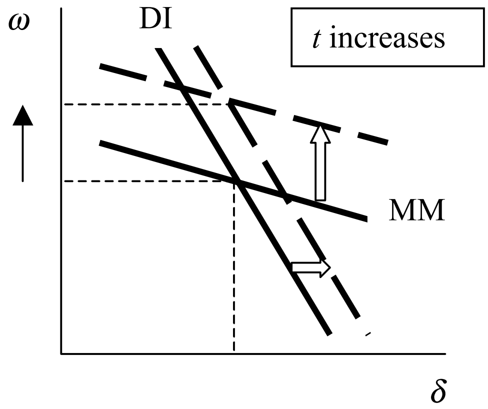

Figure 5A

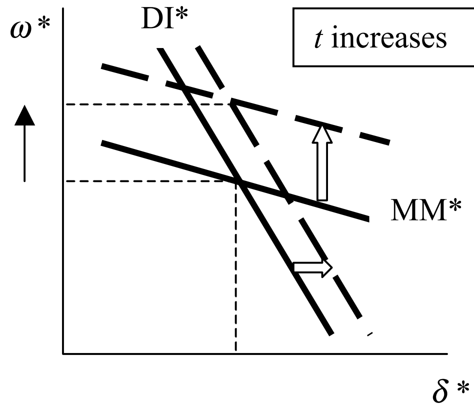

Figure 5B