Globalization, R&D and the iPod Cycle [a]

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Abstract

This paper constructs a dynamic scale-free North-South model of trade with endogenous innovation. In the North a local-sourcing-targeted race and an outsourcing-targeted R&D race take place simultaneously within each industry. The former results in the winner firm manufacturing in the North, while the latter culminates in the winner firm's immediate outsourcing to the South, generating the *iPod cycle*. We study three aspects of globalization: reductions in the resource-requirement in outsourcing-targeted R&D, increased subsidies to outsourced production, and reduced Southern imitation due to TRIPs. Each event boosts outsourcing-targeted R&D and increases the frequency of iPod cycles. The aggregate innovation rate rises despite a possible fall in local-sourcing-targeted R&D, and the North-South relative wage decreases.

Keywords: Outsourcing, innovation, product cycle, endogenous growth

JEL Classification: F12, F23, O14

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1. Introduction

In the traditional product cycle model as proposed by Vernon (1966) multinational firms serve as the main channel of North-South technology transfer. In the North entrepreneurs participate in R&D races to innovate new products. The winner of each race gains exclusive access to the technology of producing the next-generation product and starts the manufacturing process immediately in the North. By keeping production in close proximity to R&D workers, the successful innovator can efficiently monitor the production process and make the necessary modifications if needed. Over time as production becomes standardized, innovators look for ways of shifting production to the South to exploit low-cost manufacturing opportunities. This cycle is reignited when further innovation in the North renders obsolete the products manufactured in the South.

Increasingly though this type of one-product-cycle framework is facing a serious threat of creative destruction. With the decline in transportation, communication and trade costs, we have witnessed in the past two decades the emergence of globally-integrated production networks through which innovators can *bypass* the Northern standardization stage and shift manufacturing to the South immediately. In other words, entrepreneurs can explore technology transfer opportunities *during* the R&D stage without going through a standardization phase that involves mass manufacturing in the North.

Our prime example in this context is Apple's mini iPod, the state-of-the-art MP3 player of its time. When mini iPod was introduced in 2002, the labeling on the back of the product read "designed in California, manufactured in Taiwan". In subsequent periods, the labeling for iPods remained the same with one exception: Taiwan was replaced with China! There is no evidence that mass production of mini iPods has ever taken place in either California or anywhere else in the United States. Globally-integrated innovation-production networks are increasingly becoming the defining feature of multinational companies. Other examples in this context come from a variety of industries such as Dell, Hewlett-Packard Co., Motorola and Philips in electronics; and Glaxo-Smith-Kline and Eli Lilly in pharmaceuticals.[1] Simultaneous design and outsourcing efforts are also prevalent in low-tech industries as observed for clothing/footwear retailers such as GAP and Nike, and for household item makers such as Williams Sonoma, and Crate and Barrel. *Business Week* calls such firms "Speed Demons" (March 27, 2006, pp 70-76), which often combine new R&D with immediate outsourcing and mass production in the South to take advantage of lower manufacturing costs and reap potential rents.

The literature on endogenous technology transfer and growth has expanded substantially in the past decade.[2] One common feature of this literature is that it exclusively focuses on the Vernon type product cycle and misses the new phenomenon in the current wave of globalization: the *iPod cycle*. Our objective in this paper is to incorporate this iPod cycle into a North-South endogenous growth framework and study the effects of globalization, policy changes towards foreign investment, and increased Intellectual Property Rights (IPRs) protection.

Our North-South world economy consists of a continuum of industries. In each industry, Northern entrepreneurs participate in *two simultaneous R&D races* to innovate higher quality products: *local-sourcing-targeted-* and *outsourcing-targeted- R&D races*. The winner of the former race can only manufacture in the North, facing higher labor costs. The winner of the latter race can immediately produce in the South, enjoying lower labor costs. Participation in an outsourcing-targeted R&D race requires engagement in a broadly-defined R&D activity that involves not only scientists and engineers working on innovations but also a sophisticated management team that globally coordinates the innovation and technology transfer efforts of a multinational firm. Hence, outsourcing-targeted R&D races capture the essence of the iPod cycle, with "Speed Demons" corresponding to the winners of these

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[1] See Naghavi and Ottaviano (2005) for an excellent discussion on the nature and extent of company-level globally-integrated production networks. Linden et al. (2007) provide a detailed examination of the iPod phenomenon—from innovation to manufacturing— with a special focus on measuring the value created along its supply chain.

[2] Glass and Saggi (2001) analyze fragmented technology transfer to the South with endogenous innovation but without imitation. Glass (2004) extends this fragmentation framework to allow for exogenous imitation. Sayek and Şener (2006) use a similar setting to study the implications of outsourcing for wage inequality. Glass and Saggi (2002) construct a quality-ladders growth model with endogenous innovation, imitation and Foreign Direct Investment (FDI) but without fragmentation. Dinopoulos and Segerstrom (2007) also study endogenous FDI and innovation in a scale-invariant endogenous growth setting. In a recent paper, Lu (2007) introduces industry heterogeneity and shows that firms with most advanced technologies stay in the North, and the less-advanced ones move to the South. Industries with high R&D productivity have more of the former firms, while those with medium R&D productivity have more outsourcing firms. For earlier work, see Grossman and Helpman (1991), Helpman (1993) and Lai (1998). Glass and Wu (2007) and Şener (2006) provide a more thorough overview of this literature.

races. These firms realize lower production costs and thus higher profit margins and stock market valuations. Both Northern and Outsourcing industries face the threat of imitation from the South. Their technologies can fully leak to the South upon successful imitation, in which case a fringe of Southern firms manufacture the top-quality product. Further innovation leads to the replacement of Southern firms and triggers a new product cycle.

We study the impact of globalization by considering an increase in the efficiency of outsourcing-targeted R&D triggered by reduced transportation and communication costs. We find that such a change raises the aggregate rate of innovation (i.e., the sum of local-sourcing and outsourcing-targeted R&D intensities) while reducing the North-South wage gap. The rate of innovation in outsourcing-targeted-R&D increases, whereas that in local-sourcing targeted R&D moves in an ambiguous direction. These findings imply that the intensified outsourcing-targeted R&D efforts and the resulting surge in the frequency of iPod cycles play a robust role in boosting aggregate innovation. At the new equilibrium, the fraction of Outsourcing industries and the amount of outsourcing to the South both increase.

We also examine the global effects of TRIPs (Trade Related Aspects of Intellectual Property Rights) by considering a reduction in the Southern imitation rate.[3] Starting from a setting where the imitation rates that target the Northern and Outsourcing industries are equal, we show analytically that TRIPs decreases the rate of innovation in local-sourcing-targeted R&D but increases that in outsourcing-targeted R&D, and the latter dominates so that the aggregate rate of innovation rises. Thus, once again the major source of innovation is linked to the increased R&D efforts of Northern entrepreneurs aimed at generating iPod cycles. The equilibrium North-South relative wage remains unaffected.

To check the robustness of our results, we run numerical simulations for the more reasonable case where the imitation rate targeting Outsourcing industries is higher than that targeting Northern industries.

[3] TRIPs was signed under the auspices of the World Trade Organization and required all signatory countries to establish a minimum level of IPR protection by the year 2006 (with a few amendments for very low-income countries facing acute health problems). Since the Northern countries already had a well-established IPR protection system, it was effectively the Southern countries which were subject to the obligations of TRIPs. Indeed, in the period 1990-2000, low and middle income countries have increased their IPR protection levels (as measured by the Ginarte and Park Index) by about 50 percent. See Şener (2006) and Dinopoulos and Kottaridi (2008) for further details on IPR protection changes.

We find that as the gap between the imitation rates widens, the impact of TRIPs on local-sourcing-targeted R&D turns from negative to positive. For a wide enough gap, the aggregate innovation rate rises due to higher intensities of both types of R&D. This time the North-South relative wage declines.

We thus argue that TRIPs can boost both outsourcing- and local-sourcing-targeted R&D activities and thereby stimulate aggregate innovation. Moreover, it increases the fraction of Outsourcing industries and thus the extent of multinationals' manufacturing activities abroad. Hence, our model offers optimistic predictions about the growth and technology transfer effects of TRIPs. These results are consistent with the recent empirical evidence provided by Branstetter et al. (2006 and 2007). Using firm level data, they investigate the responses of US multinationals to IPR reforms in sixteen developing countries. They find that multinationals respond to stronger IPR protection by increasing the scope of their abroad activities measured by sales, employment, affiliate R&D activity and intra-firm royalty payments.

The existing endogenous growth product cycle literature provides mixed results with respect to TRIPs. For instance, Glass and Saggi (2002) find that TRIPs reduces the rates of innovation and technology transfer via FDI. On the other hand, Dinopoulos and Segerstrom (2007) and Şener (2006) find that TRIPs can accelerate within-multinational-firm activity. The former study predicts a temporary boost whereas the latter predicts a permanent decline in innovation rate. Parello (2008) finds that the FDI effects of TRIPs depend on the skill intensity of Southern labor force.[4] However, none of the existing papers consider immediate technology transfer to the South. Hence, our model is unique in highlighting the innovation effects of strengthening TRIPs that work through the iPod cycle.

In addition, we examine the consequences of more outsourcing-friendly policies by the South (which can be in the form of *manufacturing subsidies* that reduce the ex-post production costs of outsourcing firms or *technology transfer subsidies* that facilitate the ex-ante production shifting efforts of entrepreneurs engaged in outsourcing-targeted R&D). We find that such policies raise the rate of innovation in outsourcing-targeted R&D but exert an ambiguous effect on the rate of innovation in local-

[4] See Glass and Wu (2007), Dinopoulos and Segerstrom (2007), and Şener (2006) for more comprehensive overviews of the literature on TRIPs, innovation, imitation and technology transfer.

sourcing-targeted R&D. The aggregate rate of innovation and the fraction of Outsourcing industries both increase. The North-South relative wage attains a lower level.

Glass and Saggi (2001, 2002) and Dinopoulos and Segerstrom (2007) analyze similar issues, but in settings with only local-sourcing-targeted R&D races where technology transfer to the South follows Northern production and standardization. In our model with two simultaneous R&D races we can examine the compositional R&D effects of globalization. We show that globalization leads to an expansion in outsourcing-targeted R&D activity which may come at the expense of local-sourcing-targeted R&D activity. However, the aggregate innovation rate eventually increases, and consumers enjoy higher quality products at a faster pace. We identify the increased R&D efforts in outsourcing-targeted races as the major growth promoting factor triggered by globalization.

The rest of the paper is organized as follows. Section 2 outlines the building blocks of the model. Sections 3 and 4 present the comparative steady-state results. Section 5 concludes. Proofs of all propositions are relegated to the Appendices available upon request.

2. The Model

We consider a world economy of two countries: the North and the South. There is a continuum of industries indexed by ω. The size of household population in country $i \in \{N, S\}$ at time t is $L^i(t) = L_0^i e^{gt}$, where L_0^i is the initial level of population per household, and $g > 0$ is the rate of population growth.

2.1. Household Behavior

In each country, there exists a continuum of identical households, which takes goods prices, factor prices, and the interest rate as given and maximizes its utility over an infinite horizon,

$$U^i = \int_0^\infty L_0^i \, e^{-(\rho-g)t} \log u^i(t)\, dt\,, \qquad \text{for } i = N, S, \tag{1}$$

where ρ is the subjective discount rate, and $\log u^i(t)$ is the instantaneous utility defined as:

$$\log u^i(t) \equiv \int_0^1 \log \Big[\sum_j \lambda^j \, x^i(j,\omega,t)\Big] d\omega\,, \qquad \text{for } i = N, S, \tag{2}$$

where $x^i(j,\omega,t)$ is the quantity demanded of a product with quality j in industry ω at time t. Each successful innovation improves the quality of a product by $\lambda > 1$. Therefore, the total quality of a good after j innovations is λ^j.

Each household in country i allocates its per capita consumption expenditure, $c^i(t)$, to maximize $u^i(t)$ given prices at time t. Note that all products within an industry are perfect substitutes; thus, households buy only those with the lowest quality-adjusted prices. Products enter the utility function symmetrically; therefore, households spread their consumption expenditure evenly across goods. The resulting per-capita demand for each product line is $x^i(j,\omega,t) = c^i(t)/p$, where p is the relevant market price for the product that has the lowest quality-adjusted price. The household's maximization problem over all product lines is then simplified to maximizing

$$\int_0^\infty L_0^i\, e^{-(\rho-g)t} \log c^i(t)\, dt, \qquad \text{for } i = N, S, \tag{3}$$

subject to the budget constraint $\dot{B}^i(t) = W^i(t) + r^i(t)B^i(t) - c^i(t)L^i(t)$, where $B^i(t)$ denotes the family's financial assets, $W^i(t)$ is its expected wage income and $r^i(t)$ is the instantaneous rate of return.

The solution to this optimization gives the standard differential equation

$$\frac{\dot{c}^i(t)}{c^i(t)} = r^i(t) - \rho, \qquad \text{for } i = N, S. \tag{4}$$

At the steady-state equilibrium, c^i remains fixed; thus, the market interest rate is equal to the subjective discount rate: $r^i(t) = r = \rho$. From this point on we will focus on the balanced-growth path behavior of the economy; hence, we drop the time index for the variables that remain constant.

2.2. Product Cycle Dynamics

All industries in the continuum are structurally identical. In each industry, Northern entrepreneurs participate in R&D races to innovate higher quality products. They can *ex-ante* choose between *local-sourcing-targeted R&D* which leads to manufacturing in the North and *outsourcing-targeted R&D* which leads to manufacturing in the South. The two types of R&D races take place simultaneously. Successful innovators gain access to the technology of producing the state-of-the-art quality products, and exercise temporary monopoly power in the global market. We assume that no complementarity exists between the two types of R&D so that each entrepreneur just focuses on one type.

In this setting, three industry types can emerge: Northern, Outsourcing and Southern industries, and the transition rates between them are governed by stochastic Poisson processes. First, entrepreneurs successful in local-sourcing-targeted R&D manufacture their top quality products using Northern resources, generating the *Northern industries*. In a typical industry, the probability of success in this type of R&D is $\iota_N dt$, where ι_N denotes the R&D intensity and dt represents a small interval of time. Secondly, entrepreneurs successful in outsourcing-targeted R&D shift production to the South instantaneously and use the South as a platform to supply to the world market. We refer to such industries as *Outsourcing industries*. In a typical industry, the probability of success in outsourcing-targeted R&D is $\iota_O dt$, where ι_O is the intensity of this type of R&D. Lastly, the above two industries face the threat of imitation from the South. We denote with $\mu_N dt$ and $\mu_O dt$ the exogenous probability of imitation success in Northern and Outsourcing industries, respectively. With successful imitation the top technology fully leaks to the South, and a fringe of Southern firms start producing the state-of-the-art quality product under perfectly competitive conditions. We refer to these industries as *Southern industries*. Further innovation from the North results in the replacement of Southern firms.

2.3. Stock Market Valuations

Consider first the determination of $V_N(t)$, the value of a successful Northern innovator producing in the North. Over a time interval dt, the stockholders of this firm receive $\pi_N(t)$ as dividend payments. With probability $(\iota_O + \iota_N)dt$, further innovation may take place in this industry and with probability $\mu_N dt$ imitation success may materialize. In either event the stockholders realize a loss of $V_N(t)$. With probability $1 - (\iota_O + \iota_N + \mu_N)dt$, the Northern firm maintains its monopoly position. In this event the firm's valuation changes by $\dot{V}_N\, dt$. Investors fully exploit the arbitrage opportunities: the expected return from a Northern stock, $\pi_N(t)dt - (\iota_O + \iota_N + \mu_N)V_N(t)dt + [1 - (\iota_O + \iota_N + \mu_N)dt]\dot{V}_N\, dt$, must be equal to the risk-free return generated at the market interest rate $\rho(t)V_N(t)dt$. This implies (taking limits as $dt \to 0$):

$$V_N(t) = \frac{\pi_N(t)}{\rho + \iota_N + \iota_O + \mu_N - [\dot{V}_N(t)/V_N(t)]}. \tag{5}$$

Next we turn to the valuation of an Outsourcing firm $V_O(t)$. Over a time interval dt, its stockholders receive $\pi_O(t)$ as dividend payments. With probability $(\iota_O + \iota_N)\, dt$, further innovation may occur in this industry, and with probability $\mu_O dt$ the Outsourcing firm's technology can fully leak to the South. In either event, the stockholders realize a loss of $V_O(t)$. With probability $1 - (\iota_O + \iota_N + \mu_O)dt$, the Outsourcing firm maintains its monopoly position, and the firm's value changes by $\dot{V}_O(t)$. Again, the no-arbitrage condition requires (taking limits as $dt \to 0$):

$$V_O(t) = \frac{\pi_O(t)}{\rho + \iota_N + \iota_O + \mu_O + [\dot{V}_O(t)/V_O(t)]}. \tag{6}$$

Finally, consider the valuation of a Southern firm $V_S(t)$. Since production takes place in a perfectly competitive market, Southern firms price at marginal cost. Hence $\pi_S(t) = 0$ and $V_S(t) = 0$.

2.4. Manufacturing and Product Markets

We normalize the Southern wage rate to one and denote with w the North-South relative wage rate. The marginal cost of production is $MC_N = m_N w$ in Northern industries, and $MC_O = m_O(1 - \sigma_O)$ in Outsourcing industries, where m_N and m_O are respectively their unit labor requirements in final good manufacturing, and σ_O is the subsidy rate for outsourced manufacturing. In Southern industries, the unit labor requirement is set to one, resulting in the marginal cost of production as: $MC_S = 1$. We restrict attention to the steady-states in which: *i)* Northern producers realize positive profits, *ii)* marginal manufacturing costs are higher in the North than in the South, *iii)* the Northern relative wage satisfies $w > 1$. Hence, manufacturing costs must comply with:

$$\lambda > MC_N > MC_O > MC_S = 1 \qquad \Rightarrow \qquad \lambda > m_N w > m_O(1 - \sigma_O) > 1. \tag{7}$$

In each industry, firms compete in a Bertrand pricing game. Following the literature, we assume that every time an innovation occurs in the North, technology diffusion takes place so that the existing inferior technology becomes common knowledge to all firms in the global economy. Follower firms have access to the one-step-down technology, with a unit labor requirement of production set to one. With $w > 1$, the Southern followers can undercut their Northern counterparts. Thus, in a typical industry a Northern quality leader charges the limit price $\lambda MC_S - \varepsilon = \lambda - \varepsilon$ (where ε is an infinitely small positive number) and drives the Southern followers out of the market. The profit flow of a quality leader manufacturing in the North is:

$$\pi_N(t) = \frac{E(t)}{\lambda}(\lambda - MC_N), \tag{8}$$

where $E(t) \equiv c^N L^N(t) + c^S L^S(t)$ stands for the global consumption expenditure in each product line. Similarly, the profit flow of a quality leader outsourcing production to the South is:

$$\pi_O(t) = \frac{E(t)}{\lambda}(\lambda - MC_O). \tag{9}$$

Since $MC_N > MC_O$, we must have $\pi_O(t) > \pi_N(t)$, which implies that outsourced production generates larger profit flows compared to Northern local production.

2.5. Optimal Choices of R&D Intensities

Let $X_N(t)$ and $X_O(t)$ denote respectively the difficulty of conducting local-sourcing- and outsourcing-targeted R&D. The unit labor requirements for each type of R&D are $a_N X_N(t)$ and $a_O X_O(t)$, respectively. A typical entrepreneur j engaged in local-sourcing-targeted R&D chooses its R&D intensity ι_{Nj} to maximize:

$$V_N(t)\,\iota_{Nj}\,dt - wa_N X_N(t)\,\iota_{Nj} dt.$$

Free-entry in local-sourcing-targeted R&D races drives expected profits down to zero. Thus,

$$V_N(t) = wa_N X_N(t). \tag{10}$$

Similarly, an entrepreneur engaged in outsourcing-targeted R&D chooses its R&D intensity ι_{Oj} to maximize:

$$V_O(t)\,\iota_{Oj}\,dt - wa_O(1 - \sigma_{\iota O})X_O(t)\,\iota_{Oj}\,dt,$$

where $\sigma_{\iota O}$ is the subsidy rate for outsourcing-targeted R&D. Free-entry ensures:

$$V_O(t) = wa_O(1 - \sigma_{\iota O})X_O(t)\,. \tag{11}$$

2.6. Industry Flows

Denote with n_N, n_O and n_S the fraction of Northern, Outsourcing and Southern industries, respectively. Constant industry shares at the steady-state require that flows in and out of each industry must be exactly balanced. Consider the Northern industries. Every time a Northern entrepreneur participating in an outsourcing-targeted R&D race that is directed at a Northern industry becomes successful, the Northern industry is transformed into an Outsourcing industry. Imitation success by the South also transforms a Northern industry to a Southern one. Hence, the aggregate flow out of the Northern industry pool is $(\iota_O + \mu_N)n_N$. Every time a Northern entrepreneur participating in a local-sourcing-targeted R&D race directed at an Outsourcing or Southern industry becomes successful, this industry becomes a Northern one. Thus, the aggregate flow into the Northern industry pool is $(n_O + n_S)\iota_N$. Constant n_N requires:

$$(n_S + n_O)\,\iota_N = (\iota_O + \mu_N)\,n_N\,. \tag{12}$$

Next, consider the Southern industries. Every time an entrepreneur directing its innovation efforts at a Southern industry with either type of R&D becomes successful, the Southern industry is transformed into a Northern or an Outsourcing industry. Hence, the aggregate flow out of the Southern industry pool is $(\iota_O + \iota_N)n_S$. Every time the state-of-the-art technology fully leaks to the South in an Outsourcing or Northern industry, this industry is transformed into a Southern one. Thus, the aggregate flow into the Southern industry pool is $\mu_O n_O + \mu_N n_N$. Constant n_S requires:

$$(\iota_O + \iota_N)n_S = \mu_O n_O + \mu_N n_N. \tag{13}$$

Finally, we have the unit one measure of industries condition:

$$n_N + n_O + n_S = 1, \tag{14}$$

which ensures that n_O also becomes constant.

2.7. Labor Markets

In the North, the labor market equilibrium requires:

$$L^N(t) = \iota_N a_N X_N(t) + \iota_O a_O X_O(t) + n_N[E(t)/\lambda]m_N, \tag{15}$$

where $\iota_N a_N X_N(t)$ and $\iota_O a_O X_O(t)$ represent the amount of labor employed in each type of R&D, and $n_N[E(t)/\lambda]m_N$ is the amount of labor employed in manufacturing. In the South, we have:

$$L^S(t) = n_S E(t) + n_O[E(t)/\lambda]m_O, \tag{16}$$

where $n_S E(t)$ and $n_O(E(t)/\lambda)m_O$ measure the level of employment in Southern and Outsourcing industries respectively. Note that in Southern industries price equals marginal cost 1; hence, the labor demand in each Southern industry is $E(t)$. Imitation by the South is of the leakage type, which does not require labor input.

2.8. Steady-State Equilibrium

We first remove the scale effects in the spirit of Dinopoulos and Thompson (2000). In particular, we set $X_N(t) = k_N L(t)$ and $X_O(t) = k_O L(t)$, where $k_N > 0$, $k_O > 0$ and $L(t) = L^S(t) + L^N(t)$. Then we define per-capita consumption expenditure of a representative global citizen as $c(t) \equiv E(t)/L(t)$, and the relative size of Southern to Northern population as $\eta^S \equiv L^S(t)/L^N(t)$. It follows that $L^N(t) = L(t)/(1+\eta^S)$ and $L^S(t) = L(t)\eta^S/(1+\eta^S)$. At the steady-state equilibrium ι_N, ι_O, n_N, n_O, n_S, w, and c remain constant whereas $V_N(t)$, $V_O(t)$, $X_O(t)$, $X_N(t)$, $\pi_N(t)$, $\pi_O(t)$, $E(t)$ grow at the rate of g. Using the flow conditions (12), (13) and (14), the industry fractions can be expressed in terms of endogenous variables ι_N and ι_O:

$$n_N = \frac{\iota_N}{\iota_N + \iota_O + \mu_N}, \quad n_O = \frac{\iota_O}{\iota_N + \iota_O + \mu_O}, \quad n_S = \frac{\iota_N \mu_N + (\iota_O + \mu_N)\mu_O}{(\iota_N + \iota_O + \mu_N)(\iota_N + \iota_O + \mu_O)}, \tag{17}$$

Substituting (17) into (15) and (16), and using the specifications for $X_O(t)$, $X_N(t)$, $L^N(t)$ and $L^S(t)$, along with $c(t) \equiv E(t)/L(t)$, one can express the labor market conditions in c, ι_N and ι_O:

$$1/(1+\eta^S) = \iota_N a_N k_N + \iota_O a_O k_O + n_N(\iota_N, \iota_O)(c/\lambda) m_N, \qquad (c, \iota_N, \iota_O) \tag{18}$$

$$\eta^S/(1+\eta^S) = n_O(\iota_N, \iota_O)(c/\lambda) m_O + n_S(\iota_N, \iota_O) c\ . \qquad (c, \iota_N, \iota_O) \tag{19}$$

To complete the system, we need to use the stock market valuation and zero-profit conditions for R&D. Substituting $V_N(t)$ from (10) and $\pi_N(t)$ from (8) into (5) gives:

$$w a_N k_N = \frac{c(\lambda - m_N w)/\lambda}{\rho + \iota_N + \iota_O + \mu_N - g}. \qquad (c, \iota_N, \iota_O, w) \tag{20}$$

Similarly substituting $V_O(t)$ from (11) and $\pi_O(t)$ from (9) into (6) gives:

$$wa_O(1-\sigma_{\iota O})k_O = \frac{c[\lambda-(1-\sigma_O)m_O]/\lambda}{\rho+\iota_N+\iota_O+\mu_O-g}. \qquad (c, \iota_N, \iota_O, w) \qquad (21)$$

Equations (18)-(21) constitute a system of four equations in four unknowns (c, ι_N, ι_O, w). The rest of the endogenous variables can be derived in a recursive fashion using the equilibrium values of (c, ι_N, ι_O, w). To simplify exposition, we evaluate the derivatives and intercepts as the net discount rate $\rho - g$ approaches zero. This is a standard practice commonly invoked in quality-ladder models of growth (See for instance Glass and Saggi, 1999, 2002, among others). We conducted extensive numerical simulations and found that unless otherwise noted, the main results are robust to assuming positive values for $\rho - g$.

3. The Benchmark Model: Equal Imitation Rates

We first assume $\mu_N = \mu_O = \mu$, which renders the model analytically solvable. Later we drop this assumption and run numerical simulations to check the robustness of the results. Imposing $\mu_N = \mu_O = \mu$ in (17) gives (steady-state equilibrium levels are marked with *):

$$n_N = \frac{\iota_N}{\iota_N+\iota_O+\mu}, \quad n_O = \frac{\iota_O}{\iota_N+\iota_O+\mu}, \quad n_S = \frac{\mu}{\iota_N+\iota_O+\mu}. \qquad (22)$$

Taking the ratio of equations (20) and (21) yields

$$\mathrm{K} \equiv \frac{a_N k_N}{a_O k_O(1-\sigma_{\iota O})} = \frac{\lambda - m_N w}{\lambda-(1-\sigma_O)} \equiv \Pi, \qquad (23)$$

where K measures the *relative unit cost* between local-sourcing and outsourcing-targeted R&D, and Π measures the *relative profit margin* between locally-sourced and outsourced production. Π is decreasing in *w* because a higher *w* reduces Northern profit margins, whereas K does not respond to variations in *w* because *w* enters each type of R&D cost in the same proportion. With equal imitation rates, the threat of replacement faced by Northern and Outsourcing firms is the same and thus the adjusted discount factor (ρ

$+ \iota_O + \iota_N + \mu - g$) cancels out. As shown in Fig. 1a the intersection of the corresponding curves determines the equilibrium relative wage w^*. One can obtain a closed form solution for w^* as: [5]

$$w^* = \frac{1}{m_N}\left(\lambda - \frac{a_N k_N [\lambda - m_O(1-\sigma_O)]}{a_O k_O (1-\sigma_{\iota O})}\right). \tag{24}$$

Note that $w^* = w(\overset{+}{a_O}, \overset{-}{\sigma_{\iota O}}, \overset{-}{\sigma_O})$. Observe that any parameter change that leads to an increase in the profitability of local-sourcing-targeted relative to outsourcing-targeted R&D raises w^*.

Substituting w^* into (20) to express c in terms of (ι_N, ι_O) gives:

$$c(\iota_N, \iota_O) = \frac{\lambda(\rho + \iota_N + \iota_O + \mu - g)}{m_N[\lambda - (1-\sigma_O)m_O]}\left\{\lambda a_O k_O(1-\sigma_{\iota O}) - a_N k_N[\lambda - (1-\sigma_O)m_O]\right\}, \tag{25}$$

where $c(\iota_N, \iota_O) = c(\overset{+}{\iota_N}, \overset{+}{\iota_O}, \overset{+}{\mu}, \overset{+}{a_O}, \overset{-}{\sigma_{\iota O}}, \overset{-}{\sigma_O})$. Substituting (25) and (22) into (18) and (19) yields

$$\frac{1}{1+\eta^S} = \iota_N a_N k_N + \iota_O a_O k_O + [n_N(\overset{+}{\iota_N}, \overset{-}{\iota_O})\; c(\overset{+}{\iota_N}, \overset{+}{\iota_O})\; m_N / \lambda], \tag{26}$$

$$\frac{\eta^S}{1+\eta^S} = [n_O(\overset{-}{\iota_N}, \overset{+}{\iota_O})\; c(\overset{+}{\iota_N}, \overset{+}{\iota_O})\; m_O / \lambda] + n_S(\overset{-}{\iota_N}, \overset{-}{\iota_O})\; c(\overset{+}{\iota_N}, \overset{+}{\iota_O}). \tag{27}$$

We now illustrate the steady-state equilibrium by plotting (26) and (27) in (ι_N, ι_O) space.[6] Equation (26) summarizes the Northern labor market equilibrium and identifies a downward sloping curve **LN** in Fig. 1b. For a given ι_O, a higher intensity of innovation in local-sourcing-targeted R&D ι_N affects the Northern labor demand via three channels. First, it directly raises $\iota_N a_N k_N$. Second, it increases the fraction of Northern industries n_N. These two effects work to raise the Northern labor demand. Third, a higher ι_N indirectly lowers per-capita consumption expenditure c and thus reinforces the increased

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[5] Combining (23) and (7) gives the following conditions on the parameters. For $w^* > 1$, it must be that $a_O k_O(1 - \sigma_{\iota O}) > a_N k_N[\lambda - m_O(1 - \sigma_O)]/(\lambda - m_N)$. And for $m_N w^* > m_O(1 - \sigma_O)$, we must have $a_O k_O(1 - \sigma_{\iota O}) > a_N k_N$. Intuitively, these require that the unit labor requirement be sufficiently higher in outsourcing-targeted R&D than in the local-sourcing-targeted R&D. This is a plausible condition given that the former R&D involves more activities and could be more resource intensive.

[6] The existence and uniqueness of the equilibrium can be established by solving (26) and (27) simultaneously. To simplify, we evaluate them when $\rho - g \to 0$ and set the subsidies to zero $\sigma_{\iota O} = \sigma_O = 0$. For $\iota_O^* > 0$, we need $a_N k_N(m_O - \lambda)[m_O + a_O k_O(1 + \eta_S)\lambda\mu] + a_O k_O\{m_N \eta_S(m_O - \lambda) + \lambda[m_O + a_O k_O(1+\eta_S)\lambda\mu]\} > 0$. And for $\iota_N^* > 0$, we need $m_N \eta_S(\lambda - m_O) + (1 + \eta_S)\lambda\mu[a_N k_N(\lambda - m_O) - a_O k_O] > 0$. To interpret these restrictions, we combine them with the w^* expression in (7). This exercise implies that w^* must lie in a certain range, specifically, $\eta_S(\lambda - m_O)/[m_O + \mu a_O k_O \lambda(1+\eta_S)] < w^* < \eta_S[\lambda - m_O]/[(1+\eta_S)\mu a_O k_O \lambda]$.

Northern labor demand.[7] Restoring equilibrium calls for a fall in the intensity of outsourcing-targeted R&D ι_O, which reduces $\iota_O a_O k_O$ and thus the demand for Northern labor. The lower ι_O also exerts two competing effects on the Northern labor demand by raising n_N and reducing c (which exactly cancel out though as $\rho - g \to 0$). Thus (26) implies an inverse relationship between ι_O and ι_N, which captures the competing effects of the two types of R&D on the Northern resources.

Equation (27) summarizes the labor market equilibrium in the South and identifies a vertical line **LS** in Fig. 1b. For a given ι_O, a higher ι_N triggers opposing forces on labor demand. For the Outsourcing industries, a higher ι_N reduces both n_O and c. As $\rho - g \to 0$, these two forces exactly offset each other. For the Southern industries, the same opposing effects are at work and they again cancel out. Thus, variations in ι_N exert no influence on (27), and hence the vertical LS curve in Fig. 1b. The intuition is, the South's resource constraint exclusively determines the intensity of outsourcing-targeted R&D ι_O.

3.1. Globalization in the Form of Improved Efficiency of Outsourcing-Targeted R&D

We consider a decline in a_O to examine the effects of an increase in the efficiency of outsourcing-targeted R&D. This exercise is motivated by the substantial decline in transportation and communication costs observed in the past three decades.[8]

PROPOSITION 1: *A fall in a_O reduces w^* but raises ι_O^*. It also raises ι_N^* iff*

$$\iota_N > \frac{[\lambda - m_O(1-\sigma_O)]\left[a_O k_O \lambda^2 \mu(1-\sigma_{\iota O}) + a_N \iota_O k_N m_O\left[\lambda - m_O(1-\sigma_O)\right]\right]}{m_O\lambda(1-\sigma_{\iota O})\left[a_O k_O \lambda(1-\sigma_{\iota O}) - a_N k_N\left[\lambda - m_O(1-\sigma_O)\right]\right]},\ \textit{increases}\ \ \iota_A^* \equiv \iota_N^* + \iota_O^*\ \ \textit{if}$$

$\sigma_{\iota O} < [m_O(1-\sigma_O)]/\lambda$, and raises n_O^* if $\sigma_O - \sigma_{\iota O}$ is strictly positive or sufficiently small.

Proposition 1 states that a lower a_O reduces the North-South relative wage rate w^*, but increases the rate of innovation in outsourcing-targeted R&D ι_O^*. It also increases the rate of innovation in local-sourcing-targeted R&D ι_N^*, the aggregate rate of innovation ι_A^* and the fraction of Outsourcing industries

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[7] To see this, note that a higher ι_N raises the replacement rate within industry and lowers the stock market valuation of an innovator. Free-entry in R&D requires more resources to move from R&D to production and thus leads to a rise in c [eq.(25)].

[8] See Tang (2006, Figures 2 and 3) for detailed evidence on declining transport and communication costs, and Feenstra (1998) for a discussion of how such cost declines improve the efficiency of international outsourcing.

n_O* under certain conditions. These findings imply that technology improvements could be a driving force for the recent surge of joint innovation and outsourcing efforts by Northern entrepreneurs, complementing the explanations offered in the literature.[9]

To uncover the mechanisms, we first identify the wage impact using (23). A decline in a_O triggers an increase in the *relative* profitability of outsourcing-targeted to local-sourcing-targeted R&D. The K curve in Fig. 1a shifts up and equilibrium is restored via a fall in w^*, which reduces the relative profit margins in outsourced manufacturing. The reduction in w^* in turn decreases R&D costs and thus increases the *absolute* profitability of both types of R&D. Free-entry conditions (20) and (21) require that resources move from manufacturing to R&D and hence c decreases. Holding ι_N and ι_O constant, the decline in c decreases the demand for Northern manufacturing labor. This is further reinforced by the direct fall in a_O. These effects relax the Northern resource constraint, allowing for an expansion in local-sourcing-targeted R&D ι_N. As a result, the LN curve in Fig. 1b shifts to the right. For the LS curve, defined by (27), the only effect of a fall in a_O works through the induced decline in c, which reduces the demand for Southern manufacturing labor. This generates room for an expansion in Outsourcing industries n_O and thereby outsourcing-targeted R&D activity ι_O. Hence, the LS curve shifts to the right.

Glass and Saggi (2001) and Dinopoulos and Segerstrom (2007) also find that an increase in the efficiency of technology transfer reduces the North-South wage gap, increases the fraction of Outsourcing industries and the aggregate innovation rate. However, those papers consider only a local-sourcing-targeted R&D race where technology transfer to the South takes place only after Northern mass production. Our model introduces two types of simultaneous R&D races that compete for Northern resources. It reveals the effects of globalization on the composition of R&D. We especially find that due to globalization, Northern entrepreneurs intensify their simultaneous innovation-outsourcing efforts and this may come at the expense of the R&D efforts that target the North for production purposes, about

[9] Jones and Kierzkowski (1990) point out that the existence of fixed costs favors integrated production at low outputs but fragmentation at high outputs. Grossman and Helpman (2003) explain outsourcing as tradeoffs between production and search, the latter of which is affected by market thickness and the contracting environment. Long et al. (2005) show that services link and also allow the breaking up of integrated production. Service improvement facilitates fragmentation and outsourcing.

which some skeptics of globalization have been concerned. Nevertheless, the aggregate innovation rate increases under some mild parametric restrictions. This is mainly driven by the intensified outsourcing-targeted R&D efforts and reflected in the higher frequency of iPod cycles. Consequently, consumers worldwide enjoy faster product quality improvements.

3.2. Outsourcing Friendly Policies by the South

We study two policy changes towards outsourcing that can be undertaken by Southern governments: an increase in the manufacturing subsidy rate σ_O or the technology transfer subsidy rate $\sigma_{\iota O}$.[10] Proposition 2 presents our findings on changes in σ_O (an increase in $\sigma_{\iota O}$ generates similar effects.)

PROPOSITION 2: *An increase in σ_O, reduces w^* but raises ι_O^*. It increases ι_N^* iff*

$$\iota_N > \frac{[\lambda - m_O(1-\sigma_O)][a_O k_O(\iota_O m_O) + \lambda\mu]}{m_O\left[a_O k_O \lambda(1-\sigma_{\iota O}) - a_N k_N\left[\lambda - m_O(1-\sigma_O)\right]\right]},$$ *raises ι_A^* if $\sigma_{\iota O} < [m_O(1-\sigma_O)]/\lambda$, and increases n_O^* if $\sigma_O - \sigma_{\iota O}$ is strictly positive or sufficiently small.*

A higher σ_O increases the profit margins in Outsourcing industries and thus raises the relative profitability of outsourcing-targeted R&D. As a result, the Π curve in Fig. 1a shifts down and w^* decreases. The induced fall in w^* increases the *absolute* profitability of both types of R&D, which lowers the level of c that maintains the zero profit conditions in R&D. In the North, for a given ι_O, this relaxes the resource constraint and generates room for an increase in ι_N. Hence, the LN curve in Fig. 1b shifts up. In the South, the reduction in c also relaxes the resource constraint, making possible an increase in ι_O. Thus, the LS curve shifts to the right. It follows that ι_O increases whereas ι_N increases under the necessary condition stated in Proposition 2. The rest of the results are the same as a decline in a_O.

3.3. Increased Intellectual Property Rights Protection

We consider the impact of TRIPs in the form of a reduction in μ, with the following main findings:

[10] Hanson (2001) analyzes the effectiveness of such policies in attracting FDI. A higher σ_O may involve providing more tax breaks or larger subsidies in manufacturing *upon* successful technology transfer. A higher $\sigma_{\iota O}$ on the other hand may involve reducing the technology transfer costs *prior to* success in technology transfer. Such costs involve locating the appropriate production site, setting up production facilities, matching with workers and dealing with legal and financial transactions, and etc.

PROPOSITION 3: *A reduction in μ exerts no effect on w^*, decreases ι_N^*, but raises ι_O^*, n_O^*, and ι_A^* if $\sigma_{\iota O} < [m_O(1-\sigma_O)]/\lambda$.*

Under $\mu_O = \mu_N = \mu$, a lower μ exerts no influence on the *relative* R&D profitability conditions and thus no impact on w^*, because both Northern and Outsourcing firms face the same threat of replacement and thus the $(\rho + \iota_O + \iota_N + \mu - g)$ terms cancel out in (23). Nevertheless, the *absolute* profitability of both types of R&D rises. For given levels of ι_N and ι_O, this lowers the level of c that maintains the zero profit conditions in R&D.

In the North, the fall in c reduces the labor demand coming from manufacturing. Simultaneously the lower μ increases the fraction of Northern industries n_N. As $\rho - g \to 0$, the two effects exactly cancel each other and thus the LN curve in Fig 1.b remains the same. In the South, the lower μ increases the fraction of Outsourcing industries n_O and reduces that of Southern industries n_S. In the Outsourcing industries the labor market effects of the lower c and the higher n_O exactly cancel out as $\rho - g \to 0$. In the Southern industries, the lower c and n_S both work to reduce labor demand. The eventual decline in the aggregate labor demand creates room for an expansion in outsourced production and thus an increase in ι_O. This implies a rightward shift of the LS curve, leading to a higher ι_O^* but a lower ι_N^*. The aggregate innovation rate ι_A^* increases if $\sigma_{\iota O}$ is sufficiently low.

4. Unequal Imitation Rates

How robust are our main findings to allowing for unequal rates of imitation? In the real world, Outsourcing firms operate in close proximity to Southern firms. Hence it is reasonable to assume that they face a larger threat of imitation from the South compared to Northern firms; that is, $\mu_O > \mu_N$. In this case though the model becomes substantially complicated and therefore we run numerical simulations.

We borrow the baseline parameters from the empirical literature and data sources whenever possible. For the parameters that are not readily available, we choose values with the objective of generating empirically-relevant endogenous outcomes. Specifically, we use $\lambda = 1.5$, $\rho = 0.07$, $g = 0.014$, $\eta^S = 2$, $\mu_N = 0.003$, $\mu_O = 0.011$, $a_N = 1.4$, $a_O = 3.8$, $m_N = 1.05$, $m_O = 1.02$ and $\sigma_{\iota O} = \sigma_O = 0$.

We set λ at 1.5 such that the resulting price marginal cost ratios are consistent with recent estimates, which range between 1.05 and 1.4 (see Basu, 1996, and Norrbin, 1993). The discount rate ρ is set at 0.07 to reflect the average real return on the US stock market over the past century (see Mehra and Prescott, 1985). Using figures from World Bank (2003), g is obtained as the annual rate of world population growth between 1991 and 2000. The ratio of Southern population to Northern population, $\eta^S = N^S/N^N$, is calculated as the ratio of the working age population in middle income to high income countries—as defined by the World Bank (2003). We choose a_N and a_O to generate an aggregate rate of innovation ι_A= 1.28 percent, which implies a growth rate of 0.52 percent in consumer utility [as calculated by $\iota_A log\lambda$ =0.0128log(1.5)]. This is consistent with Denison (1985) who finds that the rate of growth driven by knowledge advancements is around 0.5 percent. We normalize the parameters k_N and k_O to one since they always enter as multiplicative terms attached to a_N and a_O. We impose $a_O > a_N$ to ensure the value of an Outsourcing firm to be larger than that of a Northern firm. m_N and m_O are chosen to satisfy $\lambda > m_N w > m_O(1 - \sigma_O) > 1$. We set μ_O = 0.011 and μ_N = 0.003 with the following considerations: the aggregate imitation rate is close to the aggregate innovation rate (ι_A= 0.0128), $\mu_O > \mu_N$ is satisfied and the resulting industry distribution is roughly equal.

Tables 1 and 2 present the results of the baseline simulation. Table 1 shows that the findings from the equal imitation model regarding changes in a_O and σ_O continue to hold when $\mu_O > \mu_N$ is allowed. A lower a_O or a higher σ_O gives a substantial boost to both types of R&D, ι_N* and ι_O*. A 10 percent decline in a_O increases ι_A* by 87.68 percent, and a 10 percent increase in σ_O increases ι_A* by 148.79 percent. Each shock works to reduce w* and increase n_O*. In particular, the positive impact on n_O* appears to be substantial: 46 and 69.32 percent respectively. Each shock leads to a decline in n_N* and n_S*, with the decline being larger in the latter.

Further, Table 2a shows that when $\mu_O = \mu_N = \mu$ is imposed, a lower imitation rate due to TRIPs reduces ι_N* but increases ι_O* and ι_A*, without exerting any influence on w*. In addition, n_O* increases whereas n_N* and n_S* both decrease, consistent with the findings stated in Proposition 3. Observe that the quantitative impact on ι_N* seems to be modest. Table 2b considers the more realistic case of $\mu_O > \mu_N$. This time an equi-proportionate decline in μ_O and μ_N increases both ι_N* and ι_O* and thus ι_A*. Hence, the negative impact of TRIPs on ι_N* as predicted by the equal imitation setting is now reversed. Indeed, beginning with $\mu_O=\mu_N$ and gradually increasing the gap between μ_O and μ_N, we observe that the impact of TRIPs on ι_N* turns from negative to positive.

Turning to the wage gap, we find that when $\mu_O > \mu_N$ TRIPs reduces w*. Note that in this case (23) needs to be modified as:

$$\mathrm{K} \equiv \frac{a_N k_N}{a_O(1-\sigma_{\iota O})} = \frac{\left[\lambda - m_N w\right]\left(\rho - n + \iota_A + \mu_O\right)}{\left[\lambda - (1-\sigma_O)\right]\left(\rho - n + \iota_A + \mu_N\right)} \equiv \Pi \,,$$

which reveals an additional impact on w* that works through ι_A, in particular, $dw/d\iota_A < 0$. TRIPs has the effects of reducing both μ_O and μ_N, and from the simulations TRIPs eventually raises ι_A*. The former decreases the threat of replacement but the latter increases it by accelerating the pace of creative destruction. Simulations imply that the replacement rate of both Northern and Outsourcing firms increase despite the reduction in Southern imitation (i.e., $\iota_A + \mu_N$ and $\iota_A + \mu_O$ both increase). At the new equilibrium, the increase in the Northern firm's discount factor adjusted for replacement ($\rho - g + \iota_A + \mu_N$) is proportionally larger than the increase in the replacement rate faced by the Outsourcing producers ($\rho - g + \iota_A + \mu_O$). In other words, the profitability of local-sourcing-targeted R&D relative to outsourcing-targeted R&D goes down; consequently, w* declines.

We conducted extensive numerical simulations and found that the baseline findings of Table 1 and 2 continue to hold under a wide range of parameters. The following proposition summarizes the main results of this section.

PROPOSITION 4: *When $\mu_O > \mu_N$, numerical simulations imply that each of the following events, an increase in σ_O, a decrease in a_O, or a simultaneous decrease in μ_O and μ_N, leads to: (i) lower w*, (ii) higher ι_O*, ι_N* and ι_A*, (iii) higher n_O* but lower n_N* and n_S*. The increase in the frequency of the iPod* *cycles as measured by ι_O* and the increase in the fraction of Outsourcing industries n_O are of substantial magnitudes under all three events.*

5. Conclusion

We have incorporated the `iPod cycle' into the traditional product-cycle setting, by categorizing R&D races into two types: outsourcing-targeted and local-sourcing-targeted. Entrepreneurs determine their eventual location of production by choosing which race to participate in. We have captured the iPod cycle in the context of outsourcing-targeted R&D races in which participants combine their innovation activities with simultaneous outsourcing efforts.

We have shown that globalization in the form of an improvement in the efficiency of outsourcing-targeted R&D raises the aggregate rate of innovation while reducing the North-South wage gap. We have also identified the compositional effects on R&D by finding that the intensity of outsourcing-targeted R&D rises whereas the intensity of local-sourcing-targeted R&D moves in an ambiguous direction. These imply that the higher frequency of iPod cycles through increased outsourcing-targeted R&D is a robust factor that fosters aggregate innovation. We have found that increased subsidies to outsourcing (be it to technology transfer or manufacturing) generates the same steady-state results. In addition, we have shown that TRIPs can boost not only technology transfer to the South via the iPod cycle but also the aggregate innovation rate. Hence, in the presence of immediate technology transfer to the South, TRIPs produces more optimistic results than those found in the existing literature.

We have only looked into some aspects of the globalization process. Other aspects such as tariff reductions are also important and their impacts remain to be analyzed. One might also incorporate contractual frictions to the product cycle setting along the lines of Antràs (2005) and Antràs and Helpman (2004), and model the in-house production vs. arm's length contracting decisions of multinational firms. Combining our focus on simultaneous R&D races with Antràs' (2005) contractual frictions is a fruitful undertaking, which we leave for further research.

References

Antràs, P., 2005. Incomplete contracts and the product cycle. American Economic Review 95, 1054-1073.

Antràs, P., Helpman, E., 2004. Global sourcing. Journal of Political Economy 112, 552-80.

Basu, S., 1996. Procyclical productivity: Increasing returns or cyclical utilization. Quarterly Journal of Economics 111, 709-51.

Branstetter, L., Fisman R., Foley, F., 2006. Does stronger intellectual property rights increase international technology transfer? Empirical evidence from U.S. firm-level panel data, Quarterly Journal of Economics 121, 321-349.

Branstetter, L., Fisman R., Foley F. and Saggi K., 2007. Intellectual property rights, imitation, and foreign direct investment: Theory and evidence. NBER Working Paper #13033.

Denison, E., 1985. Trends in American Economic Growth, 1929-1982. The Brookings Institution, Washington, DC.

Dinopoulos, E., Kottaridi C., 2008. The growth effects of national patent policies. Review of International Economics 16, 499-515.

Dinopoulos E., Segerstrom, P., 2007. Intellectual property rights, multinational firms and economic growth, working paper, University of Florida and Stockholm School of Economics.

Dinopoulos, E., Thompson, P., 2000. Endogenous growth in a cross section of countries. Journal of International Economics 51, 335-362.

Feenstra, R. C., 1998. Integration of trade and disintegration of production in the global economy. Journal of Economic Perspectives 12, 31-50.

Glass, A.J., Saggi, K., 1999. Foreign direct investment and the nature of R&D. Canadian Journal of Economics 32, 92–117.

Glass, A. J., Saggi K., 2001. Innovation and wage effects of international outsourcing. European Economic Review 45, 67-86.

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

Glass, A. J., 2004. Outsourcing under Imperfect Protection of Intellectual Property, *Review of International Economics* 12, 867-884.

Glass, A. J., Wu, X., 2007. Intellectual property rights and quality improvement. Journal of Development Economics 82, 393-415.

Grossman, G., Helpman, E., 1991, Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA.

Grossman, G., Helpman E., 2003. Outsourcing versus FDI in industry equilibrium. Journal of the European Economic Association 1 (2-3), 317-27.

Hanson, G. H., 2001. Should countries promote foreign direct investment? G-24 Discussion Paper Series No 9. United Nations Conference on Trade and Development.

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

Jones, R., Kierzkowski, H., 1990. The Role of Services in Production and International Trade: A Theoretical Framework, in Jones, R. and Krueger, A. (Eds.), The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin, 31-48. Oxford: Basil Blackwell.

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

Linden, G., Kraemer, K. L., Dedrick J., 2007. Mapping the value of an innovation: An analytical framework. Research paper, Personal Computing Industry Center, UC Irvine.

Long, N. V., Riezman, R., Soubeyran A., 2005. Fragmentation and services. The North American Journal of Economics and Finance 16, 137-152.

Lu, C., 2007. Moving up or moving out? A unified theory of R&D, FDI and trade. Journal of International Economics 71, 324-343.

Mehra, R., Prescott, E.C., 1985. The Equity Premium: A Puzzle. Journal of Monetary Economics 15, 145-61.

Naghavi, A., Ottaviano G., 2005. Outsourcing, contracts and growth. Working paper. Universita di Modena and Universida di Bologna.

Norrbin, S. C., 1993. The Relationship between price and marginal cost in US industry: A Contradiction. Journal of Political Economy 101, 1149-64.

Parello, C., 2008. A North-South model of intellectual property rights protection and skill accumulation. Journal of Development Economics 85, 253-281.

Sayek, S., Şener, F., 2006. Outsourcing and wage inequality in a dynamic product cycle model. Review of Development Economics 10, 1-19.

Şener, F., 2006. Intellectual property rights and rent protection in a North-South product cycle model. Working paper. Union College.

Tang, L. 2006. Communication costs and trade of differentiated goods. Review of International Economics 14, 54-68.

Vernon, R., 1966. International investment and international trade in the product cycle. Quarterly Journal of Economics 34, 225-43.

World Bank, 2003. World Development Indicators, Washington, DC.

Figure 1a: Steady-State Equilibrium

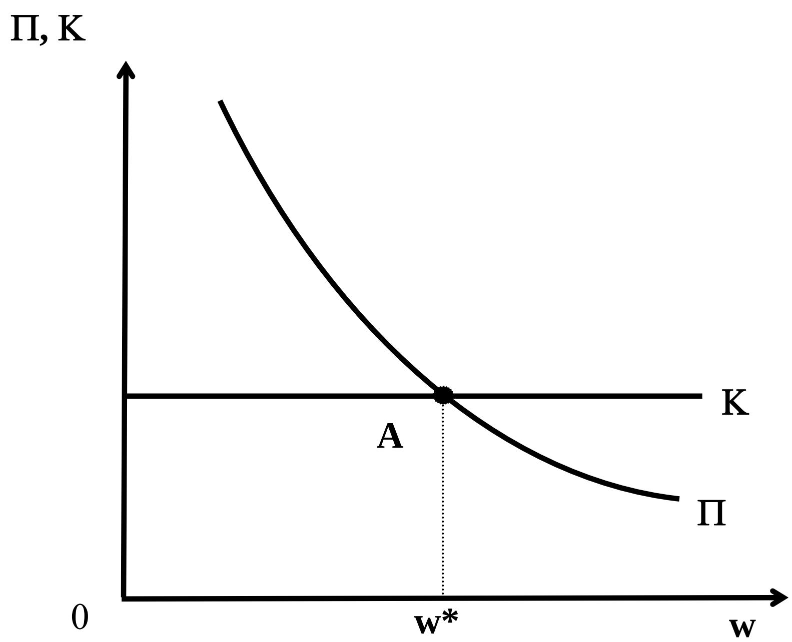

Figure 1b: Steady-State R&D Intensities