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Innovation and Production Offshoring: Implications on Welfare

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Hi-Stat Discussion Paper

Innovation and Production Offshoring: Implications on Welfare

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Abstract

I theoretically analyze the effects of a strengthening IPR protection and an improvement of technology of innovation of offshoring on the rate of innovation offshoring, rate of imitation, rate of innovation, relative wages, real wages and domestic welfare. A North-South dynamic general equilibrium model of trade with endogenous imitation and innovation and production offshoring is constructed. To trade with lower Southern wages, Northern firms confront the problem of information leakage to the Southern firms and monitoring costs if they do offshore innovation and production. The model predicts that a strengthening of IPR protection decreases the rate of innovation and the rate of imitation but increases the rate of innovation offshoring. Northern real wages also decrease with a strengthening of IPR protection but Southern real wages increase. It may hurt the North but benefit the South. An improvement in technology of innovation offshoring increases the rate of innovation, the rate of imitation and the rate of innovation offshoring. Northern relative real wages decrease with such improvement but Southern real wages increase. It may benefit the North and the South.

Keywords : offshoring, innovation, information leakage, productivity gap, welfare, trade policies

JEL classification : F12, F13, F21, F23,D43,O31

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1 Introduction

Offshoring has been steadily increasing in developed countries. Starting with offshoring of production activity decades ago, this economic phenomenon now also reaches higher value added and non-routinized areas, including research and development, and the overall sphere of innovation activity.

Business media now report the offshoring of innovation activity in sectors ranging from pharmaceutical and bio-technology to computer hardware and software. An increasing number refers to wholly owned innovation centers in countries such as Russia, China and India, or sometimes even arms length sub-contracting of innovation in these countries. Intel, for example, has labs carrying out advanced microprocessor design work in Novosibirsk and St.Petersburg in Russia, after having bought Elbrus, a leading Russian computer technology research center and boosting its Russian research staff to over 1500. Intel also has a hi-tech development center in Bangalore, India, working on digital signal processing, device drivers and process and chipset design, and a major facility in Beijing, the Intel China Research Center for the development of next-generation networking and wireless platform solutions. According to the Indian National Association of Software and Service Companies (Nasscom), the total market size of this so-called knowledge process outsourcing (KPO) business in India was around $1.2 billion in 2004, and is expected to increase substantially. Original equipment manufacturers to whom value added resellers would offshore component manufacturing, are giving way to original design manufacturers in the Asia-Pacific region. The latter design, engineer and manufacture products from the ground up with little input from their clients, whose major role often is to contribute the brand name.

The primary reason for innovation offshoring is the same as for offshoring in general-cost reductions. In additional to the cost saving, there are other reasons for this phenomenon including demand and supply of scientists, technologists and knowledge workers, interaction capabilities and new incentives. Demand (as defined by real gross national product in the world's largest and most rapidly growing economies) is doubling every 14 to 16 years, creating a host of new specialist markets sufficiently large to attract innovation. The supply of scientists, technologists and knowledge workers has dramatically increased, as have knowledge bass and access to them. Software-based analytical, modeling, communications and market-feedback technolo-

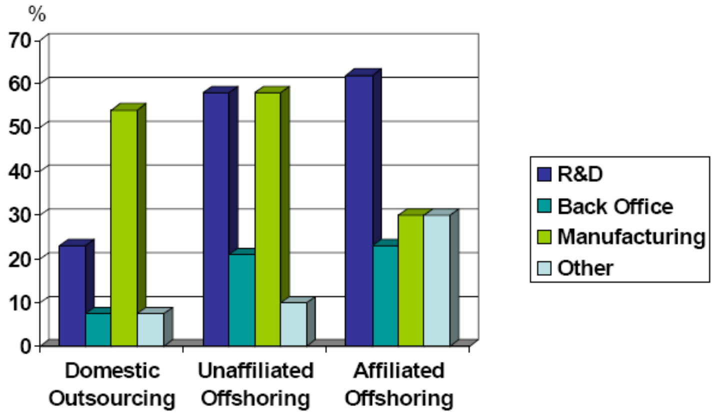

Figure 1: Nature of Activity Outsourcing and Offshoring

gies have lowered costs and risk substantially, allowing many smaller enterprises to participate in emerging markets. Interaction capabilities have grown. Combined with the internet and other information technology capabilities, interactions among technologies –including the biotech, computer, chemistry, environmental and food fields – are growing exponentially. New incentives have emerged. Lower tax rates, privatization, the relaxation of many national and international trade barriers, and the lower capital investment needed in many fields have meant greater incentives for entrepreneurs worldwide to develop and exploit advances in knowledge. New management techniques, software, and communication systems have enabled much better coordination of highly dispersed innovation activities.

Figure 1[1] shows the distribution of the nature and specific kinds of activities offshored and outsourced to various locations. It shows that while manufacturing is the most common form of activity offshored overall, there is a significant amount of R&D offshoring as well. It is interesting to note that R&D is the most significant segment in the intra-firm offshoring category, i.e. to foreign affiliates. Apparently, when it comes to carrying out R&D abroad it is important to safeguard proprietary business procedures and intellectual property rights under the aegis of your own firm. Firms match their organizational strategy and structure to the needs of innovation being pursued. As pointed out by Teece and Chesbrough (2002), "..to organize a business for innovation, managers must first determine whether the innovation in question is

[1]See Bradhan and Jafee (2005)

autonomous (it can be pursued independently) or systemic (it requires complementary innovations)", and also determine whether the capabilities needed for innovation can be easily offshored or created in-house. Within the universe of offshoring, the more routine developmental activity was subcontracted to arms length parties while more sensitive aspects were dealt with by the firm's subsidiary. Also, firms preferred to carry out research on "drastic" innovations, embodying a qualitative break from attributes of previous products or processes, within the firm, while outsourcing the search for common, marginal improvements and individual innovative elements of a product package. On the other hand, narrowing the sample to innovative firms shows that the more innovative firms do not offshore their R&D.

To my knowledge, in terms of innovation offshoring literature and product cycle literature, there has not been any work that formally models the theoretical foundation of innovation offshoring. This paper provides a theoretical framework for innovating offshoring. It mainly addresses how changes in IPR protection and technology of innovation offshoring alter the rates of innovation and imitation, the degree of innovation offshoring and welfare in both the home and host countries'. The literature on product cycle models has seen a revival in recent years. This literature is based on the seminal work done by Vernon (1966) . He presents a model where new products are first introduced in high income countries, exports begin to other high income countries, eventually production shifts to low income countries, and finally the original product may be exported back to the high income country which first introduce it. Yet while Vernons (1966) original vision of the product cycle assigns a central role to foreign direct investment (FDI), most of the new models capturing his ideas use imitation as the channel of international technology transfer from an innovating region (the North) to an imitating region (the South).

Grossman and Helpman (1991) followed the "product cycle" idea that North is the only source of innovation (new varieties of products), and the only way South can acquire technology is through technology transfer (imitation) from North. Both innovation and imitation are costly activities and their levels are endogenously determined. They study the determinants of the long run rate of innovation and imitation. An increase in labor supply in the South or a decrease in the labor requirement for imitation generates an increase in the steady-states rate of imitation. In the North, this raises the risk premium for innovation and also boosts the profits of the surviving monopolies. The second effect dominates, raising the rate of innovation. Grossman and Helpman (1991)developed a similar model were innovations are higher quality levels (the quality ladder model). An increase in the Southern labor force raises imitation and the number of Northern firms targeted for imitation. Innovation in the North may rise or fall. The Grossman-Helpman product cycle models has new products being invented by "only" Northern firms and later directly imitated by Southern firms.

In the Vernon cycle, Northern firms move production to the South by forming subsidiaries there before imitation shifts ownership but not location of production. IPR reforms were not explicitly discuss in the above mentioned models. To analyze the debate between North and South about the enforcement of stronger IPRs in the South, Helpman (1993) employs a simplified version of the Grossman and Helpman (1991) model with exogenous imitation. His main contribution is analyzing the transition dynamics between steady states following tightened IPRs in the South (modeled as a decrease in the exogenous imitation intensity): stronger IPRs initially raises the rate of innovation, but the rate of innovation subsequently declines. At the end of his paper he introduces FDI in a model with exogenous innovation and imitation. Lai (1998) modifies Helpman's model to consider the effects of imitation targeting multinational production on innovation. He considers two possible channels of production transfers between North and South: FDI and imitation. The effects of stronger IPR in South (modeled as a decrease in the exogenous imitation intensity) depend on the channel of production transfer. In the case of technology transfer through imitation (without FDI), stronger IPR lowers the rate of innovation. The effects are opposite if the transfer channel is FDI, or if both transfer channels coexist (and the rate of FDI is large). If the technology transfer is made through FDI, southern firms can imitate only after Northern firms transfer production to the South. Northern firms move production to the South in order to take advantage of lower labor costs. In this case the effect of stronger IPR does not affect the demand for Northern labor as production is entirely in the South. This will cause innovation to raise without an increase in innovation costs. Lai's (1998) results change when innovation, imitation and offshoring are endogenously determined within the model and the Southern labor supply is divided between skilled and unskilled labor. Glass and Saggi (2002) question the results of Lai (1998) where stronger Southern IPR protection encourage FDI and innovation. They employ a quality-ladder model and argue that stronger Southern IPR protection reduces the aggregate rate of innovation and the flow of FDI regardless of whether FDI or imitation targeting Northern production serves as the primary channel of international technology transfer. In their model, stronger IPR protection is an increase in the cost of imitation. Glass and Saggi (2002) conclude that the reason for the difference in their results relative to Lai (1998) appears to be the difference in how IPR protection was modeled: as an increase in the cost of imitation rather than as an exogenous decrease in the imitation intensity. But there is another important difference between the two models: the type of innovation (creating new varieties versus quality upgrading) . Glass and Wu (2007) look at how differences in the type of innovation affect the consequences of stronger IPR. Their model is based on the quality-ladder model developed by Grossman and Helpman (1991) and it assumes imitation to be exogenous. They found that stronger IPR in the South (decrease in the imitation intensity) decrease FDI and innovation, an opposite result to the one found by Lai (1998) where innovation targeted new varieties. They conclude that stronger IPR protection may shift the composition of innovation away from improvements in existing products toward development of new products. The newest extension to the Grossman and Helpman (1991) model is done by Branstetter, Fisman, Foley and Saggi (2007). They analyze theoretically and empirically the effects of strengthening IPRs in developing countries in a product variety model with endogenous innovation, imitation, and FDI. The model predicts that IPR reform in the South leads to increased FDI in the North, increased global rate of innovation and a reduction in imitation rate. On the empirical part they analyze responses of U.S.-based multinationals and domestic industrial production to IPR reforms in the 1980s and 1990s. They find that there is an overall expansion of industrial activity after IPR reform, suggesting that the expansion of multinational activity more than offsets any decline in the imitative activity of indigenous firms. Later, Branstetter and Saggi (2010) studied the effect of IPR protection with endogeneous FDI. An innovation process is took placed in the North. They found that a strengtening of IPR protection in the South reduces the rate of imitation and it increases the flow of FDI and rate of innovation.

Since there has not been any paper that studies about innovation offshoring, the effect of improvement in technology of innovation offshoring is neglected. The model of this paper extends the work of Grossman and Helpman (1991) by developing a dynamic general equilibrium model with endogenous imitation and innovation, and production offshoring. I theoretically analyze the strengthening of IPR protection

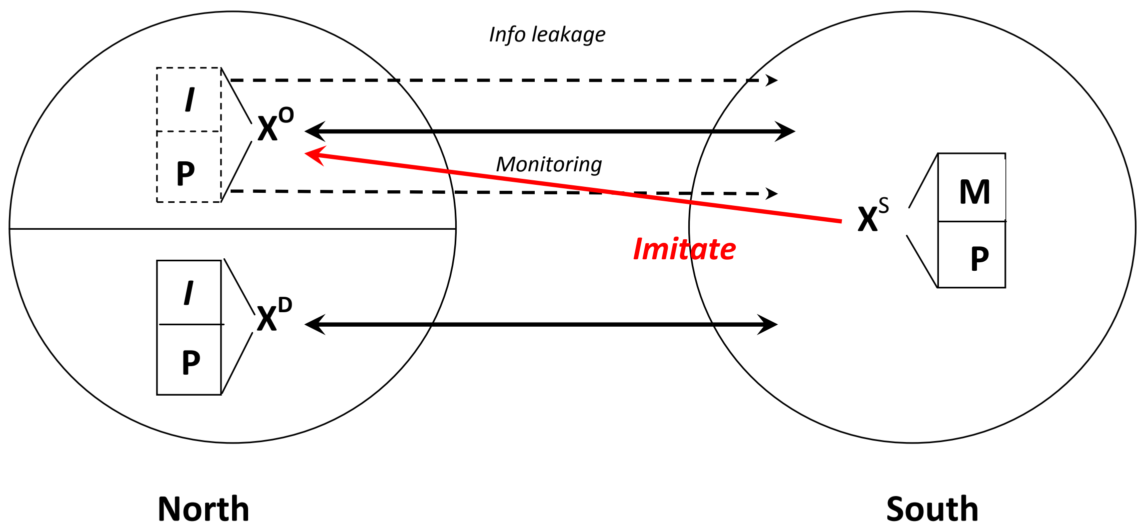

Figure 2: Model Structure

and improvement of innovation offshoring on the rate of innovation offshoring, the rate of imitation, the rate of innovation, relative wages, real wages and welfare.

Interestingly, this paper shows that when an innovation offshoring regime exists a straightening IPR protection decreases the rate of innovation and the rate of production. From a welfare perspective, the North may hurt while the South may benefit from this policy. These results are different from the previous literatures. Whereas, an improvement in technology of innovation offshoring can increase the rates of innovation imitation. Thus, both the North and the South can benefit from this phenomenon.

The structure of this paper is as follows. A basic model is presented in section 2. The effects of the strengthening IPR protection are shown in section 3.1 and the effects of an improvement of technology innovation offshoring are shown in section 3.2. Finally, the concluding remarks are provided in Section 4.

2 Basic Model

Figure 2 shows the structure of the world economy. There are two countries in the world - the North N and the South S; and both countries freely trade their differentiated products which are invented in both countries and only imitated in the

South. Labor is the only factor of production in each country. It is intersectorally mobile but internationally immobile.

2.1 Consumer Behavior

The representative household maximizes the intertemporal utility function

$$U^i = \int_t^\infty e^{-\rho(\tau - t)} \log D^i(\tau) d\tau \tag{1}$$

subject to the intertemporal budget constraint

$$\int_t^\infty e^{-r^i(\tau - t)} E(\tau) d\tau \leq \int_t^\infty e^{-r^i(\tau - t)} I^i(\tau) d\tau + A^i(t) \tag{2}$$

where $E^i(\tau), I^i(\tau), D^i(\tau)$ and $A^i(\tau)$ are the instantaneous expenditure, the instantaneous income, the instantaneous utility and the current value of assets at time τ of the representative consumer in the ith country for $i = N, S$. ρ and r^i are the rate of time preference and the nominal interest rate in the ith country, respectively.

The relevant instantaneous subutility index is assumed to have the following form

$$D^i(\tau) = \left[\int_0^{n(\tau)} x^i(j)^\alpha dj \right]^{\frac{1}{\alpha}} \tag{3}$$

where $0 < \alpha < 1$, n and $x^i(j)$ stand for the number of products and the amount of the jth variety consumed by the representative consumer in the country i.

Solving the optimization problem we obtain the following instantaneous demand function for jth variety

$$x^i(j) = \frac{Ep(j)^{-\varepsilon}}{\int_0^{n(t)} p(j)^{1-\varepsilon} dj} \tag{4}$$

where $\varepsilon = \frac{1}{1-\alpha} > 1$ is the constant elasticity of substitution between two goods and $E = E^N + E^S$ is the world total expenditure.

We also obtain the following optimal time path of expenditure[2]

$$\frac{\dot{E}^i}{E^i} = r^i - \rho \tag{5}$$

Nominal consumption expenditure grows at a rate equal to the difference between the interest rate and the subjective rate of time preference. Assume perfect capital mobility, so $r^N = r^S = r$.

2.2 Product Market

There are 3 types of firms producing goods: Domestic innovation and production Northern firms (D), Offshored innovation and production firms (O) and imitative Southern firms(S) as referred later as domestic, offshoring and Southern firms, respectively. Northern firms have an option to innovate and produce in the North or the South. A firm requires one unit of labor to produce a unit of output in the North and it requires $\xi > 1$ units of labor to produce a unit of output in the South. ξ can be interpreted as the coordination costs, monitoring costs or operating of production processes in unfamiliar foreign environment.

Innovation offshoring activity generates a problem of information or knowledge leakage to a Southern firms. This information leakage cannot be monitored by the firms or verified by a third party such as a court law. Each firm completes each other according to Bertrand price competition fashion and all goods are freely traded internationally.

The monopoly profits of the representative domestic firm and the offshoring firm producing each of the n^D and n^O varieties are , respectively, given by the following:

$$\pi^D = p^D x^D - w^N x^D \tag{6}$$

$$\pi^O = p^O x^O - \xi w^S x^O \tag{7}$$

where p^j is a price level of jth variety and w^N and w^S are Northern and Southern wages, respectively.

Given the constant elasticity demand function, the monopoly price are marks-ups

[2]Its derivation is omitted because it is similar to that in Grossman and Helpman(1991b).

over their marginal costs:

$$p^D = \frac{w^N}{\alpha} \tag{8}$$

$$p^O = \frac{\xi w^S}{\alpha} \tag{9}$$

Southern firms can produce only those goods that they have successfully imitated and they need one labor to produce a unit of goods. Assume $\xi\alpha < 1$, the narrow-gap case, the Southern producer enjoys a relatively small cost advantage over its Northern rival. In this case, if the Southern firm were to charge the monopoly price, the offshoring firm could probably undercut and force the Southern firm's sale to zero. If successful in imitating an offshoring firm, the Southern imitator sets a limit price at the level of (or just below) its competitor's cost.[3] Therefore the Southern firm's price setting and profit function are respectively given by

$$p^S = \xi w^S \tag{10}$$

$$\pi^S = (\xi - 1) w^S x^S \tag{11}$$

Let x^j denote the good that firm j where $j = D, O$ or S can sale. We know from the demand functions in equation (4) that

$$\frac{x(i)}{x(j)} = \left(\frac{p_i}{p_j}\right)^{-\varepsilon} \tag{12}$$

Substitute the price equations for the three types of goods, we have

$$\frac{x^O}{x^D} = \left(\frac{\xi w^S}{w^N}\right)^{-\varepsilon} \tag{13}$$

$$\frac{x^S}{x^D} = \left(\frac{\alpha \xi w^S}{w^N}\right)^{-\varepsilon} \tag{14}$$

$$\frac{x^S}{x^O} = \alpha^{-\varepsilon} \tag{15}$$

[3]When $\xi\alpha > 1$, the Southern imitator charges its optimal monopoly price. However, the main results would not change.

2.3 Innovation, Imitation and Offshoring

At time t there are n goods existing in the world, among which n^D goods are innovated and produced domestically, n^O goods have been internationalized by offshoring their innovation and production processes to the South and n^S are goods produced by Southern imitators. Let $n^{SO} = n^O + n^S$ denote all goods that their innovation or imitation and production are performed in the South. $n = n^N + n^O + n^S$ denotes the total number of varieties in this economy.

I define the rate of innovation offshoring ,Υ, by

$$\Upsilon = \frac{\dot{n}^O}{n^N} \tag{16}$$

i.e. Υ denotes the rate of increase of the number of offshoring firms relative to the total number of goods produced by domestic firms. In other words, at each point of time, the number of goods produced by offshoring firms increases by Υn^N.

Next, I define the rate of imitation, m, by

$$m = \frac{\dot{n}^S}{n^O} \tag{17}$$

i.e. m denotes the rate of increase of the number of imitated goods relative to the total number of goods produced by offshoring firms. Because the products of offshoring firms are targeted for imitation by Southern firms, imitation transfers ownership of a good from offshoring firms to a Southern imitators.[4]A southern firm has no incentive to imitate each other because its costs and price setting are the same.

On balance growth path or in a steady state equilibrium in which prices, nominal spending, and all goods grow at the same rate g,

$$g = \frac{\dot{n}}{n} = \frac{\dot{n}^N}{n^N} = \frac{\dot{n}^O}{n^O} = \frac{\dot{n}^S}{n^S} = \frac{\dot{n}^{SO}}{n^{SO}} = \frac{\dot{E}^i}{E^i} = \frac{\dot{E}}{E} \tag{18}$$

and $g, n^N/n, n^O/n$and n^{SO}/n are constant over time. We can calculate the steady state allocation of goods across three types of firm as follows.

$$
\begin{aligned}
\frac{n^O}{n^D} &= \frac{\Upsilon}{g} && (19)\\
\frac{n}{n^D} &= 1+\frac{\Upsilon}{g}\left[1+\frac{m}{\Upsilon}\right] && (20)\\
\frac{n^S}{n^D} &= \frac{m}{g} && (21)\\
\frac{n^{SO}}{n^D} &= \frac{\frac{\Upsilon}{g}\left[1+\frac{m}{\Upsilon}\right]}{1+\frac{\Upsilon}{g}\left[1+\frac{m}{\Upsilon}\right]} && (22)\\
\frac{n^S}{n^D} &= \frac{m}{\Upsilon} && (23)
\end{aligned}
$$

2.3.1 Value of Firms

Once a domestic firm has mastered the technology for some products, it earns an infinite stream of oligopoly profits. The owner of the domestic firm collects profits $\pi^D dt$ in a time interval of length dt. The total return on equity claims must equal the opportunity cost, r, of the invested capitals, which implies the no-arbitrary condition

$$\pi^D dt = rv^D dt \tag{24}$$

Equations (5) and (18) imply that in steady state the interest rate equals the sum of the subjective discount rate and the growth rate :

$$r = \rho + g \tag{25}$$

Thus, from equations (24) and (25), the expected present discounted lifetime value of profits of domestic firms is

$$v^D = \frac{\pi^D}{\rho + g} \tag{26}$$

An offshoring firm holding the blueprint for a product that has not yet been copied earns profits $\pi^O dt$ during the interval of length dt. This firm faces an ongoing risk that its products will be selected by a Southern entrepreneur as the target for imitation. In an interval of length dt, $\dot{n}^S dt$ products will be copied. With random selection a given firm will lose its monopoly position during such an interval with probability $\dot{n}^S dt/n^O$. In such event, the owner of the offshoring firm suffers a capital loss of size

v^O. The arbitrage condition for the offshoring firm that is the equality between the total expected return on shares and opportunity cost.

$$\pi^D dt - \frac{\dot{n}^S dt}{n^O} v^O = r v^O dt \tag{27}$$

The expected present discounted lifetime value of profits of an offshoring firms is

$$v^O = \frac{\pi^O}{\rho + m + g} \tag{28}$$

We can see that the profits of the offshoring firm is discounted by the effective rate interest rate $(r + \rho)$ but also by the rate of imitation (m). This is because imitation targets only offshoring firms. However, in reality Northern firms that domestically innovate and produce at the North have also a probability to be imitated but this risk of imitation is lower than domestic firms. For simplicity, I assume that this risk become zero. Therefore, domestic firms have an option of innovation and production in the North or in the South. To innovate and produce in the South, firms pay lower relative wages (Southern wages are lower than Northern wages in equilibrium as I will show later) but they confront with the risk of imitation depending on the rate of information leakage and the stock of knowledge in the South.

Next, I will consider the value of a Southern firm. Once a Southern firm successfully imitates offshoring firm's products, it earns an infinite stream of oligopoly profits. Southern firm's owners receive profits πdt in a time interval of length dt. Therefore, the arbitrage condition for a Southern firm is

$$\pi^S dt = r v^S dt \tag{29}$$

The expected present discounted lifetime value of profits of a Southern firm is

$$v^S = \frac{\pi^S}{\rho + g} \tag{30}$$

2.3.2 Costs of Innovation and Imitation

Following Grossman and Helpman (1991), the costs of innovation by a domestic firm are assumed to be

$$C_I^D = \frac{w^N a_I^D}{n} \tag{31}$$

where a_I^D is the cost parameter of innovation in the North, $1/n$ captures the spillover effect of knowledge generated on efficiency of current innovation. In other words, the efficiency of product development in the North increases with n, which is proxy for the cumulative knowledge generated as by-products of all past innovations in the North.

The costs of innovation offshored to the South can be modeled as the same fashion as the costs of innovation in the North but an offshoring firm pays Southern wages w^S and costs a_I^O. Therefore, The costs of innovation for an offshoring firm in the South is

$$C_I^O = \frac{w^S a_I^O}{n} \tag{32}$$

where a_I^O is the cost parameter of innovation in the South. Assume $a_I^D < a_I^O$. Intuitively, this is due to the costs of operating and conducting an innovation in unfamiliar foreign environments.

The imitation activity in the South is an investment activity similar to the innovation. Because in reality it requires managerial talent, scientists, and technicians, much like any other type of research. The South can gain the ability to produce an existing variety by devoting $a^S/\gamma n^{SO}$ units of labor to the task of imitation. Here n^{SO} represents the number of technologies that the South has already acquired. In the other words, n^{SO} is the number of products innovated, imitated and produced in the South. Innovation offshoring generates a problem information leakage to Southern firms. $0 < \gamma < 1$ captures the degree of information or knowledge leakage to the South. We can interpret that a lower in γ is a strengthening of IPR protection in the South or vice versa. Therefore, The costs of imitation are

$$C_M^S = \frac{w^S a^S}{\gamma(n^O + n^S)} = \frac{w^S a_M^S}{\gamma n^{SO}} \tag{33}$$

Assume $a_M^S < a_I^D < a_I^O$. Intuitively, the labor required for imitation is less than newly invent a goods.

2.4 Free Entry into Innovation in North and South and Imitation

Free entry and profit maximization imply that the expected lifetime present value of domestic and offshoring firms must be equal to the costs of innovation. Also, the expected life time present value of a Southern firm must be equal to the costs of imitation. Therefore,

$$v^N = \frac{w^N a_I^D}{n} \Leftrightarrow \frac{\pi^N}{\rho+g} = \frac{w^N a_I^D}{n} \tag{34}$$

$$v^O = \frac{w^S a_I^O}{n} \Leftrightarrow \frac{\pi^O}{\rho+m+g} = \frac{w^S a_I^O}{n} \tag{35}$$

$$v^S = \frac{w^S a_M^S}{n^{SO}} \Leftrightarrow \frac{\pi^S}{\rho+g} = \frac{w^S a_M^S}{\gamma n^{SO}} \tag{36}$$

Substituting profit functions of each type of firms into equation (34)- (36) gives the output of each firm as follows :

$$x^N = \frac{\alpha}{1-\alpha}\frac{a_I^D(\rho+g)}{n} \tag{37}$$

$$x^O = \frac{a_I^O \alpha(\rho+g+m)}{\xi(1-\alpha)n} \tag{38}$$

$$x^S = \frac{a_M^S \alpha^{\varepsilon}(\rho+g)}{(\xi-1)\gamma n^{SO}} \tag{39}$$

From equation (34) and (35), we can calculate relative wages as follows,

$$\frac{w^N}{w^S} = \omega = \left(\frac{a_I^O \xi^{\varepsilon-1}(m+\rho+g)}{a_I^D(\rho+g)}\right)^{\frac{1}{\varepsilon}} > 1 \tag{40}$$

Note that $a_I^O > a_I^D$ and $\xi > 1$. Northern relative wages are always greater than one. They have a positive relationship with the production disadvantage caused by coordination and monitoring difficulties faced by offshoring firms (ξ), costs parameter of offshoring innovation relative to domestic innovation (a_I^O/a_I^D) and the rate of imitation (m) because they discourage domestic firms to offshore to the South. This reluctance to shift innovation and production processes to the South. They implicitly increase Northern labor demand and finally relative wages.

From equations (34) and (36) we have

$$\frac{w^N}{w^S} = \frac{1}{\gamma}\frac{n}{n^{SO}}\frac{a_M^S}{a_I^D}\frac{v^N}{v^S} \tag{41}$$

Free entry condition in innovation and imitation can be reexpressed as

$$\frac{\gamma\alpha^{1-\varepsilon}}{\xi}\frac{n^{SO}}{n}\frac{a_I^O}{a_M^S}\frac{\xi-1}{1-\alpha}\left(\frac{\rho+g+m}{\rho+g}\right)^{\frac{\varepsilon}{\varepsilon-1}} = 1 \tag{42}$$

$$\left(\frac{\gamma\alpha^{1-\varepsilon}}{\xi}\right)\frac{\frac{\Upsilon}{g}\left(1+\frac{m}{g}\right)}{1+\frac{\Upsilon}{g}\left(1+\frac{m}{g}\right)}\frac{a_I^O}{a_M^S}\frac{\xi-1}{1-\alpha}\left(\frac{\rho+g+m}{\rho+g}\right)^{\frac{\varepsilon}{\varepsilon-1}} = 1 \tag{43}$$

Intuitively, this condition follows the assumption of free entry into imitation and innovation and it ensures that no activities lead to excess profits for the firms that are successful in such activities.

2.5 Labor Markets

In the North domestic firms demand $n^D x^D$ units of labor for manufacturing while $a_I^D \dot{n}^D/n$ to conduct research in the North. Northern labor market equilibrium requires that

$$L^N = \frac{a_I^D \dot{n}^D}{n} + n^D x^D \tag{44}$$

where L^N is the supply of labor in the North. Similarly $n^S x^S$ units of labor used for manufacturing of Southern goods, while $a^S \dot{n}^S/\gamma n^{SO}$ are engaged in imitation. Moreover, $\xi n^O x^O$ units of labor used for manufacturing for offshoring Northern firms and $a^O \dot{n}^O/n$ are engaged in an innovation activity of offshoring northern firms in the South. Southern labor market equilibrium requires that

$$L^S = \frac{a_I^O \dot{n}^O}{n} + \frac{a_M^S \dot{n}^S}{\gamma n^{SO}} + \xi n^O x^O + n^S x^S \tag{45}$$

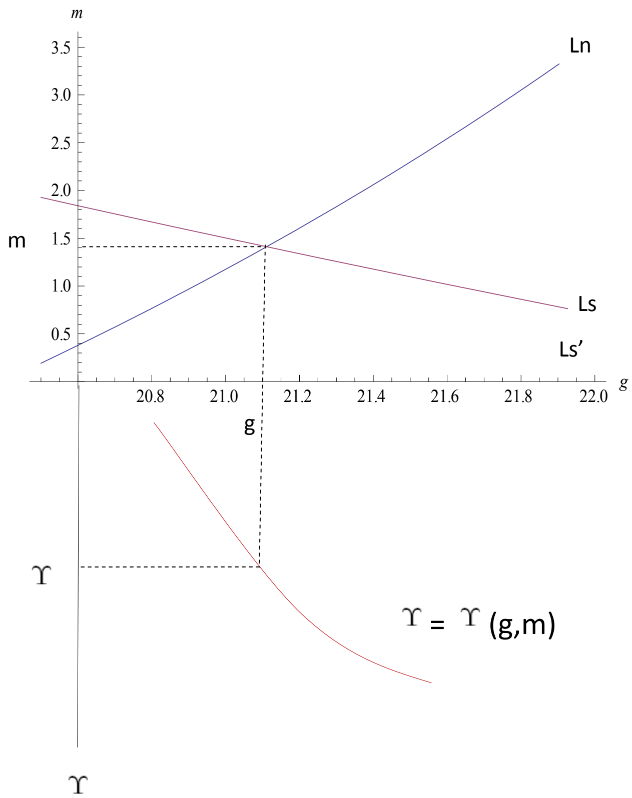

Figure 3: Equilibrium value of rate of innovation offshoring (Υ), rate of imitation (m) and rate of innovation (g)

Substitute equations (18)-(23) and demand function into above labor clearing condition we get,

$$L^N = \frac{a_I^D g^2}{g+\Upsilon+m} + \frac{g}{g+\Upsilon\left(1+\frac{m}{g}\right)} \frac{\alpha a^N(\rho+g)}{1-\alpha} \tag{46}$$

$$L^S = \frac{a_I^O g\Upsilon}{g+\Upsilon+m} + \frac{\xi a_M^S(\rho+g)\alpha^\varepsilon}{(\xi-1)\gamma}\left(\frac{g}{g+m}\right) + \frac{a_M^S gm}{\gamma(g+m)} + \left(\frac{m}{g+m}\right)\frac{a_M^S(\rho+g)}{(\xi-1)\gamma} \tag{47}$$

So far we get three equilibrium conditions, equations (43), (44) and (45), to solve for the steady state equilibrium of rate of innovation offshoring (Υ), the rate of imitation (m) and the rate of innovation (g).

We can draw the relationship among the three equilibrium variables in figure 3.

Northern labor market constraint is upward sloping in the (g, m) space. Since a higher rate of imitation means a higher risk of being copied and a higher number of Southern firms relative to number of domestic firms (see equation (21)). The decrease in a number of domestic firms lowers demand for manufacturing domestic goods in the North. Thus, there has more Northern labor resources available for an innovation activity in the North. The rate of innovation increases. It generates the property that Northern labor market constraint is upward sloping.

Southern labor market constraint is downward sloping in the $(g.m)$ space. In other words, since the South has only a fixed amount of labor resources, an increase in the Southern rate of imitation m implies that labors required for imitation activity and production of imitative Southern products increase. Then, Southern labors available for innovation in the South are lower. The rate of innovation g that can be supported by the global economy must be lower.[5]

The free entry condition constraint showing an equilibrium relationship between g and Υ is upward sloping. Intuitively, from equation (20) and (21), the higher the rate of innovation the lower share of products innovated and produced by offshoring firms including products imitated by Southern firms (n^{SO}). Moreover, from equation (40), it decreases relative wages so as the value of domestic firm relative to Southern firms. To balance the equation (43), the rate of innovation offshoring has to increase.

For a unique steady state equilibrium to exist, the L^N and L^S curves must have a unique intersection in the (g, m) space. I show that L^N curve has a monotonic upward sloping and L^S has a monotonic downward sloping. So the two curves must intersect each other at only one point.[6]

2.6 Welfare

Next, I will consider Northern and Southern welfare. The instantaneous utility function of the representative individual of the North and the South is given by

$$U^i(t) = E^i[n^D p^{D1-\varepsilon} + n^O p^{O1-\varepsilon} + n^S p^{S1-\varepsilon}]^{\frac{1}{\varepsilon-1}} \tag{48}$$

where E^i is per capita income in the i. The North derives its income from total revenues of domestic firms and operating profits of offshoring firms minus innova-

[5]The mathematical proof of slopes is in the appendix.

[6]The mathematical proof of existence of equilibrium is in the appendix.

tion costs. The profits of offshoring firms are generated from offshoring companies whose products have not been imitated, and they equal a fraction $(1-\alpha)$ of revenue. Therefore, Northern income equals

$$\begin{aligned} E^N &= \frac{p^D n^D x^D + n^O \pi^O - n^O C_I^O}{L^N} && (49) \\ &= \frac{p^D n^D x^D + n^O \pi^O - n^O \frac{\pi^O}{\rho+g+m}}{L^N} && (50) \\ &= \frac{p^D n^D x^D + (1-\alpha) n^O p^O x^O (1 - \frac{1}{\rho+g+m})}{L^N} && (51) \\ &= \frac{p^D n^D x^D}{L^N}[1 + \frac{(1-\alpha) p^O n^O x^O (1 - \frac{1}{\rho+g+m})}{p^D n^D x^D}] && (52) \end{aligned}$$

The flow of utility for a representative Northern worker is

$$U^N(t) = \frac{n^D x^D}{L^N}[1+\frac{(1-\alpha)p^O n^O x^O (1-\frac{1}{\rho+g+m})}{p^D n^D x^D}] n^{D\frac{1}{\varepsilon-1}} [1+\frac{n^O}{n^D}(\frac{p^O}{p^D})^{1-\varepsilon} + \frac{n^S}{n^D}(\frac{p^S}{p^D})^{1-\varepsilon}]^{\frac{1}{\varepsilon-1}} \tag{53}$$

In the South gross income equals revenues from the Southern firms and incomes from hiring Southern labors to innovate and produce goods by offshoring firms. Therefore Southern gross income is

$$\begin{aligned} E^S &= \frac{p^S n^S x^S + \alpha p^O n^O x^O + n^O C_I^O}{L^S} && (54) \\ &= \frac{p^S n^S x^S + \alpha p^O n^O x^O + n^O \frac{\pi^O}{\rho+g+m}}{L^S} && (55) \\ &= \frac{p^S n^S x^S}{L^S}[1 + \frac{p^O n^O x^O (\alpha + \frac{1-\alpha}{\rho+g+m})}{p^S n^S x^S}] && (56) \end{aligned}$$

The flow of utility for a representative Southern worker is

$$U^S(t) = \frac{n^S x^S}{L^S}[1 + \frac{p^O n^O x^O (\alpha + \frac{1-\alpha}{\rho+g+m})}{p^S n^S x^S}] n^{S\frac{1}{\varepsilon-1}} [\frac{n^D}{n^S}(\frac{p^D}{p^S})^{1-\varepsilon} + \frac{n^O}{n^S}(\frac{p^O}{p^S})^{1-\varepsilon} + 1]^{\frac{1}{\varepsilon-1}} \tag{57}$$

The level of welfare(discounted at period 0) of a representative in the country $i \in N, S$ is given by

$$W^i(0) = \int_0^\infty e^{-\rho t} log U^i(t) dt \tag{58}$$

3 Comparative Steady State Effects

3.1 Effects of Strengthening IPR Protection

The objective of this section is to study how a strengthening IPR protection in the South, as captured by a decrease in the rate of information leakage γ, affects relative wages (ω), the rate of innovation (g), the rate of imitation (m), and the rate of innovation offshoring (Υ). The effects of strengthening IPR protection can be shown by figure 4.

From equation (46), a decrease in parameter γ indirectly affects the Northern labor constraint via its effect on the rate of innovation offshoring (Υ). A decrease in γ increases the costs of imitation. This immediately implies that the rate of imitation decreases. As a result, an offshoring firm faces a lower risk to be copied, its expected returns increase. The rate of innovation offshoring increases (Υ curve shifts upward in figure 4b). The increase in Υ decreases labor demand in the North in all activities (i.e. innovation and production by domestic firms). This is equivalent to an outward shift in Northern labor market constraint in the (g, m) space.

On the other hand, from equation (47), the decrease in γ affects Southern labor constraint in two ways: direct and indirect. The direct way is that it increases labor demand in the South in three activities (i.e. production by offshoring firms and Southern firms and imitation activity). The indirect way is from the increase in the rate of innovation offshoring. It increases the Southern labor demand for innovation by offshoring firms. Thus, Southern labor market constraint shifts inward. As a result of these two forces effecting the L^S curve, L^S relatively shifts higher than the shift of L^N. Therefore, the effect of a strengthening IPR protection on equilibrium rates of innovation offshoring, imitation and innovation can be derived as follows,

Proposition 1 *A strengthening of IPR protection decreases the rate of innovation and the rate of imitation but increases the rate of innovation offshoring.*

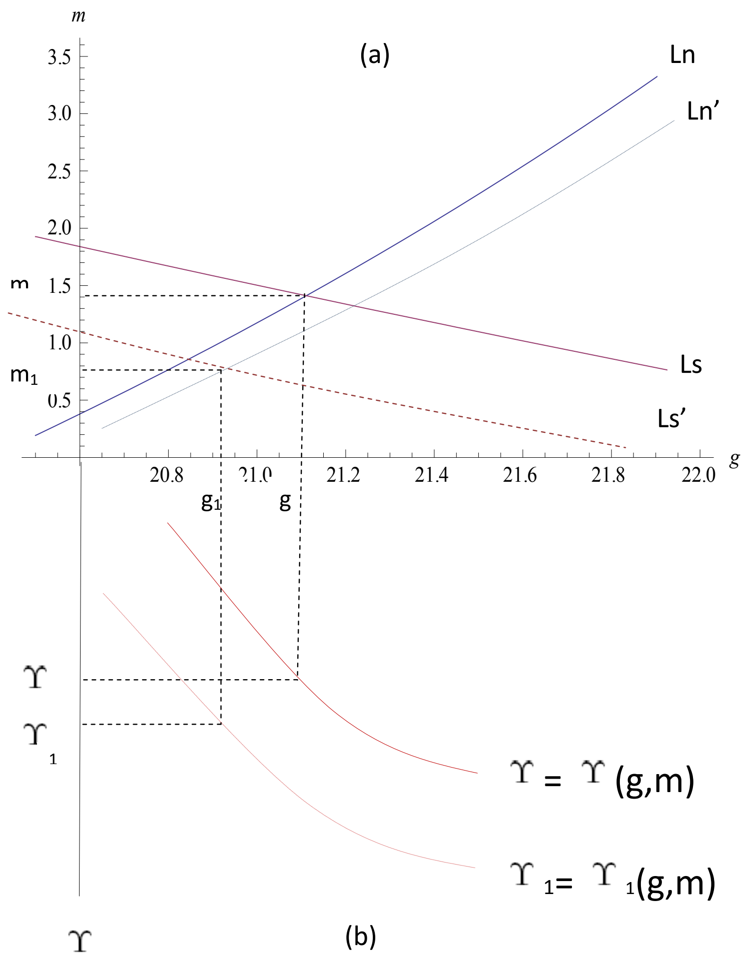

Figure 4: Effects of Strengthening IPR Protection

Intuitively, a strengthen of IPR protection decreases Northern labor demand but increases Southern labor demand. Therefore, relative Northern wages decrease. As a result of a strengthen IPR protection and decrease in relative wages, the costs of imitation increase. Southern firms loss from imitation activity so they exit the market. Then, the rate of imitation decreases. The lower in the rate of imitation Increases an incentive for offshoring firms to place both innovation and production activities in the South since they face a lower risk of being copied. Thus, Northern firms attempt to offshore more. The number of offshoring firms relative to domestic firms increases. So the rate of innovation offshoring rises.

When the production reallocates from domestic to offshoring firms, the labours available for an innovation activity in the North increase so the rate of innovation of domestic firms increases. On the other hand, a higher demand for imitation reduces the labor supply available for innovation of offshoring firms. So, the rate of innovation in the South for offshoring firms decreases. Note that the gross rate of innovation is weighted average between the rate of innovation from domestic and offshoring firms. The weighted index is the share of number of each firm in the total number of firms in the economy. As the result of the decrease in a number of domestic firms and increase in those of offshoring firms, the rate of innovation decreases because the decrease in an innovation of offshoring firms in the South dominates the increase in an innovation of domestic firms in the North.

Next, we will study the effects of a strengthening of IPR protection on real wages in the North and the South. The real wage effect of a strengthening of IPR protection depends on nominal wages in the North and the South and prices of goods produced by three types of firms: domestic firms(D), offshoring firms(O) and southern imitators(S). Recall that

$$\begin{aligned} p^D &= \frac{w^N}{\alpha} \\ p^O &= \frac{\xi w^S}{\alpha} \\ p^S &= \xi w^S \end{aligned}$$

We can calculate Northern real wages in terms of the three types of goods as follows,

$$\frac{w^N}{p^D} = \alpha \tag{59}$$
$$\frac{w^N}{p^O} = \frac{\alpha}{\xi}\frac{w^N}{w^S} \tag{60}$$
$$\frac{w^N}{p^S} = \frac{w^N}{\xi w^S} \tag{61}$$

In other words, Northern real wages in terms of goods produced by domestic firms are unaffected by Southern IPR protection whereas in terms of the other two goods, they move in the same direction as Northern relative wages (ω). Consider now the effects on Southern real wages, We have

$$\frac{w^S}{p^D} = \frac{1}{\xi} \tag{62}$$
$$\frac{w^S}{p^O} = \frac{\alpha w^S}{w^N} \tag{63}$$
$$\frac{w^S}{p^S} = \frac{\alpha}{\xi} \tag{64}$$

In other words, only Southern real wages in terms of Northern goods innovated and produced in the South are affected. The Southern real wages in terms of offshoring innovation and production firms' price increases. We can now state the following:

Proposition 2 *A strengthening of IPR protection decreases Northern real wages but increases Southern real wages.*

Next, we will study the effects of the strengthening of IPR protection to the price index and Northern and Southern domestic welfare. I conducted a series of numerical simulations. Table 1 reports the results of one such typical simulation. Assuming the following parameter values: $L^N = 170$, $L^S = 150$, $a^S_M = 2.8$, $a^D_I = 3.0$, a^O_I =3.5, $\rho = 0.01$, $\alpha = 0.5$, ε= 2, $\xi = 1.3$.

According to table 1, the simulation shows that as IPR in the South is strengthening, the measure of goods produced by domestic firms (n^D) decreases, the measure of goods produced by offshoring firms (n^O) increases, while the measure of imitated

γ	$\frac{n^D}{n}$	$\frac{n^O}{n}$	$\frac{n^S}{n}$	$\frac{w^N}{w^S}$	$logE^N$	$logE^S$	$logP$	W^N	W^S
1.0	0.37	0.21	0.42	3.15	0.57	0.45	0.34	23	11
0.8	0.26	0.33	0.41	3.07	0.62	0.49	0.37	25	12
0.6	0.19	0.51	0.3	2.91	0.55	0.55	0.41	14	14
0.4	0.15	0.62	0.23	2.33	0.52	0.65	0.49	3	16
0.2	0.13	0.72	0.15	2.07	0.59	0.74	0.57	2	17

Table 1: Effects of Strengthening IPR protection

products (n^S) decreases. Relative wage decreases, the price index increase and Northern domestic welfare decreases, while Southern welfare increases.

Proposition 3 *A strengthening of IPR protection may hurt the North but benefit the South.*

The intuition underlying the results is as follows: A strengthening of IPR protection makes imitation less attractive, thereby lowing the rate of imitation. A lower risk of imitation makes offshoring activity in the South more attractive to offshoring firms which respond by increasing the rate of innovation offshoring. It can translate into a greater share of goods produced by offshoring firms of the world's basket of goods (n^O/n), while the share of goods produced by domestic firms and Southern firms of the world's basket of goods (n^D/n and n^S/n) fall.

While goods produced by offshoring firms are cheaper than those produced by domestic firms ($p^O < p^S$), it is Southern imitators that produce the cheapest goods ($p^S < p^O$). Recall that a strengthening of IPR protection shifts production away from domestic firms and Southern imitators to offshoring firms, the reallocation of production from domestic firms to offshoring firms helps lower price, while the reallocation of southern production in favor of offshoring firms' products and away from Southern imitators tends to increase prices. From the numerical simulation in table 1, it implies that the latter effect is substantial so the price index decreases when an IPR protection is stronger.

From the results of numerical simulation, we found that Northern welfare decreases. The intuition is as follows: a strengthening of IPR protection increases profits of offshoring firms but decreases income from domestic firms and increases innovation costs in the South. When an IPR protection is still weak an increase in profits of offshoring firms is outweighed by a decrease in incomes from domestic firms and an increase in innovation costs so Northern income decreases. Once an IPR protection is stronger, a decrease in incomes from domestic firms and an increase in innovation costs are outweighed so Northern income is higher. As the results of increase in price index and change of Northern income, so the instantaneous real income decreases. It means Northern welfare decreases.

On the other hand, Southern welfare increases. the South generates income from two sources: income from selling imitated goods and from hiring Southern labor of offshoring firms. Recall that a strengthening of IPR protection decreases the share of imitated goods of the world's basket so the income from imitated goods decreases, while it increases the rate of offshoring so the income from hiring of offshoring firms to innovate and produce products increases. The former effect is less than the latter effect so Southern income increases. The rate of increase in price index is less than that of Southern income, then Southern welfare increases.

For simplicity, we can interpret in another way. Both countries's welfare are derived from two sources: real wages and varieties consumers in both countries can consume. A strengthening of IPR protection decreases Northern real wages and varieties so Northern welfare decreases. In the South, Southern real wages increase but varieties decrease. The latter effect is outweighed by the former effect so Southern welfare increases.

3.2 Effects of an Improvement in Technology of Innovation Offshoring

Changes in corporate innovation management as well as by the globalization of markets for technology and knowledge workers make an innovation offshoring more convenient. In other words, a technology of innovation offshoring improves. This section investigates the effects of an improvement in technology of innovation offshoring, as captured by a decrease in parameter a_I^O, on relative wages (ω), the rate of innovation (g), the rate of imitation (m), the rate of innovation offshoring (Υ) and Northern and Southern welfare. The effects of an improvement in the technology of innovation offshoring can be shown by figure 5.

From equation (46), same as a decrease in parameter γ in the previous section , a decrease in parameter a_I^O indirectly affects Northern labor constraint via its effect on the rate of innovation offshoring (Υ). A decrease in a_I^O reduces the costs of

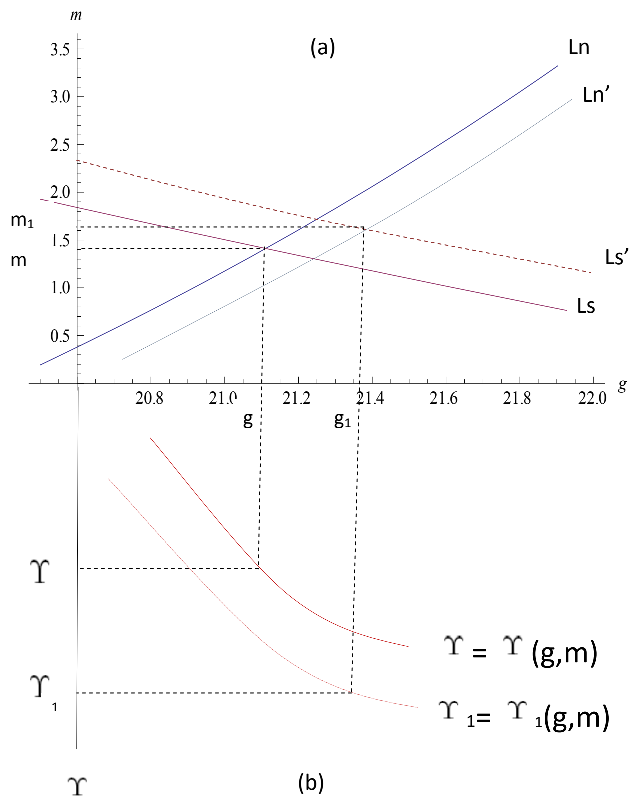

Figure 5: Effects of Improvement in Technology of Innovation Offshoring

innovation at the South for offshoring firms. The expected returns of offshoring firms become higher than the costs of innovation at the South so firms do offshoring increasingly. It implies that a number of offshoring firms increases and the rate of offshoring increases (Υ curve shifts upward in figure 5b). An increase in Υ decreases labor demand in the North in all activities (i.e. innovation and production by domestic firms). Northern labor market constraint shifts outward (from L_n to L_n') in the (g, m) space. Moreover, from equation (47), a decrease in a_I^O affects Southern labor constraint via labor demand for innovation of offshoring firms in two opposite ways . It directly decreases Southern labor demand whereas an increase in the rate of innovation offshoring increases the Southern demand. However, the former effect is greater than the latter effect so the Southern demand for innovation of offshoring firms decreases. Southern labor demand constraint shifts outward (from L_s to L_s'). Therefore, the effect of an improvement in technology of innovation offshoring on equilibrium rates of innovation offshoring, imitation and innovation can be derived as follows,

Proposition 4 *The effect of an improvement in technology of innovation offshoring increases the rate of innovation, the rate of imitation and the rate of innovation offshoring.*

Intuitively, an improvement in technology of innovation offshoring decreases innovation costs of offshoring firms at the South. An incentive for performing product development in the South has risen. This implies the rate of innovation offshoring increases. A flow of offshoring firms which offshore both innovation and production to the South increases a stock of Southern knowledge. This reduces costs of imitation, so the rate of imitation increases. It induces Southern labor demand relative to Northern labor demand to increase and pressures relative Northern wages to decrease (from equation (40)). As a result of an increase in the rate of offshoring, there are much more available labors left for an innovation activity in the North. Moreover, an innovation activity in the South is more profitable because the costs of innovation at the South decrease. An increase of an innovation activity in the North and the South makes the rate of innovation higher.

Next, we will study the effects of improvement in a technology of innovation offshoring on real wages. As we have already known, relative Northern wages decrease. From equations (60) to (64), Northern real wages in terms of offshoring firm and

a_I^O	$\frac{n^D}{n}$	$\frac{n^O}{n}$	$\frac{n^S}{n}$	$\frac{w^N}{w^S}$	$logE^N$	$logE^S$	$logP$	W^N	W^S
3.5	0.17	0.54	0.29	2.86	0.63	0.55	0.41	22	14
3.4	0.15	0.55	0.30	2.83	0.66	0.57	0.38	28	19
3.3	0.12	0.57	0.31	2.77	0.69	0.60	0.36	33	24
3.2	0.09	0.59	0.32	2.74	0.72	0.62	0.33	39	29
3.1	0.04	0.62	0.34	2.70	0.75	0.65	0.28	47	37

Table 2: An improvement in technology of innovation offshoring

Southern firm product's price move in the same direction as Northern relative wages (ω), while Southern real wages in terms of domestic firm product's price move in the opposite direction as the Northern relative wages. We can derive the effects of an improvement in technology of innovation offshoring on real wages as follows:

Proposition 5 *An improvement in technology of innovation offshoring decreases Northern real wages but increases Southern real wages.*

Next, we will investigate the effect of improvement in technology of innovation offshoring on the price index and both countries' domestic welfare. The results of numerical simulation are shown in the table 2[7]

According to table 2, this simulation shows that as the technology for innovation offshoring has improved, the measure of goods produced by domestic firms (n_D) decreases, the measure of goods produced by offshoring firms (n_O) and the measure of imitated products (n_S) increases relative wages decrease, the price index decreases, and Northern domestic welfare and Southern domestic welfare both increase.

Proposition 6 *An improvement in technology of innovation offshoring may benefit the North and the South.*

The intuition underlying the results is as follows: an improvement in technology of innovation offshoring lowers costs of innovation at the South so it makes innovation offshoring more attractive, thereby higher the rate of innovation offshoring. It means the share of goods produced by offshoring firms of the world's basket of goods increases, while those of domestic firms decreases . Moreover, an increase in a number of offshoring firms lowers the costs of imitation. It implies that the share of goods

[7]Assuming the following parameter values : $\gamma = 1.6$,$L^N = 170$, $L^S = 150$, $a_M^S = 2.8$, $a_I^D = 3.0$, a_I^O =3.5, $\rho = 0.01$, $\alpha = 0.5$, ε= 2, $\theta = 1.3$.

produced by Southern firms of the world's basket of goods (n_S/n) increases. Recall that $p^S < p^O < p^D$, the reallocation of production from domestic firms to offshoring firms and Southern firms helps lower the price index. From now on , I will consider the change in both countries' income per capita. Northern income per capita increases since a decrease in income from domestic firms is outweighed by an increase income from offshoring firms and costs of innovation in the South also decrease. Southern income per capita also increases because an increase in incomes from imitators and wage bills paid by offshoring firms. As Northern and Southern income capita increase and the price index decreases, both countries' real income per capita increase. This implies welfare of both countries increases. On the other hand, I can say that a loss from an decrease in Northern real wages is outweighed by a benefit from a rising in varieties. The Northern welfare improves. Whereas, an increase in Southern real wages and varieties make Southern welfare increase.

4 Concluding Remarks

Innovation offshoring plays a prominent role in the current world economy. Media now report an innovation offshoring in sectors ranging from pharmaceutical and bio-technology to computer hardware and software. An increasing number refers to wholly owned innovation centers in countries such as Russia, China, and India, or sometimes even arms length sub-contracting of innovation in these countries. Five powerful forces are currently driving the innovation revolution – lower wage rates, higher demand, increase in the supply of scientists, technologists and knowledge workers, growth in interaction capabilities and new incentives in developing countries. Therefore, the understanding of this emerging new forms of international trade and cross-border businesses are important to highlight.

This paper I have studied a two-region world economy with an industrialized North and a middle-income South. The product development can take place in both the North and the South. In this model, innovation and production are adhered together to be offshored to the South. To offshore innovation, offshoring firms have to pay monitoring costs and face the problem of information of product leakage to the Southern firms. That means offshoring firms face a risk of being imitated. While, a production offshoring generates costs of coordinating decisions over large distances and operating in unfamiliar environments. In the less advanced region, by contrast, entrepreneurs devote resources to the tasks of learning and adapting technologies that have been developed in the North and the South.

The effects of strengthening IPR protection in the South and improvement in the technology of innovation offshoring on the rate of innovation, rate of imitation, rate of innovation offshoring, relative wages, real wages and welfare are investigated. To answer the research questions, I introduced innovation and production offshoring into Grossman and Helpman (1991) model with endogenous innovation and imitation. Previous authors who employed the Grossman and Helpman model in order to analyze the effects of stronger IPR and the technology of innovation offshoring were more interested in determining the rate of imitation and in the steady state equilibrium without investigating the effects of existence of innovation and production offshoring.

The major results of the effect of strengthening IPR protection are as follows. The strengthening IPR protection directly increases the costs of imitation so it discourages imitation in the South. A fall in imitation make risks of being copied of offshoring firms declines. Thus, it induces Northern firms to offshore innovation to the South. The number of offshoring firms relative to domestic firms increases. It is implied that the rate of innovation offshoring rises. As the results a decline in imitation, the relative demand for Southern labor increases because the South a more attractive location for offshoring firms. Northern real wages decrease, while Southern real wages increase. Domestic welfare of each country is derived from real per capita income. Prices of those goods that are reallocated from domestic firms to offshoring firms fall, prices of goods that are reallocated from imitators to offshoring firms increase. Due to the model's underlying complexity, I have analyzed the results by numerical simulation. The numerical results found that, for specific parameter values the price index increases because the effectof reallocation from domestic firms to offshoring firms dominates those of reallocation from imitators to offshoring firms. Northern income changes in U-shape because the increase in profits of offshoring firms is outweighed by the decreases income from domestic firms in the first stage of strengthening IPR protection but it reverses later. Both effects on the price index and income per capita make Northern welfare decrease. While, per capita income of the South derived from the incomes of imitators and wage bills paid by offshoring firms increases, so the Southern welfare increases.

The effects of an improvement in technology of innovation offshoring are as follows. The improvement decreases innovation costs of offshoring firms at the South and the rate of innovation offshoring rises. The increase in the rate of innovation offshoring implies that the increase in the number of offshoring firms. This enlarges the stock of Southern knowledge so the costs of imitation increase. Both a demand from offshoring firms and an imitation activity in the South increase the relative Southern labor demand so relative Northern wages decrease.

There are more labors available for an innovation activity of domestic firms since offshoring firms move their innovation and production processes to the South. Moreover, an innovation in the South of offshoring firms also increases since the costs of innovation fall. Therefore, the rate of innovation increases.

Northern income per capita increases since a decrease in income from domestic firms is outweighed by an increase income from offshoring firm and costs of innovation in The South also decrease. Southern income per capita also increases due to the fact that incomes from imitators and wage bills paid offshoring firms increase. The price index decreases since the reallocation of production from domestic firms to offshoring firms and Southern firms As a result of the effects on the price index and per capital income , both countries' welfare increase .

5 Appendix

5.1 Proof for upward slope of L^N

Recall from equation (43)

$$\frac{\left(\frac{\gamma\alpha^{1-\varepsilon}}{\xi}\right)\frac{\Upsilon}{g}\left(1+\frac{m}{g}\right)}{1+\frac{\Upsilon}{g}\left(1+\frac{m}{g}\right)}\frac{a_I^O}{a_M^S}\frac{\xi-1}{1-\alpha}\left(\frac{\rho+g+m}{\rho+g}\right)=1 \tag{65}$$

I can calculate Υ as the function of g and m as following.

$$\Upsilon=\frac{a_M^S g^2(1-\alpha)\alpha^{\epsilon}\xi(g+\rho)}{(g+m)\left(a_M^S(\alpha-1)\alpha^{\epsilon}\xi(g+\rho)+a_I^O\alpha\gamma(\xi-1)(g+m+\rho)\right)}$$

For positive value of Υ , the second parenthesis of denominator that is $a_M^S(\alpha-1)\alpha^{\epsilon}\xi(g+\rho)+a_I^O\alpha\gamma(\xi-1)(g+m+\rho)$ must be greater than zero or

$$g<\frac{a_M^S(\alpha-1)\alpha^{\epsilon}\xi\rho+a_I^O\alpha\gamma(\xi-1)(m+\rho)}{a_I^O\alpha\gamma(\xi-1)+a_M^S(\alpha-1)\alpha^{\epsilon}\xi}$$

From equation (46), we know that $L^N = L^N(g, m, \Upsilon(g, m))$. Thus the slope of L^N in the (m, g) space is

$$\frac{\partial m}{\partial g} \mid_{dL^N=0} = -\left(\frac{\frac{\partial L^N}{\partial g} + \frac{\partial L^N}{\partial \Upsilon}\frac{\partial \Upsilon}{\partial g}}{\frac{\partial L^N}{\partial m} + \frac{\partial L^N}{\partial \Upsilon}\frac{\partial \Upsilon}{\partial m}} \right) > 0$$

$$\begin{aligned}
\frac{\partial L^N}{\partial g} &= a^N g \left(-\frac{g}{(g+\Upsilon+m)^2} + \frac{2}{g+\Upsilon+m} + \frac{g\alpha}{(g(g+i)+\Upsilon m)(1-\alpha)} \right) \\
&\quad + a^N g \left(-\frac{(g^2-\Upsilon m)\,\alpha(g+\rho)}{(g(g+\Upsilon)+\Upsilon m)^2(1-\alpha)} - \frac{\alpha(g+\rho)}{(g(g+\Upsilon)+\Upsilon m)(1-\alpha)} \right) > 0 \\
\frac{\partial L^N}{\partial m} &= a^N g^2 \left(-\frac{1}{(g+\Upsilon+m)^2} - \frac{\Upsilon\alpha(g+\rho)}{(g(g+\Upsilon)+\Upsilon m)^2(1-\alpha)} \right) < 0 \\
\frac{\partial L^N}{\partial \Upsilon} &= a^N g^2 \left(-\frac{1}{(g+\Upsilon+m)^2} - \frac{(g+m)\alpha(g+\rho)}{(g(g+\Upsilon)+\Upsilon m)^2(1-\alpha)} \right) < 0 \\
\frac{\partial \Upsilon}{\partial m} &= \frac{a_M^S g^2(\alpha-1)\alpha^\epsilon \xi(g+\rho)\left(a_M^S(\alpha-1)\alpha^\epsilon\xi(g+\rho) + a_I^O\alpha\gamma(\xi-1)(2(g+m)+\rho)\right)}{(g+m)^2\left(a_M^S(\alpha-1)\alpha^\epsilon\xi(g+\rho) + a_I^O\alpha\gamma(\xi-1)(g+m+\rho)\right)^2} < 0
\end{aligned}$$

$$\frac{\partial \Upsilon}{\partial g} = \frac{a_M^S g(1-\alpha)\alpha^\epsilon\xi\left(a_M^S(g+2m)(\alpha-1)\alpha^\epsilon\xi(g+\rho)^2 + a_I^O\alpha\gamma(\xi-1)\left(g(g+m)(g+3m)+(2g+m)(g+2m)\rho+(g+2m)\rho^2\right)\right)}{(g+m)^2\left(a_M^S(\alpha-1)\alpha^\epsilon\xi(g+\rho)+a_I^O\alpha\gamma(\xi-1)(g+m+\rho)\right)^2} > 0$$

5.2 Proof for upward slope of L^S

From equation 47, we know that $L^S = L^S(g, m, \Upsilon(g, m))$. Thus the slope of L^S in the (m, g) space is

$$\frac{\partial m}{\partial g} = -\left(\frac{\frac{\partial L^S}{\partial g} + \frac{\partial L^S}{\partial \Upsilon}\frac{\partial \Upsilon}{\partial g}}{\frac{\partial L^S}{\partial m} + \frac{\partial L^S}{\partial \Upsilon}\frac{\partial \Upsilon}{\partial m}} \right) < 0$$

$$\begin{aligned}
\frac{\partial L^S}{\partial g} &= \frac{a_I^O\Upsilon(\Upsilon+m)}{(g+\Upsilon+m)^2} + \frac{a_M^S m(m\xi-\rho) + a_M^S\alpha^\epsilon\xi\,(g^2+2gm+m\rho)}{(g+m)^2\gamma(\xi-1)} > 0 \\
\frac{\partial L^S}{\partial m} &= -\frac{a_I^O gi}{(g+\Upsilon+m)^2} + \frac{a_M^S g\,(g\xi+\rho-\alpha^\epsilon\xi(g+\rho))}{(g+m)^2\gamma(\xi-1)} < 0 \\
\frac{\partial L^S}{\partial \Upsilon} &= \frac{a_I^O g(g+m)}{(g+i+m)^2} > 0
\end{aligned}$$

5.3 Existence of Equilibrium

The L^N curve intersects the vertical axes at m^N where

$$m^N \equiv \frac{\xi^2 L^N(\alpha-1) + \sqrt{\xi^4 L^{N2}(\alpha-1)^2}}{2\xi L^N(1-\alpha)}.$$

Similarly, the L^S curve intersects the vertical axis at m^S where

$$m^S \equiv \frac{\xi L^S\gamma(\xi-1) - a_M^S\xi\rho - \sqrt{\xi^2(L^S\gamma - L^S\gamma\xi + a_M^S\rho)^2}}{2(L^S(\gamma-\gamma\xi) + a_M^S\rho)}.$$

Since $m^N < m^S$ and L^N is upward sloping, while L^S is downward sloping, the two curves must intersect each other at once.

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