Intellectual property rights and quality improvement

Amy Jocelyn Glass[a,*], Xiaodong Wu[b]

[a]Department of Economics, Texas A&M University, College Station, TX 77843, USA

[b]Department of Economics, University of North Carolina, Chapel Hill, NC 27599, USA

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Abstract

This paper explores why theories about the effects of intellectual property rights (IPR) protection on foreign direct investment (FDI) and innovation have reached mixed conclusions. In our model, Northern firms innovate to improve the quality of existing products and may later shift production to the South through FDI. Southern firms may then imitate the products of multinationals. We find that imitation increases FDI and innovation, the opposite of existing models in which innovators develop new varieties. Hence, stronger IPR protection, by reducing imitation, may shift the composition of innovation away from improvements in existing products toward development of new products.

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*Corresponding author. Tel: +1-979-845-8507; fax: +1-979-847-8757.

E-mail address: aglass@econmail.tamu.edu (A.J. Glass).

1. Introduction

Intellectual property rights (IPR) protection is the subject of heated debate in international policy negotiations. Many developing countries feel that the Trade-Related Aspects of Intellectual Property (TRIPs) agreement signed in the Uruguay round benefits rich countries at the expense of the poor. McCalman (2002) finds evidence sympathetic to their view: his calculations indicate that the United States is the major beneficiary and developing countries are major contributors. Consequently, developing countries are now pushing to have intellectual property issues revisited in the new Doha round.

Stronger IPR protection is claimed to encourage foreign direct investment (FDI) and innovation. FDI is heralded as the key to international technology transfer. Yet the bulk of FDI occurs between developed countries – see Markusen (1995). So developing countries need to have stronger IPR protection to attract FDI that will bring in state-of-the-art technologies, or so the story goes.

Logic along these lines was used to help sell the TRIPs agreement to reluctant developing countries. But how robust is this reasoning? How does protection of IPR affect FDI and innovation? Are there circumstances in which stronger protection of IPR does not encourage FDI and innovation? Is there a risk that IPR protection could impede, rather than promote, the development prospects for countries that lag behind the technology frontier?

A literature has emerged to address these questions.[1] In Helpman (1993), innovation occurs in the North and imitation in the South. Weaker protection of intellectual property is an increase in the exogenous imitation intensity so that Northern firms face a higher risk that their products will be imitated. Yet he finds that weak protection of intellectual property rights increases the aggregate rate of innovation.[2] Helpman also considers a model with FDI, but innovation is then exogenous. Lai (1998) modifies Helpman's model to consider the effects of imitation targeting multinational production on innovation. He finds that the aggregate rate of innovation and the flows of FDI increase with stronger intellectual property rights in the South.[3]

Glass and Saggi (2002) cast doubt on whether stronger Southern IPR protection must

[1] See Maskus (2000) for a broader review.

[2] Taylor (1994) has argued that lack of patent protection reduces aggregate R&D in a two-country endogenous growth model.

[3] Yang and Maskus (2001) find that better IPR protection can increase innovation and technology transfer when firms license their technologies. Stronger IPR protection reduces the costs of licensing contracts and increases the licensor's profit share in their model.

always encourage FDI and innovation. They argue that stronger Southern IPR protection reduces the aggregate rate of innovation and the flow of FDI regardless of whether FDI or imitation targeting Northern production serves as the primary channel of international technology transfer. In their model, stronger IPR protection is an increase in the cost of imitation, which causes a reduction in the rate of imitation. They identify two effects of the increased cost of imitation: a labor wasting effect due to the increased amount of labor used for imitation, and an imitation tax effect due to the decreased incentive for imitation. They show that each effect reduces FDI and innovation, and neither effect arose in previous analysis with exogenous and costless imitation. So *the reason for the difference in results appears to be the difference in how IPR protection was modeled: as an increase in the cost of imitation rather than as an exogenous decrease in the imitation intensity.*

But the models differ in another important way. In the Glass and Saggi model, innovations are improvements in the quality of existing products rather than introduction of new varieties. Could the difference in the type of innovation alter the consequences of IPR protection? To answer that question, this paper considers an exogenous decrease in the imitation intensity in a setting with FDI and where innovations take the form of quality improvements. We find that stronger Southern IPR protection discourages FDI and innovation, or (in the reverse direction) that greater imitation encourages both FDI and innovation. These results match those of Glass and Saggi (2002) but cannot stem from higher imitation cost since imitation is costless here.[4]

Our model is kept identical to Lai's model in all respects possible except for the type of innovation, so we conclude that the effects of IPR protection depend on the nature of innovation. *When innovations are new varieties, stronger Southern IPR protection encourages*

[4]Further research should construct a model with variety innovations, FDI, and endogenous reductions in imitation through an increase in the difficulty of imitation. If the results of such a model were to differ from Lai (1998), then treating imitation as endogenous versus exogenous would provide an independent reason.

FDI and innovation, but when innovations are higher quality levels, FDI and innovation fall. When there is FDI, stronger Southern IPR protection may shift the composition of innovation away from improvements in existing products toward the development of new products. The overall effect on innovation (and FDI) is then unclear.

However, when there is no FDI, an exogenous increase in imitation always increases innovation, regardless of the type of innovation. We provide a discussion of the different forces that arise, with and without FDI and for quality or variety inventions. This comparison helps to clarify why imitation discourages innovation only for variety innovations that occur when there is FDI. This discussion also includes an analysis of the different effects of imitation on the Northern relative wage: *imitation increases the relative wage if there is FDI but otherwise decreases the relative wage.* Effects on the relative wage are important as they lead to reallocation of income across countries. Our analysis helps explain differences in results in order to be better equipped to assess implications for IPR policy.

2. Product cycles with FDI and exogenous imitation

We begin with a description of the model. Consumers live in either the North or the South, and choose from a continuum of products available at different quality levels. Due to assumed differences in the technological capabilities of the two countries, only Northern firms can push forward the quality frontier of existing products through innovation. Northern firms, by becoming multinationals, can shift their production to the South. Costs are lower in the South, but multinationals face the risk that their design may be imitated. The North exports newly innovated products and imports the products of multinational firms and imitated products.

2.1. Consumers

The specification of the consumer's problem follows Grossman and Helpman (1991a). Consumers choose from a continuum of products $j \in [0,1]$. Quality level m of product j provides quality $q_m(j) \equiv \lambda^m$. By the definition of quality improvement, new generations are better than the old: $q_m(j) > q_{m-1}(j) \rightarrow \lambda^m > \lambda^{m-1} \rightarrow \lambda > 1$. All products start at time $t = 0$ at quality level $m = 0$, so the base quality is $q_0(j) = \lambda^0 = 1$.

A consumer from country $i \in \{N, S\}$ has additively separable intertemporal preferences given by lifetime utility

$$U_i = \int_0^\infty e^{-\rho t} \log u_i(t) dt, \tag{1}$$

where ρ is the common subjective discount factor. Instantaneous utility is

$$\log u_i(t) = \int_0^1 \log \sum_m (\lambda)^m x_{im}(j,t) dj, \tag{2}$$

where $x_{im}(j,t)$ is consumption by consumers from country i of quality level m of product j at time t.

Consumers maximize lifetime utility subject to an intertemporal budget constraint. Since preferences are homothetic, aggregate demand is found by maximizing lifetime utility subject to the aggregate intertemporal budget constraint

$$\int_0^\infty e^{-R(t)} E_i(t) dt \leq A_i(0) + \int_0^\infty e^{-R(t)} Y_i(t) dt, \tag{3}$$

where $R(t) = \int_0^t r(s) ds$ is the cumulative interest rate up to time t and $A_i(0)$ is the aggregate value of initial asset holdings by consumers from country i. Individuals hold assets in the form of ownership in firms, but with a diversified portfolio, any capital losses appear as capital gains elsewhere so that only initial asset holdings matter. Aggregate labor income of all consumers from country i is $Y_i(t) = L_i w_i(t)$, where $w_i(t)$ is the wage in country i at time

t and L_i is the labor supply there, so $L_i w_i(t)$ is total labor income in country i at time t. Aggregate expenditure of all consumers in country i is

$$E_i(t) = \int_0^1 \left[\sum_m p_m(j,t) x_{im}(j,t) \right] dj, \tag{4}$$

where $p_m(j,t)$ is the price of quality level m of product j at time t, and $E_i(t)$ is aggregate expenditure of consumers in country i, where aggregate expenditure is $E(t) = E_N(t) + E_S(t)$. Due to assumed free trade, price levels do not vary across countries.

A consumer's maximization problem can be broken into three stages: the allocation of lifetime wealth across time, the allocation of expenditure at each instant across products, and the allocation of expenditure at each instant for each product across available quality levels. In the final stage, consumers allocate expenditure for each product at each instant to the quality level $\widetilde{m}(j,t)$ offering the lowest quality-adjusted price, $p_m(j,t)/\lambda^m$. Consumers are indifferent between quality level m and quality level $m-1$ if the relative price equals the quality difference $p_m(j,t)/p_{m-1}(j,t) = \lambda$. Settle indifference in favor of the higher quality level so the quality level selected is unique. Only the highest quality level available will sell in equilibrium.

In the second stage, consumers spread expenditure evenly across the unit measure of all products, $E_i(j,t) = E_i(t)$, as the elasticity of substitution between any two products is constant at unity. Consumers demand $x_{i\widetilde{m}}(j,t) = E_i(t)/p_{\widetilde{m}}(j,t)$ units of quality level $\widetilde{m}(j,t)$ of product j and zero units of other quality levels of that product. In the first stage, consumers evenly spread lifetime expenditure across time, $E_i(t) = E_i$, as the utility function for each consumer is time separable and the aggregate price level does not vary across time $\log p_{\widetilde{m}}(j,t) = \log p_{\widetilde{m}}(j)$. Since aggregate expenditure is constant across time, the interest rate at each point in time reflects the discount rate $r(t) = \rho$, so $R(t) = \rho t$ in the intertemporal budget constraint.

2.2. Research and development

The premium consumers are willing to pay for quality gives firms an incentive to improve the quality of existing products. Our model shares the properties of endogenous and costly innovation with Grossman and Helpman (1991a) and Segerstrom et al (1990), but we allow for FDI by allowing Northern firms to become multinationals and produce in the South. Also, imitation will be kept exogenous.

To produce a certain quality level of a product, a firm must first devote effort to designing it. We model innovation success as a continuous Poisson process so that innovation resembles a lottery: at each point in time, firms pay a cost for a chance at winning a payoff. Assume that a firm undertaking innovation intensity ι_N for a time interval dt experiences success with probability $\iota_N dt$ but requires $a_N \iota_N dt$ units of labor at cost $w_N a_N \iota_N dt$. The innovation intensity represents how much effort a firm devotes to innovation and hence how likely a firm targeting a product for improvement is to experience an innovation success at a given instant. A larger innovation intensity ι_N yields a higher probability of success, but no level of investment in innovation can guarantee success.

Only the current level of innovation activity determines the chance of innovation success, since innovation is memory-less for simplicity. The potential for quality improvement is unbounded. Assume innovation races occur simultaneously for all products, with all innovating firms able to target the quality level $m+1$ above the current highest quality level m and all imitating firms able to target the current highest quality level m for each product. Due to Bertrand behavior in product markets, once a quality level of a product has been invented, another firm never invents the same quality level.

For simplicity, we assume that Northern innovation will not target the products of other Northern firms by making the following assumptions. Innovators can be separated into two groups: leaders and followers. Leaders are firms who developed the most recent quality improvement; followers are all other firms. Leaders are likely to enjoy a cost advantage in designing the next highest quality level due to their experience in having successfully designed the current highest quality level, as spillovers are apt to be incomplete. Assume the labor requirement in innovation for followers is sufficiently large relative to the labor requirement in innovation for leaders so that innovation is undertaken only by the firm that made the previous innovation for that product. Also assume the quality increment λ is sufficiently large that Northern leaders do not undertake further innovation until their most recent innovation has been imitated. Thus, innovation targets only production by Southern firms.

When undertaking innovation, a firm endures costs $w_N a_N \widetilde{\iota}_N dt$ and gains an expected reward $v_N \widetilde{\iota}_N dt$. Each firm chooses its innovation intensity $\widetilde{\iota}_N$ to maximize its expected gain from innovation

$$\max_{\widetilde{\iota}_N \geq 0} \int_0^\infty e^{-(\rho+\iota_N)t} \left(v_N - w_N a_N\right) \widetilde{\iota}_N dt = \max_{\widetilde{\iota}_N \geq 0} \left(\frac{v_N - w_N a_N}{\rho + \iota_N}\right) \widetilde{\iota}_N, \tag{5}$$

where v_N denotes the reward to successful innovation, the value of a Northern firm once successful in innovation. The term $e^{-\iota_N t}$ captures the probability that no other firm will have succeeded in innovation in the same industry prior to time t, and ι_N is the innovation intensity of other firms (taken as given). Each nonproducing firm chooses its innovation intensity to maximize the difference between the expected reward and the costs of innovation: $\max_{\widetilde{\iota}_N \geq 0} \left(v_N - w_N a_N\right) \widetilde{\iota}_N$.

Firms engage in innovation with nonnegative intensity whenever the expected gains are no less than their costs. To generate finite rates of innovation, expected gains must not exceed their cost, with equality when innovation occurs with positive intensity

$$v_N \leq w a_N, \ \iota_N > 0 \Longleftrightarrow v_N = w a_N. \tag{6}$$

The Southern wage is normalized to one, $w_S = 1$, so that $w = w_N$ is the North-South relative wage (called the Northern relative wage).

Northern firms also optimally choose the intensity at which to attempt to shift their production to the South. For simplicity and to make our model more comparable to Lai (1998), we assume that becoming a multinational is costless. The FDI intensity ϕ_F indicates how likely a Northern firm is to become a multinational (and thus how much FDI occurs). At each instant, each firm still producing in the North determines whether its value would be higher as a multinational. If $v_F > v_N$, the FDI intensity would be infinite as all would choose FDI; if $v_F < v_N$, the FDI intensity would be zero as none would choose FDI. Hence, if $v_F = v_N$, Northern firms are indifferent between producing in the North or producing in the South through FDI, as must be the case in any equilibrium with $\phi_F > 0$:

$$v_F - v_N \leq 0, \ \phi_F > 0 \Longleftrightarrow v_F = v_N. \tag{7}$$

Appendix A shows that our results hold in the general case where the cost of becoming a multinational is positive $a_F \geq 0$ as well. Now we turn to determining these values v_N and v_F for Northern firms and multinationals.

2.3. *Production*

A Northern firm successful in innovation earns the reward

$$v_N = \frac{\pi_N}{\rho}, \tag{8}$$

where π_N is instantaneous profits for a Northern firm. The firm's value as a multinational is

$$v_F = \frac{\pi_F}{\rho + M}, \tag{9}$$

where π_F is instantaneous profits for a multinational and M is the exogenous imitation intensity. The imitation intensity represents how likely a multinational's product is to be imitated at a point in time. When a multinational's design is imitated, its value becomes zero. An increase in imitation intensity M (holding all else equal) clearly decreases the value of a multinational firm. Imitation makes FDI less attractive by shortening the duration of profits. The imitation intensity M captures imperfect protection of intellectual property rights. In fact, M may capture any behavior that ends profits for the multinational. The imitation intensity M is exogenous to match the way Lai (1998) modelled IPR protection: through exogenous changes in imitation intensity (the probability that a multinational's product will be imitated in the next instant).

Labor is the only factor of production, and production is assumed to exhibit constant returns to scale. Normalize the unit labor requirement in production to 1 in each country. Once successful in innovation, each firm chooses its price p to maximize its profits $\pi = (p - c)\,x$, where c is marginal cost and x is sales. Under Bertrand competition, the market outcomes depend on the extent of competition from rivals priced out of the market. Each producing firm chooses a limit price that just keeps its rival from earning a positive profit from production (this price equals the second highest marginal cost in quality-adjusted terms).

Since each new innovation is one level above the quality of the existing variety imitated by Southern imitators, Northern innovators choose a price equal to the quality increment times the marginal cost of Southern production. A Northern firm charges price $p_N = \lambda$ and makes sales $x_N = E/\lambda$ with marginal cost $c_N = w$, yielding instantaneous profits

$$\pi_N = E\left(1 - \frac{w}{\lambda}\right). \tag{10}$$

A multinational charges price $p_F = \lambda$ and makes sales $x_F = E/\lambda$ with marginal cost $c_F = 1$ (due to producing in the South), yielding instantaneous profits

$$\pi_F = E\left(1 - \frac{1}{\lambda}\right). \tag{11}$$

The higher profit of multinationals relative to Northern firms compensates multinationals for their exposure to imitation risk.

$$\frac{\pi_F}{\pi_N} = \frac{\lambda - 1}{\lambda - w} > 1 \tag{12}$$

Southern imitators charge a price $p_S = 1$ equal to marginal cost $c_S = 1$, make sales $x_S = E$ but zero economic profits.

2.4. Labor constraints

Let n_N denote the measure of Northern production, which is the fraction of all production that is done in the North by Northern firms. Similarly, let n_F be the measure of multinational production (the fraction of all production that is done in the South by multinational firms) and n_S the measure of Southern production (the fraction of all production that is done in the South by Southern firms). Each is a fraction of total production so the measures sum to one.

In each country, the supply of labor is fixed and the demand for labor must equal the supply of labor in equilibrium. In the North, labor demand for innovation is $a_N \iota_N n_S$ and for production is $n_N E/\lambda$.

$$a_N \iota_N n_S + n_N \frac{E}{\lambda} = L_N \tag{13}$$

In the South, labor demand for production is $n_F E/\lambda + n_S E$.

$$n_F \frac{E}{\lambda} + n_S E = L_S \tag{14}$$

Now we address the properties of the steady-state equilibrium of this model.

2.5. *Steady-state system*

We focus on steady-state equilibria. If both innovation and multinational production occur, our model is a system of four equations. First, substituting profits (10) and values (8) into equation (6) gives the innovation valuation condition

$$E\left(1-w\delta\right)=wa_N\rho, \tag{15}$$

where $\delta\equiv 1/\lambda$. Second, when innovation and FDI occur in equilibrium, $\iota_N>0$ and $\phi_F>0$, the FDI valuation condition (7) can be rewritten using $v_N=wa_N$ from the innovation valuation condition (6) as

$$\iota_N>0,\ \phi_F>0\Longrightarrow v_F=wa_N. \tag{16}$$

Substituting profits (11) and values (9) into equation (16) gives the FDI valuation condition

$$E\left(1-\delta\right)=wa_N\left(\rho+M\right). \tag{17}$$

The other two equations come from the labor constraints (13) and (14).

Using equations (12), (15) and (17), the difference in the profit of multinationals relative to Northern firms matches the higher effective discount rate due to exposure to imitation risk.

$$\frac{\pi_F}{\pi_N}=\frac{\lambda-1}{\lambda-w}=1+\frac{M}{\rho}>1 \tag{18}$$

As a consequence, an increase in imitation intensity leads to an increase in the equilibrium profitability of multinational relative to Northern production. The relative profit condition (18) suggests that such an adjustment can occur through an increase in the Northern relative wage w. The higher relative wage decreases the profits of Northern firms (since w is the cost of production in the North) and thus increases the gain in profits from becoming a multinational firm.

This system is stated in terms of four endogenous variables: the innovation intensity ι_N, the FDI intensity ϕ_F, the Northern relative wage w, and aggregate expenditure E. To proceed, first we want to convert the system to be in terms of the aggregate rate of innovation and the measure of Southern production (as well as the Northern relative wage and aggregate expenditure), since we are more interested in the aggregate rate of innovation than its intensity. The innovation intensity indicates the likelihood that innovation will be successful (in any instant) for a given product targeted. Multiplying the innovation intensity by the measure of products targeted yields the aggregate rate of innovation. The aggregate rate of innovation provides a measure of the speed of innovation that is occurring across all products. Hence, define the aggregate (or average) rate of innovation as the innovation intensity times the measure of Southern production $\iota \equiv \iota_N n_S$ as innovation targets only Southern production. Similarly define the flow of FDI as the FDI intensity times the measure of Northern production $\phi \equiv \phi_F n_N$.

Additionally, the flows in must equal the flows out of each market measure so that each market measure remains constant in the steady-state equilibrium. Hence, the flows into FDI must equal the flows out due to imitation $\phi_F n_N = M n_F$ and the flows into production by Southern firms due to imitation must equal the flows out due to innovation $M n_F = \iota_N n_S$. The property that the measures must sum to one ensures constancy of the measure of Northern production (if the other two measures are held constant). These conditions imply the following substitutions, $\iota_N = \iota / n_S$, $\phi = \iota$, $n_F = \iota / M$, and $n_N = 1 - n_S - \iota / M$.

However, although they imply $\iota = M n_F$, these conditions do not require the aggregate rate of innovation ι to be positively related to the imitation intensity M since the measure of multinational production n_F is an endogenous variable. If a rise in imitation intensity causes n_F to fall by a large enough degree, the aggregate rate of innovation ι could fall even though the imitation intensity M rose.

Applying the substitutions to rewrite the Northern labor constraint (13) gives

$$a_N \iota + \left(1 - \frac{\iota}{M} - n_S\right) E\delta = L_N, \tag{19}$$

and to rewrite the Southern labor constraint (14) gives

$$\frac{\iota}{M} E\delta + n_S E = L_S. \tag{20}$$

The valuation conditions (15) and (17), along with these labor constraints (19) and (20) form a system to solve for E, w, ι, and n_S.

When shifting production to the South is costless, our model has an explicit solution. Equilibrium aggregate expenditure

$$E = a_N \frac{\rho\delta + M}{\delta(1-\delta)} \tag{21}$$

and the equilibrium Northern relative wage

$$w = \frac{\rho\delta + M}{\delta\,(\rho + M)} \tag{22}$$

can be found from the innovation valuation condition (15) and the FDI valuation condition (17) alone.

Substituting these two equations into the labor constraints (19) and (20) gives the equilibrium aggregate rate of innovation

$$\iota = \frac{M\left[a_N(\rho\delta + M) - (1-\delta)(L_N + \delta L_S)\right]}{a_N \rho\delta(1-\delta)} \tag{23}$$

and the equilibrium measure of Southern production

$$n_S = \frac{\left[M(L_N + \delta L_S) + \rho\delta(L_N + L_S)\right](1-\delta) - a_N(\rho\delta + M)^2}{a_N \rho(M + \rho\delta)(1-\delta)}. \tag{24}$$

We focus on parameter values for which the aggregate rate of innovation is positive $\iota > 0$ and the measure of Southern production is positive and less than one $0 < n_S < 1$. Now we are ready to determine the effects of the imitation intensity M on these endogenous variables.

3. Protection of intellectual property rights

We begin by determining how imitation affects foreign direct investment and innovation. Suppose the imitation intensity M increases due to lack of enforcement of intellectual property rights.

3.1. *Comparative statics results*

To determine the effects of an increase in imitation intensity, differentiate the equilibrium values (derived in the section above) with respect to the imitation intensity M. An increase in imitation intensity leads to a higher aggregate rate of innovation and FDI flow

$$\frac{\partial \iota}{\partial M} = \frac{\partial \phi}{\partial M} = \frac{\iota}{M} + \frac{M}{\rho\delta\left(1-\delta\right)} > 0. \tag{25}$$

and a lower measure of Southern production

$$\frac{\partial n_S}{\partial M} = -\left[\frac{1}{\rho\left(1-\delta\right)} + \frac{L_S\delta\left(1-\delta\right)}{a_N\left(\rho\delta+M\right)^2}\right] < 0. \tag{26}$$

Also, the Northern relative wage increases

$$\frac{\partial w}{\partial M} = \frac{\rho\left(1-\delta\right)}{\delta\left(\rho+M\right)^2} > 0, \tag{27}$$

and aggregate expenditure increases

$$\frac{\partial E}{\partial M} = \frac{a_N}{\delta\left(1-\delta\right)} > 0. \tag{28}$$

Using $n_F = \iota/M$ and $n_N = 1 - n_F - n_S$, the measure of multinational production rises

$$\frac{\partial n_F}{\partial M} = \frac{1}{\rho\delta\left(1-\delta\right)} > 0 \tag{29}$$

and the measure of Northern production falls

$$\frac{\partial n_N}{\partial M} = -\left[\frac{a_N\left(\rho\delta+M\right)^2/\rho\delta - L_S\delta\left(1-\delta\right)}{a_N\left(\rho\delta+M\right)^2}\right] < 0, \tag{30}$$

where $a_N (\rho\delta + M)^2 / \rho\delta > L_S \delta (1 - \delta)$ is ensured by a positive aggregate rate of innovation. From equation (23), $\iota > 0 \rightarrow a_N (\rho\delta + M) > (L_N + L_S \delta)(1 - \delta)$.

Since the aggregate rate of innovation ι rises but the measure of Southern production n_S falls, the innovation intensity ι_N must rise due to $\iota \equiv \iota_N n_S$. Similarly, since FDI flows ϕ rise but the measure of Northern production n_N falls, the FDI intensity ϕ_F must rise due to $\phi \equiv \phi_F n_N$. Any given imitated product is more likely to be targeted for innovation, and any given item produced in the North is more likely to have shifted production to the South through FDI.

3.2. Economic intuition

As expected, increased imitation does reduce the incentive to become a multinational firm by reducing the expected duration of profits. Yet, the above analysis shows that this negative effect is dominated by the increase in aggregate expenditure and the Northern relative wage, both boosting profits, so that, overall, the reward to innovation rises. In particular, the higher relative wage restores the incentive to become a multinational since a larger w implies a larger cost savings from FDI. Both the flow of FDI ϕ and the extent of FDI (the measure of multinational production) n_F rise with an increase in imitation intensity M.

Reduction in the measure of Southern production n_S leads to a higher aggregate price level

$$p = (1 - n_S)\lambda + n_S, \tag{31}$$

since Southern firms charge a lower price $p_S = 1$ than other firms $p_N = p_F = \lambda > 1$. In quality ladder models, multinational firms charge the same price as Northern firms. The shift in production from Northern firms to multinationals does not lower the price level, as it does in variety-based models. Thus, here the higher price level is a force toward reduced overall sales and thus reduced total demand for labor at the world level. With the higher aggregate price level, aggregate expenditure rises to restore the demand for labor at the world level. A higher aggregate expenditure E generates more sales, which increases the demand for Northern and Southern labor for production.

A smaller n_S also increases the demand for Northern labor by increasing the fraction of products being produced in the North by Northern firms n_N, holding all else equal. To restore labor market equilibrium, the aggregate rate of innovation ι increases, which leads to a larger fraction of products being produced by multinational firms $n_F = \iota/M$ (since ι increases by more than M). The rise in multinational production shifts labor demand for production from the North to the South. The increase in n_F is larger than the decrease in n_S, so the measure of Northern production n_N falls, which reduces the demand for Northern labor in production and thus frees the Northern labor needed for the faster aggregate rate of innovation.

We can illustrate our results by substituting the solution for aggregate expenditure E into the Northern and Southern labor constraints (19) and (20)

$$\iota + \left(1 - \frac{\iota}{M} - n_S\right)(\rho\delta + M) = \frac{L_N}{a_N}(1-\delta) \tag{32}$$

$$\left(\frac{\iota}{M} + \frac{n_S}{\delta}\right)(\rho\delta + M) = \frac{L_S}{a_N}(1-\delta) \tag{33}$$

and then totally differentiating the two constraints.

$$\frac{\delta}{M}(\rho + M)d\iota + (\rho\delta + M)dn_S = \left(1 - n_S + \frac{\iota\rho\delta}{M^2}\right)dM \tag{34}$$

$$\frac{\delta}{M}d\iota + dn_S = -\frac{\iota\delta^2\rho/M^2 - n_S}{\rho\delta + M}dM \tag{35}$$

Both labor constraints are *downward sloping*, as shown in Figure 1, with the aggregate rate of innovation ι on the vertical axis and the measure of Southern production n_S on the horizontal axis.

$$\left.\frac{d\iota}{dn_S}\right|_{L_N} = -\frac{M}{\delta}\left(\frac{\rho\delta + M}{\rho + M}\right) < 0, \ \left.\frac{d\iota}{dn_S}\right|_{L_S} = -\frac{M}{\delta} < 0 \tag{36}$$

The equilibrium is of course where the two constraints cross.

FIGURE 1 HERE

The Northern labor constraint is flatter than the Southern labor constraint as $\lambda > 1$ so that $\delta \equiv 1/\lambda < 1$. Two elements contribute to the slope of the Northern labor constraint being flatter. On the one hand, the magnitude of the effect of an increase in n_S on labor demand is smaller in the North because Northern firms make fewer sales than Southern firms due to their higher prices charged. On the other hand, a decrease in ι has the same magnitude effect on labor demand for production in the two countries because multinationals charge the same prices as Northern firms. Hence for a given increase in n_S, a smaller decrease in ι is needed to restore the Northern labor constraint to equality than for the Southern labor constraint.

How does an increase in imitation intensity M shift the equilibrium? The Northern labor constraint shifts to the right. A rise in M reduces the measure of multinational production $n_F = \iota/M$ and increases equilibrium aggregate expenditure (21). Both the reduction in multinational production (by raising the measure of Northern production $n_N = 1 - n_F - n_S$) and the increase in aggregate expenditure raise the demand for labor in production in the North. For a given aggregate rate of innovation ι, the measure of Southern production n_S must *rise* to reduce Northern labor demand and thus sustain the labor market equilibrium in the North. This rise in n_S shifts the Northern labor constraint to the right.

Correspondingly, an increase in M shifts the Southern labor constraint to the left. The increase in aggregate expenditure raises the demand for labor in production in the South, but the reduction in the measure of multinational production reduces the demand for Southern labor. In this case, the production increase through E has a bigger impact on labor demand than the reduction in multinational production n_F as the increase applies to all labor demand, whereas the decrease in n_F is irrelevant for the labor demand by imitators. For a given aggregate rate of innovation ι, the measure of Southern production n_S must fall to reduce Southern labor demand and thus sustain the labor market equilibrium in the South. This reduction in n_S shifts the Southern labor constraint to the left.

The shift of the Northern labor constraint to the right and of the Southern labor constraint to the left implies that the aggregate rate of innovation ι rises while the measure of Southern production n_S falls in the move to the new steady-state equilibrium as shown in Figure 1. The same is also true for the case where $a_F \geq 0$ as derived in Appendix A. In the new steady-state, a higher aggregate rate of innovation and hence more flows of FDI occur with a higher aggregate expenditure and a higher Northern relative wage. We demonstrate that the transitional dynamics move the economy to the steady-state equilibrium in Appendix B.

Proposition 1 *In the presence of FDI, an increase in imitation intensity M increases the aggregate rate of innovation, the flow of FDI (and its extent), the Northern relative wage, and aggregate expenditure but decreases the measure of Southern production and the measure of Northern production.*

4. Product cycles without FDI

Now we turn our attention to product cycles without FDI to see how results depend on the existence of FDI. By comparison to the case without FDI in Lai (1998), we will be able to determine whether the results depend on the type of innovation (quality or variety) in the absence of FDI. And by comparison to Glass and Saggi (2002), we will be able to determine whether the effects of weak IPR protection in the absence of FDI depend on whether imitation is modeled exogenously.[5]

FDI may fail to arise if the costs of becoming a multinational a_F are prohibitively high so that the FDI valuation condition (41) is an inequality: $v_F - v_N < a_F$. The profits of a Northern firm (10) are the same, but now firms producing in the North are exposed to imitation, and they do not choose to shift their production to the South. The value of a Northern firm (the reward to innovation) is now

$$v_N = \frac{\pi_N}{\rho + M}, \tag{37}$$

which leads to a valuation condition for innovation

$$E\left(1 - w\delta\right) = wa_N\left(\rho + M\right). \tag{38}$$

Compared to the previous valuation condition (15), there is an additional term involving the imitation intensity due to the exposure to the risk that the profit stream will be terminated by imitation. When the imitation intensity rises, the reward to innovation falls due to the shorter expected duration of profits. Once again, this profit destruction effect receives primary attention in discussions regarding IPR protection.

The Northern labor constraint (13) remains the same, but using the steady-state condition $\iota = Mn_N$ to replace the measure of Northern production with $n_N = \iota/M$ yields

$$a_N\iota + \left(\frac{\iota}{M}\right)E\delta = L_N. \tag{39}$$

Without any multinational production, the Southern labor constraint simplifies to equating Southern labor demand for production to the Southern labor supply $n_SE = L_S$. Since

[5]Results could differ depending on whether imitation is endogenous – compare Grossman and Helpman (1991b) to Krugman (1979) for example.

$n_S = 1 - n_N = 1 - \iota/M$, the Southern labor constraint becomes

$$\left(1 - \frac{\iota}{M}\right) E = L_S. \tag{40}$$

Examining the two labor constraints, an increase in the imitation intensity M, holding all else fixed, leads to a reallocation of production from the North to the South resulting in a fall in the measure of Northern production $n_N = \iota/M$ and concurrent rise in the measure of Southern production $n_S = 1 - \iota/M$.

Because imitated products are priced less than newly invented products, the expansion in the fraction of goods that have been imitated lowers the aggregate price level as shown in equation (31). A fall in price increases sales and thus the total demand for labor for production in the world. This excess labor demand causes a drop in aggregate expenditure. As sales fall, the Northern relative wage falls so that the costs of Northern production fall and the profit incentive for innovation is preserved. The labor freed from Northern production (when production is shifted to the South) goes into expanding innovation. In the face of shorter duration of profits, the profits at each point in time become larger. In contrast to the case with FDI, here both aggregate expenditure and the Northern relative wage fall (rather than rise). Appendix C provides the derivation of these effects for the case without FDI.

Proposition 2 *In the absence of FDI, an increase in imitation intensity M increases the aggregate rate of innovation and the measure of Southern production but decreases the Northern relative wage, aggregate expenditure and the measure of Northern production.*

5. Discussion

When there is no FDI, an increase in imitation intensity M always leads to faster innovation and a lower Northern relative wage, regardless of the type of innovation. An increase in M shifts production from the North to the South. The reduced demand for labor in

Northern production frees up labor so that innovation rises. Thus our results for the case without FDI are consistent with those in Lai (1998). Results are similar for quality versus variety innovations when there is no FDI.

Yet with FDI, the effects of imitation depend on whether innovations involve the introduction of new varieties or quality improvements. When innovations are quality improvements, we have shown that an increase in imitation intensity increases the aggregate rate of innovation and the Northern relative wage. In contrast, when innovations are new varieties (and there is FDI), Lai (1998) has shown that an increase in imitation intensity decreases the aggregate rate of innovation.

Why doesn't our model with FDI yield results similar to Lai (1998)? Lai explains his result when FDI is present as follows. With FDI, an increase in imitation intensity M shifts production from multinationals to Southern firms. But multinationals are producing in the South. The demand for Southern labor rises because Southern imitators charge a lower price than multinationals and hence make a larger volume of sales. However, there is no corresponding reduction in the demand for Northern labor, as there was in the absence of FDI. As a result of the tighter Southern labor constraint, FDI contracts, which reallocates labor demand from the South back to the North. The increase in labor demand for production in the North (due to the drop in FDI) then causes innovation to fall.

In contrast to variety-based models with FDI, here multinational firms do not drop their prices. In the variety case, firms charge a fixed markup over cost. The increase in multinational profits comes from an increased volume of sales due to the lower price. In the quality case here, firms charge a fixed markup (reflecting the size of the quality increment) over the cost of Southern firms able to produce the lower quality level. The increase in multinational profits comes from a larger markup of price over cost rather than from increased sales. This distinction stems from the difference in the type of innovation:

quality improvement versus new variety. Thus, in our quality ladders model, aggregate expenditure, the Northern relative wage, FDI, and innovation all rise.

The effect of an increase in imitation intensity on the Northern relative wage depends on whether or not there is FDI. Different movements in the relative wage are important because they alter the world distribution of income. When there is FDI, the increase in the relative wage in response to increased imitation leads to a rise in the share of world income that belongs to the North. But without FDI, the same increase in imitation intensity causes the North's share of world income to fall.

The effects of an exogenous increase in the imitation intensity on the Northern relative wage exhibit a clear pattern. With FDI, increases in M lead to increases in w. A higher risk of imitation shortens the expected duration of profits as a multinational compared to a Northern firm. As a result, profits as a multinational must rise relative to profits as a Northern firm to restore balance. An increase in the Northern relative wage achieves the necessary adjustment in relative profits. However, without FDI, increases in M lead to decreases in w. The shorter duration of profits in this case is born by Northern firms. The Northern relative wage falls to lower the costs of Northern production and thus maintain the incentives for Northern firms to innovate.

In Glass and Saggi (2002)'s case without FDI, weaker IPR protection, by making imitation easier, increases imitation, increases the aggregate rate of innovation, but may decrease the Northern relative wage and decreases aggregate expenditure. Glass and Saggi find no effect on the Northern relative wage for the case with FDI because imitation targets both Northern and multinational firms. Two effects are present there but not here where imitation is exogenous. First, a higher w alleviates demand for Southern labor by reducing sales since Southern imitators charge a price equal to w. Second, increases in w increase profits for Southern firms, which helps offset the higher cost of imitation. Here, Southern firms charge a price equal to their cost of one and make zero profit.

The negative effect on the Northern relative wage and the positive effect on innovation are the same here as in Lai (1998) for the case without FDI, despite the difference in the type of innovation considered. Thus, the type of innovation seems to be vital only in the presence of FDI. When there is FDI, the effects of changes in the imitation intensity depend on whether innovations are variety-expanding or quality-enhancing in nature; however, when there is no FDI, the direction of the effects does not depend on the type of innovation.

6. Conclusion

This paper examines the impact of imitation on FDI and innovation. When products are more likely to be imitated when produced through FDI, innovators are more inclined to keep production in the North where they are safer from being imitated. Also, the shorter duration of profits suggests that the incentive to innovate should fall. However, the full story is more complex, as aggregate expenditure and the Northern relative wage rise to restore and even expand the incentives for FDI and innovation. In the end, increased imitation need not reduce FDI or innovation.

In Lai (1998), innovation involves developing new varieties (instead of higher qualities), and an exogenous increase in imitation intensity reduces FDI and innovation. But in Glass and Saggi (2002), innovations are quality improvements and imitation (endogenously modeled through a reduction in the cost of imitation) increases FDI and innovation. Our work demonstrates that the findings of Glass and Saggi (2002), that imitation spurs on FDI and innovation, hold even when imitation is exogenous. Our work therefore sheds light on why the findings of Lai (1998) and Glass and Saggi (2002) differ: it cannot be only due to whether imitation is endogenous. Our model matches Lai's model in all aspects but the type of innovation. We conclude that, in the presence of FDI, the type of innovation influences the effects of imitation on FDI and innovation. *When there is FDI, imitation may encourage quality improvements in existing products, while discouraging the introduction of new varieties.*

A Appendix

This appendix shows the resource constraints are downward sloping, the Northern constraint is flatter, and the movement of the two constraints as M rises for the case where the cost is of becoming a multinational is positive, $a_F \geq 0$. First consider how the key equations need to be modified. The FDI valuation condition becomes

$$v_F - v_N \leq a_F,\ \phi_F > 0 \Longleftrightarrow v_F - v_N = a_F. \tag{41}$$

When successful at becoming a multinational, a firm experiences the capital gain $v_F - v_N \geq 0$, the difference between the value of a multinational and the value of a Northern firm. The FDI valuation condition (41) can be rewritten using $v_N = wa_N$ from the innovation valuation condition (6) as

$$\iota_N > 0,\ \phi_F > 0 \Longrightarrow v_F = a_F + wa_N. \tag{42}$$

A Northern firm successful in innovation earns the reward

$$v_N = \frac{\pi_N + \phi_F(v_F - v_N - a_F)}{\rho}, \tag{43}$$

which still simplifies to $v_N = \pi_N/\rho$ by imposing $v_F - v_N = a_F$ when $\phi_F > 0$. FDI still does not offer excess returns because the degree that the value of a multinational firm exceeds the value of a Northern firm exactly equals the cost of becoming a multinational. In the South, labor demand for FDI efforts is $a_F\phi_F n_N$ so the Southern labor constraint becomes

$$a_F\phi_F n_N + n_F\frac{E}{\lambda} + n_S E = L_S. \tag{44}$$

Finally, when profits are inserted, the FDI valuation condition becomes

$$E(1-\delta) = (a_F + wa_N)(\rho + M). \tag{45}$$

Solving the innovation valuation condition (15) for w gives

$$w = \frac{E}{E\delta + a_N\rho} \rightarrow \frac{w}{E} = \frac{1}{E\delta + a_N\rho}. \tag{46}$$

The innovation valuation condition (15) and the above expression for the relative wage imply

$$E(1-w\delta) = wa_N\rho \rightarrow 1 - w\delta = \frac{w}{E}a_N\rho = \frac{a_N\rho}{E\delta + a_N\rho}. \tag{47}$$

Substituting the expression for the relative wage w (46) into the FDI valuation equation

$$E(1-\delta) = \left(a_F + \frac{E}{E\delta + a_N\rho}a_N\right)(\rho + M), \tag{48}$$

and totally differentiating gives

$$AdE = (a_F + wa_N)\, dM, \tag{49}$$

where

$$\begin{aligned} A &\equiv \frac{(1-\delta)(E\delta + a_N\rho)^2 - a_N^2\rho(\rho + M)}{(E\delta + a_N\rho)^2} \\ &= (1-\delta) - \left(\frac{a_N\rho}{E\delta + a_N\rho}\right)\frac{w}{E}(a_N(\rho + M)) \\ &= \frac{1}{E}\left[E(1-\delta) - (1-w\delta)\, wa_N(\rho + M)\right] > 0. \end{aligned}$$

The main expression (in square brackets) is positive by the FDI valuation condition (45) as $w\delta > 0 \rightarrow 1 - w\delta < 1$ and $a_F \geq 0 \ \rightarrow wa_N \leq wa_N + a_F$. Therefore,

$$\frac{\partial E}{\partial M} = \frac{a_F + wa_N}{A} = \frac{E(a_F + wa_N)}{E(1-\delta) - (1-w\delta)\, wa_N(\rho + M)} \tag{50}$$

$$= \frac{(a_F + wa_N)\, E}{(a_F + w^2a_N\delta)(\rho + M)} > 0 \tag{51}$$

To derive $\partial\iota/\partial M$ and $\partial n_S/\partial M$, examine the slope and the shift of the resource constraints as M increases. Totally differentiating the Northern resource constraint

$$a_N\iota + \left(1 - \frac{\iota}{M} - n_S\right) E\delta = L_N, \tag{52}$$

gives

$$\left(\frac{E\delta}{M} - a_N\right) d\iota + E\delta dn_S = \left(\delta\left(1 - \frac{\iota}{M} - n_S\right)\frac{\partial E}{\partial M} + \frac{\iota}{M^2}E\delta\right) dM \tag{53}$$

Using (45) to substitute out M from the left-hand-side gives

$$\begin{aligned}\frac{E\delta}{M} - a_N &= \frac{(E\delta + a_N\rho)(a_F + wa_N) - a_N E(1-\delta)}{E(1-\delta) - \rho(a_F + a_N w)} \\ &= \frac{(E\delta + a_N\rho)\, a_F + a_N E\delta}{E(1-\delta) - \rho(a_F + a_N w)}\end{aligned} \tag{54}$$

The denominator is positive from condition (45) if FDI exists, and the numerator was rewritten to be clearly positive by substituting in for the relative wage (46). Thus, the Northern resource constraint is downward sloping: an increase in the measure of Southern production n_S requires a reduction in the aggregate rate of innovation ι.

$$\frac{\partial\iota}{\partial n_S} = -\frac{E\delta}{\frac{E\delta}{M} - a_N} < 0 \tag{55}$$

As $n_N = 1 - \frac{\iota}{M} - n_S > 0$, an increase in the imitation intensity M shifts the Northern resource constraint up: more innovation ι is possible for any given n_S.

Totally differentiating the Southern resource constraint

$$a_F\iota + \frac{\iota}{M}E\delta + n_S E = L_S. \tag{56}$$

gives

$$\left(a_F + \frac{1}{M}\delta E\right) d\iota + E dn_S = -\frac{\iota}{M}\left(\left[\delta + \frac{M}{\iota}n_S\right]\frac{\partial E}{\partial M} - \frac{\delta E}{M}\right) dM \tag{57}$$

The Southern resource constraint is also downward sloping: an increase in the measure of Southern production n_S requires a reduction in the aggregate rate of innovation ι.

$$\frac{\partial \iota}{\partial n_S} = -\frac{E}{a_F + \frac{1}{M}\delta E} < 0 \tag{58}$$

The Northern resource constraint is less steeply downward sloping than the Southern resource constraint as the absolute value of their relative slopes is

$$\frac{\left[a_F + \frac{1}{M}\delta E\right]\delta}{\frac{E\delta}{M} - a_N} = 1 - \frac{\rho\left[E\delta\left(a_N^2 + a_F\left(2a_N + \delta\right)\right) + \rho a_F a_N\left(a_N + a_F\delta\right)\right]}{\left(E\delta + \rho a_N\right)\left[E\delta\left(a_N + a_F\right) + \rho a_F a_N\right]} < 1 \tag{59}$$

The right-hand-side of equation (57) is negative if ρ is near zero as

$$\lim_{\rho\to 0}\frac{\partial E}{\partial M} > \frac{E}{M} > \frac{E}{M + \frac{M}{\delta}\frac{M}{\iota}n_S}. \tag{60}$$

So provided ρ is close enough to zero, an increase in the imitation intensity M shifts the Southern resource constraint down: less innovation ι is possible for any given n_S.

B Appendix

Davidson and Segerstrom (1998) and Cheng and Tao (1999) have expressed concerns about the stability of single country quality ladders models with innovation and imitation such as Segerstrom (1991). They observe that when a R&D subsidy (to innovation or imitation) creates excess returns to R&D and firms respond by increasing their R&D intensities, the economy does not move to the new steady-state equilibrium. Cheng and Tao link this trouble to the trait that determination of the innovation and imitation intensities is backward in Segerstrom's model: the valuation (zero-profit) condition for innovation determines the imitation intensity, and the valuation condition for imitation determines the innovation intensity. This property arises because innovation terminates the profits of an imitator, and imitation reduces the profits of an innovator.

Our model is free from such shortcomings. Why is our model different? The value of a multinational does depend on the imitation intensity, but the imitation intensity is exogenous and thus is not determined by the valuation condition for FDI. Because the imitation intensity is exogenous, the value of an imitation is always zero and thus does not depend on the innovation intensity. FDI yields no excess returns (the value of a multinational is the same as that of a Northern firm in equilibrium), so the value of an innovation does not depend on the FDI intensity. Hence, there is no backward determination of the R&D intensities here.

To see what does happen, start from an initial steady state with both innovation and FDI so that successful innovators are indifferent between continuing to produce in the North and shifting production to the South through FDI. Now have the imitation intensity rise, but briefly hold everything else fixed at the aggregate level. Due to the higher imitation intensity, the value as a multinational falls, making firms no longer indifferent about FDI. But firm are free to keep producing in the North, and FDI was not generating any excess returns, so the value of these firms is unaffected. In the next instant, aggregate expenditure E and the relative wage w immediately rise to the new steady-state levels (21) and (22). Their immediate adjustment ensures that the returns to innovation and FDI are never excess (or lacking).

Transitional dynamics arise through adjustment in the market measures, which must obey $\dot{n}_F = \phi_F n_N - M n_F$ and $\dot{n}_S = M n_F - \iota_N n_S$. The innovation and FDI intensities ι_N and ϕ_F rise immediately and sufficiently to ensure $\dot{n}_F > 0$ and $\dot{n}_S < 0$, as required to reach the new steady-state equilibrium. As the measure of multinational production n_F rises and the measure of Southern production n_S falls, the magnitude of the adjustments in the market measures shrinks to become $\dot{n}_F = \dot{n}_S = 0$ in the steady-state. Hence, the steady-state equilibrium is stable.

C Appendix

Here we derive the effects in the absence of FDI. Totally differentiating the system of three equations (Southern labor constraint, innovation valuation condition, and Northern labor constraint) with respect to the imitation intensity yields

$$\begin{bmatrix} M-\iota & -E & 0 \\ 1-w\delta & 0 & -E\delta - a(\rho+M) \\ \iota\delta & E\delta + aM & 0 \end{bmatrix} \begin{bmatrix} \partial E \\ \partial \iota \\ \partial w \end{bmatrix} = \begin{bmatrix} (L_S - E)\,\partial M \\ aw\partial M \\ (L_N - a\iota)\,\partial M \end{bmatrix}. \tag{61}$$

Noting $M > \iota$ as $Mn_N = \iota$ so $M = \iota/n_N > \iota$ as $n_N < 1$, an increase in the imitation intensity increases the aggregate rate of innovation and decreases aggregate expenditure and the Northern relative wage.

$$\frac{\partial E}{\partial M} = -\frac{wa\iota\,(\rho+M)}{M\,[M-\iota+w\delta\,(\rho+\iota)]} < 0 \tag{62}$$

$$\frac{\partial \iota}{\partial M} = \frac{w\delta\iota\,(\rho+M)}{M\,[M-\iota+w\delta\,(\rho+\iota)]} > 0 \tag{63}$$

$$\frac{\partial w}{\partial M} = -\frac{w\,(1-w\delta)\,[\iota\rho\,(1-w\delta)+M\,(M+w\delta\rho)]}{M\,(\rho+M)\,[M-\iota+w\delta\,(\rho+\iota)]} < 0 \tag{64}$$

Using $n_N = \iota/M$ and $n_S = 1 - n_N$, the measure of Northern production falls while the measure of Southern production rises.

$$\frac{\partial n_N}{\partial M} = -\frac{1}{M}\left(\frac{\iota}{M} - \frac{\partial \iota}{\partial M}\right) < 0,\ \frac{\partial n_S}{\partial M} > 0 \tag{65}$$

since

$$\frac{\partial \iota}{\partial M} = \frac{\iota}{M}\left[\frac{w\delta\,(\rho+M)}{M-\iota+w\delta\,(\rho+\iota)}\right] < \frac{\iota}{M} \tag{66}$$

as $1-w\delta > 0 \rightarrow w\delta < 1 \rightarrow w\delta\,(M-\iota) < M-\iota \rightarrow w\delta M < M-\iota+w\delta\iota \rightarrow w\delta\,(\rho+M) < M-\iota+w\delta\,(\rho+\iota)$.

References

Cheng, L.K. and Z. Tao, 1999, The impact of public policies on innovation and imitation: The role of R&D technology in growth models. International Economic Review 40, 187-207.

Davidson, C. and P. Segerstrom, 1998, R&D subsidies and economic growth. RAND Journal of Economics 29, 548-577.

Glass, A.J. and K. Saggi, 2002, Intellectual property rights and foreign direct investment, Journal of International Economics 56, 387-410.

Grossman, G.M. and E. Helpman, 1991a, Quality ladders and product cycles, Quarterly Journal of Economics 106, 557-586.

Grossman, G.M. and E. Helpman, 1991b, Endogenous product cycles, Economic Journal 101, 1214-1229.

Helpman, E., 1993, Innovation, imitation, and intellectual property rights, Econometrica 61, 1247-1280.

Krugman, P.R., 1979, A model of innovation, technology transfer, and the world distribution of income, Journal of Political Economy 87, 253-266.

Lai, E.L.C., 1998, International intellectual property rights protection and the rate of product innovation, Journal of Development Economics 55, 133-153.

Markusen, J.R., 1995, The boundaries of multinational enterprises and the theory of international trade, Journal of Economic Perspectives 9, 169-190.

Maskus, K.E., 2000, Intellectual property rights in the global economy (Institute for International Economics, Washington DC).

McCalman, P., 2002, Reaping what you sow: An empirical analysis of international patent harmonization, Journal of International Economics 55, 161-186.

Segerstrom, P.S., 1991, Innovation, imitation, and economic growth, Journal of Political Economy 99, 807-827.

Segerstrom, P.S., T.C.A. Anant, and E. Dinopoulos, 1990, A Schumpeterian model of the product life cycle, American Economic Review 80, 1077-1091.

Taylor, M.S., 1994, TRIPS, trade and growth, International Economic Review 35, 361-381.

Yang, G. and K.E. Maskus, 2001, Intellectual property rights, licensing, and innovation in an endogenous product-cycle model, Journal of International Economics 53, 169-187.