International Intellectual Property Rights Protection and the Rate of Product Innovation

by

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Abstract

Using a dynamic general equilibrium model of the international product cycle, we found that the effects of strengthening intellectual property rights protection (IPP) in South depend crucially on the channel of production transfer from North to South. Stronger IPP in South increases the rate of product innovation, production transfer and Southern relative wage if foreign direct investment is the channel of production transfer, but has opposite effects if production is transferred through imitation. Stronger IPP can be more broadly interpreted as any incentive given by South to encourage Northern FDI.

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1 Introduction

According to the terms of the Uruguay Round of the General Agreement on Tariffs and Trade, less developed countries (LDCs, hereinafter called the 'South') are required to strengthen intellectual property rights protection (IPP) in their countries. To economists who are concerned with long-term economic growth, the immediate questions are: What are the long-term repercussions of this on global rate of technological progress, technology diffusion and world distribution of income between the 'North' (the more advanced countries) and 'South'? As pointed out by Helpman (1993), if the rate of innovation is exogenous, it is quite clear that LDCs stand to lose from stronger IPP, since both the terms of trade and efficiency effects go against the welfare of the LDCs. He also finds that the steady state rate of innovation will be decreased as IPP is strengthened, provided that imitation is the only channel by which production is transferred to South. However, when he allows for the possibility of foreign direct investment (FDI) from North to South as a channel of production transfer, Helpman only deals with exogenous rate of innovation.

We think it is important to investigate the long-term effects of Southern IPP on the global rate of innovation and technology diffusion. Recently, there has been various attempts to model the long-term effects of IPP on the rate of product innovation, economic growth and terms of trade in the international product cycles (Vernon, 1966). Segerstrom, Anant and Dinopoulos (1990) find that a lengthening of patent duration for Northern firms lowers the rate of product innovation. Grossman and Helpman (1991b) and Helpman (1993) find that strengthening IPP (or subsidy to imitation) in South has a negative effect on the rate of innovation when imitation is the only channel of international production transfer. In these three models, where R&D output is linear in research effort, and imitation is the only channel by which production is transferred to South, there is a positive feedback from the rate of imitation to the rate of innovation. As a result, a strengthening of IPP lowers the rate of innovation and the rate of production transfer.[1] All these results seem to go against the intuition furnished by Schumpeter (1942) and his followers (such as Romer, 1991) that stronger protection of the fruit of R&D should encourage innovation.

[1] In a paper where a 'quality ladder' model is employed for the analysis, Grossman and Helpman (1991a, or Chapter 12 of 1991c) find similar result in the 'inefficient follower' case, viz. a reduction in the cost of Southern imitation increases the rate of innovation in North. In the 'efficient follower' case, where there is no positive feedback from the rate of imitation to the rate of innovation, subsidy to Southern imitation (which can be viewed as a weakened IPP) reduces the Northern rate of innovation (G-H, 1991c, p.323), a result similar to ones in this paper.

The principal objective of this paper is to compare and contrast between the cases when (i) FDI and (ii) imitation is the channel of international production transfer, with respect to the long-run effects of IPP on rate of product innovation, rate of international production transfer and world income distribution. For the present endeavor, we adopt the 'product cycle' (Vernon, 1966 or Krugman, 1979) paradigm that North is the only source of innovation, and the only way South can acquire technology is through 'technology transfer' from North. We modify the model of Grossman and Helpman (1991b) and Helpman (1993), which study the North-South product cycle where South can only acquire new technology by imitating products produced in North. Our modifications are (i) to allow Northern firms to undertake FDI in South (a process called 'multinationalization'); and (ii) assume that, in the 'multinationalization' regime, Southern firms can imitate only after Northern firms transfer production to South.[2]

We find that the effects of IPP in South depends crucially on whether imitation or multinationalization (prior to imitation) is the channel of international production transfer from North to South. If *imitation* is the channel of production transfer, stronger IPP lowers the rate of innovation, rate of production transfer and wage of South relative to North; if *multinationalization (prior to imitation)* is the channel of production transfer, IPP *has exactly the opposite effects*. In fact, the latter effects hold even when both channels co-exist, as long as the rate of multinationalization is sufficiently large.

The first scenario mentioned in the last paragraph is that described in Grossman and Helpman (1991b) and Helpman (1993). According to this scenario, production is transferred to South only through imitation of goods produced in North. There are two counteracting effects of enforcing stronger IPP in South. First, it lowers the rate of imitation and prolongs the expected duration of monopoly of each Northern innovator. This raises the returns to innovation. Second, since firms produce longer in North, it raises the demand for Northern labor and Northern wage, and hence raises the cost of innovation. Thus, it lowers the profits from innovation at each date. As shown by Grossman and Helpman, it turns out that the the second effect dominates the first one, and the rate of innovation declines. The contribution of the present paper lies mainly in the analysis of the second scenario described in the last paragraph. Under this scenario, production is transferred internationally through multinationalization (prior to imitation). Northern firms move production to South to take advantage of the lower wage, which they balance against the probability that they will lose

[2] We shall maintain the assumption that R&D output is linear in research effort.

their monopoly to imitators after multinationalization. A stronger IPP in South increases the rate of innovation in two stages. First, it increases the expected lives of monopolies. However, because the resulting increase in demand for labor falls entirely on South, the return to innovation rises without a rise in cost. Second, since the return to multinationalization increases, firms will move more quickly to South. This lowers the demand for Northern labor, Northern wage, and costs, thus increasing the return to innovation further.

Section 2 presents a benchmark product cycle model with FDI as the channel of production transfer to South. Section 3 presents the reduced form equilibrium conditions and investigates the effects of IPP. Section 4 presents the case where imitation is the channel of production transfer. Section 5 concludes and discusses some caveats and extensions.

2 The Product Cycle Model with Foreign Direct Investment

In this paper, we are only concerned with the steady state, i.e. the long run equilibrium. For the present purpose, we are not interested in welfare analysis in transition. We define steady state as a state at which the growth rate of the economy is constant over time, generally termed the 'balanced growth path.'

There are two countries (North and South) in the world, where free trade is allowed. A Northern firm develops a product by incurring an upfront innovation cost. It then earns the opportunity to make a stream of future profits. There is infinite patent life in North and the South, but patent law enforcement in North is perfect while enforcement in South is imperfect. Therefore, there is no imitation by Northern firms, and imitation only occurs in South. It is assumed that imitation is costless. It is assumed that the efficiency of Southern labor in innovation is so much lower than that of North that, in equilibrium, only Northern firms will innovate.

There is only one factor input, labor. It is used for research and development (R&D) and production in North and for production only in South. At any instant, a number of differentiated products (denoted by n) have been developed by North. Each innovation takes the form of the introduction of a new differentiated product in the economy by a firm. In equilibrium Northern firms will transfer production to South through FDI, a process we call 'multinationalization', since wage is lower in South. In this paper, we do not differentiate between multinationalization through wholly owned subsidiary, partly owned subsidiary or technology licensing. We assume that under perfect foresight all three forms of production transfer yield the same gain to Northern innovator. Hereinafter, we speak of multinationalization as the setting up of a multinational corporation (MNC) by a Northern firm. Since Southern wage is lower, the Nothern firm will stop production in the North once it has multinationalized production.

In this section, we assume that multinationalization (prior to imitation) is the only form of production transfer to South. In other words, a product will not be imitated until its production has been multinationalized by the innovator. We assume that after production is transferred to South (by multinationalization or otherwise), the unit labor requirement for production in South is the same as that in North. The only motivation for production transfer is the lower production cost in South. In Section 4, we shall investigate the case where imitation is the channel of production transfer to South.

2.1 The Demand for goods

Following Grossman and Helpman (1991b), we assume there is a world representative agent (or, alternatively, one representative agent in each country) who chooses instantaneous expenditure $E(\tau)$ to maximize intertemporal utility at time t:

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

subject to the intertemporal budget constraint [3]

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

where $0 \leq \sigma \leq 1$ and σ = intertemporal elasticity of substitution; ρ is the time rate of preference; r is the nominal interest rate ; $U(\tau)$ is instantaneous utility at time τ ; $E(\tau)$ is instantaneous expenditure at τ ; $I(\tau)$ is instantaneous income at τ ; $A(t)$ is the current value of assets at t. At each date τ, the agent takes $A(\tau)$, $I(\tau)$, r and prices of goods as given.

It is also assumed that, at any time t, the instantaneous utility[4] is

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

[3]The 'flow equation' implied from the 'stock equation' shown here is $I(t) - E(t) + rA(t) = \dot{A}(t)$.

[4]Alternatively, $U(\tau)$ can be regarded as quantity of final goods produced from a set of intermediate goods, with production function (3).

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

The dynamic optimization problem specified by (1) and (2) can be reduced to a two-stage budgeting problem, where the agent solves a dynamic optimization problem of allocating $E(t)$ over time, then solves a static optimization problem of choosing the various $x(z)$ subject to a budget constraint of $E(t)$ at time t.

It is shown in Appendix A that the dynamic optimization problem has a solution which yields the equation:

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

where $\frac{\dot{E}}{E}$ is the growth rate of total expenditure on goods. Equation (4) implies that the more people discount the future, the higher the interest rate needs to be to maintain the amount of savings to sustain the same growth rate of expenditure. Define $\frac{\dot{n}}{n} = g$ in steady state. We normalize by setting $\frac{\dot{E}}{E} = \frac{\dot{n}}{n}$.[5] Hence, equation (4) becomes $r = \rho + \phi g$, where $\phi = 1-(1-\sigma)(\frac{1-\alpha}{\alpha}) \leq 1$. We assume that $\alpha \geq 1-\sigma$ (which will include the case of logarithmic utility in the intertemporal utility function stated in equation (1)) so that $0 \leq \phi \leq 1$. This will ensure the stability of the general equilibrium.[6]

The static optimization problem of the two-stage budgeting problem is:

$$\max_{x(z)} \quad U(t)$$

s. t.

$$\int_0^n x(z)p(z)dz = E(t). \tag{5}$$

We hereafter drop the time argument t for convenience, unless otherwise stated.

The standard solution to the static maximization problem (5) leads to

$$x(z) = \frac{p(z)^{-\epsilon}}{\int_0^n p(u)^{1-\epsilon}du}E \tag{6}$$

where $\epsilon = \frac{1}{1-\alpha}$ is the elasticity of substitution between any two goods, and $\epsilon > 1$.

We assume constant returns to scale production technology, and that the unit labor requirement for production is the same in both countries and for all goods. Due to the

[5] It can be shown that this is equivalent to setting the market value of each firm to one at each date.

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

symmetry of all goods in the preference function (3), $x(z)$ is the same for all goods produced in the same country.

2.2 The Steady State

At time t, there are n goods existing in the world, among which n_s goods have been multinationalized and n_N goods continue to be produced in North. Therefore, $n = n_s + n_N$. Moreover, $n_s = n_i + n_m$ where n_i = number of products imitated by South; n_m = number of products produced by Northern MNCs. Because of symmetry of all goods in the demand function, x_N stands for the demand for any good produced by a Northern firm, while x_m stands for the demand for any good produced by a Northern subsidiary (MNC) in South. The variables x_N and x_m are determined by demand function (6) when the prices of the n goods are known. Because transportation cost is zero and there are no trade barriers, the producer of a good always sells to the world market. Let π_N be the instantaneous profit of a Northern firm, and π_m be that of a MNC whose product has not been imitated at that instant. Wage rates in North and South are denoted by w_N and w_s respectively.

On the 'balanced growth path', $\frac{\dot{n}_s}{n_s} = \frac{\dot{n}_i}{n_i} = \frac{\dot{n}_m}{n_m} = \frac{\dot{n}}{n} = \frac{\dot{E}}{E} = g$, and $g, \frac{n_s}{n}, \frac{n_i}{n}$ and $\frac{n_m}{n}$ are constant over time. It can be deduced from (6) to (8) and symmetry of all $x(z)$ in the utility function that at steady state, π_N and π_m are constant over time. L_s and L_N are the exogenous supply of labor in South and North respectively.

2.3 Innovation and International Technology Transfer

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

Assume for simplicity that each product is developed and produced by a different firm.[7] Firms compete with each other by setting prices. Assuming time separability of the intertemporal profits function, an innovator firm or MNC producing good z chooses price $p(z)$, given the prices of other goods, to maximize instantaneous profit $\pi(z)$, subject to the demand function (6). Therefore, a Northern firm or its subsidiary in South solves

[7] It is not necessary to have all products developed by different firms, but it is necessary to have sufficiently large number of firms so that we can ignore the effects of any single producer's action on the denominator of demand function (6).

$\max_{p(z)} \quad \pi(z) = x(z)[p(z) - c(z)]$ subject to the demand function (6), where $c(z)$ is the per unit production cost of good z.

Thus, we obtain from the first order condition the mark-up pricing rule for a Northern innovator or an MNC (Dixit and Stiglitz, 1977)

$$p(z) = \frac{c(z)}{\alpha} \tag{7}$$

The market power of a Northern firm or its subsidiary can be maintained as long as its IPR are protected. The North offers full IPP, while the South only offers partial IPP. Once a product is imitated (by Southern firms), no firms producing that product have any market power, and its price will be driven down to marginal cost, and no firms can make any profits from selling that product.

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

$$c(z) = w \tag{8}$$

where w = wage rate in the country where production of good z takes place.

Differentiating (5) with respect to time, invoking demand equation (6), mark-up pricing equation (7) and production cost function (8), and imposing the steady state condition $\frac{\dot{E}}{E} = \frac{\dot{w}}{w}$, it can be shown that the steady state growth rate of utility $\frac{\dot{U}}{U} = (\frac{1-\alpha}{\alpha})g = (\frac{1-\alpha}{\alpha})\frac{\dot{E}}{E}$.

2.3.1 Innovation, Multinationalization and Imitation

We define the (Poisson arrival) rate of imitation by Southern firms from MNCs as $\frac{\dot{n}_i}{n_m}$, denoted by $i\delta$; and the (Poisson arrival) rate of multinationalization as $\frac{\dot{n}_s}{n_N}$, denoted by ω. The rate $i\delta$ is the 'hazard rate', i.e. the probability that a multinationalized product will be imitated at the next instant. Similarly, ω is the 'hazard rate' at which a North-produced product will be multinationalized in the next instant.[8] The rate of multinationalization ω is

[8] If we assume the duration τ between the time of multinationalization and time of imitation to have an exponential distribution with cumulative density $Pr(\tau \leq t) = 1 - e^{-i\delta t}$, then $i\delta$ is the 'hazard rate' or Poisson arrival rate at which a good will be imitated in the next instant provided that it has not been imitated. Similarly, the cumulative density function of $\hat{\tau}$, the duration between the time of innovation and time of multinationalization, is given by $Pr(\hat{\tau} \leq v) = 1 - e^{-\omega v}$ where ω is the Poisson arrival rate at which the product will be multinationalized in the next instant. See also Helpman (1993) for a discussion of 'hazard rate'.

endogenous, based on optimization of Northern firms, as shown below. The rate of imitation δi is composed of two parts. i is assumed to be exogenously determined by technology (i.e. by how quickly the technology can be reverse engineered given the complexity of the technology); while δ is a policy parameter determined by Southern authority. A smaller δ reflects a stronger IPP. When $\delta = 0$, patent law enforcement is perfect. When $\delta = 1$, there is no enforcement of patent laws. We can interpret this as follows. Of all attempts to imitate, only a fraction δ successfully slip through the surveillance of the patent authority in the South. In this case, a smaller δ means weaker criteria in convicting violators of patents in South. An alternative interpretation is that Southern authority will enforce patent laws in a fraction δ of illegally imitated products. All firms that is not imitated have equal chance of being imitated at any date. Therefore, all MNCs face the same $i\delta$. The fractions δi and ω are both constant over time in steady state.

Knowing $i\delta$, a Northern firm will decide whether or not to multinationalize at each date. There is symmetry among all Northern firms. At any date, the equilibrium value of ω is the one that leaves all Northern firms indifferent between multinationalizing and continuing production in North. If ω is below the equilibrium value, the PDV of profits from multinationalizing is higher than that from continuing production in the North for each firm. Thus, more Northern firms transfer their production to South, leading to an increase of ω. If ω is above the equilibrium value, there are gains from moving production back to the North. As some firms move back to the North to seek higher profits, ω decreases. Therefore, ω is a stable equilibrium.[9]

The Cost of Innovation

Following Grossman and Helpman (1991b), the cost of innovation (product development) by a Northern firm is assumed to be

$$C_d = a_d \frac{w_N}{n} \tag{9}$$

where a_d is the cost parameter of innovation, $\frac{1}{n}$ captures the spillover effect of knowledge generated from past innovation on efficiency of current innovation. In other words, the efficiency of product development in North increases with n, which is a proxy for the cumulative

[9]There are other reasons for Northern firms to produce in North, where production cost is higher. For example, Vernon (1966) suggested that production needs to stay in North in the standardization period, when the product design, inputs, and production process need to be standardized for large scale, more mechanized production. However, if all multinationalization decisions are due to technological factors, such as this one, then ω would be exogenous.

knowledge generated as by-products of all past innovations in North (Romer, 1990).

Imitation

We assume that there is zero cost of imitation. Once a product is imitated, it will be sold at marginal cost. That is, the price of a South-imitated product is $p_s = w_s$. This is because price competition between the MNC and the imitator(s) will drive price down to marginal cost. The imitator hires from the same pool of labor as the MNC. Since all firms face the same cost of labor, the MNC loses all profits once the product is imitated.

2.3.2 Pricing Strategy of Northern Firms and MNCs

When production location is in North, a Northern innovator-producer firm prices at the monopoly level according to (7) and (8), so that the price of a Northern good is

$$p_N = \frac{w_N}{\alpha}. \tag{10}$$

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

$$p_m = \frac{w_s}{\alpha} \tag{11}$$

The demand function (6), production cost function (8), and mark-up pricing rules (10), (11) show that the profit of the MNC, π_m, and that of a Northern firm, π_N, are related by

$$\frac{\pi_m}{\pi_N} = (\frac{w_s}{w_N})^{1-\epsilon} \tag{12}$$

In equilibrium, it must be true that $\frac{w_s}{w_N} < 1$, otherwise there is no incentive to shift production location to South. Since $\epsilon > 1$, it must be true that $\pi_m > \pi_N$ in equilibrium. It is shown below that this must be true in equilibrium.

2.3.3 Multinationalization Equilibrium

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

$$\Pi_m = \frac{\pi_m}{r + i\delta} \tag{13}$$

For more detailed derivation and interpretation of the equation, refer to Appendix B and Lee and Wilde (1980).

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

$$\frac{\pi_N}{\pi_m} = \frac{r}{\delta i + r} \tag{14}$$

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

2.3.4 Northern Free Entry Condition

Finally, free entry and profit maximization of Northern firms imply that the expected PDV of profits in the future must be equal to the cost of innovation in steady state equilibrium. Therefore,

$$\frac{\pi_N}{r} = \Pi_N = \frac{a_d}{n} w_N \tag{15}$$

3 Solution of the Model

3.1 Reduced Form Equations in Steady State

In this section, we want to find the reduced form of (i) Northern free entry condition and (ii) multinationalization equilibrium in terms of two variables, g and ω. Then we shall be able to find the effects of changes in the parameters on g, ω and other endogenous variables. Because unit labor requirement for all goods is one, as shown in (8), and price is constant mark-up over cost as shown in (10) and (11), we have $\pi_m = x_m(p_m - w_s) = x_m w_s(\frac{1-\alpha}{\alpha})$ where $x_m = \frac{L_m}{n_m}$ and L_m is the quantity of labor hired by MNCs (for production) in South; Similarly, $\pi_N = x_N w_N(\frac{1-\alpha}{\alpha})$ where $x_N = \frac{L_N^p}{n_N}$ and L_N^p = quantity of labor devoted to production in North.

Hence, we have

$$\pi_m = \frac{L_m}{n_m} w_s (\frac{1-\alpha}{\alpha}) \tag{16}$$

$$\pi_N = \frac{L_N^p}{n_N} w_N (\frac{1-\alpha}{\alpha}) \tag{17}$$

From Appendix C, it can be shown that

$$L_m = \frac{L_s}{\frac{\delta i}{g}\alpha^{-\epsilon} + 1} \tag{18}$$

In North the quantity of labor devoted to R&D is equal to $a_d \frac{\dot{n}}{n} = a_d g$ at each date. Therefore,

$$L_N^p = L_N - a_d g \tag{19}$$

Moreover, it can be shown that in steady state[10]

$$\frac{n_s}{n_N} = \frac{\omega}{g} \quad \text{and} \quad \frac{n}{n_N} = \frac{\omega}{g} + 1 \quad \text{and} \quad \frac{n_m}{n_N} = \frac{\omega}{g + i\delta} \tag{20}$$

Divide (17) by (16), and, in the resulting equation, substitute for $\frac{w_s}{w_N}$, $\frac{\pi_m}{\pi_N}$, L_m, L_N^p and $\frac{n_m}{n_N}$ from (12), (14), (18), (19) and (20) respectively, we obtain the reduced form of the multinationalization equilibrium in terms of g and ω:

$$[\frac{\omega}{g}(\frac{g + i\delta\alpha^{-\epsilon}}{g + i\delta})(\frac{L_N - a_d g}{L_s})]^\alpha = \frac{r}{\delta i + r} \tag{21}$$

To obtain the reduced form of Northern free entry condition in terms of g and ω, we invoke (15), (17), (19) and (20) to obtain

$$(\frac{1-\alpha}{\alpha})(L_N - a_d g)(\frac{\omega}{g} + 1) = a_d r \tag{22}$$

Therefore, we have obtained two equations (21) and (22) in two unknowns g and ω. We are now ready to carry out the comparative steady state analysis concerning the two variables.

3.2 Comparative Steady States Analysis

If we express $\frac{\omega}{g}$ in terms of g from (22) and substitute the expression into (21), we obtain

$$[(\frac{g + i\delta\alpha^{-\epsilon}}{g + i\delta})(\frac{a_d r(\frac{\alpha}{1-\alpha}) - L_N + a_d g}{L_s})]^\alpha = \frac{r}{\delta i + r} \tag{23}$$

[10]By definition, $\frac{n_s}{n_N} = \frac{n_s}{n - n_s} = \frac{\dot{n}_s}{n - n_s}(\frac{n_s}{\dot{n}_s}) = \frac{\omega}{g}$ in steady state. Moreover, $\frac{n_m}{n_N} = (\frac{n_m}{n_s})(\frac{n_s}{n_N})$. By definition, $\dot{n}_i = n_m i\delta$, which implies that $n_i g = n_m i\delta \Rightarrow \quad (n_s - n_m)g = n_m i\delta \Rightarrow \quad \frac{n_m}{n_s} = \frac{g}{\delta i + g}$. Hence, $\frac{n_m}{n_N} = \frac{\omega}{\delta i + g}$.

where $r = \rho + \phi g$. It must be true that $L_N > a_d \rho \frac{\alpha}{1-\alpha}$ if North can sustain positive growth as a closed economy.[11] It is demonstrated in Appendix D that an increase in g leads to an increase in $\frac{LHS}{RHS}$ of the above equation.[12] On the other hand, an increase in δ leads to an increase in $\frac{LHS}{RHS}$ of the equation. It follows, from the implicit function theorem, that a decrease in δ leads to an increase in g. That is, a strengthening of IPP in South increases the rate of innovation in North. Moreover, from (22), an increase in g corresponds to an increase in $\frac{\omega}{g}$, which implies that ω must also increase. That is, the rate of multinationalization also increases with stronger IPP in South.

The intuition is as follows. Northern firms move production to South to take advantage of the lower wage, which they balance against the probability that they will lose their monopoly to imitators after multinationalization. A stronger IPP in South increases the rate of innovation in two stages. First, it increases the expected lives of monopolies. However, because the resulting increase in demand for labor falls entirely on South, the return to innovation rises without a rise in cost. Second, since the return to multinationalization increases, firms will move more quickly to South on the average (rate of multinationalization increases). This lowers the demand for Northern labor, Northern wage, and costs, thus increasing the return to innovation further.

Relative Wage between North and South

From (12) and (14),

$$\frac{w_s}{w_N} = (\frac{\pi_N}{\pi_m})^{\frac{1}{\epsilon-1}} = (\frac{\rho + \phi g}{i\delta + \rho + \phi g})^{\frac{1}{\epsilon-1}} \tag{24}$$

A decrease in δ leads to an increase in g, both leading to an increase in the relative wage in South. An increase in IPP leads to more production shifted to South, increasing the demand for Southern labor. Therefore, an increase in IPP leads to an increase in relative wage (or terms of trade) of South.

Result 1 *Stronger IPP leads to higher rate of innovation, higher rate of production transfer from North to South and higher wage of South relative to the North if multinationalization is the channel of international production transfer.*

[11] Without production transfer to South, the equilibrium condition in North is $\frac{1-\alpha}{\alpha}(L_N - a_d g) = a_d(\rho + \phi g)$, which implies that $L_N > a_d \rho \frac{\alpha}{1-\alpha}$

[12] LHS = left hand side; RHS = right hand side.

It might be argued that the imitated products can only be sold in South since the products violate the patent laws of the North. In that case, an MNC loses its profits only in the Southern market when its product is imitated, and its profits in North are preserved. It is shown in an appendix, available from the author upon request, that the qualitative aspects of the results are preserved even with this modification.

4 Imitation as the Channel of Production Transfer

This section is essentially G-H's (1991b) model adapted to the environment of this paper. We now modify the model specified in Sections 2 and 3. Assume that instead of FDI, imitation is the only channel of production transfer from North to South. Let the (Poisson arrival) rate of imitation from North-produced products be $j\delta$. Since there is no multinationalization, $\omega = 0$, and $n_m = 0$. Therefore, the total number of goods imitated is n_s. Hence, $j\delta = \frac{\dot{n}_s}{n_N}$. In steady state, $g = \frac{\dot{n}_s}{n_s}$. Also, $n = n_s + n_N$ continues to hold. By the same token as before, we can derive the Northern free entry condition as

$$\frac{\pi_N}{j\delta + r} = \Pi_N = \frac{a_d}{n} w_N$$

the reduced form of which is

$$(\frac{1-\alpha}{\alpha})(L_N - a_d g)(\frac{j\delta}{g} + 1) = a_d(\rho + \phi g + j\delta) \tag{25}$$

since $\frac{n}{n_N} = \frac{n_s}{n_N} + 1 = \frac{j\delta}{g} + 1$.

This equation is the same as the NN curve is Grossman and Helpman (1991b). Since discount must dominate growth in order for the intertemporal budget to be finite, it must be the case that $r > g$. Therefore, $\frac{\partial}{\partial \delta}(\frac{r+j\delta}{g+j\delta}) < 0$. It follows from (25) that a decrease in δ will *decrease* g. Hence, a stronger IPP in South leads to *lower* rate of product innovation in North, as in Grossman and Helpman (1991b) and Helpman (1993).

The intuition for the above result is: If South can only acquire technology by imitation of goods produced in North, there are two counteracting effects of enforcing stronger IPP in South. First, it lowers the rate of imitation and prolongs the expected duration of monopoly of each Northern innovator. This raises the returns to innovation. Second, since firms produce longer in North, it raises the demand for Northern labor and Northern wage and hence raises the cost of innovation. Thus, it lowers the profit from innovation at each date.

As shown by Grossman and Helpman, it turns out that the second effect dominates the first one (as r is necessarily greater than g), and the rate of innovation declines.

Relative Wage between North and South

Let x_s be the demand for a good produced by a Southern imitator. According to (6) and $p_s = w_s$, the demand for goods produced in South relative to that of North is

$$\frac{x_s}{x_N} = (\frac{w_s}{w_N/\alpha})^{-\epsilon}$$

Since $L_s = n_s x_s$, and $L_N = n_N x_N$, and $\frac{n_s}{n_N} = \frac{j\delta}{g}$, it can be easily shown that

$$\frac{w_s}{w_N} = (\frac{L_s}{L_N}\frac{g}{j\delta})^{-\frac{1}{\epsilon}}\frac{1}{\alpha}.$$

From (25), a decrease in δ leads to a decrease in g, which in turn leads to a decrease in $\frac{j\delta}{g}$. It follows that $\frac{w_s}{w_N}$ decreases. Therefore, $\frac{w_s}{w_N}$ decreases as IPP is strengthened, a result opposite to that obtained in Section 3. Here, since imitation is the only channel of production transfer to South, stronger IPP in South lowers the number of products produced by South and hence lowers the demand for Southern labor, leading to lower relative wage of South.

Result 2 *Stronger IPP leads to lower rate of innovation, lower rate of production transfer from North to South and lower wage of South relative to the North if imitation is the channel of international production transfer.*

The summary of Results 1 and 2 is shown in the following table:

Table 1: Effects of Stronger IPP

	Channel of Production Transfer	
	Multinationalization	Imitation
Rate of Innovation	**increase**	**decrease**
Rate of Prod. Transf.	**increase**	**decrease**
Relative wage of S.	**increase**	**decrease**

In Appendix E, we show the more general case that both imitation and multinationalization (prior to imitation) are channels of production transfer at the same time. Assuming that IPP is enforced to the same degree before or after multinationalization, it is shown that a stronger IPP has the impact as shown in the middle column of Table 1 when the rate of multinationalization is sufficiently large ($\omega \geq \rho$) or the rate of imitation (prior to multinationalization) is small. Therefore, we have

Result 3 *If both imitation and multinationalization are channels of production transfer, stronger Southern IPP leads to higher rate of innovation in the North, higher rate of production transfer to the South and higher Southern relative wage as long as the rate of multinationalization is sufficiently high or the rate of pre-FDI imitation is small.*

5 Conclusion

The effects of IPP in South depends crucially on whether imitation or multinationalization (prior to imitation) is the channel of international production transfer from North to South. If imitation is the channel of production transfer, stronger IPP lowers the rate of innovation, rate of technology transfer and wage of South relative to North; if multinationalization is the channel of production transfer, IPP has exactly the opposite effects. The latter results hold even when both channels co-exist, as long as the rate of multinationalization is sufficiently large or the rate of imitation (prior to multinationalization) is sufficiently small. Therefore, the literature which focuses on imitation as the sole channel of production transfer from North to South can lead to misleading implications. The consequence of changes that increase the rate of Southern imitation of Northern goods on global economic growth, international technology diffusion and world income distribution can be very different from what this literature predicts.

Although our analysis has focused on the effects of IPP in the South, we can actually interpret IPP more broadly as any incentive given by South to encourage Northern FDI. Interpreted this way, our theoretical results can be tested empirically in a variety of situations.

We have abstracted from other key factors that affect the rate of multinationalization from North to South. For example, the rate of standardization of technology will constrain the rate of FDI, since a production can only be readily transferred to another country after the inputs, designs, etc. have been standardized in the home country, as suggested by Vernon (1966). Also, (the fear of) trade barriers such as tariffs and quotas imposed by another country will accelerate the rate of multinationalization of a production, as in the case of Japanese motorcycle firms setting up in Taiwan, or US and Japanese firms setting up in the European Union before its establishment.

There are some other important caveats. First, we have used a general equlibrium model with one 'knowledge-intensive' production sector. We have assumed that labor supply is constant in this sector in both North and South. Because of the absence of a non-knowledge-intensive sector, we cannot account for the effects of IPP on resource allocation between the knowledge-intensive and non-knowledge-intensive sectors, which will have repercussions on the rate of innovation and production transfer. This should be the goal of our next research. Second, we have not looked at the effects of IPP on the welfare of South, which is certainly a concern of policy-makers. Third, and not the least, the use of a product cycle ignores the possibility of endogenous innovation taking place in South. Our intuition is that a stronger IPP in South should encourage domestic innovation while discourage domestic imitation in South. It will be interesting to find out the effects of IPP on both the rate of imitation and innovation in South in a more general model where Southern firms choose between imitation and innovation.

There are several possible extensions of the paper in future work. First, we can make imitation costly, and, consequently, profitable in equilibrium. Second, for realism, we should capture the likely outcome that multinationals bear higher labor cost than local firms, though lower cost than firms in North. Third, multinationalization is a risky business when compared with production in North, and so there should be a risk premium associated with FDI. Fourth, both Northern firms and multinationals may face the risk of imitation. The imitation costs should be different in the two cases. An increase in IPP, which increases imitation costs, would likely affect the rate of innovation, total rate of production transfer, etc. in more interesting ways.

Appendix

A Derivation of Equation (4)

From (3) and symmetry of all goods,

$$U = (nx^{\alpha})^{\frac{1}{\alpha}} = n^{\frac{1}{\alpha}}x = n^{\frac{1}{\alpha}}\frac{E}{np} = n^{\frac{1-\alpha}{\alpha}}\frac{E}{p} \tag{26}$$

The current value Hamiltonian to the dynamic optimization problem (1) and (2) is

$$H = \frac{U^{1-\sigma}-1}{1-\sigma} + m[I(t) - E(t) + rA(t)]$$

where m is the current value Lagrangian multilpier. The first order condition is therefore

$$H_E = U^{-\sigma}\frac{\partial U}{\partial E} - m = 0$$

From (26), $\frac{\partial U}{\partial E} = \frac{n^{\frac{1-\alpha}{\alpha}}}{p}$. Therefore,

$$m = \frac{U^{-\sigma}n^{\frac{1-\alpha}{\alpha}}}{p}. \tag{27}$$

Another first order condition is

$$\dot{m} = \rho m - H_A = \rho m - rm = (\rho - r)m \tag{28}$$

(27) implies that $\frac{\dot{m}}{m} = -\sigma\frac{\dot{U}}{U} + (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} - \frac{\dot{p}}{p}$. Substituting this into (28), we obtain

$$\rho - r = -\sigma\frac{\dot{U}}{U} + (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} - \frac{\dot{p}}{p} \tag{29}$$

Now, (26) implies that

$$\frac{\dot{U}}{U} = (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} + \frac{\dot{E}}{E} - \frac{\dot{p}}{p} = (\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n}. \tag{30}$$

The last equality comes from the fact that $npx = E$ which implies $pX = E$, where X is total labor devoted to production (which is constant over time in steady state). Substituting (30) into (29), and imposing the normalization $\frac{\dot{n}}{n} = \frac{\dot{E}}{E} = \frac{\dot{p}}{p}$, we obtain

$$\rho - r = (1-\sigma)(\frac{1-\alpha}{\alpha})\frac{\dot{n}}{n} - \frac{\dot{E}}{E}.$$

QED.

B Discounted Expected Profits of an MNC

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

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

Therefore,

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

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

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

It is straightforward to show that the RHS is equal to $\frac{\pi_m}{r+i\delta}$.

C Expression for L_m in Section 3

By definition,

$$\frac{L_s}{L_m} = \frac{n_i x_i + n_m x_m}{n_m x_m} = \frac{n_i}{n_m}(\frac{x_i}{x_m}) + 1$$

On the other hand, from (6) and (7),

$$\frac{x_i}{x_m} = (\frac{w_s}{w_s/\alpha})^{-\epsilon} = \alpha^{-\epsilon} > 1.$$

Moreover,

$$\frac{n_i}{n_m} = \frac{\dot{n}_i}{n_m}\frac{n_i}{\dot{n}_i} = \frac{\delta i}{g}.$$

Hence, substituting the last two equations into the first equation, we obtain

$$L_m = \frac{L_s}{\frac{\delta i}{g}\alpha^{-\epsilon} + 1}.$$

D Comparative Steady States Analysis in the Multinationalization Regime

To compute the effect of an decrease in δ on g, we shall use the implicit function theorem.

Let $P = \rho + \phi g$, $Q = g + i\delta$, $R = g - A$ and $S = \rho + \phi g + i\delta$, where $A = \frac{L_N}{a_d} - \rho(\frac{\alpha}{1-\alpha}) > 0$. Now,

$$\frac{\partial}{\partial g}(\frac{LHS_{23}}{RHS_{23}}) > 0 \qquad \text{as long as} \qquad \frac{\partial}{\partial g}(\frac{R^\alpha S}{PQ^\alpha}) > 0$$

where LHS_i (RHS_i) denotes left hand side (right hand side) of equation i. And

$$\frac{\partial}{\partial g}(\frac{R^\alpha S}{PQ^\alpha}) = \frac{1}{P^2 Q^{2\alpha}}[PQ^\alpha(\phi R^\alpha + S\alpha R^{\alpha-1}) - R^\alpha S(P\alpha Q^{\alpha-1} + \phi Q^\alpha)]$$

$$= \frac{1}{P^2 Q^{2\alpha}}[PQ^{\alpha-1}R^\alpha(\phi Q - \alpha S) + Q^\alpha S R^{\alpha-1}(\alpha P - \phi R)] \tag{31}$$

Now, $\phi Q - \alpha S = -[\alpha\rho - (1-\alpha)\phi g - (\phi - \alpha)i\delta]$, while $\alpha P - \phi R = \alpha\rho + A\phi - (1-\alpha)\phi g$. Since $A > 0$, the latter is positive as long as $0 \leq \phi \leq 1$ and $g < \frac{L_N}{a_d}$. The last inequality must be true since $\frac{L_N}{a_d}$ is the innovation rate when all labor in North is used for innovation. If $\phi Q - \alpha S > 0$, RHS_{31} is obviously positive. Suppose, however, that $\phi Q - \alpha S < 0$. The fact that $Q > R$ and $S > P$ implies that $PQ^{\alpha-1}R^\alpha < Q^\alpha S R^{\alpha-1}$. The assumption $\alpha \geq 1-\sigma$ stated in section 2.1 implies that $\phi \geq \alpha$. If $\phi Q - \alpha S < 0$, it is clear that $|\phi Q - \alpha S| < |\alpha P - \phi R|$. It follows from (31) that $\frac{\partial}{\partial g}(\frac{R^\alpha S}{PQ^\alpha}) > 0$.

It is straigtforward to show that $\frac{\partial}{\partial \delta}(\frac{LHS_{23}}{RHS_{23}}) > 0$. Therefore, by the implicit function theorem, $\frac{dg}{d\delta} < 0$, and stronger IPP leads to higher rate of innovation.

E Both Multinationalization and Imitation are Channels of production Transfer

We assume that Southern firms can imitate from Northern firms or the subsidiaries of Northren firms in South. It is assumed for simplicity that all products are equally protected under Southern patent laws. However, it seems reasonable to assume that it is technically harder to imitate from Northern firms than from their subsidiaries in South when both are equally protected under Southern jurisdiction. Therefore, the imitation rate of North-produced product, $j\delta$, is assumed to be less than the imitation rate of MNC-produced product in South, $i\delta$, or $j < i$.

Hence, it is straightforward to show that the counterparts of (14), (21) and (22) are, respectively,

$$\frac{\pi_N}{\pi_m} = \frac{\delta j + r}{\delta i + r}$$

$$[\frac{\omega}{g}(\frac{g+i\delta\alpha^{-\epsilon}}{g+i\delta})(\frac{L_N-a_dg}{L_s})]^\alpha=\frac{\delta j+r}{\delta i+r}$$

$$(\frac{1-\alpha}{\alpha})(L_N-a_dg)(\frac{\omega+\delta j}{g}+1)=a_d(r+\delta j) \tag{32}$$

The last two equations reduce to

$$[(\frac{g+i\delta\alpha^{-\epsilon}}{g+i\delta})(\frac{a_d(r+\delta j)(\frac{\alpha}{1-\alpha})-(L_N-a_dg)(1+\frac{\delta j}{g})}{L_s})]^\alpha=\frac{\delta j+r}{\delta i+r} \tag{33}$$

The LHS of (33) is re-written as

$$[(\frac{g+i\delta\alpha^{-\epsilon}}{g+i\delta})(\frac{[a_d(\frac{\alpha}{1-\alpha})-(\frac{L_N-a_dg}{g})]\delta j+a_dr(\frac{\alpha}{1-\alpha})-(L_N-a_dg)}{L_s})]^\alpha$$

Define $D\equiv a_d(\frac{\alpha}{1-\alpha})-(\frac{L_N-a_dg}{g})$. It follows that $\frac{\partial}{\partial\delta}(\frac{LHS_{33}}{RHS_{33}})>0$ if $D\geq 0$. On the other hand, from (32), $(\frac{1-\alpha}{\alpha})(L_N-a_dg)=a_d(\frac{r+\delta j}{\omega+g+\delta j})g$. Therefore, $D\geq 0$ iff $(\frac{1-\alpha}{\alpha})(L_N-a_dg)\leq a_dg\Leftrightarrow a_d(\frac{r+\delta j}{\omega+g+\delta j})g\leq a_dg\Leftrightarrow\omega+g\geq r=\rho+\phi g\Leftrightarrow\omega+(1-\phi)g\geq\rho$. A sufficient condition of the last inequality is $\omega\geq\rho$. Therefore, a sufficient condition for $\frac{\partial}{\partial\delta}(\frac{LHS_{33}}{RHS_{33}})>0$ is $\omega\geq\rho$. The other sufficient condition for $\frac{\partial}{\partial\delta}(\frac{LHS_{33}}{RHS_{33}})>0$ is, of course, when j is sufficiently small so that the effect of $j\delta$ on $\frac{LHS_{33}}{RHS_{33}}$ is small.

If North can sustain positive growth without multinationalization, then $L_N>a_d(\rho+\delta j)(\frac{\alpha}{1-\alpha})$. Hence, by a similar derivation as the one stated in Appendix D, $\frac{\partial}{\partial g}(\frac{LHS_{33}}{RHS_{33}})>0$. By the implicit function theorem, therefore, a sufficient condition for $\frac{dg}{d\delta}<0$ is $\omega\geq\rho$. That is, stronger Southern IPP leads to higher rate of innovation in North as long as $\omega\geq\rho$, or if j is small.

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