Technological Leaders and Followers In a World Economy

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Abstract

This paper develops a dynamic general equilibrium model of North-South trade and economic growth in a world economy with a continuum of countries. Countries are different in research productivity. Innovation, imitation and the relative wage between countries are endogenously determined as well as the number of the country that specialize in innovative or imitative R&D. We investigate how equilibrium is affected by globalization, intellectual property right protection, industrial policy, competition and migration. The model is also extended to introduce foreign direct investment.

Key Words: Innovation, imitation, growth, trade, North, South
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Preliminary and incomplete

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1 Introduction

The world economy is highly unequal. Of 166 countries, there are 33 countries whose real income per capita in 2000 is less than 5% of US GDP per capita in the same year.[1] This fact is often explained by differences in productivity levels. Caselli (2005) summarizes the literature by noting that about a half of income differences is attributable to differences in total factor productivity. Although several factors can affect it (e.g. capacity utilization), TFP is generally interpreted as reflecting the level of technology adopted in economies. Indeed, Klenow and Rodríguez-Clare (2005) show that real GDP per capita and the ratio of R&D over GDP are highly correlated. Although this calculation is suggestive, the finding accords well with the literature. Moreover, Lederman and Maloney (2003) demonstrate that "take-offs" of economies like Korea are often associated with a dramatic surge in the share of R&D in GDP.

Against this background, the present paper aims to examine the link between R&D and inequality in the world economy in the North-South framework of endogenous technical progress. A defining feature of our model is that international trade endogenously divides a continuum of countries into Northern economies with innovative R&D and Southern economies with imitative R&D. This allows us to investigate the issue of industrialization and measure the degree of inequality of the world economy in terms of the number of developed and developing countries, which is taken as given in existing studies.

To motivate our paper further, we make two more observations on the link between R&D and income inequality. First, formal innovative activity is highly concentrated in rich economies. According to Board (2006), global R&D expenditure in 2000, which was at least US$729 billion, is performed by the US and Japan. OECD (2005) also shows only 16% of world R&D expenditure in 2003 is accounted for by non-OECD countries.[2] Furthermore, DTI (2006) reports that of 1250 firms from 39 countries, 82.1% of total R&D expenditure is conducted by companies based in the largest five countries (US, Japan, Germany, France and UK). This observation clearly indicates a high concentration of innovative research activity.

[1] The world is also unequal in terms of growth. Twenty five out of 109 countries grew at the rate of 0.5% or less on average in 1960-2000, whereas the average growth rate of the sample countries is 1.8%.

[2] Those countries are Argentina, China, Romania, Israel, Russia, Singapore, Slovenia, South Africa, Taiwan.

Second, imitation is pervasive in the world market. For example, the WHO says that 6%-10% of medicine on the world market or about a quarter of medicines used in developing countries are counterfeited, and the total sale is estimated to be more than $35 billion per year.[3] Another example is related to piracy. According to International Data Corporation (2006), 35% of software installed on PCs in the world in 2005 is illegal with the loss to the industry amountng to more than US$33 billion. Although these numerical claims should be treated with care,[4] it is undenyiable that software piracy is a serious problem facing the world economy. Indeed, infringement of intellectual property rights has been so problematic, that the WTO introduced an agreement on TRIPS. On the other hand, imitation is widely considered as a means of technology transfer, which contributes to income convergence across countries (e.g. Bernard and Jones, 1996). The point is that imitation affects incentives for innovative R&D, which is an important determinant of inequality across countries.

We develop a North-South trade model with those two features (concentration of R&D and imitation), which we believe are essential for the analysis of the link between R&D and inequality across countries. In our model, there are a continuum of countries with a continuum of variety consumption goods. Countries differ in productivity of innovative R&D, which expands the number of variety goods over time. International trade takes place because technology transfer occurs through costly imitation. That is, innovating countries, called North, export innovative goods and import products that are already copied. Similarly, imitating countries, termed South, export copied goods and import innovative products. In this setting, comparative advantage based on innovative R&D cost relative to imitative R&D cost determines the identity of innovators and imitators. This contrasts with standard trade models where relative production costs determine trade patters. We believe that trade patterns based on relative reseach productivities are ituitive and consistent with the world market of many high-tech goods, like computers and biotechnology products.

Using this model, we show several interesting results. The first result con-

[3]See the following links on these points. `http://www.wpro.who.int/media_centre/press_releases/pr_20050503.htm` (accessed on 25 April 2007) and `http://news.bbc.co.uk/2/hi/health/3261385.stm` (accessed on 25 April 2007). Those counterfeit medicines are often used for malaria, TB and Aids.

[4]Business Software Alliance, which publishes International Data Corporation (2006), is a trade association and lobby group based in US.

cerns globalization, which we capture by an increase in the number of countries with low R&D productivity. A new enterant country into the world trading system increases not only the growth rate of the world economy, but the number of Northern countries. That is, globalization is conducive to industrialization of countries which are relatively more productive in innovative R&D than others. We also consider the effect of strengthening IPR protection in South. Somewhat surprisingly, the number of Northern economies is shown to unambiguouly fall in response. This suggests the possibility that stronger IPR protection stifles the seed of industrialization. Apart from these exercises, we consider the effects of industrial policy, competition, migration and FDI. We believe that our approach sheds new light on issues that are discussed in the literature.

Our model is related to the literature of North-South trade models with innovation and imitation. This type of investigation started with Grossman and Helpman (1991) and Helpman (1993). More recent contributions include Glass and Saggi (2001), Grossman and Lai (2004), Dinopoulos and Segerstrom (2005). A crucial point of departure of our model from those studies is that the number of Northern and Southern countries are assumed to be fixed (i.e. one country in each block) in existing models, whereas our study introduces a continuum of countries, which are endogenously grouped into North and South.

Our model is also related to studies on models with a continuum of countries. For example, Kaneda (1995) and Yanagawa (1996) consider the issue of industrialization. However, there is no endogenous innovation and/or imitation in those studies. Matsuyama (1996) shows that the world economy, consisting of identical economies, is endogenously divided into countries producing a large and small number of variety goods. However, the model is static in nature. Melitz (2003) is a dynamic trade model with many countries with heterogeneous firms. However, his focus is on the role of heterogeneous firms and countries remain symmetric before and after trade. A study closest to ours is Haruyama (2007), who considers a continuum of identical countries with endogenous technical progress. Without trade, each economy faces the possibility of poverty trap with no active R&D. Haruyama (2007) explores whether international trade helps reduce the likelihood of poverty trap.

The remainder of the paper is organized as follows. Section 2 develops the basic structure of the model. The world economy equilibrium and comparative statics are explored in section 3. Section 4 introduces foreign direct investmen into the model. Section 5 concludes.

2 The Model

2.1 Consumers

There are a continuum of countries, indexed by $i \in [0, M]$. Those economies are identical in every respect, except the level of productivity of innovative R&D.

The number of consumers in each country is L. Each of them supplies one unit of labor services. The utility function is

$$U_i = \int_0^\infty e^{-\rho t} \ln X_i(t) dt \tag{1}$$

$$X_i(t) = \left(\int_0^{N(t)} x_{ij} (t)^\alpha \, dj \right)^{1/\alpha}, \quad 0 < \alpha < 1, \tag{2}$$

where ρ is the rate of time preference, x_{ij} is differentiated products and N denotes a range of x_{ij}. Given the instantaneous utility (1), the demand function of x_{ij} is given by

$$x_{ij}(t) = \sigma_{ij} (t) \frac{E_i (t)}{p_{ij} (t)} \tag{3}$$

$$\sigma_{ij}(t) = \frac{p_{ij} (t)^{-\frac{\alpha}{1-\alpha}}}{\int_0^{N(t)} p_{ij} (t)^{-\frac{\alpha}{1-\alpha}} dj} \tag{4}$$

where E_i is consumption expenditure in a country i and p_{ij} is the price of x_{ij}.

Making use of (3) and (4), it is easy to establish that utility-maximizing total expenditure obeys the familiar Euler condition $\dot{E}_i/E_i = r - \rho$ where r is the rate of interest which is determined in the world financial market. Furthermore, given that a world economy is considered in the paper, it proves to be useful to define $E = \int_0^M E_i di$ as the world consumption expenditure. Then, the Euler condition for a country i can be easily shown to be rearranged into

$$\frac{\dot{E} (t)}{E (t)} = r (t) - \rho. \tag{5}$$

2.2 Final Output Sectors

Differentiated products are produced by local monopolists, which hold patents for the goods. To obtain patents, firms must succeed in R&D first. Patents are assumed to be protected for ever. However, innovative goods can be copied through imitative R&D. Economies where product innovation takes place are called North, and imitation activity takes place in South. In equilibrium, product cycles occur where products are initially produced in North and the production site moves to South later. Imitative R&D is a sole source of product cycles, and the possibility of FDI is initially ruled out. Let $\mathcal{N}$ denote the set of Northern economies.

First consider the pricing decision of Norther firms. One worker is required to produce one unit of goods. Given the price elasticity of demand $-1/(1-\alpha)$ in (4), a monopoly firm sets the price of x_{ij} to

$$p_{ij}(t) = \frac{w_i(t)}{\alpha}, \quad i \in \mathcal{N} \tag{6}$$

where w_i is wage in country i. Wages are shown later to be different across Northern economies because of differences in innovative R&D productivity. Northern monopoly firms in country i which captures the world market earns

$$\pi_i = (1-\alpha)\,\sigma_i(t)\,E(t), \quad i \in \mathcal{N}. \tag{7}$$

Turning to South, firms which succeed in imitative R&D, can produce goods with marginal cost of w_S, which is wage. Wage is identical in all Southern economies, since those countries are identical. On the other hand, "other" Southern firms are assumed to be able to produce the goods, but with a higher marginal cost of γw_S, $\gamma > 1$. The difference in marginal costs between successful innovators and other firms is due to the fact that the former gain deeper knowledge about the product through costly imitative R&D. Given these assumptions, successful imitators charge the price of

$$p_i(t) = \frac{w_i(t)}{\theta} \quad \text{where } \theta \equiv \begin{cases} \alpha & \text{for } \gamma \geq 1/\alpha \\ 1/\gamma & \text{for } \gamma < 1/\alpha \end{cases}. \tag{8}$$

The case of $\theta = 1/\gamma$ is a limit price such that products of "other" firms are not demanded. Therefore, imitators' profits are

$$\pi_S = (1-\theta)\,\sigma_S(t)\,E(t)\,. \tag{9}$$

2.3 R&D

Let m denote the number of Northern countries and $M-m$ the number of Southern economies. Use N_i to refer to the cumulative number of variety goods created through R&D in a Northern economy i up to time t, so that $N = \int_0^m N_i di$ holds in steady state. Of these, $N_S = (M-m)\,n_S$ number of variety goods are copied where n_S denotes the number of variety goods produced in a Southern economy. The remaining variety goods are still produced in North, and their number is denoted by $N_N = \int_0^m n_i di$ where n_i denotes the number of variety goods that are produced in a Northern economy i. Then, the following must hold in steady state:

$$\underbrace{\int_0^{m(t)} N_i(t)\,di}_{N(t)} = \underbrace{\int_0^{m(t)} n_i(t)\,di}_{N_N(t)} + \underbrace{(M-m(t))\,n_S(t)}_{N_S(t)}. \tag{10}$$

To describe innovative R&D technology, consider a Northern economy i. The number of variety goods created in that country increases according to

$$\dot{N}_i(t) = a_i R_i(t)\,N(t)\,. \tag{11}$$

R_i is the number of R&D workers and the presence of N captures knowledge spillover in R&D. Research productivity a_i is the only source of differences Northern economies. We assume that

$$\frac{\partial a_i}{\partial i} < 0, \quad a_0 < \infty, \quad a_M > 0. \tag{12}$$

This means that some countries have absolute advantage in innovative R&D, inducing them to be specialized in innovative R&D and the production of relatively newer products.

Using (11), one can easily show that the number of variety goods created in the world changes according to $\dot{N}(t) \equiv \int_0^m \dot{N}_i di = \int_0^m a_i R_i N di$. Therefore, the rate of technical progress is

$$g(t) \equiv \frac{\dot{N}(t)}{N(t)} = \int_0^{m(t)} a_i R_i(t)\, di. \tag{13}$$

This shows that the world technology advances at a faster rate as more workers are used in R&D or/and more countries join the group of Northern economies.

Turning to imitative R&D, all countries have access to the same imitation technology. The number of goods produced in a Southern economy increases according to

$$\dot{n}_S(t) = a_S R_S(t) N_S(t). \tag{14}$$

This equation implies that the rate of technology imitation is given by

$$g_S(t) \equiv \frac{\dot{N}_S(t)}{N_S(t)} = a_S (M - m(t)) R_S. \tag{15}$$

Goods produced in North have different prices because Northern wages are different. From Southern imitators' perspective, however, all Northern goods are "symmetric", since profits that Southern firm gain after imitation is independent of the origin of country. This implies that Southern imitators are indifferent to any Northern products as targets of their imitative R&D. Therefore, we assume that Northern products are randomly imitated. More specifically, a given Norther product is assumed to be copied with an instantaneous probability of $h = \dot{N}_S/N_N$ during a time interval dt, given that the range of Southern goods increases by $\dot{N}_S$ during dt.

Now define $\phi = N_N/N$ as the share of Northern goods in all variety goods. Using this definition, a Poisson rate of imitation h can be rewritten as

$$h(t) = g_S(t) \frac{1 - \phi(t)}{\phi(t)}. \tag{16}$$

This means that the risk of a given Northern product being copied increases with the rate of imitation. However, the risk falls with the share of Northern goods in all variety goods. This is because of the assumption that Southern imitators randomly choose Northern goods for copying. This means that the risk of a given product being copied falls as the number of targets for imitation increases.

Let V_i and V_S denote the expected present value of profits earned by Northern and Southern monopoly firms which succeed in innovative and imitative

R&D, respectively. They are defined by the following equations:

$$r(t)V_i(t) = \pi_i(t) + \dot{V}_i(t) - h(t)V_i(t), \quad i \in \mathcal{N} \tag{17}$$

$$r(t)V_S(t) = \pi_S(t) + \dot{V}_S(t). \tag{18}$$

h in (17) represents the risk of Northern goods being copied by Southern firms, which results in the loss of profits. We assume free entry in R&D sectors in North and South. Therefore, given R&D technologies (12) and (15), the following conditions hold.

$$V_i(t)a_iN(t) = (1-s_N)w_i(t) \tag{19}$$

$$V_S(t)a_SN_S(t) = (1-s_S)w_S(t) \tag{20}$$

where s_N and s_S are the rates of subsidy or tax to innovative and imitative R&D.

2.4 Northern Wages

It is useful at this stage to consider Northern wages for later analysis. Substituting (5), (7) and (19) into (17) yield

$$\frac{\dot{E}(t)}{E(t)} - \frac{\dot{w}_i(t)}{w_i(t)} + g(t) + h(t) + \rho = \frac{(1-\alpha)a_i\sigma_i(t)E(t)N(t)}{(1-s_N)w_i(t)}. \tag{21}$$

The right-hand side is interpreted as a dividend rate associated with firms in country i. Since E/w_i is constant in steady state, the dividend rate must be equalized across Northern economies. Therefore, we have

$$\frac{w_i}{w_0} = \left(\frac{a_i}{a_0}\right)^{1-\alpha}, \quad i \in \mathcal{N}, \tag{22}$$

making use of (6) and (21). This shows that wage is higher in a country with a higher innovative R&D productivity.

2.5 Comparative Advantage

All consumption goods are traded. In a usual setting, comparative advantage based on the production costs of those goods would determine trade patterns. However, the production of goods requires patents for those products, which are gained only through successful R&D. In addition, the location of production moves to South due to imitative R&D. This implies that R&D productivity, innovative and imitative, is an important determinant of comparative advantage. This observation is consistent with the world market of high-tech industries, such as biotechnology products. That is, there is a strong link between R&D productivity and comparative advantage. Having said this, firms may decide manufacturing location through foreign direct investment on the basis of production costs or for other reasons. This aspect seems to be increasingly important in these years.[5] However, in order to emphasize an important role of R&D in determining trade patterns, we initially rule out the possibility of FDI, meaning that the production of high-tech goods must take place in countries where blueprints for those goods are created and copied through deliberate R&D.[6]

Given these assumptions, trade patterns depend on relative costs of innovative and imitative R&D. Consider a country i. A unit cost of innovative R&D is $C_{iI} = (1 - s_N)w_i/a_iN$ from (11), and that of imitative R&D is $C_{iC} = (1 - s_S)w_i/a_SN_S$ from (14). Therefore, the relative costs are given by

$$\frac{C_{iI}}{C_{iC}} = \frac{(1 - s_N)\, a_S N_S}{(1 - s_S)\, a_i N}. \tag{23}$$

Given that a_i is falling in i, the relative R&D costs are increasing in i, taking N_S/N as given. This is shown Figure 1.

Next, consider V_i/V_S, the relative values of innovative R&D to imitative R&D that prevails in the world market. It can be re-expressed as

$$\frac{V_i\,(t)}{V_S\,(t)} = \frac{(1-\alpha)\,\sigma_i\,(t)\,E\,(t)}{V_S\,(t)\left[\dot{E}\,(t)\,/E\,(t) - \dot{w}_i\,(t)\,/w_i\,(t) + g\,(t) + h\,(t) + \rho\right]} \tag{24}$$

using (7), (17) and (19). In steady state where E/w_i is constant, V_i/V_S depends on i only through σ_i. (4) shows that σ_i is decreasing in w_i, which in turn means that the relative values of innovative R&D to imitative R&D is increasing in i due to (22). This is illustrated in Figure 1 where "other" variables are taken as given. Assuming that a_0 is sufficiently high, the following inequality holds for economies with a high innovative R&D productivity:

$$\frac{V_i}{V_S} > \frac{C_{iI}}{C_{iC}}. \tag{25}$$

[5] For example, see Markusen (2002).
[6] This assumption will be relaxed later.

Those countries have comparative advantage in innovation and is specialized in innovative R&D and the production of newly created goods. On the other hand,

$$\frac{V_i}{V_S} < \frac{C_{iI}}{C_{iC}} \tag{26}$$

holds for economies with a lower innovative R&D productivity. They are specialized in imitative R&D and the manufacturing of copied products. The threshold country which divides the world into North and South is characterized by $V_i/V_S = C_{iI}/C_{iC}$, which is equivalent to

$$\frac{V_m}{V_S} = \frac{(1-s_N)\, a_S N_S}{(1-s_S)\, a_m N} \tag{27}$$

where $m \in (0, M)$. This condition is equivalent to saying that free entry conditions of innovative and imitative R&D (19) and (20) simultaneously hold in the threshold country.

2.6 Labor Markets

In a Norther economy i, there are two sources of labor demand: manufacturing and innovative R&D. In the R&D sector, R_i workers are employed, and manufacturing labor demand is $n_i \sigma_i E/p_i$. Therefore, full employment of workers in a Northern country i requires

$$L = R_i(t) + n_i(t)\, \sigma_i(t)\, \alpha \frac{E(t)}{w_i(t)}, \quad i \in \mathcal{N}. \tag{28}$$

Similarly, workers in a Southern economy are fully employed if

$$L = R_S(t) + n_S(t)\, \sigma_S(t)\, \theta \frac{E(t)}{w_S(t)}. \tag{29}$$

3 The World Economy Equilibrium

3.1 Steady State Equilibrium

We focus on steady state with constant E/w_i and $g = g_S$. After integrating (28) from 0 to m, one can rearrange the resulting equation into

$$\rho\phi + g = \frac{1-\alpha}{\alpha} \frac{LA(m) - g}{1 - s_N}, \qquad \text{where } A(m) = \int_0^m a_i di \tag{30}$$

using (13), (16), (21) and (28). This condition captures innovative R&D incentives of Northern firms. Next, the following condition can be derived from (5), (9), (18) and (29):

$$\rho + g = \frac{1-\theta}{\theta} \frac{La_S (M-m) - g}{1 - s_S}. \tag{31}$$

This equation represents imitative R&D incentives of Southern firms. The next condition is derived in Appendix A:

$$\Delta \frac{\rho + g}{\rho + g/\phi} = \frac{(1 - s_N) a_S}{(1 - s_S) a_m} (1 - \phi), \tag{32}$$

where $\Delta \equiv \frac{1-\alpha}{1-\theta} \left(\frac{\alpha}{\theta}\right)^{\alpha/(1-\alpha)}$. This determines the threshold country m, given g and ϕ. An interpretation of (32) is simple. Its right-hand side , which is equivalent to the right-hand side of (27), is the relative costs of innovative R&D to imitative R&D. Naturally, the left-hand side of (27) is the relative value of innovative R&D to imitative R&D. Three equations (30), (31) and (32) determine g, m and ϕ.

To reduce the number of endogenous variables, let us write (32) as

$$\phi = \phi(g, m), \qquad \phi_g > 0, \ \ \phi_m > 0, \ \ \phi(0, m) = 0. \tag{33}$$

This allows us to rewrite (30) as

$$\rho\phi(g, m) + g = \frac{1-\alpha}{\alpha} \frac{LA(m) - g}{1 - s_N}. \tag{34}$$

Now, we have the system of two equations (31) and (34) with two unknowns g and m.

We depict the combination of g and m that satisfy (31) by the curve labeled SS in Figure 2. It is represented by a downward-sloping line. The curve labeled NN in Figure 2 shows the combination of g and m that satisfy (34). It is represented by a non-monotonic curve. Appendix B shows that the property of the NN curve. In principle, multiple equilibria are a possibility. However, we focus on the case of a unique equilibrium to avoid taxonomic analysis. The intersection of SS and NN curves at point a defines the rate of growth rate and the number of Northern countries in a steady state equilibrium.

3.2 Other Endogenous Variables

Once equilibrium values of g and m are determined, other endogenous variables can be recovered. The share of Northern products in all variety goods ϕ is given in (33). In Figure 2, an iso-ϕ contour could be drawn, taking a convex shape towards the origin.

Regarding a Poisson rate of imitation h, (16) and (33) imply that it relates to g and m such that

$$h\left(g,m\right)=g\frac{1-\phi\left(g,m\right)}{\phi\left(g,m\right)},\qquad h_g\lesseqgtr 0,\ \ h_m<0. \tag{35}$$

Unfortunately, this shows that changes in h in response to parameter changes are ambiguous in general.

Turning to North-South relative wages, there are two points worth mention. First, recall that the threshold country has no comparative advantage in either innovative or imitative R&D. Indeed, this property translates into the result of $w_m/w_S=1$.[7] Second, (22) implies that the following equation must hold for all Northern economies:

$$\frac{w_i}{w_S}=\left(\frac{a_i}{a_0}\right)^{1-\alpha}\frac{w_0}{w_S}=\left(\Delta\frac{1-s_S}{1-s_N}\frac{\rho+g}{\rho+g/\phi\left(g,m\right)}\frac{1}{1-\phi\left(g,m\right)}\frac{a_i}{a_S}\right)^{1-\alpha},\quad i\in\mathcal{N}. \tag{36}$$

The second equality is derived from (A4) in Appendix A. Note that this equation must hold even in the threshold country if it had been specialized in innovative R&D. An interpretation of these two results is that the threshold country is in fact specialized in imitative R&D, and (36) for $i=m$ defines the lowest bound of Northern relative wages. This result is illustrated in Figure 3. A jump at m is due to linear R&D technology assumed.

3.3 Comparative Statics

In this subsection, we study the steady state equilibrium properties of the model. We investigate how the growth rate g and the number of northern countries m are affected by globalization and other parameters of interest.

[7] This result can be easily checked by using (32) and (A6) in Appendix A.

3.3.1 Globalization

Globalization is interpreted as the increase in the number of countries that join the world trading system. As an example, one can think of the increasing presence of China in world trade in the last decades. We assume that countries with lower R&D productivity than $a(M)$ enter the world trading system with an increase in M. An increase in the size of M implies that g increases for given m in (31). The SS curve shifts up in (g, m) space, as illustrated in Figure 4. An increase in Mleads to a new steady state equilibrium point given by b from a. Thus, the increase in M leads to an increase in both g and m. Intuitively, the result is explained as follows. When M increases, the scale of southern countries becomes larger and increases imitative R&D workers, which raises economic growth (remember $g = g_S$). This makes innovative R&D activities more profitable, so that the number of countries that operate innovative R&D increases. Therefore, globalization improves economic growth and promotes industrialization which can be taken as a shift from imitative to innovative R&D.

3.3.2 Intellectual Property Right (IPR) protection

In this model, strengthening IPR can be interpreted as an increase of difficulty in imitation activity; a decrease in a_S. Suppose that a permanent decrease of a_S occurs by modifing IPR protection policy. A decrease in a_S implies that g decreases for given m in (31). The SS curve shifts down in (g, m) space. Since $\partial\phi/\partial a_S > 0$ from (32), g increases for given m in (34), shifting up the NN curve in (g, m) space. The new equilibrium is at point b in Figure 5. Thus, the decrease in a_S decreases m, but the effect on g is ambiguous.

To interpret this result, recall $g = g_S$ in steady state. This requirement implies that a decrease in a_S reduces economic growth. A slower growth makes innovative R&D acitivity less profitable, so that the number of Northern countries with active innovative R&D falls. On the other hand, a stronger IPR protection decreases the share of Northern productsϕ, implying that workers availbale for innovating R&D activity increase. This has a positive effect on economic growth, which makes imitative R&D activity more profitable, so that the number of Southern counrties rises. As a result, strengthening IPR protection decreases the number of northern countries, but the effect on g is ambiguous.

3.3.3 Innovative R&D productivity

We investigate the effect of an increase in innovative R&D productivity a_i. An increase in a_i has no effect on the imitative R&D incentive condition (31). Using $\partial\phi/\partial a_m < 0$ from (32) and $\partial A(m)/\partial a_i > 0$ from (34), an increase in a_i decreases g for given m in (34), which means an upward shift of the NN curve shift in (g, m) space. In Figure 5, equilibrium moves from point a to point c. This is a somewhat surprising result, as a higher innovative R&D productivity is expected to be conducive to industrialization.

Intuitively, an increase in a_i increases g, while m decreases. An increase in the productivity of innovative R&D improves economic growth, which makes imitative R&D activity more profitable. Then, in steady state imitative R&D also increases, so that the number of Southern countries $(M - m)$ increases. As a result, the increase in the productivity of innovative R&D increase the growth rate and decrease the number of northern countries.

3.3.4 Industrial Policy

Here we consider innovative R&D subsidies and imitative R&D subsidies. Let us start with the effect of innovative R&D subsidies. Using $\partial\phi/\partial s_N < 0$ from (32), an increase in s_N increases g for given m in (34). The NN curve shifts up in (g, m) space and this is illustrated in Figure 6. An increase in s_N leads to a new steady state equilibrium point b from point a. Thus, the industrial policy promotes growth, but discourages industrialization (i.e. a fall in$m$). The latter result is similar to the effect of a higher innovative R&D productivity $a(i)$.

Intuitively, the result is explained as follows. Innovative R&D subsidies increases incentives for innovative R&D, which raises growth. A higher economic growth makes imitative R&D activity more profitable, so that the number of Southern countries increases. Consequently, the policy raises growth but decreases the number of northern countries.

Next, we examine the effect of imitative R&D subsidies. An increase in s_S implies that g increases for given m in (31). The SS curve shifts up in (g, m) space. We can also show $\partial\phi/\partial s_S > 0$ from (32), which means a fall in g for given m in (34). This implies that the NN curve shifts down in (g, m) space. The equilibrium moves to c from a in Figure 6. Thus, an increase in s_S leads to a higher m, but the effect on g is ambiguous.

An intuition goes as follows. The subsidies raise economic growth, since

$g = g_S$ holds in steady state. This makes innovative R&D more profitable, leading to an increase in the number of northern countries. On the other hand, the imitative R&D subsidies increase the share of Northern goodsϕ, which decreases workers available for innovative R&D. This tends to reduce growth, which makes imitative R&D activity less profitable. This decreases the number of southenr counrties, which means an increase in the number of Northern countries. The effect that the subsidies of imitative R&D have on steady state equilibrium is the same as the policy of weakening IPR.

3.3.5 Competition

We examine the effect of intensified competition in the product market. We two cases, depending on the prices of Southern goods: (i) $\theta = \alpha, (\gamma \geq 1/\alpha)$ (ii) $\theta = 1/\gamma, (\gamma < 1/\alpha)$. First consider the case (i). An increase in α is interpreted as intensified competition in both Northern and Southern industries. A higher α implies that g decreases for given m in both (31) and (34).[8] The SS and NN curve shift down in (g, m) space. These are illustrated in Figure 7. As a result, intensified competition in the product market decreases g, but the effect on the number of northern countries is ambiguous.

Next consider the case (ii). We can examine the competition in each region. An increase in α represents intensified competition in Northern industries, while a decrease in γ represents intensified competition in Southern industries. An increase in α has no effect on the Southern condition (31). Using $\partial\phi/\partial\alpha > 0$ from (32), an increase in α decreases g for given m in (34). The NN curve shifts down in (g, m) space. These are illustrated in Figure 8, and the equilibrium is given by point b. It shows that intnsified competition in Northern industries reduces g, and increases m.

On the other hand, a decrease in γ implies that g decreases for a given m in (31). The SS curve shifts down in (g, m) space. Since we obtain $\partial\phi/\partial\gamma > 0$ from (32), a decrease in γ increases g for given m in (34). The NN curve shifts up in (g, m) space. These are illustrated in Figure 8, the equilibrium is given by point c. Intesified competition in Southern industries decreases m, but the effect on g is ambiguous.

Note that the negative effect of intensified competition in Northern industries on growth is a standard result. However, the effect of intensified competition in Southern industries on growth rate can be positive.

[8] In case (i), we obtain $\partial\phi/\partial\alpha = 0$, since $\Delta = 1$ from (32).

3.3.6 Migration

We investigate the effect of migration to North from South on equilibrium. Let denote $\varepsilon_N$workers who emigrate to a Northern economy, ε_S workers who imigrate from a Southern economy. In equilibrium, the flow into the Northern economy $\varepsilon_N m$ must be equal to the flow out of the Southern economy $\varepsilon_S(M - m)$, that is

$$\varepsilon_S(M - m) = \varepsilon_N m. \tag{37}$$

In a Northern economy, labor supply increases to $L+\varepsilon_N$, while labor supply decreases to $L - \varepsilon_S$ in each of Southern economy. Then, using (37), the SS curve (31) and the NN curve (34) can be rewritten as

$$\rho + g = \frac{1-\theta}{\theta} \frac{La_S(M-m) - a_S\varepsilon_N m - g}{1 - s_S}. \tag{38}$$

$$\rho\phi(g, m) + g = \frac{1-\alpha}{\alpha} \frac{A(m)[L + \varepsilon_N] - g}{1 - s_N}. \tag{39}$$

On one hand, an increase in ε_N implies that g decreases for given m in (38). The SS curve shifts down in (g, m) space. On the other hand, an increase in ε_N implies that g increases for given m in (39). The NN curve shifts up in (g, m) space. These are illustrated in Figure 9, the equilibrium point moves to b from a. Thus, the migration from South to North decreases m, but the effect on g is ambiguous. It shows that migration is detrimental to industrialization of Southern economies.

Intuitively, the effect is explained as follows. Migration from Southern economies has a negative effect on imitative R&D acitivity, which leads to low economic growth. This makes innovative R&D less profitable, and the number of Northern countries falls. In contrast, migration to a Northern economy has positive effect on R&D innovative acitivity, since labor force in each of Northern economy expands. Furthermore, this effect leads to an increase in imitative R&D incentives with a rise in the number of Southern countries. In net, the number of Southern countries $(M - m)$ unambiguosly increases.

Migration causes two opposing effects on g, hence the result is ambiguous. However, a positive effect always dominates the negative effect if migration is initially small. Using (38) and (39), we find that as long as ε_N (or ε_S) are small enough, the effect of migration on growth rate satisfies

$$\left.\frac{dg}{d\varepsilon_N}\right|_{\varepsilon_N=0} = \frac{1}{\xi}\frac{a_S(1-\alpha)(1-\theta)}{\alpha\theta(1-s_N)(1-s_S)}\left[L\left(A(m)-a_m m\right)+\frac{(1-s_N)\alpha}{1-\alpha}\rho\phi_m m\right] > 0, \tag{40}$$

where

$$\xi \equiv \left[\rho\phi_g + 1 + \frac{1-\alpha}{\alpha(1-s_N)}\right]\frac{(1-\theta)a_S L}{\theta(1-s_S)} + \left[\frac{(1-\alpha)a_m L}{\alpha(1-s_N)} - \rho\phi_m\right]\left[1+\frac{1-\theta}{\theta(1-s_S)}\right] > 0. \tag{41}$$

It shows that a marginal rise of migration from zero raises growth.

4 Foreign Direct Investment

4.1 Introduction of FDI

Analysis so far assumes the absence of FDI. This section introduces FDI as a chanell of technology transfer and discusses how equilibrium properties are affected. To simplify analysis, all of newly created variety goods in North are produced in South, and innovative R&D only is conducted in North. Although these assumptions are simple, they are sufficient to highlight key results concerning the effects of FDI.

Let p_{SF} denote the price of Norther products produced in South. The price of Northern goods is assumed to be higher than the price of Southern goods, i.e. we focus on the case of $1/\theta = \gamma$ in (8).

$$p_{SF} = \frac{1}{\alpha}w_S > \frac{1}{\theta}w_S = p_S. \tag{42}$$

This assumption is required to generate incentive for Southern firms to imitatate Northern products.

In a Northern economy, all workers are used for innovative R&D:

$$L = R_i, \quad i \in \mathcal{N}. \tag{43}$$

In a Southern economy, Rs workers are used for imitative R&D, and labor demand arising from manufacturing Southern products is given by $n_S x_S$. On the other hand, the production of all Northern products in the world requries workers $\int_0^m n_i x_i di$. Therefore, a full employment of workers in a Southern economy is achieved when the following condition holds.

$$L = R_S + n_S \sigma_S \theta \frac{E}{w_S} + \frac{1}{M-m} \int_0^m n_i \sigma_{SF} \alpha \frac{E}{w_S} di. \quad (44)$$

$$= R_S + \sigma_S \frac{E}{w_S} \frac{N_S}{M-m} \theta \left[1 + \left(\frac{\alpha}{\theta} \right)^{1/(1-\alpha)} \frac{N_N}{N_S} \right]. \quad (45)$$

where

$$\sigma_S = \left(\frac{1}{\theta} w_S \right)^{-\frac{\alpha}{1-\alpha}} \frac{1}{\int_0^N p_j^{-\frac{\alpha}{1-\alpha}} dj}, \quad \sigma_{SF} = \left(\frac{1}{\alpha} w_S \right)^{-\frac{\alpha}{1-\alpha}} \frac{1}{\int_0^N p_j^{-\frac{\alpha}{1-\alpha}} dj} \quad (46)$$

Note that given that all Southern economies are identical, the third term on the right-hand side of (45) denotes workers used to produce Northern goods in each of Southern economy.

From (9), (18) and (20), we obtain the following equation;

$$g + \rho = \frac{(1-\theta) a_s \sigma_s E N_s}{(1-s_S) w_s}. \quad (47)$$

From (15), (45) and (47), we obtain

$$\rho + g = \frac{1}{1 + \left(\frac{\alpha}{\theta} \right)^{1/(1-\alpha)} \frac{\phi}{1-\phi}} \frac{1-\theta}{\theta} \frac{L a_S (M-m) - g}{1 - s_S}. \quad (48)$$

After multiplying (43) by a_i, integrating the equation from 0 to m and using (13), one can rearrange the resulting

$$A(m)L = g, \quad \text{where } A(m) = \int_0^m a_i di. \quad (49)$$

From (5), (7), (9), (17), (18), (19), (20) and constant E/w in steady state, the present value of profits earned by the firms in threshold country and Southern country is given by

$$V_m = \frac{(1-\alpha) \sigma_{SF} E}{\rho + g + h}, \quad V_S = \frac{(1-\theta) \sigma_S E}{\rho + g}. \quad (50)$$

Substituting these equations into (27) and using (16), we obtain

$$\Delta \frac{\rho + g}{\rho + g/\phi} = \frac{(1-s_N) a_S}{(1-s_S) a_m} (1-\phi) \implies \phi = \phi(g, m) \quad (51)$$

This equation is equivalent to (32), which represents comparative advantage condition. This allowe us to rewrite (48) as

$$\rho + g = \frac{1}{1+\left(\frac{\alpha}{\theta}\right)^{1/(1-\alpha)}\frac{\phi(g,m)}{1-\phi(g,m)}}\frac{1-\theta}{\theta}\frac{La_S(M-m)-g}{1-s_S}. \tag{52}$$

Now, we have the system of two equations (49) and (52) with two unknowns g and m. Those two equilibrium conditions are illustrated in Figure 10.

4.2 FDI v.s. No FDI

Now, we compare the equilibrium of the economy with FDI to that of the base model without FDI. In Figure 11, (49) is represented by the NN_{FDI} curve represents and (52) by the SS_{FDI} curve. Equilibrium poins are given by b and a, respectively. The figure shows that the NN_{FDI} curve is entirely located above the NN curve. On the other hand, the SS_{FDI} curve is entirely located below the SS curve.[9]

Intuitively, there are two opposing effects on growth. First, FDI reduces the number of manufacturing workers (to zero in this case), which means that more workers are available for innovative R&D than in the case of no FDI. Therefore, FDI tends to increase growth, and this effect is represented by the relative positions of the NN and NN_{FDI} curves. Second, the number of workers engaged in imitative R&D activity decreases in each of Southern country because more workers are employed to manufacture products due to FDI. Therefore, the rate of imitation falls, and the effect is represented by the fact that SS_{FDI} curve is located below that SS curve. In net, the effect of FDI on growth is ambiguous.

On the other hand, the effect of FDI on m is unambiguous. The fact that FDI increases workers available for R&D in North makes imitative R&D more profitable. This leads to an increase in the number of Southern economies. Moreover, the fact that FDI reduces workers for imitative R&D in South renderns innovative R&D less profitable. This effect reduces the number of Northern economies. In equilibrium, the introduction of FDI has a negative effect on the number of North country m. That is, FDI is detrimental to industrialization of Southern economies.

[9]These are proved in Appendix C.

5 Conclusion

This paper develops a dynamic general equilibrium model of North-South trade and economic growth in a world economy with a continuum of countries. Northern countries are specilized in innovation and the production of innovative products, and Southern economies in imitative R&D and the manufacturing copied goods. Imitation and the division of countries into North and South are are endogenously determined on the basis of comparative advantage of research activities. We examined the equilibrium properties of the model and explored policy implications.

Appendix

A Derivation of (28)

Substituting (5), (9), (15) and (20) into (18) yields

$$\frac{\dot{E}(t)}{E(t)} - \frac{\dot{w}_S(t)}{w_S(t)} + g_S(t) + \rho = \frac{(1-\theta)\, a_S \sigma_S(t)\, E(t)\, N_S(t)}{(1-s_S)\, w_S(t)}. \tag{A1}$$

From (A1) and (21), in steady state where E/w_S and E/w_i are constant and $g_S = g$, we obtain the following equations

$$g + \rho = \frac{(1-\theta)\, a_S \sigma_S E N_S}{(1-s_S)\, w_S}. \tag{A2}$$

$$g + h + \rho = \frac{(1-\alpha)\, a_i \sigma_i E N}{(1-s_N)\, w_i}. \tag{A3}$$

After using (A2) and (A3) to eliminate E, one can rewrite the resulting equation as

$$\left(\frac{w_i}{w_S}\right)^{\frac{1}{1-\alpha}} = \frac{(1-\alpha)(1-s_S)}{(1-\theta)(1-s_N)} \left(\frac{\alpha}{\theta}\right)^{\frac{\alpha}{1-\alpha}} \frac{\rho+g}{\rho+g+h} \frac{a_i N}{a_S N_S}, \tag{A4}$$

using (4), (6) and (8).

The following two equations can be derived from (19), (20), (A2), (A3)

$$V_S = \frac{(1-\theta)\, \sigma_S E}{\rho + g}, \qquad V_m = \frac{(1-\alpha)\, \sigma_m E}{\rho + g + h}. \tag{A5}$$

Substituting (A5) into (27) yields

$$\left(\frac{w_m}{w_S}\right)^{\frac{1}{1-\alpha}} = \left(\frac{(1-\alpha)(1-s_S)}{(1-\theta)(1-s_N)}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha}{\theta}\right)^{\frac{1}{1-\alpha}} \left(\frac{\rho+g}{\rho+g+h}\right)^{\frac{1}{\alpha}} \left(\frac{a_m N}{a_S N_S}\right)^{\frac{1}{\alpha}}. \tag{A6}$$

Equating (A4) in $i = m$ and (A6) gives (32).

B Properties of (30)

(i) Derivation of $\phi(g,m)$: (32) can be rewritten as

$$\rho\phi^2 + (\Gamma + g - \rho)\phi - g = 0, \tag{B1}$$

where $\Gamma \equiv \Delta\frac{1-s_S}{1-s_N}\frac{am}{a_S}(\rho+g)$. Solving for $\phi(g,m)$ gives

$$\phi(g,m) = \frac{1}{2\rho}\left[-(\Gamma+g-\rho) \pm \sqrt{(\Gamma+g-\rho)^2 + 4\rho g}\right]. \tag{B2}$$

It confirms that one root is positive and the other is negative all values of (g,m), and the former is a relevant root.

(ii) The slope of (34): Differentiate the expression to obtain

$$\frac{dg}{dm} = \frac{\frac{1-\alpha}{\alpha}\frac{La_m}{1-s_N} - \rho\phi_m}{1 + \frac{1-\alpha}{\alpha(1-s_N)} + \rho\phi_g}, \tag{B3}$$

$$\text{where}\quad \phi_g = \frac{1}{\sqrt{(\Gamma+g-\rho)^2 + 4\rho g}}\frac{\rho}{\rho+g}(1-\phi)^2 > 0,$$

$$\phi_m = \frac{\Delta\frac{1-s_S}{1-s_N}\frac{-a'_m}{a_S}(\rho+g)}{\sqrt{(\Gamma+g-\rho)^2+4\rho g}}\phi > 0.$$

(B3) is reduced to

$$\left.\frac{dg}{dm}\right|_{m=0} = \frac{\frac{1-\alpha}{\alpha}\frac{La_m}{1-s_N}}{1 + \frac{1-\alpha}{\alpha(1-s_N)} + \rho\sqrt{(\Gamma-\rho)^2}} > 0 \tag{B4}$$

for $m = 0$ and $g = 0$. The slope of NN curve is positive at the origin $(0,0)$.

C Properties of NN and SS Curves with FDI

(i) NN curve: the NN curve in no FDI case is given by (34) and in FDI case by (49). We obtain the slope of these curves as follows

$$\left.\frac{dg}{dm}\right|_{FDI} = La_m > \left.\frac{dg}{dm}\right|_{noFDI} = \frac{La_m - \rho\phi_m(1-s_N)\frac{\alpha}{1-\alpha}}{1+(1+\rho\phi_g)(1-s_N)\frac{\alpha}{1-\alpha}}, \tag{C1}$$

Thus, the NN curve with FDI is upward to the NN curve with no FDI, and these curve intersects at origin.

(ii) SS curve: the SS curve with no FDI is given by (31) and the SS curve with FDI by (52). These equation is rewritten by

$$\text{FDI: } (\rho+g)\left[1+\left(\frac{\alpha}{\theta}\right)^{\frac{1}{1-\alpha}}\frac{\phi(g,m)}{1-\phi(g,m)}\right] = \frac{1-\theta}{\theta}\frac{La_S(M-m)-g}{1-s_S} \tag{C2}$$

$$\text{no FDI: } \rho+g = \frac{1-\theta}{\theta}\frac{La_S(M-m)-g}{1-s_S} \tag{C3}$$

The right hand side of the above equations is equivalent and decreases in g, given m. The left hand side of the above equations increases in g, given m. The left hand side of FDI case is larger than that of no FDI case. Thus, the growth rate g in FDI case is lower than in no FDI case for given m, so that the SS curve with FDI is downward to that of no FDI. Also, these curve intersects at $m = M - \rho/[La_s(1-\theta)/\theta(1-s_S)]$, in which these curve cuts the horizontal line.

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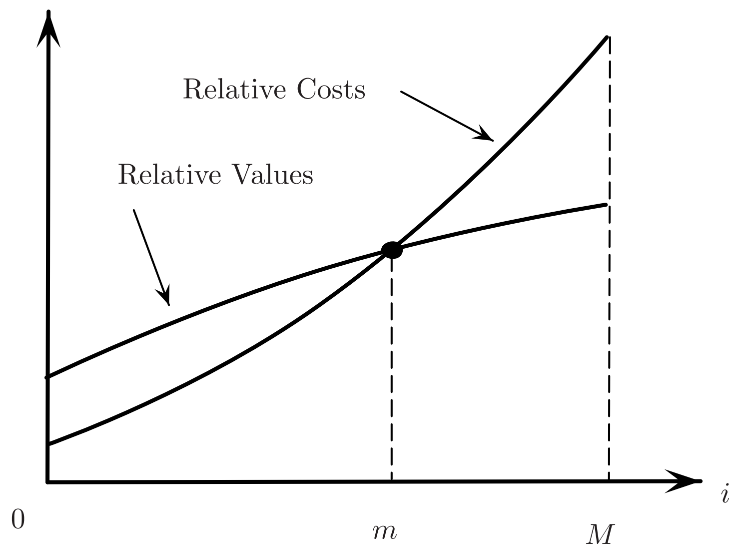

Figure 1: Comparative advantage and the determination of m.

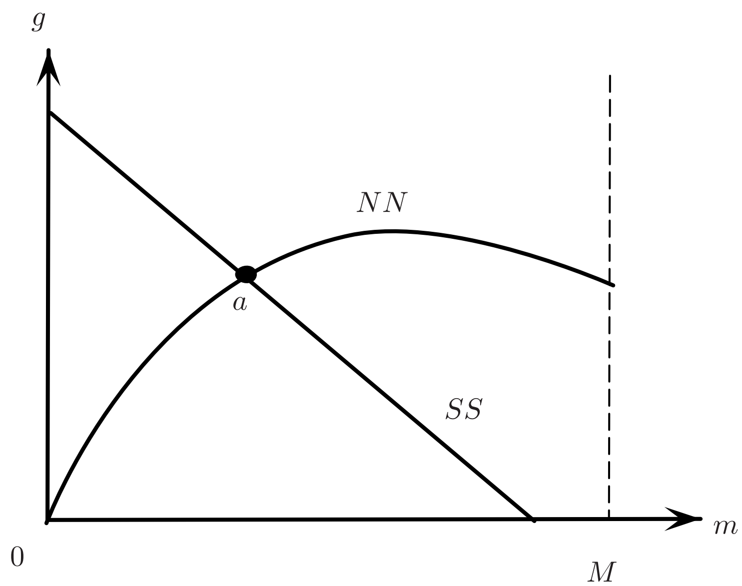

Figure 2: Steady state equilibrium.

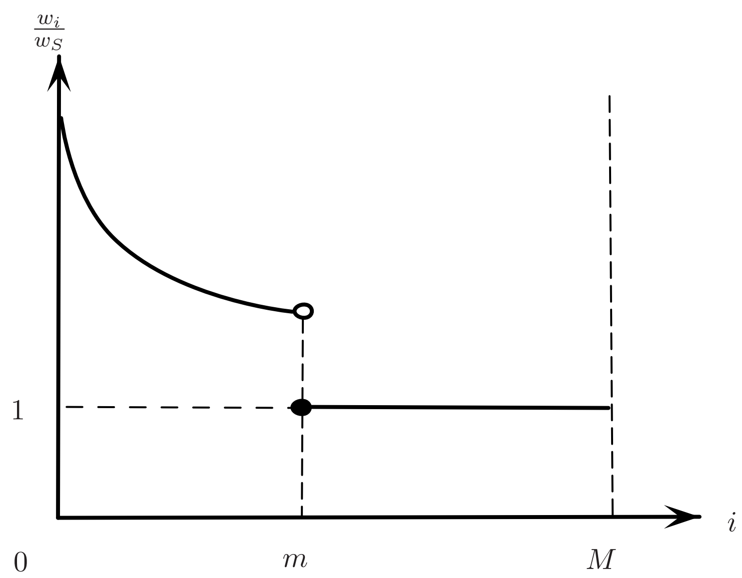

Figure 3: North-South relative wages.

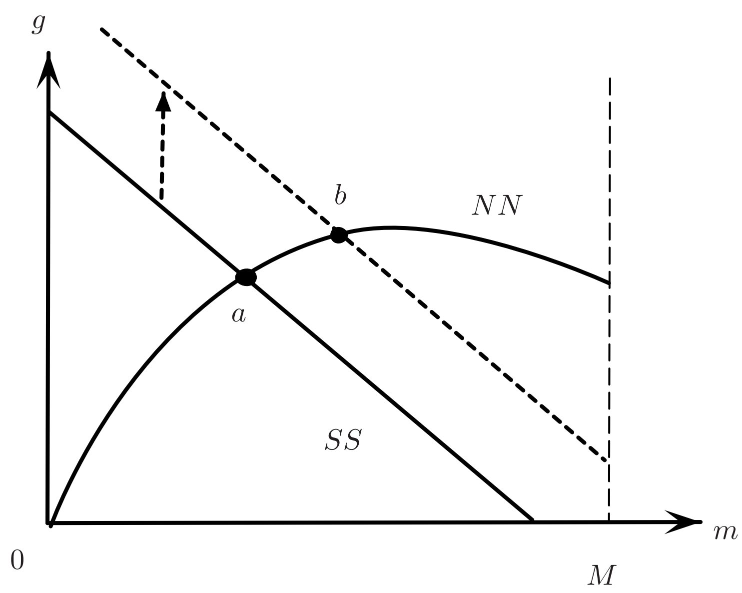

Figure 4: The effect of globalization.

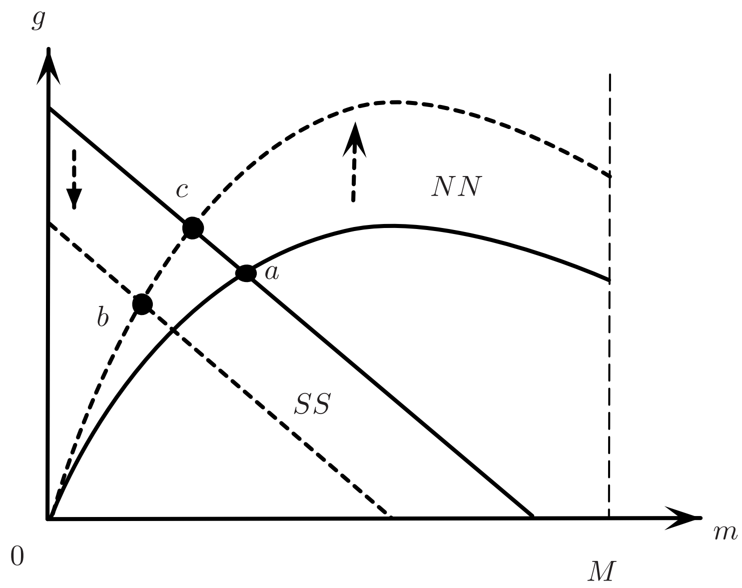

Figure 5: The effects of IPR protection and an incrase in innovative R&D productivity.

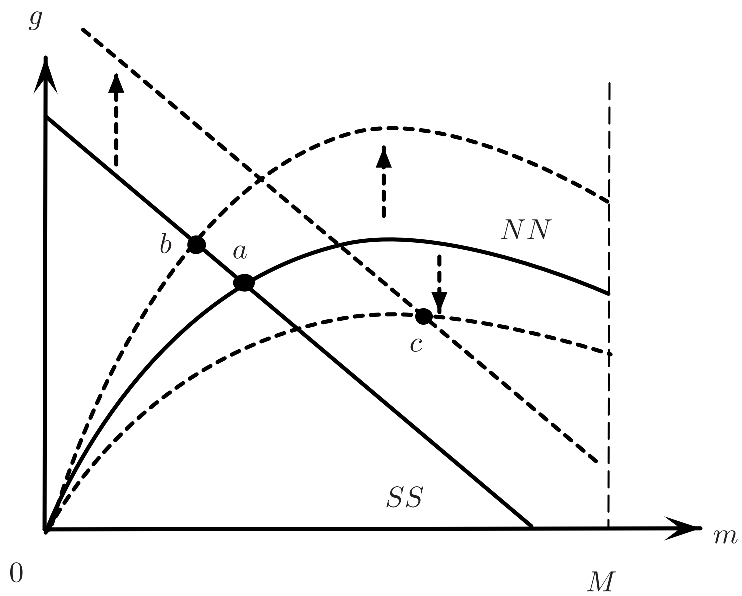

Figure 6: The effects of subsidies to innovative and imitative R&D.

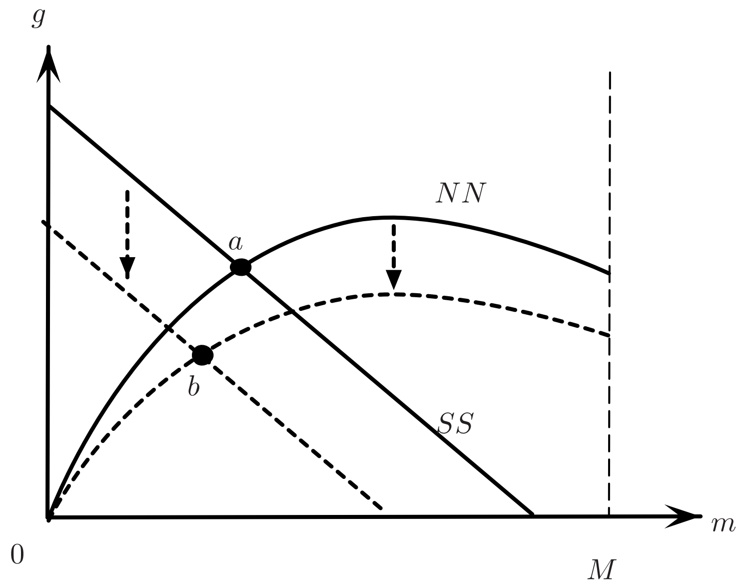

Figure 7: The effects of intensified competition both in North and South for $\gamma \geq 1/\alpha$.

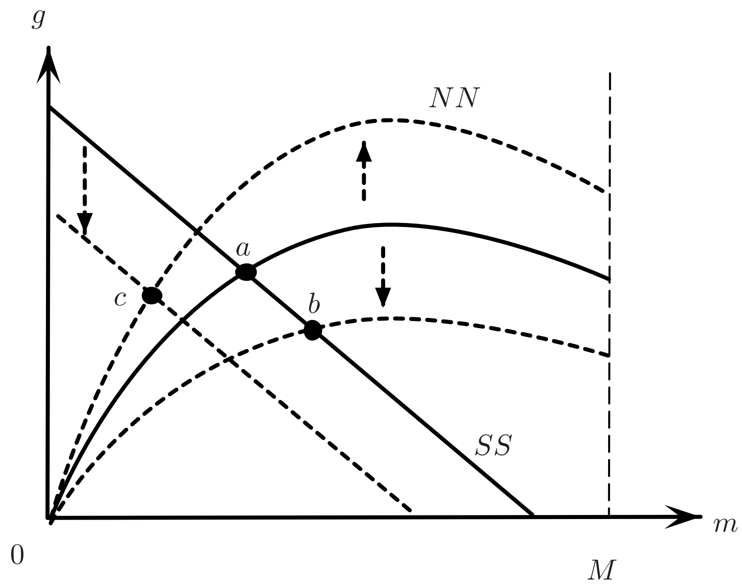

Figure 8: The effects of intensified competition either in North or South only for $\gamma < 1/\alpha$.

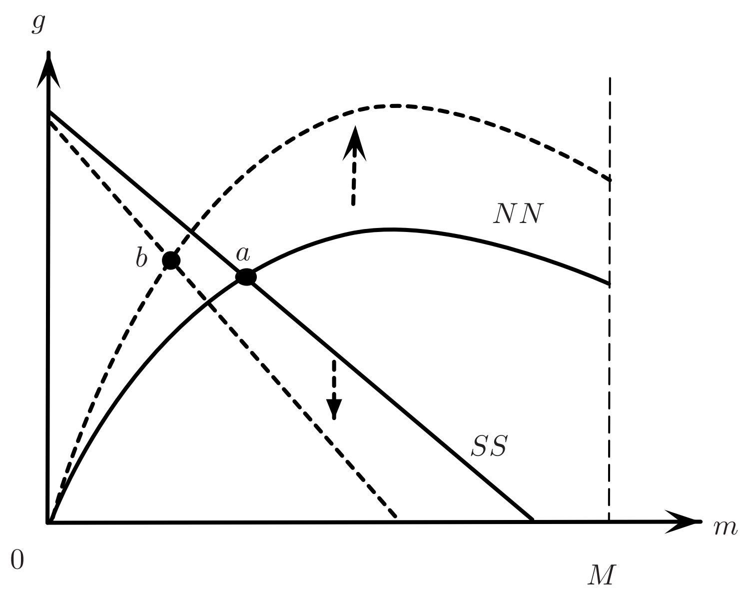

Figure 9: The effects of migration to North from South.

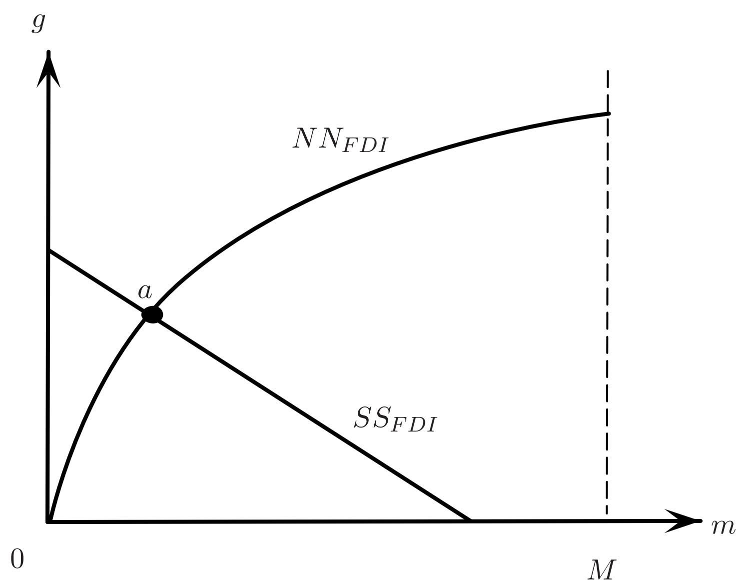

Figure 10: An equilibrium in the presence of FDI.

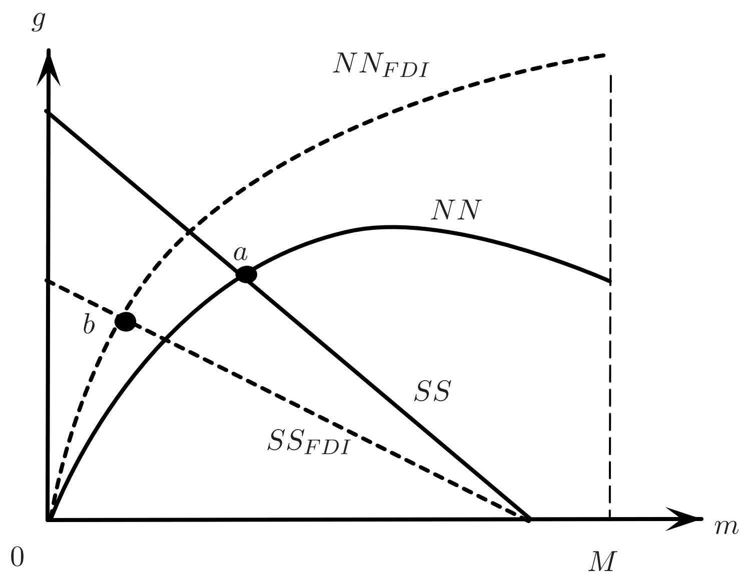

Figure 11: The effect of FDI.