

Intellectual property rights and quality improvement

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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 can increase FDI and innovation for quality improvements, whereas the opposite occurs when innovators develop new varieties. Hence, stronger IPR protection, by reducing imitation, may shift innovation away from improvements in existing products toward development of new products.

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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

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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 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 can depend on the nature of

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.

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.

innovation. When innovations are new varieties, stronger Southern IPR protection encourages FDI and innovation, but when innovations are higher quality levels, FDI and innovation can 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 also check our results for robustness to allowing innovation to be done by followers (firms other than the former incumbents). 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 for variety innovations (or quality innovations by followers) 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

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

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

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

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

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

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

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

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 $\tilde{m}(j, t)$ 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 $x_{im}(j, t) = E_i(t) / p_m(j, t)$ units of quality level $\tilde{m}(j, t)$ 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 $\log p_{\tilde{m}}(j, t) = \log p_{\tilde{m}}(j)$. 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 i_N for a time interval dt experiences success with probability $i_N dt$ but requires $a_N i_N dt$ units of labor at cost $w_N a_N i_N dt$. 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 i_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 $w_N a_N i_N dt$ and gains an expected reward $v_N i_N dt$. Each firm chooses its innovation intensity i_N to maximize its expected gain from innovation

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

where v_N denotes the reward to successful innovation, the value of a Northern firm once successful in innovation. The term $e^{-i_N t}$ captures the probability that no other firm will have succeeded in innovation in the same industry prior to time t and i_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: $\max_{i_N \geq 0} (v_N - w_N a_N) i_N$.

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

$$v_N \leq w_N a_N, \quad i_N > 0 \iff v_N = w_N a_N. \tag{6}$$

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 $\phi_F > 0$:

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

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. Note that E is aggregate expenditure, so firms are selling to both countries regardless of where production occurs.

2.4. Labor constraints

Let n_N denote the measure of Northern production, which is the fraction of all products that are produced in the North by Northern firms. Similarly, let n_F be the measure of multinational production (the fraction of all products that are produced in the South by multinational firms) and n_S the measure of Southern production (the fraction of all products that are produced in the South by Southern firms). 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 $a_N t_N n_S$ and for production is $n_N E/\lambda$.

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

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 with both innovation and FDI. The case without FDI is addressed in Section 4. If both innovation and multinational production occur, our model is a system of four equations. First, substituting profits (10) and values (8) into Eq. (6) gives the innovation valuation condition

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

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

$$t_N > 0, \phi_F > 0 \Rightarrow v_F = w a_N. \tag{16}$$

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

$$E(1 - \delta) = wa_N(\rho + M). \quad (17)$$

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

This system is stated in terms of four endogenous variables: the innovation intensity t_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 $\iota \equiv t_N n_S$ 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 $M n_F = \iota n_S$. 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, $t_N = \iota / n_S$, $\phi = \iota$, $n_F = \iota / M$ 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

$$a_N \iota + \left(1 - \frac{\iota}{M} - n_S\right) E \delta = L_N, \quad (18)$$

and to rewrite the Southern labor constraint (14) gives

$$\frac{\iota}{M} E \delta + n_S E = L_S. \quad (19)$$

The valuation conditions (15) and (17), along with these labor constraints (18) and (19), 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,

$$E = a_N \frac{\rho \delta + M}{\delta(a - \delta)}, \quad (20)$$

and the equilibrium Northern relative wage,

$$w = \frac{\rho \delta + M}{\delta(\rho + M)}, \quad (21)$$

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

Substituting these two equations into the labor constraints (18) and (19) gives the equilibrium aggregate rate of innovation,

$$i = \frac{M[a_N(\rho\delta + M) - (1 - \delta)(L_N + \delta L_S)]}{a_N\rho\delta(1 - \delta)}, \quad (22)$$

and the equilibrium measure of Southern production,

$$n_S = \frac{[M(L_N + \delta L_S) + \rho\delta(L_N + L_S)](1 - \delta) - a_N(\rho\delta + M)^2}{a_N\rho(M + \rho\delta)(1 - \delta)}. \quad (23)$$

We focus on parameter values for which the aggregate rate of innovation is positive $i > 0$ 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.

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

$$\frac{\partial i}{\partial M} = \frac{\partial \phi}{\partial M} = \frac{i}{M} + \frac{M}{\rho\delta(1 - \delta)} > 0, \quad (24)$$

and a lower measure of Southern production

$$\frac{\partial n_S}{\partial M} = - \left[\frac{1}{\rho(1 - \delta)} + \frac{L_S\delta(1 - \delta)}{a_N(\rho\delta + M)^2} \right] < 0. \quad (25)$$

Also, the Northern relative wage increases

$$\frac{\partial w}{\partial M} = \frac{\rho(1 - \delta)}{\delta(\rho + M)^2} > 0, \quad (26)$$

and aggregate expenditure increases

$$\frac{\partial E}{\partial M} = \frac{a_N}{\delta(1 - \delta)} > 0. \quad (27)$$

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

$$\frac{\partial n_F}{\partial M} = \frac{1}{\rho\delta(1 - \delta)} > 0, \quad (28)$$

and the measure of Northern production falls

$$\frac{\partial n_N}{\partial M} = - \left[\frac{a_N(\rho\delta + M)^2/\rho\delta - L_S\delta(1 - \delta)}{a_N(\rho\delta + M)^2} \right] < 0, \quad (29)$$

where $a_N(\rho\delta + M)^2/\rho\delta > L_S\delta(1 - \delta)$ is ensured by a positive aggregate rate of innovation. From Eq. (22), $\iota > 0 \rightarrow a_N(\rho\delta + M) > (L_N + L_S\delta)(1 - \delta)$.

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.

As expected, increased imitation does reduce the incentive to become a multinational firm by reducing the expected duration of profits. Yet, this negative effect is dominated by a higher relative wage restoring 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 .

Using Eqs. (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.

$$\frac{\pi_F}{\pi_N} = \frac{\lambda - 1}{\lambda - w} = 1 + \frac{M}{\rho} > 1. \quad (30)$$

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 (30) suggests that such an adjustment occurs 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.

An increase in aggregate expenditure restores the reward to innovation—to compensate for the increased cost due to the increased Northern relative wage. The higher level of aggregate expenditure increases 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.

To offset the increased sales due to higher aggregate expenditure, reduction in the measure of Southern production n_S leads to a higher aggregate price level

$$p = (1 - n_S)\lambda + n_S, \quad (31)$$

since Southern firms charge a lower price $p_S = 1$ than other firms $p_N = p_F = \lambda > 1$. The higher price level is a force toward reduced overall sales and thus reduced total demand for labor at the world level.

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. 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 here, as it does in variety-based models. 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.

The overall effect of increased imitation can be broken into two separate effects. The FDI disincentive effect arises purely from the increased imitation intensity decreasing the incentive for FDI, based on the FDI valuation condition (17). We totally differentiate the system with respect to the imitation intensity M in the FDI valuation condition, holding the M in the two labor constraints constant—see Appendix A.1. The FDI disincentive effect increases the Northern relative wage w to restore the reward to FDI. Due to the higher w , aggregate expenditure must rise to restore the reward to innovation. Then, the measure of Southern production n_S falls and the rate of innovation ι rises to reduce overall labor demand and shift labor demand from the North to the South, as previously described.

The labor demand adjustment effect arises purely from increasing the imitation intensity M in the two labor constraints, holding M in the FDI valuation condition constant. In the Northern labor constraint, increasing M causes the measure of multinational production n_F to fall and the measure of Northern production n_N to rise so that the labor constraint tightens in the North. In the Southern labor constraint, increasing M causes the measure of multinational production n_F to fall so that the labor constraint loosens in the South. Adjustments are needed to shift some labor demand to the South. Therefore, the measure of Southern production n_S falls, n_F rises, and n_N falls. The shift from production by Southern firms to production by multinationals reduces demand for Southern labor by increasing the price level. The shift from production by Northern firms to production by multinationals shifts labor demand from the North to the South, allowing the rate of innovation ι to rise.

Adding the FDI disincentive effect and the labor demand adjustment effect together yields the overall effect of increased imitation: faster innovation, higher Northern relative wage and aggregate expenditure, and less Southern production (along with more multinational production and less Northern production). The effects on E and w stem purely from the FDI disincentive effect. The adjustment of n_S and ι depend crucially on how to reduce labor demand: n_S falls and n_F rises when Southern labor demand needs to fall, n_N falls and n_F rises when Northern labor demand needs to fall.

We can illustrate our results by substituting the solution for aggregate expenditure E into the Northern and Southern labor constraints (18) and (19)

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

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

and then totally differentiating the two constraints.

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

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

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

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

The equilibrium is where the two constraints cross and is unique.

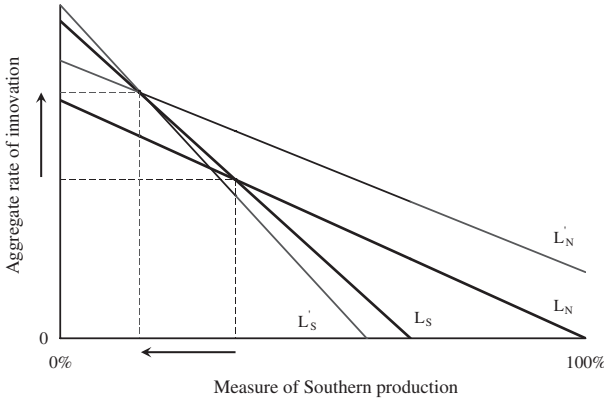


Fig. 1. Increased imitation.

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? Following the increase in M , the Northern labor constraint lies to the right (higher n_S) of the Southern labor constraint at the original equilibrium value of ι :

$$\left. \frac{dn_S}{dM} \right|_{L_N} - \left. \frac{dn_S}{dM} \right|_{L_S} = \frac{1}{\rho\delta + M} \left(1 + \rho\delta(1 + \delta) \frac{\iota}{M^2} \right) > 0. \tag{37}$$

Therefore, 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 Fig. 1. The same is also true for the case where there are costs of becoming a multinational (details available from the authors). 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 steady-state equilibrium is stable in Appendix A.2.

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 (7) 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

$$v_N = \frac{\pi_N}{\rho + M}, \quad (38)$$

which leads to a valuation condition for innovation

$$E(1 - w\delta) = wa_N(\rho + M). \quad (39)$$

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 $l = Mn_N$ to replace the measure of Northern production with $n_N = l/M$ yields

$$a_{Nl} + \left(\frac{l}{M}\right)E\delta = L_N. \quad (40)$$

Without any multinational production, the Southern labor constraint simplifies to equating Southern labor demand for production to the Southern labor supply $n_S E = L_S$. Since $n_S = 1 - n_N = 1 - l/M$, the Southern labor constraint becomes

$$\left(1 - \frac{l}{M}\right)E = L_S. \quad (41)$$

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 $n_N = l/M$ and concurrent rise in the measure of Southern production $n_S = 1 - l/M$.

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 Eq. (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 A.3 provides the derivation of these effects for the case without FDI.

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

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. Innovation by followers

Is the main result that an increase in the imitation intensity causes an increase in the rate of innovation robust to allowing innovation to target Northern and multinational production? This version of the model breaks the direct link between the rates of innovation and imitation: imitation is no longer required for subsequent innovation to occur. To ensure that innovation targets all types of markets, no matter where production occurs, assume that followers are no less efficient at innovation than leaders, firms who made the most recent improvement for a product.

Unlike Grossman and Helpman (1991a), we do not allow for a separate innovation intensity for leaders and followers: here, all products are targeted by innovation to the same degree.⁶ The rate of innovation and the innovation intensity are now the same since innovation targets all products. We assume that when followers successfully innovate a product still being produced in the North, knowledge of the older technology becomes available to the South. Thus, all successful innovators face competition from Southern firms producing one quality level lower. This access to discarded technology ensures that all innovations yield the same reward—otherwise, followers would only target Northern producers. As a result, leaders still innovate once their product has been imitated; followers target all products.

5.1. Efficient followers with FDI

Several changes arise in the key equations. First, the innovation intensity enters into the effective discount rate of Northern and multinational firms since their products are now targeted for innovation. The Northern valuation condition becomes

$$E(1 - w\delta) = wa_N(\rho + \iota_N), \quad (42)$$

and the multinational valuation condition becomes

$$\frac{E(1 - \delta)}{\rho + \iota_N + M} = \frac{E(1 - w\delta)}{\rho + \iota_N}. \quad (43)$$

Second, labor demand for innovation is just $a_N \iota_N$ (since the rate of innovation and innovation intensity are the same now) so the Northern resource constraint becomes

$$a_N \iota_N + n_N E\delta = L_N. \quad (44)$$

Also, in the flow conditions for a steady-state equilibrium, the flows out of multinational production now include innovation so $\phi_F n_N = (M + \iota_N) n_F$.

Applying $n_F = 1 - n_N - n_S$, the steady-state conditions $\iota_N(1 - n_N) = \phi_F n_N$ and $M n_F = \iota_N n_S$ are solved for ϕ_F and $n_N = 1 - n_S - \iota_N n_S / M$, which implies $n_F = \iota_N n_S / M$. The remaining four equations (two labor constraints and valuation conditions for Northern firms and multinationals) are totally

⁶ If FDI were simply added to their model, only Northern firms with Southern rivals would engage in FDI (the gain in value is greater due to lower price). As a result, markets would eventually all become Northern firms with Northern rivals and there would be no steady state.

differentiated with respect to the rate of innovation i_N , the measure of Southern production n_S , aggregate expenditure E and the Northern relative wage w . The derivatives are reported in Appendix A.4 taking the limit as ρ goes to zero to simplify the expressions.

Proposition 3. *When followers conduct innovation so that innovation targets all markets in the presence of FDI, an increase in imitation intensity M can decrease the aggregate rate of innovation and the measure of multinational production (the extent of FDI), but increases aggregate expenditure, the Northern relative wage and the measure of Northern production.*

5.2. Efficient followers without FDI

For the case without FDI, the Northern valuation condition

$$E(1 - w\delta) = wa_N(\rho + M + i_N), \quad (45)$$

reflects the risk that the profit stream will be terminated through either imitation or further innovation. The Southern labor remains simply $n_S E = L_S$, as in the base case without FDI. The Northern resource constraint is the same as for innovation by followers with FDI

$$a_N i_N + n_N E \delta = L_N. \quad (46)$$

Noting $n_S = 1 - n_N$, the steady-state condition $i_N n_S = M n_N$ is solved for $n_N = i_N / (i_N + M)$. The three main equations (two labor constraints and innovation valuation condition) are solved for the rate of innovation

$$i_N = \frac{M L_N}{\delta L_S + M a_N}, \quad (47)$$

aggregate expenditure

$$E = L_S \left(1 + \frac{L_N}{\delta L_S + M a_N} \right), \quad (48)$$

and the Northern relative wage

$$w = \frac{L_S (L_N + \delta L_S + M a_N)}{(\delta L_S + M a_N) (L_N + \delta L_S + M a_N + \rho a_N)}. \quad (49)$$

Differentiating each expression with respect to the imitation intensity yields that an increase in the imitation intensity increases the rate of innovation

$$\frac{\partial i_N}{\partial M} = \frac{\delta L_N L_S}{(\delta L_S + M a_N)^2} > 0, \quad (50)$$

decreases aggregate expenditure

$$\frac{\partial E}{\partial M} = -\frac{a_N L_N L_S}{(\delta L_S + M a_N)^2} < 0, \quad (51)$$

and decreases the Northern relative wage

$$\frac{\partial w}{\partial M} = -\frac{a_N L_S [(\delta L_S + M a_N)^2 + L_N (L_N + 2\delta L_S + 2M a_N + \rho a_N)]}{(\delta L_S + M a_N)^2 (L_N + \delta L_S + M a_N + \rho a_N)^2} < 0. \quad (52)$$

The effects of an increase in the imitation intensity on the measures of Northern and Southern production are calculated using $n_N = t_N / (t_N + M)$ and $n_S = 1 - n_N$. An increase in the imitation intensity decreases the measure of Northern production and increases the measure of Southern production

$$\frac{\partial n_N}{\partial M} = -\frac{a_N L_N}{(L_N + \delta L_S + M a_N)^2} < 0, \quad \frac{\partial n_S}{\partial M} = -\frac{\partial n_N}{\partial M} > 0. \quad (53)$$

Define the aggregate rate of imitation as $\Upsilon \equiv M n_N$. Increased intensity of imitation increases the rate of imitation

$$\frac{\partial \Upsilon}{\partial M} = \frac{L_N (L_N + \delta L_S)}{(L_N + \delta L_S + M a_N)^2} > 0. \quad (54)$$

Thus, the effects of an increase in imitation intensity need not be altered by allowing innovation by followers, provided followers are as efficient as leaders in conducting innovation.

Proposition 4. *When followers conduct innovation in the absence of FDI, an increase in imitation intensity M increases the aggregate rate of innovation, the aggregate rate of imitation and the measure of Southern production, but decreases the Northern relative wage, aggregate expenditure and the measure of Northern production.*

6. 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 (except possibly if followers innovate). 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.⁷ Thus, in our quality ladders model, aggregate expenditure, the Northern relative wage, FDI and innovation all rise.

In Glass and Saggi's (2002) case without FDI, weaker IPR protection, by making imitation easier, increases imitation, increases the aggregate rate of innovation, but decreases aggregate expenditure and may decrease the Northern relative wage. 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.

Why does introducing innovation by followers switch the results of the effect of increased imitation intensity on the rate of innovation, only in the presence of FDI? Start with the simplest model: followers inefficient and no FDI. Here production of a product occurs in the North following innovation or in the South following imitation. Increased imitation causes the product cycle to go around faster. Imitation is crucial for spurring on innovation because innovation is done only by Northern firms (former incumbents) once imitation has terminated their profit stream. With FDI and inefficient followers, following innovation, some production is shifted to the South by multinationals, and then imitation occurs. Again increased imitation causes this three-stage cycle to go around faster.

With efficient followers and no FDI, a new cycle is added from production in the North back to production in the North after innovation by followers. When imitation increases, both cycles go around faster, since followers are as efficient as leaders so the innovation intensity of leaders and followers is the same. However, with efficient followers and FDI, a third cycle forms from production by multinationals back to production in the North after innovation by followers. This cycle reallocates production between the South and the North, which has important consequences for the availability of labor for innovation in the North.

With efficient followers, adding FDI need not always reverse the effects of increased imitation. If followers were less efficient than leaders, increased imitation could decrease innovation, even without FDI. Increased innovation by less efficient followers could leave less labor available for innovation and thus cause the rate of innovation to fall. In Grossman and Helpman (1991a), the imitation intensity for leaders and followers differs due to their differing efficiency. According to their results, taxing imitation or reducing the Southern labor supply (the two aspects of increased imitation cost) reduce the rate of imitation and thus the rate of innovation by leaders. However, the rate of innovation by followers increases, leaving the aggregate rate of innovation virtually unchanged (effects proportional to ρ).

⁷ If our model allowed for greater substitutability among products, perhaps this difference would be reduced or eliminated.

Table 1
Effects of an exogenous increase in imitation intensity

	Inefficient followers		Efficient followers	
	FDI	No FDI	FDI	No FDI
i	+	+	–	+
w	+	–	+	–
E	+	–	+	–
n_S	–	+	+	+
n_F	+	NA	–	NA
n_N	–	–	+	–

It is also conceivable that models of FDI with efficient followers may exist for which imitation still spurs innovation since there are competing effects. Glass and Saggi (2002) find that increasing the cost of innovation deters innovation when followers are efficient, whether or not there is FDI—details are available from the authors. When imitation is endogenous, there are added effects that operate through the incentive to imitate. So whether imitation is modeled as increasing exogenously or endogenously through reduced cost can affect results when followers are efficient and there is FDI.

Finally, 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. Table 1 summarizes our results.

7. 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, can 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.

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Appendix A

A.1. FDI disincentive and labor demand adjustment effects

Totally differentiating the system of four equations (innovation valuation condition, FDI valuation condition, Southern labor constraint and Northern labor constraint)

$$\begin{aligned}
 E(1 - w\delta) &= wa_N\rho \\
 (1 - \delta)\rho &= (1 - w\delta)(\rho + M) \\
 \left(\frac{i\delta}{M} + n_S\right)E &= L_S \\
 a_N i + \left(1 - n_S - \frac{i_S}{M}\right)E\delta &= L_N
 \end{aligned} \tag{55}$$

with respect to the imitation intensity yields

$$\begin{bmatrix} 0 & 0 & -E\delta - \rho a_N & 1 - w\delta \\ 0 & 0 & \delta(\rho + M_1) & 0 \\ EM_2 & E\delta & 0 & \delta i + n_S M_2 \\ -E\delta M_2 & a_N M_2 - \delta E & 0 & \delta((1 - n_S)M_2 - i) \end{bmatrix} \begin{bmatrix} \partial n_S \\ \partial i \\ \partial w \\ \partial E \end{bmatrix} = \begin{bmatrix} 0 \\ c_2 \partial M_1 \\ c_3 \partial M_2 \\ c_4 \partial M_2 \end{bmatrix}, \tag{56}$$

where $c_2 = 1 - w\delta$, $c_3 = L_N - a_N i - E\delta(1 - n_S)$ and $c_4 = L_S - En_S$.

The FDI disincentive effect increases the rate of innovation

$$\frac{\partial i}{\partial M_1} = \frac{i(1 - \delta) + M}{\rho\delta(1 - \delta)} > 0, \tag{57}$$

increases aggregate expenditure

$$\frac{\partial E}{\partial M_1} = \frac{a_N}{\delta(1 - \delta)} > 0, \tag{58}$$

and increases the Northern relative wage

$$\frac{\partial w}{\partial M_1} = \frac{\rho(1 - \delta)}{\delta(\rho + M)^2} > 0. \quad (59)$$

The measure of Southern production rises or falls

$$\frac{\partial n_S}{\partial M_1} = \frac{-(\iota - \rho n_S)(1 - \delta) + M + \rho\delta}{\rho(1 - \delta)(\rho\delta + M)}. \quad (60)$$

The labor demand adjustment effect increases the rate of innovation

$$\frac{\partial \iota}{\partial M_2} = \frac{\iota(\rho\delta + M)}{\rho M \delta} > 0, \quad (61)$$

and leaves aggregate expenditure and the Northern relative wage unchanged

$$\frac{\partial E}{\partial M_2} = \frac{\partial w}{\partial M_2} = 0. \quad (62)$$

The measure of Southern production falls

$$\frac{\partial n_S}{\partial M_2} = \frac{-\iota}{\rho M} < 0. \quad (63)$$

A.2. Stability

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.

Why is our model free from such shortcomings? 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. Due to the higher imitation intensity, the value as a multinational briefly falls, making firms no longer indifferent about FDI. In the next instant, aggregate expenditure E and the relative wage w immediately rise to the new steady-state levels (20) and (21). Their

immediate adjustment ensures that the returns to innovation and FDI are never excess (or lacking).⁸

Transitional dynamics arise through adjustment in the market measures, which 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 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.

A.3. No FDI

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

$$\begin{aligned} E(1 - w\delta) &= wa_N(\rho + M) \\ \left(1 - \frac{\iota}{M}\right)E &= L_S \\ a_N \iota + \left(\frac{\iota}{M}\right)E\delta &= L_N \end{aligned} \quad , \tag{64}$$

with respect to the imitation intensity yields

$$\begin{bmatrix} 1 - w\delta & 0 & -E\delta - a(\rho + M) \\ M - \iota & -E & 0 \\ \iota\delta & E\delta + aM & 0 \end{bmatrix} \begin{bmatrix} \partial E \\ \partial \iota \\ \partial w \end{bmatrix} = \begin{bmatrix} aw\delta M \\ (L_S - E)\partial M \\ (L_N - a\iota)\partial M \end{bmatrix}. \tag{65}$$

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.

$$\frac{\partial E}{\partial M} = -\frac{wai(\rho + M)}{M[M - \iota + w\delta(\rho + \iota)]} < 0, \tag{66}$$

$$\frac{\partial \iota}{\partial M} = \frac{w\delta \iota(\rho + M)}{M[M - \iota + w\delta(\rho + \iota)]} > 0, \tag{67}$$

$$\frac{\partial w}{\partial M} = -\frac{w(1 - w\delta)[\iota\rho(1 - w\delta) + M(M + w\delta\rho)]}{M(\rho + M)[M - \iota + \delta(\rho + \iota)]} < 0. \tag{68}$$

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

$$\frac{\partial n_N}{\partial M} = -\frac{1}{M} \left(\frac{\iota}{M} - \frac{\partial \iota}{\partial M} \right) < 0, \quad \frac{\partial n_S}{\partial M} > 0, \tag{69}$$

⁸ Ad hoc stability similar to Cheng and Tao (1999) or Davidson and Segerstrom (1998) is not possible here because neither labor constraint depends on w . Sener (2004) finds that IPR protection discourages innovation even when scale effects are removed from R&D.

since

$$\frac{\partial i}{\partial M} = \frac{i}{M} \left[\frac{w\delta(\rho + M)}{M - i + w\delta(\rho + i)} \right] < \frac{i}{M}, \tag{70}$$

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

A.4. Efficient followers, FDI

Totally differentiating the system of four equations (innovation valuation condition, FDI valuation condition, Southern labor constraint and Northern labor constraint)

$$\begin{aligned} E(1 - w\delta) &= wa_N(\rho + i) \\ (1 - \delta)(\rho + i) &= (1 - w\delta)(\rho + i + M) \\ \frac{in_S}{M} E\delta + n_S E &= L_S \\ a_N + \left(1 - n_S - \frac{in_S}{M}\right) E\delta &= L_N \end{aligned} \tag{71}$$

with respect to the imitation intensity yields

$$\begin{bmatrix} 0 & -wa_N & b_{13} & 1 - w\delta \\ 0 & \delta(w - 1) & b_{23} & 0 \\ E\left(1 + \frac{\delta i}{M}\right) & \frac{\delta En_S}{M} & 0 & n_S\left(1 + \frac{\delta i}{M}\right) \\ -E\delta\left(1 + \frac{i}{M}\right) & a_N - \frac{\delta En_S}{M} & 0 & \delta\left(1 - n_S - \frac{in_S}{M}\right) \end{bmatrix} \begin{bmatrix} \partial n_S \\ \partial i \\ \partial w \\ \partial E \end{bmatrix} = \begin{bmatrix} 0 \\ c_2 \partial M \\ c_3 \partial M \\ c_4 \partial M \end{bmatrix}, \tag{72}$$

where $b_{13} = -E\delta - a_N(\rho + i)$, $b_{23} = \delta(\rho + i + M)$, $c_2 = 1 - w\delta$, $c_3 = in_S E\delta / M_2$ and $c_4 = -in_S E\delta / M^2$.

Define $D \equiv L_N(M + \delta I_N)^2 + \delta^2 L_S(M + I_N)^2$. An increase in the imitation intensity M decreases the rate of innovation

$$\frac{\partial i}{\partial M} = -\frac{L_N(M + \delta I_N)^2 + \delta L_S(M + I_N)^2}{D} < 0, \tag{73}$$

increases aggregate expenditure

$$\frac{\partial E}{\partial M} = \frac{L_N(1 - \delta)(M + \delta I_N)[L_N(M + \delta I_N) + \delta L_S(M + I_N)]}{\delta(M + I_N)D} > 0, \tag{74}$$

and increases the Northern relative wage

$$\frac{\partial w}{\partial M} = \frac{(1 - \delta)(M + \delta I_N)[L_N(M + \delta I_N) + \delta L_S(M + I_N)]}{\delta(M + I_N)D} = \frac{1}{L_N} \frac{\partial E}{\partial M} > 0. \tag{75}$$

The measure of Northern production rises

$$\frac{\partial n_N}{\partial M} = \frac{\delta L_S(1 - \delta)(M + \delta I_N)^2 [2L_N(M + \delta I_N) + \delta L_S(M + I_N)]}{(M + \delta I_N)[L_N(M + \delta I_N) + \delta L_S(M + I_N)]D} > 0, \tag{76}$$

the measure of multinational production falls

$$\frac{\partial n_F}{\partial M} = - \frac{\delta L_S(M + i_N)[L_N(M(M + i_N) + \delta i_N^2(1 - \delta) + i_N(M + \delta i_N)) + N]}{(M + \delta i_N)[L_N(M + \delta i_N) + \delta L_S(M + i_N)]D} < 0, \quad (77)$$

where $N \equiv \delta L_S(M + i_N)^2$, and the measure of Southern production may rise

$$\frac{\partial n_S}{\partial M} = \frac{\delta L_S(M + \delta i_N)^2[L_N(\delta^2(i_N + M)^2 - M^2(1 - \delta)^2) + \delta^2 L_S(M + i_N)^2]}{(M + \delta i_N)[L_N(M + \delta i_N) + \delta L_S(M + i_N)]D}. \quad (78)$$

The rate of imitation γ and the flow of FDI $\phi \equiv \phi_F n_N$ rise if $\delta i_N > M$

$$\frac{\partial \gamma}{\partial M} = \frac{\partial \Phi}{\partial M} = \frac{\delta L_S(i_N + M)^2(\delta i_N - M)}{(\delta i_N + M)D}. \quad (79)$$

Note that, by $i_N(1 - n_N) = M n_F$, must have $i_N > M$ since $M/i_N = n_F/(n_F + n_S) < 1$ but $\delta < 1$.

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