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## Intellectual property rights and foreign direct investment

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### Abstract

This paper develops a product cycle model with endogenous innovation, imitation, and foreign direct investment (FDI). We use this model to determine how stronger intellectual property rights (IPR) protection in the South affects innovation, imitation and FDI. We find that stronger IPR protection keeps multinationals safer from imitation, but no more so than Northern firms. Instead, the increased difficulty of imitation generates resource wasting and imitation disincentive effects that reduce both FDI and innovation. The greater resources absorbed in imitation crowd out FDI. Reduced FDI then transmits resource scarcity in the South back to the North and consequently contracts innovation. © 2002 Elsevier Science B.V. All rights reserved.

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### 1. Introduction

In recent years, the literature on product cycle models has made some important strides. Yet while Vernon's (1966) original vision of the product cycle assigns a central role to foreign direct investment (FDI), most models capturing his ideas cast imitation as the only channel of international technology transfer from an innovating region (the North) to an imitating region (the South) — see Krugman

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(1979), Grossman and Helpman (1991) and Segerstrom et al. (1990). Two recent exceptions are Helpman (1993) and Lai (1998); however, imitation is exogenous in these models.

An important contribution of our paper is to provide a product cycle model in which innovation, imitation, and FDI are all endogenous.<sup>1</sup> Starting from the quality ladders model of Grossman and Helpman (1991), we determine the composition of international technology transfer between imitation and FDI. A common perception is that due to local knowledge spillovers, Southern firms can more easily imitate the products of multinationals producing in the South relative to firms producing in the North. We formalize this idea by assuming that the costs of imitating a multinational's product are lower than costs of imitating a Northern firm's product. By distinguishing between imitation that targets the products of Northern firms and imitation that targets the products of multinationals, we are able to determine the effects of parameter changes on the imitation exposure of multinationals relative to Northern firms.

We apply our model to determine the effects of increased intellectual property rights (IPR) protection in the South, which we assume increases the cost of imitation due to stricter uniqueness requirements. This increased cost results in an *endogenous* decline in imitation. While products like books, videos and compact disks receive much press about conflicts over IPR protection, imitating most products is not so simple. Empirical evidence indicates that imitation is a costly activity for a wide range of high technology goods, such as chemicals, drugs, electronics and machinery. For example, Mansfield et al. (1981) finds that the costs of imitation average 65% of the costs of innovation, and very few products were below 20%. Since Southern firms must devote substantial effort to backward engineering products prior to producing imitations, IPR protection may affect the effort required by specifying how similar an imitation can be to the original.

We find that stronger Southern IPR protection makes multinationals more secure from imitation in absolute terms but no more secure from imitation relative to successful innovators still producing in the North. Consequently, stronger Southern IPR protection does not alter the expected profit stream from becoming a multinational *relative* to remaining a Northern firm and hence does not encourage FDI. The past literature could not address relative imitation exposure because imitation was exogenous.

An interesting result of our model is that FDI decreases with a strengthening of Southern IPR protection. This result arises because an increase in the cost of imitation crowds out FDI through tighter Southern resource scarcity. Less efficient imitation absorbs more Southern resources despite the reduction in the rate of imitation stemming from the reduced profitability of imitation. Additionally, the

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<sup>1</sup>Here, FDI is endogenously determined through costly adaptation of technologies, unlike in Glass and Saggi (1999) where FDI opportunities arrived exogenously.

contraction in FDI tightens Northern resource scarcity. Increased Northern production leaves fewer resources for innovation, so the rate of innovation falls.

To highlight the forces behind our results, we show that an increased cost of imitation has both an *imitation disincentive effect* similar to a tax on imitation and a *resource wasting effect* similar to a reduction in the Southern labor supply. These two effects reinforce each other in reducing FDI and innovation. This decomposition demonstrates that even if the resource wasting consequences of stronger IPR protection were not present, the reduced incentive for imitation would still generate a reduction in FDI and innovation.

## 2. Product cycles with endogenous FDI

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, Northern firms push forward the quality frontier of existing products through innovation, while Southern firms pursue the quality frontier through imitation. The increased utility from higher quality levels of products will be shown to drive innovation, while cost savings will drive imitation and FDI. Northern firms, by becoming multinationals, can shift their production to the South.

### 2.1. Consumers

The specification of the consumer’s problem follows Grossman and Helpman (1991). 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  $\rho$  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 only initial asset holdings remain. 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 overall 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 then evenly spread expenditure 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  $x_{i\tilde{m}}(j, t) = E_i(t)/p_{\tilde{m}}(j, t)$  units of quality level  $\tilde{m}(j, t)$  of product  $j$  and no units of other quality levels of that product. In the first stage, consumers evenly spread lifetime expenditure across time,  $E_i(t) = E_t$ , as the utility function for each consumer is time separable and the aggregate price level will be shown to 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 R&D with Grossman and Helpman (1991), but we introduce several unique features to capture the role of multinational firms. Firstly, we allow Northern firms to adapt technologies so that they can produce in the South. Secondly, we allow imitation targeting a multinational's product to be easier than imitation targeting a Northern firm's product.

To produce a quality level of a product, a firm must first devote resources 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 undertaking R&D intensity  $\iota$  for a time interval  $dt$  requires  $a\iota dt$  units of labor at cost  $w\iota dt$  and leads to success with probability  $\iota dt$  (subscripts suppressed). A higher investment in innovation 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 R&D 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. Finally, assume free entry into R&D, with an endless pool of potential innovators and imitators.

In our model, the process of adapting techniques for Southern production resembles the process of conducting R&D. The resource requirements are  $a_N$  in innovation,  $a_F$  in adaptation,  $(1 + \kappa)a_S$  in imitation targeting a Northern firm's product, and  $(1 + \kappa)\gamma a_S$  in imitation targeting a multinational's product.<sup>2</sup> The corresponding R&D intensities are  $\iota_N$ ,  $\iota_F$ ,  $\iota_{SN}$ , and  $\iota_{SF}$ .

Higher levels of  $\kappa$  can be viewed as representing a strengthening of IPR protection: Southern firms must spend more resources for a given imitation intensity.<sup>3</sup> Stronger IPR protection can reduce imitation efficiency through various channels. Firms may need to add traits to the product that distinguish the imitation

<sup>2</sup>Subscripts denote the type of firms (Northern, FDI/multinational or Southern) that can produce the highest quality level available of a product if R&D is successful.

<sup>3</sup>We distinguish imitation from copying (or pirating), which is illegal duplication of a protected product design.

in the view of legal authorities.<sup>4</sup> Prolonged legal battles may be required to prove that a product is sufficiently unique. As IPR protection is strengthened, aspects of the design that would have been copied may have to be innovated anew. Thus,  $\kappa$  can be thought of as measuring how much of the design must be unique to satisfy the standard.

In our model, due to Bertrand behavior in product markets, once a quality level of a product has been invented, another Northern firm never invents the same quality level. Similarly, once a quality level has been imitated, another Southern firm never imitates the same quality level. For simplicity, we do not allow Northern innovation to target other Northern firms by making the necessary assumptions for such innovation to fail to earn the market rate of return.

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 resource requirement in innovation for followers is sufficiently large relative to the resource 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  $\lambda$  is sufficiently large that Northern leaders do not undertake further innovation until their most recent innovation has been imitated. Thus, innovation targets products produced by Southern firms while imitation targets products produced by Northern firms and multinationals.

Our model distinguishes between imitation that targets multinationals and imitation that targets Northern firms. We assume that *the resource requirement in imitation is lower when targeting multinationals compared to Northern firms*:  $\gamma < 1$ . This assumption reflects the idea that Southern imitation of brands produced through FDI in the South may be easier than imitation of brands produced in the North due to larger knowledge spillovers. Moving production in close proximity to Southern firms trying to imitate a product may lower the cost of imitation, since Southern firms can more easily learn about the production techniques of multinationals than those of Northern firms. A Southern firm targeting a multinational's product can hire away some of the multinational's workers, spy on the multinational's production facilities or use similar means of acquiring information more feasible with proximity. Also, multinationals have already made adaptations for the Southern economic environment that have the side effect of making successful imitation easier to accomplish for Southern firms.

When undertaking R&D, a firm endures costs  $w\tilde{a}dt$  and gains an expected

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<sup>4</sup>A legal imitation must be sufficiently distinct from the original innovation according to an  $ABC \neq ABD \Leftrightarrow C \neq D$  rule, where at least one significant aspect of the production process or design must differ.

reward  $v\tilde{d}t$  (subscripts suppressed). Each firm chooses its intensity of innovation  $\tilde{t}$  to maximize its expected gain from R&D

$$\max_{\tilde{t} \geq 0} \int_0^{\infty} e^{-(\rho+\iota)t} (v-wa)\tilde{d}t = \max_{\tilde{t} \geq 0} \left( \frac{v-wa}{\rho+\iota} \right) \tilde{t} \Leftrightarrow \max_{\tilde{t} \geq 0} (v-wa)\tilde{t}, \tag{5}$$

where  $v$  denotes the reward to successful R&D, the value of a firm in the appropriate product market where the firm produces if successful in R&D. The term  $e^{-\iota t}$  captures the probability that no other firm will have succeeded in R&D in the same industry prior to time  $t$ , and  $\iota$  is the R&D intensity of other firms (taken as given). Each nonproducing firm chooses its R&D intensity to maximize the difference between the expected reward and the costs of R&D.

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

$$v_N \leq wa_N, \iota_N > 0 \Leftrightarrow v_N = wa_N \tag{6}$$

and similarly for imitation of Northern firms

$$v_{SN} \leq (1+\kappa)a_S, \iota_{SN} > 0 \Leftrightarrow v_{SN} = (1+\kappa)a_S \tag{7}$$

and imitation of multinationals

$$v_{SF} \leq (1+\kappa)\gamma a_S, \iota_{SF} > 0 \Leftrightarrow v_{SF} = (1+\kappa)\gamma a_S, \tag{8}$$

where we have normalized the Southern wage to one  $w_S = 1$ , so that  $w = w_N$  is the relative wage.

Northern firms also optimally choose how hard to attempt to adapt their production techniques for use in the South, so by similar logic, the cost of adaptation must equal the expected reward when the adaptation intensity is positive

$$v_F - v_N \leq a_F, \iota_F > 0 \Leftrightarrow v_F - v_N = a_F. \tag{9}$$

When successful at adapting its technology for Southern production, 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 adaptation process required to achieve lower costs through FDI resembles process R&D: expenses are incurred to achieve a lower marginal cost of production.

### 2.3. Production

Southern firms are exposed to only innovation since further imitation is not immediately possible, while Northern firms and multinationals are exposed to only imitation since further innovation has been assumed prohibitively costly.

A Northern firm successful in innovating over a product produced by a Southern firm earns the reward

$$v_N = \frac{\pi_N + \iota_F(v_F - v_N - a_F)}{\rho + \iota_{SN}} = \frac{\pi_N}{\rho + \iota_{SN}}, \quad (10)$$

where  $\pi_N$  is instantaneous profits for a Northern firm and the simplification imposes (9) assuming  $\iota_F > 0$ . Once successful in adaptation, its value becomes

$$v_F = \frac{\pi_F}{\rho + \iota_{SF}}, \quad (11)$$

where  $\pi_F$  is instantaneous profits for a multinational. Meanwhile, a Southern firm successful in imitating a brand produced by a Northern firm earns the reward

$$v_{SN} = \frac{\pi_{SN}}{\rho + \iota_N}, \quad (12)$$

while a Southern firm successful in imitating a brand produced by a multinational earns the reward

$$v_{SF} = \frac{\pi_{SF}}{\rho + \iota_N}, \quad (13)$$

where  $\pi_{SN}$  and  $\pi_{SF}$  are similarly defined. The effective discount rate is the subjective discount rate  $\rho$  plus the probability that the profit stream will end due to imitation or innovation.

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. However, we assume that the unit labor requirement for multinationals is greater than one ( $\zeta > 1$ ), so that *multinationals face higher production costs relative to Southern firms*. Multinationals experience logistical difficulties when coordinating decisions over large distances and suffer from their lack of familiarity with the Southern economic environment. The theory of the multinational firm emphasizes that multinationals need advantages based on superior product design, advertising, or reputation to offset operating cost disadvantages relative to native firms: see Markusen (1995).

Once successful in R&D, 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). Firms that have just succeeded in innovation have a one-quality level lead over the former producer; they choose a price equal to the quality increment times their rival's marginal cost. When competing against a Southern firm, a Northern firm charges price  $p_N = \lambda$  and makes sales  $x_N = E/\lambda$  with marginal cost  $c_N = w$ , yielding instantaneous profits

$$\pi_N = E \left( 1 - \frac{w}{\lambda} \right). \tag{14}$$

When competing against a Southern firm, a multinational charges price  $p_F = \lambda$  and makes sales  $x_F = E/\lambda$  with marginal cost  $c_F = \zeta$ , yielding instantaneous profits

$$\pi_F = E \left( 1 - \frac{\zeta}{\lambda} \right). \tag{15}$$

For Northern production to be profitable ( $\pi_N > 0$ ), the quality increment must be large enough to exceed the relative wage in equilibrium ( $\lambda > w$ ), which will imply  $\lambda > \zeta$ , as needed for  $\pi_F > 0$ . The equilibrium value of the relative wage (24) will be derived shortly.

Firms that have just succeeded in imitation have no quality lead over the former producer; they choose a price equal to their rival’s marginal cost. When competing against a Northern firm, a Southern firm charges price  $p_{SN} = w$  and makes sales  $x_{SN} = E/w$  with marginal cost  $c_{SN} = 1$ , yielding instantaneous profits

$$\pi_{SN} = E \left( 1 - \frac{1}{w} \right). \tag{16}$$

When competing against a multinational, a Southern firm charges price  $p_{SF} = \zeta$  and makes sales  $x_{SF} = E/\zeta$  with marginal cost  $c_{SF} = 1$ , yielding instantaneous profits

$$\pi_{SF} = E \left( 1 - \frac{1}{\zeta} \right). \tag{17}$$

Southern production with multinational rivals is profitable ( $\pi_{SF} > 0$ ) because Southern firms are assumed to have a cost advantage relative to multinationals ( $\zeta > 1$ ). We will show that  $\zeta > 1$  also implies that the relative wage will exceed one ( $w > 1$ ), which ensures that  $\pi_{SN} > 0$ .

#### 2.4. Resource constraints

Let  $n_N$  denote the measure of Northern production,  $n_F$  the measure of multinational production,  $n_{SN}$  the measure of Southern production with Northern rivals, and  $n_{SF}$  the measure of Southern production with multinational rivals (each as a fraction of all production so the measures sum to one). Define the measure of Southern production as  $n_S \equiv n_{SN} + n_{SF}$ .

In each country, the fixed supply of labor is allocated between R&D and production. For equilibrium in each labor market, the demand for labor must equal the supply of labor in each country. In the North, labor demand for innovation is  $a_N t_N n_S$  and for production is  $n_N E/\lambda$

$$a_N t_N n_S + n_N \frac{E}{\lambda} = L_N. \tag{18}$$

In the South, labor demand for imitation is  $(1 + \kappa)a_S[\iota_{SN}n_N + \gamma\iota_{SF}n_F]$ , for adaptation is  $\iota_F a_F n_N$  and for production is  $n_F E/\lambda + n_{SN} E/w + n_{SF} E/\zeta$

$$(1 + \kappa)a_S[\iota_{SN}n_N + \gamma\iota_{SF}n_F] + a_F \iota_F n_N + \left[ \frac{n_{SN}}{w} + \frac{n_{SF}}{\zeta} + \frac{n_F}{\lambda} \right] E = L_S. \tag{19}$$

The usual steady-state conditions for market measures to remain constant (that flows in equal flows out)  $\iota_F n_N = \iota_{SF} n_F$ ,  $\iota_{SF} n_F = \iota_N n_{SF}$ ,  $\iota_{SN} n_N = \iota_N n_{SN}$  and sum to one  $n_S + n_F + n_N = 1$  complete the model.

*2.5. Steady-state system*

We focus on steady-state equilibria and begin with the case where all four R&D activities occur so that international technology transfer occurs through both imitation and FDI. In Section 3 we establish results for this equilibrium and in Section 4 we show that they also hold for equilibria with only FDI or only imitation as the channel of international technology transfer.

If all four R&D activities occur  $\iota_F > 0$ ,  $\iota_N > 0$ ,  $\iota_{SF} > 0$ , and  $\iota_{SN} > 0$ , our model is a system of six equations. The four valuation conditions are gathered below from the appropriate profits and values of producing firms: innovation valuation condition from (6), (10) and (14)

$$E\left(1 - \frac{w}{\lambda}\right) = w a_N (\rho + \iota_{SN}) \tag{20}$$

adaptation valuation condition from (6), (9), (11) and (15)

$$E\left(1 - \frac{\zeta}{\lambda}\right) = (a_F + w a_N) (\rho + \iota_{SF}) \tag{21}$$

imitation of Northern firms valuation condition from (7), (12) and (16)

$$E\left(1 - \frac{1}{w}\right) = (1 + \kappa) a_S (\rho + \iota_N) \tag{22}$$

and imitation of multinationals valuation condition from (8), (13) and (17)

$$E\left(1 - \frac{1}{\zeta}\right) = (1 + \kappa) \gamma a_S (\rho + \iota_N). \tag{23}$$

The other two equations are the resource constraints (18) and (19).

The two imitation valuation conditions (22) and (23) are solved for the relative wage

$$w = \frac{\gamma \zeta}{\gamma \zeta - (\zeta - 1)}. \tag{24}$$

The lower cost of imitation targeting multinationals relative to Northern firms ( $\gamma < 1$ ) implies production costs are higher for Northern firms than for multina-

tionals ( $w > \zeta$ ). Also, wages are higher in the North than the South ( $w > 1$ ) since  $\zeta > 1$  by assumption. In the limit as  $\zeta \rightarrow 1$ , the relative wage goes to one,  $w \rightarrow 1$ . From (24), Southern IPR protection does not affect the relative wage and neither does a tax on imitation or a reduction in Southern resources.<sup>5</sup>

Define the cost of adaptation relative to innovation as  $\theta \equiv a_F/wa_N$ . Next solve the innovation and adaptation valuation conditions (20) and (21) for the relative effective discount rate

$$\xi \equiv \frac{\rho + \iota_{SF}}{\rho + \iota_{SN}} = \left( \frac{1}{1 + \theta} \right) \left( \frac{\lambda - \zeta}{\lambda - w} \right). \tag{25}$$

The relative effective discount rate is the degree that multinational profits are deflated relative to the profits of Northern firms due to differences in exposure to imitation. In the limit as  $\zeta \rightarrow 1$ ,  $\gamma \rightarrow 1$  and  $\theta \rightarrow 1$ , the relative effective discount rate goes to one,  $\xi \rightarrow 1$ .

Our model conforms to the perception that multinationals face greater exposure to imitation than Northern firms (Mansfield, 1994; Helpman, 1993) when Northern firms face sufficiently slight adaptation costs

$$\xi > 1 \Leftrightarrow \theta < \tilde{\theta} \equiv \frac{w - \zeta}{\lambda - w}. \tag{26}$$

The threshold level  $\tilde{\theta}$  for  $\xi = 1$  stipulates that adaptation relative to innovation costs equals the cost reduction margin from adaptation ( $w - \zeta$ ) relative to the profit margin from innovation ( $\lambda - w$ ).<sup>6</sup> While the greater exposure of multinationals to imitation does in part reflect our assumption that their products are easier to imitate, it is nonetheless a result (provided  $\theta < \tilde{\theta}$ ).

By encompassing both the Grossman and Helpman (1991) imitation product cycle and the Vernon (1966) FDI product cycle (see Fig. 1), our model determines the fraction of technology transferred to the South through imitation rather than FDI. To explore the consequences of Southern IPR protection on the rate of innovation and flows of FDI to the South, we first define these measures of interest and translate the system into these variables.

Let  $\eta$  be the fraction of all product cycles, and hence the fraction of international technology transfer, that occurs through imitation of Northern firms. Define the rate of innovation as the intensity of innovation times the measure of Southern production  $\iota \equiv \iota_N n_S$ , which captures the frequency of product cycles. Similarly, define the rate of imitation as the sum of imitation targeting Northern firms and multinationals  $\mu \equiv \iota_{SN} n_N + \iota_{SF} n_F$ . In the steady-state equilibrium, the rate of innovation must equal the rate of imitation,  $\iota = \mu$ , so that production shifts to the South at the same rate as production returns to the North.

Define the flow of FDI as the adaptation intensity times the measure of Northern

<sup>5</sup>This invariance likely depends on the assumed constant returns to scale in R&D.

<sup>6</sup>For  $\zeta = 6/5$ ,  $\lambda = 4$ , and  $w = 3/2$ , the threshold is  $\tilde{\theta} = 3/25 = 12\%$ .

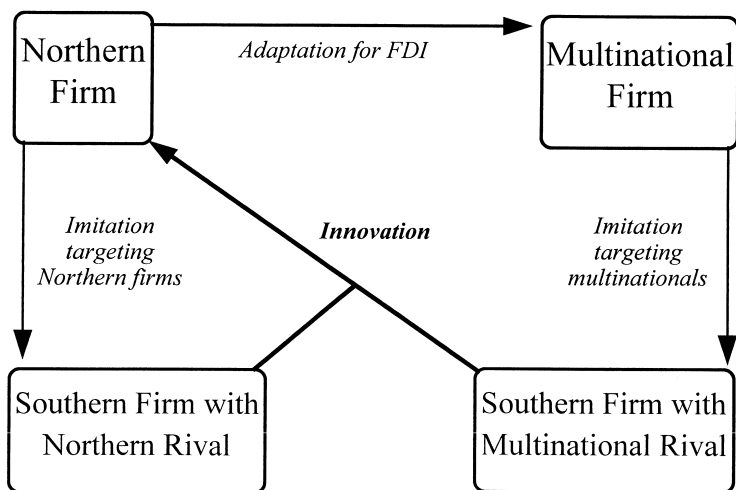


Fig. 1. Product cycle composition.

production  $\phi \equiv \iota_F n_N$ . Of all the  $\iota = \mu$  flows in the product cycle,  $\mu_N \equiv \iota_{SN} n_N = \eta \iota$  occur through imitation of Northern firms and  $\phi = (1 - \eta) \iota = \iota_{SF} n_F \equiv \mu_F$  occur through FDI (and then imitation of multinationals). In addition to the flow of FDI  $\phi$ , the measure of multinational production  $n_F$  can also be used as a gauge of the extent of FDI.

The solutions for the relative wage (24) and the relative effective discount rate (25) take the place of the valuation conditions for adaptation (21) and imitation of multinationals (23), leaving *four remaining equations*: the Northern resource constraint (18), Southern resource constraint (19), innovation valuation condition (20) and imitation valuation condition (22). Making substitutions for  $\{\iota_N, \iota_F, \iota_{SN}, n_F, n_S, n_{SN}, n_{SF}\}$  into the four remaining equations achieves a system in the *four remaining endogenous variables*: aggregate expenditure  $E$ , the measure of Northern production  $n_N$ , the rate of innovation  $\iota$ , and the fraction of all product cycles that occur through imitation  $\eta$ .

The equilibrium can be seen graphically by solving the innovation and imitation valuation equations for  $E$  and  $n_N$  and then inserting these expressions into the Northern and Southern resource constraints. The two resource constraints then determine the rate of innovation  $\iota$  and the fraction of international technology transfer that occurs through imitation of Northern firms  $\eta$  as in Fig. 2. The Northern resource constraint LN is downward sloping (larger  $\eta$  requires slower  $\iota$ ) while the Southern resource constraint LS is upward sloping (larger  $\eta$  permits faster  $\iota$ ). A larger  $\eta$  dictates that a smaller fraction of products that have not yet been imitated are produced in the South (through FDI) relative to the North

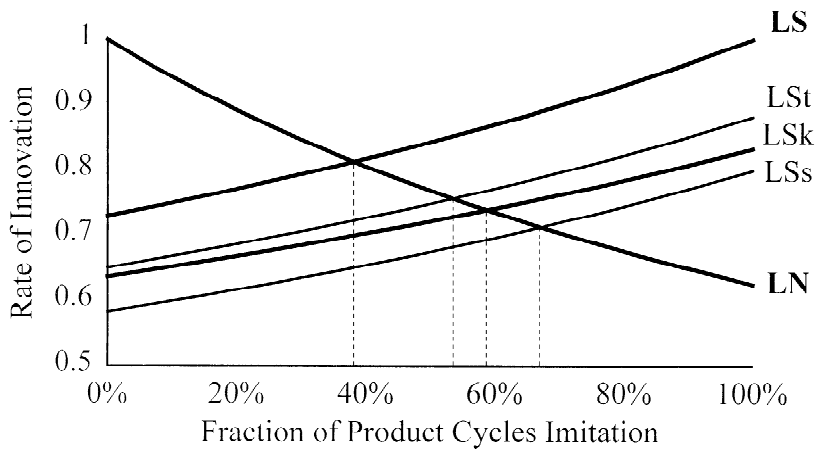


Fig. 2. Resource constraint shifts.

( $n_R \equiv n_F/n_N$  falls). With more labor demand for production in the North and less in the South, Northern resources support a smaller rate of innovation, while Southern resources support a larger one. The equilibrium values of  $\iota$  and  $\eta$  occur at the intersection of LN and LS.

Introduce a multiplicative term  $(1 + \tau)$  on the right-hand (cost) side of the imitation valuation conditions (22) and (23) to represent a tax on imitation and introduce a multiplicative term  $(1 - \psi)$  on the right-hand (supply) side of the Southern resource constraint (19) to represent a reduction in Southern resources. In the next section, we will relate the effects of changes in  $\kappa$  to those of changes in  $\tau$  and  $\psi$ .

### 3. Intellectual property rights protection

We now determine how strengthening IPR protection in the South, through increasing the costs of imitation, affects the imitation exposure of multinationals relative to Northern firms, the composition of international technology transfer, FDI, imitation and innovation.<sup>7</sup> We also show that the reduced efficiency of imitation due to stronger Southern IPR protection is equivalent to a tax on imitation combined with a reduction in Southern resources.

<sup>7</sup>Additional details on the derivation of our results appear in an Appendix available on the web at <http://economics.sbs.ohio-state.edu/pdf/glass/iprsup.pdf>.

### 3.1. Relative imitation exposure

First note that stronger Southern IPR protection increases the profit incentive for Northern firms to undertake FDI in the South only if imitation of multinationals falls relative to imitation of Northern firms as a result. Our model is the first to determine the intensities of imitation targeting the products of multinationals and Northern firms in order to establish whether stronger Southern IPRs will increase the relative return to conducting FDI.

From (25), it is obvious that the relative effective discount rate is invariant to the strength of Southern IPR protection  $\kappa$ .<sup>8</sup> The value of a multinational relative to a Northern firm reflects relative profits deflated by the relative effective discount rate

$$v_R \equiv \frac{v_F}{v_N} = \frac{\pi_F/(\rho + \iota_{SF})}{\pi_N/(\rho + \iota_{SN})} = \frac{\pi_R}{\xi}. \tag{27}$$

Since the instantaneous profits of a multinational relative to a Northern firm are not affected

$$\pi_R \equiv \frac{\pi_F}{\pi_N} = \frac{E\left[1 - \frac{\zeta}{\lambda}\right]}{E\left[1 - \frac{w}{\lambda}\right]} = \frac{\lambda - \zeta}{\lambda - w}, \tag{28}$$

a strengthening of Southern IPR protection does not affect the relative imitation exposure faced by multinationals.<sup>9</sup>

**Proposition 1.** *The imitation exposure of multinationals relative to Northern firms is independent of a strengthening of Southern IPR protection, a tax on imitation, or a reduction in Southern resources.*

While multinationals become safer from imitation with a strengthening of Southern IPR protection, so do Northern firms. The intensity of imitation targeting the products of Northern firms decreases

$$\frac{\partial \iota_{SN}}{\partial \kappa} = \left(\frac{\zeta - 1}{w\xi}\right) \frac{\partial \iota}{\partial \kappa} = -\left(\frac{\zeta - 1}{w\xi}\right) \frac{\iota}{D} < 0, \tag{29}$$

as  $\partial \iota / \partial \kappa = -\iota / D < 0$  (see Proposition 4).

<sup>8</sup>This invariance likely depends on stronger Southern IPR protection raising the costs of imitation to the same degree when targeting the product of a Northern firm as when targeting the product of a multinational.

<sup>9</sup>Applying the equilibrium relative effective discount rate (25) to the relative multinational to Northern profits (28), the higher profits of multinationals relative to Northern firms reflect the additional costs of adaptation and any greater exposure to imitation  $\pi_R = \xi(1 + \theta) > 1$ .

### 3.2. Composition of international technology transfer

Since multiple channels of international technology transfer are active in this equilibrium of our model, we can study the effect of a strengthening of IPR protection on the composition of international technology transfer between imitation and FDI. We find that the fraction of technology flowing to the South through imitation expands with stronger Southern IPR protection

$$\frac{\partial \eta}{\partial \kappa} = \frac{\frac{\lambda}{w} - (1 - \eta)}{D} > 0, \tag{30}$$

where the denominator is

$$D \equiv 1 + \frac{En_N \left(1 - \frac{1}{\zeta}\right) \left[1 + \theta \xi \left(\frac{\lambda}{w} - 1\right)\right]}{\gamma a_s \xi \eta \iota} > 1. \tag{31}$$

For future reference, note that, in addition to other factors, the extent that the denominator  $D$  exceeds one is related to the extent that: adaptation costs exist ( $\theta > 0$ ), multinationals are easier to imitate than Northern firms ( $\gamma < 1$ ), and multinationals suffer a cost disadvantage relative to Southern firms ( $\zeta > 1$ ).

**Proposition 2.** *The fraction of international technology transfer that occurs through imitation of Northern firms increases with a strengthening of Southern IPR protection, a tax on imitation, or a reduction in Southern resources.*

Southern imitation absorbs more resources when Southern IPRs are strengthened due to imitation becoming more difficult. Southern resource demand in imitation is

$$L_S^R \equiv (1 + \kappa) a_s \iota [\eta + \gamma(1 - \eta)]. \tag{32}$$

Differentiating with respect to  $\kappa$  yields:

$$\frac{\partial L_S^R}{\partial \kappa} = a_s \left\{ [\eta + \gamma(1 - \eta)] \left( \iota + \frac{\partial \iota}{\partial \kappa} \right) + \iota(1 - \gamma) \frac{\partial \eta}{\partial \kappa} \right\} > 0. \tag{33}$$

The second term is clearly positive and represents the shift toward more difficult imitation of Northern firms. The first term is positive: innovation falls by less than the rate of innovation  $|\partial \iota / \partial \kappa| = -\iota / D < \iota$  because  $D > 1$  in (31) — see Proposition 4. Within the first term, the portion involving  $\iota$  represents each unit of imitation using more resources and the term involving  $\partial \iota / \partial \kappa$  represents the reduction in the overall level of imitation (therefore using fewer resources).

With greater Southern resources demanded for imitation, labor demand for production must be shifted from the South to the North to restore equilibrium. When products cycle through imitation, they generate more labor demand for

production in the North relative to the South than when products cycle through FDI:  $n_R \equiv n_F/n_N$  declines in  $\eta$ . With FDI, production occurs in the South that would have occurred in the North in the absence of FDI.

### 3.3. Foreign direct investment

We find that stronger Southern IPR protection discourages FDI. FDI flows are the fraction of all product cycles that occur through imitation times the frequency of product cycles  $\phi = (1 - \eta)\iota$ . Since the rate of innovation  $\iota$  falls (Proposition 4) and a larger fraction of international technology transfer occurs through imitation  $\eta$  (Proposition 2), the flows of FDI to the South doubly fall

$$\frac{\partial \phi}{\partial \kappa} = - \left[ \frac{\iota}{1 - \frac{w}{\lambda}(1 - \eta)} \right] \frac{\partial \eta}{\partial \kappa} = \frac{\lambda}{w} \frac{\partial \iota}{\partial \kappa} = - \left( \frac{\lambda}{w} \right) \frac{\iota}{D} < 0. \tag{34}$$

The measure of multinational production  $n_F$ , an alternative measure of FDI, also decreases

$$\frac{\partial n_F}{\partial \kappa} = - \eta \xi \left[ \lambda(1 - n_F) + n_F(\lambda - \zeta) + 1 \right] \frac{\partial \eta}{\partial \kappa} < 0. \tag{35}$$

Thus, FDI declines with stronger Southern IPR protection.

We further find that the rate of imitation of Northern firms  $\mu_N \equiv \iota_{SN} n_N = \eta \iota$  actually increases

$$\frac{\partial \mu_N}{\partial \kappa} = - \left( \frac{\lambda}{w} - 1 \right) \frac{\partial \iota}{\partial \kappa} = \left( \frac{\lambda}{w} - 1 \right) \frac{\iota}{D} > 0. \tag{36}$$

While product cycles occur more slowly due to the slower rate of innovation, more of them occur through imitation, and this positive effect dominates.<sup>10</sup>

**Proposition 3.** *FDI flows to the South decrease while flows of production to the South through imitation of Northern firms increase with a strengthening of Southern IPR protection, a tax on imitation, or a reduction in Southern resources.*

### 3.4. Innovation and imitation

We find that stronger Southern IPR protection discourages innovation in our model. Stronger Southern IPR protection shifts international technology transfer toward imitation of Northern firms, which shifts labor demand for production from the South to the North. Resource scarcity in the South is transmitted back to the North and impinges on innovation

<sup>10</sup>While imitation substitutes for FDI in transferring technology to the South, the substitution is incomplete as the total flows of technology to the South  $\mu_N + \phi = \iota$  fall (Proposition 4).

$$\frac{\partial \iota}{\partial \kappa} = - \left[ \frac{\iota}{\frac{\lambda}{w} - (1 - \eta)} \right] \frac{\partial \eta}{\partial \kappa} = - \frac{\iota}{D} < 0. \tag{37}$$

**Proposition 4.** *The rates of innovation and imitation decrease with a strengthening of Southern IPR protection, a tax on imitation, or a reduction in Southern resources.*

The positive effect on the fraction of product cycles that occur through imitation  $\eta$  and negative effect on the rate of innovation  $\iota$  can be seen graphically in Fig. 2. Stronger IPR protection in the South (increase in  $\kappa$ ) shifts the Southern resource constraint down to LSk (smaller  $\iota$  for a given  $\eta$ ) due to the larger resource requirements in imitation. The Northern resource constraint is unaffected. Thus the equilibrium shifts down along the downward-sloping Northern resource constraint to larger  $\eta$  and smaller  $\iota$ . While the increased cost of imitation does reduce incentives for imitation, the total resources devoted to imitation increase, increasing resource scarcity in the South.

The parameters used to construct Fig. 2 are Northern labor supply  $L_N = 3$ , Southern labor supply  $L_S = 6$ , resource requirement in innovation  $a_N = 3$ , resource requirement in imitation  $a_S = 2$ , resource requirement in imitation of multinationals relative to Northern firms  $\gamma = 1/2 = 50\%$ , resource requirement in adaptation relative to imitation  $\theta = 1/10 = 10\%$ , cost disadvantage of multinationals relative to Southern firms  $\zeta = 6/5$ , subjective discount rate  $\rho = 1/20$ , and quality increment  $\lambda = 4$ . The initial equilibrium is for  $\kappa = 0$ ,  $\psi = 0$  and  $\tau = 0$ . In the subsequent equilibrium Southern IPRs are strengthened to  $\kappa' = 1/5$  in LSk.<sup>11</sup> Table 1 shows how the equilibrium values are affected: for all cases in Table 1, multinationals are exposed to slightly more imitation than are Northern firms  $\xi = 1.02$ . These calculations confirm that there is indeed an equilibrium with all four types of R&D active, and that  $\kappa$  can be shifted without disturbing the type of equilibrium, provided that the shift is not too large. For these parameters, we can increase  $\kappa$  to  $\bar{\kappa} = 143/250 = 0.572$  or decrease  $\kappa$  to  $\underline{\kappa} = -97/250 = -0.388$

Table 1  
Both FDI and imitation product cycles

$\kappa$	$\iota$	$\eta$	$E$	$w$	$n_N$	$n_S$	$n_F$	$\phi$
-0.388	1.000	0%	11.0	1.5	0%	33.8%	66.2%	1.000
-0.2	0.893	19.4%	10.9	1.5	11.8%	40.1%	48.1%	0.720
0	0.801	40.1%	10.8	1.5	22.1%	45.6%	32.3%	0.480
0.2	0.725	61.0%	10.8	1.5	30.6%	50.2%	19.2%	0.283
0.4	0.663	81.9%	10.7	1.5	37.7%	54.0%	8.2%	0.120
0.572	0.617	100%	10.7	1.5	43.0%	57.0%	0%	0

<sup>11</sup>The other shifts depicted are  $\psi' = 1/5$  for LSs and  $\tau' = 1/5$  for LSt.

and still achieve an interior solution.<sup>12</sup> Further numerical examples illustrating the equilibria for other values of  $\kappa$  are provided in Section 4.

### 3.5. Decomposition

Fig. 2 also illustrates that when  $\kappa$ ,  $\tau$  or  $\psi$  (depicted by LSk, LSt and LSs) are increased to the same degree, the effects of  $\kappa$  are in the same direction but between the smaller effects of a tax on imitation  $\tau$

$$\frac{\partial \eta / \partial \tau}{\partial \eta / \partial \kappa} = \frac{\partial \phi / \partial \tau}{\partial \phi / \partial \kappa} = \frac{\partial \mu_N / \partial \tau}{\partial \mu_N / \partial \kappa} = \frac{\partial \iota / \partial \tau}{\partial \iota / \partial \kappa} = \frac{\eta}{w} + \frac{1 - \eta}{\zeta} < 1 \tag{38}$$

and the larger effects of a reduction in Southern resources  $\psi$  in magnitude

$$\frac{\partial \eta / \partial \psi}{\partial \eta / \partial \kappa} = \frac{\partial \phi / \partial \psi}{\partial \phi / \partial \kappa} = \frac{\partial \mu_N / \partial \psi}{\partial \mu_N / \partial \kappa} = \frac{\partial \iota / \partial \psi}{\partial \iota / \partial \kappa} = \frac{L_S}{\iota a_S \gamma} \left( 1 - \frac{1}{\zeta} \right) > 1. \tag{39}$$

The effect of  $\psi$  is a proportionate reduction in the entire Southern labor supply, while  $\kappa$  involves an expansion in labor demand of only the labor engaged in imitation. An increase in  $\kappa$  combines resource wasting and imitation disincentive effects, which reinforce each other in lowering  $\iota$  and raising  $\eta$ .

A reduction in Southern resources (an increase in  $\psi$ ) captures the *resource wasting effect*. When Southern resources contract, more product cycles must occur through imitation of Northern firms. A higher fraction of product cycles occurring through imitation  $\eta$  reduces labor demand in Southern production by keeping more production back in the North ( $n_F/n_N$  falls) and shifting Southern production toward higher priced products with lower sales ( $n_{SF}/n_{SN}$  falls). Also, a lower rate of innovation  $\iota$  reduces labor demand in R&D in both countries to restore equilibrium. Thus, the composition of international technology transfer  $\eta$  adjusts the distribution of labor demand across countries, while the speed of the product cycles  $\iota$  adjusts the overall level of labor demand.

A tax on imitation (an increase in  $\tau$ ) captures the *imitation disincentive effect*. The reduction in the rate of innovation helps both conserve Southern resources in imitation and restore the equality between the expected benefits of imitation and the greater costs of imitation. When the rate of innovation falls, a successful imitation earns a longer expected duration of profits due to the reduced probability of innovation terminating the profit stream. The increase in the reward to imitation needed to offset its increased cost due to the tax is also accomplished through an increase in aggregate spending, which increases profits. However, the increase in aggregate spending increases labor demand primarily in the South due to more lower priced production occurring there, implying larger sales. The extent that the

<sup>12</sup>Imitation costs at the upper bound are  $(1 + \bar{\kappa}) / (1 + \underline{\kappa}) = 256\%$  of imitation costs at the lower bound.

increase in labor demand occurs disproportionately in the South must be offset by increasing the importance of imitation of Northern firms in the product cycle, as  $\eta$  serves the function of reallocating labor demand across the two countries.

#### 4. Other equilibria

Now we turn to considering equilibria for parameters such that one form of imitation or the other does not occur in equilibrium. As a result, in these equilibria, only one of the two types of product cycles occurs, either FDI or imitation. We find, however, that our results do not depend on the type of equilibrium that emerges.

##### 4.1. Imitation cycle only

Here we consider the equilibrium of the model in which only innovation and imitation of Northern firms occur (with no FDI and no imitation of multinationals). The Northern labor constraint is

$$a_N \iota + n_N \frac{E}{\lambda} = L_N. \tag{40}$$

The Southern labor constraint is

$$(1 + \kappa)a_S \iota w + (1 - n_N)E = L_S w. \tag{41}$$

The valuation condition for innovation is

$$E n_N \left(1 - \frac{w}{\lambda}\right) = w a_N (\rho n_N + \iota). \tag{42}$$

The valuation condition for imitation targeting a Northern firm’s product is

$$E(1 - n_N)(w - 1) = (1 + \kappa)a_S [\rho(1 - n_N) + \iota], \tag{43}$$

where  $\iota = \iota_N n_S = \iota_S n_N = \mu$  is the rate of innovation, which equals the rate of imitation and  $n_{SN} = n_S$  for notational ease. The system determines  $\{E, w, \iota, n_N\}$ . The valuation condition for adaptation (21) must be an inequality, with *rewards less than costs*.<sup>13</sup>

Using comparative statics techniques, we find that an increase in Southern IPR protection decreases the rate of innovation

$$\frac{\partial \iota}{\partial \kappa} = - \frac{\iota}{1 + \frac{\lambda - w}{w(w - 1)}} < 0, \tag{44}$$

<sup>13</sup>The model here is essentially the same as Glass (1997) but with only one quality level of each product selling in equilibrium.

decreases the relative wage

$$\frac{\partial w}{\partial \kappa} = \left( \frac{\lambda - w}{\iota} \right) \frac{\partial \iota}{\partial \kappa} < 0, \tag{45}$$

increases the measure of Northern production

$$\frac{\partial n_N}{\partial \kappa} = -n_N(1 - n_N) \left( \frac{\lambda - w}{w\iota} \right) \frac{\partial \iota}{\partial \kappa} > 0, \tag{46}$$

and increases aggregate expenditure. In this equilibrium, any force that reduces the rate of imitation also reduces the rate of innovation, since the two rates are equal. These results mirror those of Grossman and Helpman’s (1991) inefficient Northern followers equilibrium, if the effect of decreasing the Southern labor supply is combined with taxing imitation in the spirit of our decomposition result. Similarly, Helpman (1993) and Lai (1998) find that a reduction in the intensity of imitation leads to a slower rate of innovation.<sup>14</sup>

Table 2 shows equilibria with only the imitation product cycle that arise for large values of  $\kappa > \bar{\kappa}$ . For  $\kappa = \bar{\kappa}$ , the reward to adaptation exceeds its costs according to the valuation condition (21), so lower levels of  $\kappa \leq \bar{\kappa}$  do not support an equilibrium with only the imitation product cycle — the FDI cycle also emerges.<sup>15</sup>

#### 4.2. FDI cycle only

Now we consider the equilibrium of the model in which only innovation, FDI, and imitation of multinationals occur (with no imitation of Northern firms). The Northern labor constraint is

$$a_N \iota + (1 - n_F - n_S) \frac{E}{\lambda} = L_N. \tag{47}$$

Table 2  
Only imitation product cycle

$\kappa$	$\iota$	$\eta$	$E$	$w$	$n_N$	$n_S$	$n_F$	$\phi$
0.572	0.617	100%	10.7	1.50	43.0%	57.0%	0%	0
1	0.577	100%	11.2	1.65	45.4%	54.6%	0%	0
1.4	0.540	100%	11.6	1.80	47.4%	52.6%	0%	0
1.8	0.522	100%	11.9	1.87	48.3%	51.7%	0%	0

<sup>14</sup>In similar spirit, Taylor (1994) shows that failure to protect foreign patents reduces R&D by causing innovators to use inferior technologies. Aoki and Prusa (1993) find that discriminatory protection based on where a firm is located may decrease R&D.

<sup>15</sup>Rewards exceed costs by 144 for these parameters (at  $\kappa = \bar{\kappa} = 0.572$ ).

The Southern labor constraint is

$$[(1 + \kappa)\gamma a_S + a_F]\iota + \left(\frac{n_F}{\lambda} + \frac{n_S}{\zeta}\right)E = L_S. \tag{48}$$

The valuation condition for innovation is

$$E\left(1 - \frac{w}{\lambda}\right) = wa_N\rho. \tag{49}$$

The valuation condition for imitation of multinationals is

$$En_S\left(1 - \frac{1}{\zeta}\right) = (1 + \kappa)\gamma a_S(\rho n_S + \iota). \tag{50}$$

The valuation condition for adaptation is

$$En_F\left(1 - \frac{\zeta}{\lambda}\right) = (a_F + wa_N)(\rho n_F + \iota), \tag{51}$$

where  $\iota = \iota_N n_S = \phi = \iota_F n_N = \mu = \iota_S n_F$  is the rate of innovation, which equals the flow of FDI and the rate of imitation, and  $n_{SF} = n_S$  for notational ease. The valuation condition for imitation targeting a Northern firm’s product (22) must be an inequality, with *rewards less than costs*.<sup>16</sup> We solve the innovation valuation condition for the relative wage, so the remaining system determines  $\{E, \iota, n_F, n_S\}$ .

Using comparative statics techniques, we find that an increase in Southern IPR protection decreases the rate of innovation

$$\frac{\partial \iota}{\partial \kappa} = \frac{\partial \phi}{\partial \kappa} = \frac{\partial \mu}{\partial \kappa} = - \frac{\iota n_S(1 + \theta)}{\left(n_S + \frac{n_F}{\lambda}\right)(1 + \theta) + \theta n_F\left(1 - \frac{\zeta}{\lambda}\right)} < 0. \tag{52}$$

Since the rate of innovation and the flow of FDI are one in the same, FDI flows decrease as well. Using the measure of multinational production as the extent of FDI yields the same result: the extent of FDI declines

$$\frac{\partial n_F}{\partial \kappa} = \frac{n_F}{\iota} \left(1 - n_F \frac{\zeta}{\lambda} + \frac{n_F}{\lambda}\right) \frac{\partial \iota}{\partial \kappa} < 0. \tag{53}$$

Again, here any force that reduces the rate of imitation also reduces the rate of innovation because they are equal. Now, the flows of FDI also equal these rates and thus also decline.<sup>17</sup> So regardless of the equilibrium considered, stronger Southern IPR protection reduces FDI (if it is present) and innovation.<sup>18</sup>

Table 3 shows equilibria with only the FDI product cycle that arise for low values of  $\kappa < \underline{\kappa}$ . For  $\kappa = \underline{\kappa}$ , the reward to imitation targeting the product of a

<sup>16</sup>Rewards exceed costs by 10.7 for these parameters (at  $\kappa = \underline{\kappa} = -0.388$ ).

<sup>17</sup>Markusen (2001) examines the effects of Southern IPRs on FDI, but does not model R&D.

<sup>18</sup>The numerical solutions do indicate that an increase in  $\kappa$  may increase  $\iota$  at the boundary  $\kappa = \underline{\kappa}$  which switch equilibria from FDI only to having both product cycles.

Table 3  
Only FDI product cycle

$\kappa$	$\iota$	$\eta$	$E$	$w$	$n_N$	$n_S$	$n_F$	$\phi$
-1	1.000	0%	19.2	3.88	0%	0%	100%	1.000
-0.8	0.716	0%	18.9	3.88	18.0%	9.1%	72.8%	0.716
-0.6	0.555	0%	18.7	3.88	28.6%	14.4%	57.0%	0.555
-0.388	0.452	0%	18.6	3.88	35.4%	17.9%	49.7%	0.452

Northern firm exceeds its costs according to the valuation condition (22), so higher levels of  $\kappa \geq \underline{\kappa}$  do not support an equilibrium with only the FDI product cycle — the imitation cycle also emerges. When Southern IPR protection is the weakest ( $\kappa = -1$ ), all products are produced by multinationals in the South.

## 5. Conclusion

This paper examines the effect of strengthening Southern IPR protection on the imitation exposure of multinationals relative to Northern firms, the composition of international technology transfer, FDI, innovation and imitation. Given the lively policy debate on these issues (see Maskus, 2000), our analysis has more than theoretical interest.

We focus on the case where FDI and imitation both serve as channels of international technology transfer, but Southern IPR protection crowds out FDI and innovation even when only one channel is present. In our model, stronger IPR protection in the South makes multinationals no more secure from imitation relative to Northern firms. Furthermore, by making imitation more costly, stronger Southern IPR protection forces the South to spend more resources for a given probability of imitation success. The scarce resources drawn into imitation in the South leave fewer resources for production, causing FDI to contract — a *resource wasting effect* that acts like a reduction in the Southern labor supply. The resources drawn into production in the North due to less FDI then leave fewer resources for innovation, causing innovation to contract as well. There is also an *imitation disincentive effect* that acts like a tax on imitation by making imitation more costly.

Past work by Helpman (1993) and Lai (1998) assumed stronger Southern IPR protection caused an exogenous reduction in the intensity of imitation. Since imitation was assumed to be costless, no resource wasting effects resulted — no labor was absorbed into imitation because no labor was needed for imitation. In contrast, we assume stronger Southern IPR protection raises the cost of imitation, which then causes the intensities of imitation to fall. However, we show that more labor is used in imitation, which crowds out FDI and consequently reduces innovation. Our model has the property that the effect of strengthening Southern

IPR protection on the rate of innovation does *not* depend on whether FDI or imitation is the channel of international technology transfer.

Several related topics beg for further research. Firstly, a varieties product cycle model with endogenous innovation, imitation, and FDI would be useful for determining which, if any, of our results depend on the quality ladders framework. Secondly, a product cycle model with FDI should be modified to remove the scale effect (innovation increasing with the labor supply) to see how the results change. Thirdly, trade restrictions should be added to consider how they affect the transfer of technology across countries. Fourthly, more work could be done to capture the full complexity of a country's IPR policy and thus derive further insights regarding policy alternatives. Finally, how Southern IPR protection affects internalization — whether Northern firms choose to license their technologies or opt for FDI — should be addressed.<sup>19</sup> Nevertheless, the model constructed here sheds new light on the complex inter-relationships between innovation, imitation, and FDI.

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<sup>19</sup>For an analysis of how IPR protection affects economic growth when licensing serves as the channel of technology transfer, see Yang and Maskus (2001). Glass and Saggi (2001) model policy toward FDI when licensing is an alternative.

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