Does stronger Intellectual Property Rights Protection Always Promote Economic Growth?

A North-South General Equilibrium Model with Learning-By-Doing

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Abstract

Whether strengthening intellectual property rights (IPR) protection in the developing countries (the South) promotes global economic growth has been one of the most contentious issues in both economics and international relations. When foreign direct investment (FDI) serves as the technology transfer channel, existing theoretical models suggest an unambiguously positive relationship between Southern IPR protection and global economic growth. However, one common assumption of these models is that Southern production efficiency is not affected by the penetration of foreign investment, which is inconsistent with the empirical findings in the FDI spillover literature. By introducing horizontal FDI spillovers in the production sector based on the some recent empirical evidence and proposing a mechanism of learning-by-doing (LBD), we reexamine the relationship between Southern IPR and long-run global economic growth in a North-South general equilibrium model. Our analysis obtains that, consistent with empirical evidence, the effect of strengthening Southern IPR protection on Southern productivity depends on the current protection level, and that the relationship between Southern IPR protection and global economic growth is no longer monotonic. When Southern IPR protection level is below (above) a certain threshold, further strengthening of IPR in the South will increase (decrease) the FDI rate and global economic growth rate and narrow (widen) the North-South wage gap. Our numerical simulation based on the calibrated model confirms the existence of an inverted-U relationship between Southern IPR protection and the long-run global economic growth. However, the numerical exercise reveals that the current Southern IPR protection in reality is still below the optimal level, suggesting that an IPR harmonization policy that aims at bringing up the Southern IPR protection level will be growth enhancing at the present stage.

1 Introduction

Intellectual property rights (IPR) has long been one of the most contentious issues in international relations ever since the start of globalization in the 1980s. Conventionally, the developed countries (the North) benefit from strong IPR protection regimes as exemplified by their capablility to encourage domestic R&D activities. For this reason, the North has been continuously criticizing the developing countries (the South) for what they perceive as inadequacies in IPR protection standards. This battle in the arena of political economy resulted in the promulgation of the Agreement of Trade-Related Aspects of Intellectual Property Rights (TRIPS), one of the most influential outcomes in the Uruguay Round of world trade negotiations in the early 1990s. TRIPS required all WTO members to adopt at least the same minimal IPR protection standard established and practiced in developed countries.[1] Lured by the enormous trading opportunities from WTO membership, many developing countries have drastically reformed their national IPR regimes as a compromise to address the pressures from the North in the recent decades. Figure 1 exhibits such trend for both the North and the South, using the Ginarte-Park Index (GP Index) as the proxy for the level of IPR protection across countries.[2]

Figure 1 depicts that while the developed countries have been consistently reinforcing national IPR protection regimes at a relatively stable pace from 1960 to 2005, only marginal efforts have been exerted in developing countries before 1990. However, considerable changes took place after 1995. The majority of developing countries have made substantial progress in raising national IPR protection standards based on those established in the North. The stark difference in the treatment of national IPR protection regimes by the developing countries before and after the early 1990s was more likely to be a result of the TRIPS Agreement, rather than that of a sudden change in the attitudes towards IPR protection regimes in the majority of developing countries.

[1]For example, a minimum protection duration of 20 years for patents since the date of granting must be established in the national IPR laws for all WTO member countries.

[2]The GP Index is a popular measure of IPR protection developed by Ginarte and Park (1997) and subsequently extended by Park (2008). The index covers a large cross-section of 122 countries and regions, and a longitude dimension from 1960 to 2005 on quinquennial basis. According to its methodology, the GP Index is defined as a statutory measure of IPR protection based on the evaluations of national IPR regimes in five major categories, namely, the duration of protection, coverage, membership in international treaties, enforcement mechanisms, and restrictions on patent scope, such as compulsory licensing. See Park (2007) for a detailed discussion of this index and its comparison with other IPR measures, such as those developed by Rapp and Rozek (1990) and Lee and Mansfield (1996).

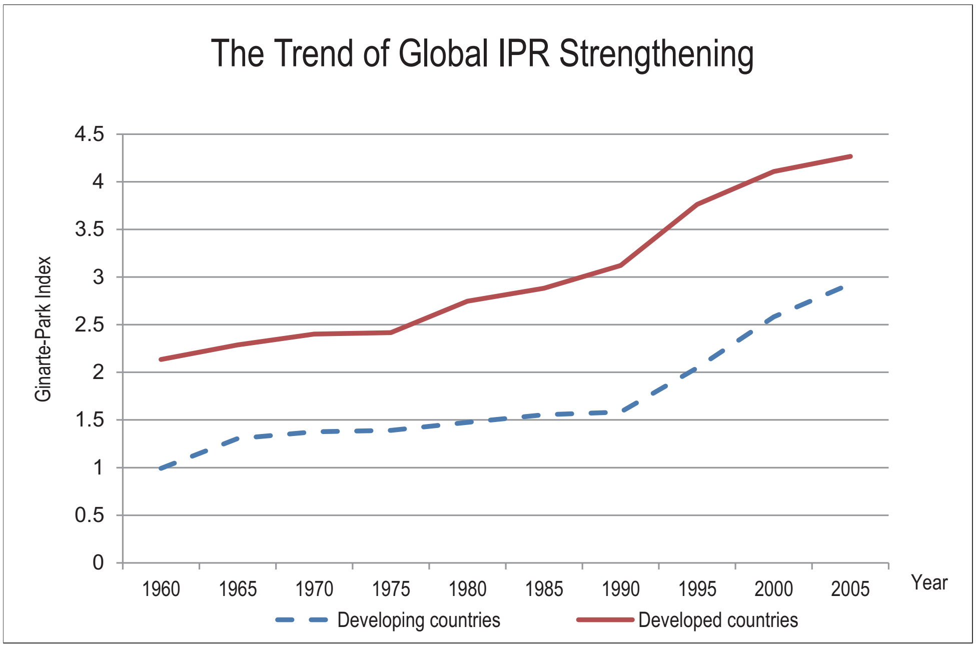

Figure 1: The Global Strengthening Trend of IPR Protection

Source: based on Park (2008) and the author's calculation

Understandably, the advanced North tends to embrace a tight IPR protection regime toward the end that it grants the proprietary rights for intellectual property (IP) owners and hence, encourages R&D activities. By contrast, the developing South has its own righteous justifications for keeping the national IPR protection at a low level, including welfare concerns (Grossman and Lai, 2004; Chen and Puttitanun, 2005; Chu, Cozzi and Galli, 2014, etc.). Therefore, IPR advocators generally emphasize the dynamic gains of strong IPR protection on long-run economic growth, which is conventionally regarded as beneficial for autarky in developed countries (Kwan and Lai, 2003). As Lucas (1988) stated, once one starts to think about the implications on economic growth by exercising certain economic policies, "it is hard to think about anything else." The global IPR *harmonization* is desirable only if a tighter IPR protection regime in the South unambiguously leads to faster long-run economic growth for both North and South. Otherwise, a global IPR *coordination* is more appropriate. Hence, we focus on the consequences of Southern IPR protection changes on the long-run global economic growth in this study.

From the theoretical point of view, the effect of Southern IPR protection on global economic growth has been extensively studied under the North-South product cycles framework, an idea proposed by Vernon (1966) and formalized by Krugman (1979) using the seminal monopolistic competition structure in Dixit and Stiglitz (1977). The results of the existing studies are still inconclusive, but tend to be in favor of a positive relationship. Grossman and Helpman (1991) and Helpman (1993) extended Krugman's model by endogenizing the innovation process following the method of Romer (1990), where innovation is endogenously driven by R&D investment and imitation is the technology transfer channel.[3] Both Grossman and Helpman (1991) and Helpman (1993) showed that strengthening IPR protection in the South will reduce Northern innovation and hence world economic growth in the long run. By contrast, Lai (1998) modified the model in Helpman (1993) by changing the technology transfer channel from imitation to FDI and contrasting outcomes were obtained: a tightened IPR regime in the South will encourage FDI, innovation, and global economic growth in the long run. Other examples include Mondal and Ranjan Gupta (2009) and Branstetter and Saggi (2011). Mondal and Ranjan Gupta (2009) only modified Grossman and Helpman (1991) in considering localized knowledge spillover in the innovation process, but reached completely opposite predictions: stronger IPR protection in the South will lead to a higher innovation rate even when imitation remains to be the technology transfer channel. On the other hand, Branstetter and Saggi (2011) extended Lai (1998) by endogenizing the imitation process. Imitation is no longer costless and a tightening IPR protection increases the cost of imitation. This modification, however, does not change the main findings in Lai (1998): stronger IPR protection in the South will always promote Northern innovation and global economic growth.

Despite the mixed results, the existing studies share a common feature: the unit production cost is exogenous and constant. This implies neither FDI nor IPR protection has any effect on the efficiency components of Southern production, such as human capital. This is not supported by the widely-documented empirical evidences of FDI spillovers. Although the assumption of exogenous productivity is plausible from the modeling perspective, it is no doubt an oversimplification of the real world, and hence entails the risk of generating spurious predictions. In particular, all the current studies under the product cycle framework predict monotonic relationships between IPR protection and economic growth, and the results are inclined to suggest a unambiguously positive relationship with FDI serving as the technology transfer channel. Hence, the present study is motivated by two questions: (1) What is the mechanism through which FDI and IPR protection affect the production efficiency in the South? (2) Does the monotonic relationships between IPR and global economic growth still hold if we allow production efficiency in the South

[3]One major difference in the model setup is that imitation is endogenous in Grossman and Helpman (1991) and exogenous in Helpman (1993).

to be endogenously determined by FDI and IPR protection?

To address Question (1), we explore current empirical studies on FDI spillovers in the first place. As summarized in a comprehensive review in Görg and Greenaway (2004), the signs of the spillovers depend crucially on the nature of FDI. For vertical (inter-industry) FDI, the signs of spillovers are mostly positive. However, for horizontal (intra-industry) FDI, the signs of spillovers are either inconclusive or negative. We focus on horizontal spillovers in this study in particular, because the Dixit-Stiglitz aggregation used in the theoretical model is more suitable for the horizontal market structure.

As has been revealed in Görg and Greenaway (2004), the hypothesis of a positive intra-industy spillover effect from foreign firms in developing countries is generally not supported by firm-level panel data. On the contrary, some studies identified negative spillovers, meaning a larger penetration of foreign capital within an industry tends to reduce the productivity of other firms within the same industry in Venezuela and Mexico (Aitken and Harrison, 1999). Similarly, for transition economies such as Czech Republic, Bulgaria, Romania and Poland, negative spillovers are identified.[4] Based on a firm-level sample consisting of firms in Bulgaria, Romania and Poland during the mid 1990s, Konings (2001) investigated the effect of FDI spillovers on the productivity of domestic firms. While no evidence of positive spillovers were detected in Poland, significant negative spillover effects were identified in the cases of Bulgaria and Romania.

Smeets and de Vaal (2011) provided novel empirical evidence which suggested that the ambiguity of FDI spillovers could be non-monotonically related to the strength of IPR protection in the host country in addition to the nature of FDI. In particular, they found that horizontal spillovers to be positive (negative) when IPR protection level is below (above) a certain threshold. One explanation of such an observation is that strengthening IPR protection has two opposing effect. First, it represents an incentive of FDI and encourages international technology transfer, which resembles an enlarged pool of knowledge for the South. A larger pool of knowledge represents a larger potential to enhance Southern human capital, therefore this serves as the positive effect of horizontal FDI on productivity. On the other hand, strengthening IPR protection also limits the knowledge learning process, because it enhances the ability of multinational companies (MNCs) to protect their specific assets from being assimilated by the others. This effect resembles a narrowed pipe of knowledge diffusion, which negatively affect the Southern human capital

[4]See Table 2 on Page 31, Görg and Greenaway (2004).

accumulation process. When the current IPR protection is relatively weak, the former effect dominates, and the overall effect is positive. When the current IPR protection is sufficiently strong, the latter effect dominates, and the overall effect is negative. Hence, a trade-off exists through such a mechanism, which implies a non-monotonic relationship between IPR protection and the horizontal spillovers, and an optimal level of IPR protection which maximizes the horizontal FDI spillover effect. We apply the mechanism of learning-by-doing (LBD) to model such a process, an approach inspired by Furukawa (2007).

The idea of LBD is not new in itself, and its effect on the R&D sector for most of the conventional R&D-based growth models has long been recognized as an indispensable component for endogenous growth. However, far less effort has been taken to embrace LBD in the production sector, where the concept of LBD originates and where its existence is well-documented with evidence. Recent studies including Furukawa (2007, 2010) have contributed to the growth literature by highlighting LBD in the production sector. In their closed economy models, a strengthening in the IPR protection regime reduces the amount of intermediate goods used by each worker in the final good production sector, which reduces the speed of learning and leads to a decrease in the human capital in the long run. We modify the LBD process in Furukawa (2007) so as to make it suitable for a general equilibrium model in the open economy environment.

we can move on to answer Question (2) with a specified LBD process. Because lower production cost in the South is the main reason for FDI, therefore the changes in production efficiency will certainly affect future FDI decisions. When Southern IPR protection is weak, the overall horizontal spillover effect is positive, and hence both the long-run FDI rate and global economic growth rate will increase in response to a strengthening in Southern IPR protection, which is similar to previous studies. But when the current Southern IPR protection is sufficiently strong, the negative spillover effect will dominate. In this case, the response of FDI will be two-folds: first, an immediate increase in FDI rate will occur because strengthened IPR protection extends the monopolistic duration of MNCs. Second, as the negative horizontal spillovers dominate, human capital will decrease and future FDI is discouraged. Hence, both the long-run FDI rate and global economic growth rate will decrease subsequently, which implies a non-monotonic relationship between Southern IPR protection and economic growth. The case when the current IPR protection is sufficiently strong is shown in Figure 2.

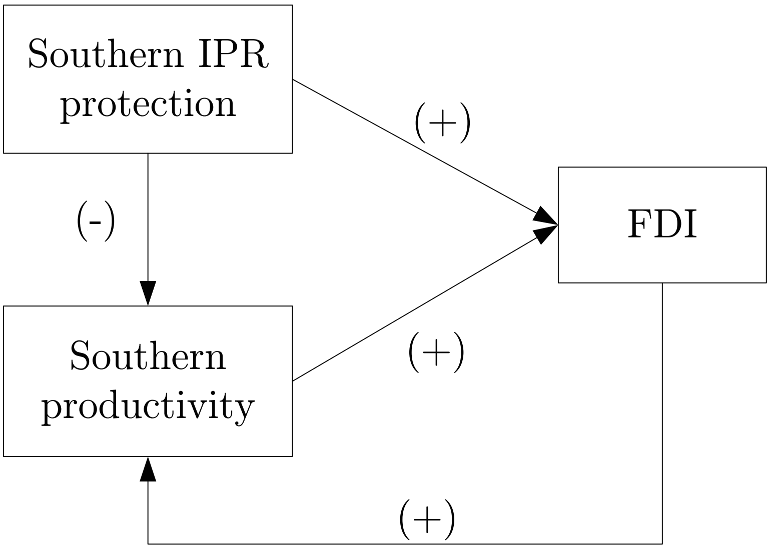

Figure 2: The Interrelationship among IPR, FDI and Productivity Development when the Current IPR Protection Sufficiently Strong

In summary, this study is closely related to three strains of researches. First, it is related to the North-South product cycles literature, particularly those with FDI as the technology transfer channel, such as Lai (1998) and Branstetter and Saggi (2011). Second, it is related to the FDI spillovers literature, such as Görg and Greenaway (2004) and Smeets and de Vaal (2011). Third, it is related to the LBD literature, such as Furukawa (2007) and Furukawa (2010). As far as our knowledge goes, our work is the first study attempting to integrate product cycle, FDI spillovers and LBD into one general equilibrium model in the open economy.

The rest of the paper is organized as follows. In Section 2, we propose the basic structure of a North-South product cycles model with LBD process for the Southern production sector; In Section 3, we discuss in detail the structure of the LBD process in our model; In Section 4, we focus on the analytical properties of the steady state, and show the existence of an inverted-U relationship between IPR and economic growth from an analytical point of view. In Section 5, we calibrate the structural parameters and solve the steady state numerically. We also conduct several comparative static analysis with changes in some structural parameter. In Section 6, we provide an extension for the benchmark model, where FDI may contribute to human capital and productivity development in the South. Finally, we conclude in Section 7.

2 Benchmark Model

2.1 Household

In this model, the world economy is composed of two regions, an advanced North and a developing South. In each region lives a representative household, who maximizes her discounted lifetime utility by consuming a composite good comprised of differentiated products. If we use the superscription j to indicate different regions, then the discounted lifetime utility in Region j can be defined as:

$$U_t^j = \int_t^\infty e^{-\rho t} \ln(C_t^j) \mathrm{d}t,$$

where U_t^j is the discounted lifetime utility and C_t^j is the instantaneous consumption of the composite good in Region $j \in \{N, S\}$, where N stands for the "*North*" and S for the "*South*".[5] ρ is the subjective discount rate which is assumed to be the same for both North and South.[6]

The consumption of composite good C_t^j is defined as the Dixit-Stiglitz aggregation of the consumption of differentiated products in Region j, $x_{i,t}^j$, where subscription i is the variety index:

$$C_t^j = \left[\int_0^{n_t^j} (x_{i,t}^j)^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}i \right]^{\frac{\epsilon}{\epsilon-1}},$$

where ϵ is the (constant) elasticity of substitution between differentiated goods. We assume $\epsilon > 1$; thus, the differentiated goods are gross substitutes.

In general, the bundles of differentiated products for consumption are different across countries. For example, a certain differentiated product available in the region where it is manufactured may not be available in another region. Therefore n_t^j is used to represent the number of available varieties of differentiated products in Region j. However, if we assume that: (1) once invented, the demand for any differentiated product emerges in both North and South[7] and (2) all differentiated products can be freely traded across regions, then households in both North and South will consume the same bundle of

[5] It will be more general to assume a form like $U_t^j = \int_t^\infty e^{-\rho t} \frac{(C_t^j)^{1-\sigma^j} - 1}{1-\sigma^j} \mathrm{d}t$ where σ^j represents the inverse of the intertemporal elasticity of substitution in Region j. Without loss of generality, we study the case of unit intertemporal elasticity of substitution (logarithm utility) to focus on the main trade-offs.

[6] In general cases, households in different countries may be different in terms of patience. Therefore, the North and South do not necessarily share the same value of ρ in reality. However, we believe that allowing for difference in patience across regions does not change the main results in this paper. Therefore we keep ρ to be the same for both North and South.

[7] I thank one examiner for pointing out the fact that, in reality, a time lag usually exists before the demand for a Northern-originated product starts to emerge in the South. If such a lag is taken into consideration, then at each time, a certain fraction of world varieties will be only consumed and produced in the North. If this is the case, then the economic

differentiated products regardless of their production locations, which is exactly the whole set of differentiated products in the world. Therefore $n_t^j = n_t$, $\forall j \in \{N, S\}$.

An international financial market exists which allows households from both regions make intertemporal decisions on consumption. The asset budget constraint therefore can be written as:

$$\dot{A}_t^j = w_t^j L^j + \Pi_t^j + r_t A_t^j - E_t^j,$$

where $w_t^j L^j$ is the total wage income, Π_t^j is the total profit earned by the household in Region j at date t, w_t^j is the wage rate, and L^j is the total amount of labor employment in Region j. A_t^j is the asset held by the representative household in Region j and r_t is the interest rate. E_t^j is the total expenditure on differentiated products in Region j at date t so that $E_t^j = \int_0^{n_t} p_{i,t}^j x_{i,t}^j \mathrm{d}i$, where $p_{i,t}^j$ and $x_{i,t}^j$ represent the price and quantity of consumption of differentiated product indexed by i and sold in Region j at date t.

Then, the infinite-horizon optimization problem for household in Region j can be written as:

$$\begin{aligned} \max \quad U_t^j &= \int_t^\infty e^{-\rho t} \ln(C_t^j) \mathrm{d}t \\ \text{s.t.} \quad C_t^j &= \left[\int_0^{n_t} (x_{i,t}^j)^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}i \right]^{\frac{\epsilon}{\epsilon-1}}, \\ \dot{A}_t^j &= w_t^j L^j + \Pi_t^j + r_t A_t^j - E_t^j. \end{aligned}$$

As shown by the classic work in Dixit and Stiglitz (1977), this intertemporal optimization problem can be solved in two stages. In the first stage, the household maximizes the consumption of the composite good C_t^j at each date by rationalizing a fixed total expenditure E_t^j over the consumptions of all differentiated products, $x_{i,t}^j$. As the optimal distribution of expenditure over differentiated products is determined, the household chooses the amount of total expenditure with a given income to maximize her discounted lifetime utility in the second stage.

With the given price $p_{i,t}^j$ and total expenditure E_t^j, we can solve the demand for differentiated products in the first stage. The iso-elastic demand function for product i

growth will be slower for both North and South at any IPR protection level in the steady state, because a larger fraction of Northern labor has to be reserved for producing the products which are only demanded in the North, and hence the supply of labor for R&D will be reduced. However, this treatment will substantially increase the complexity of the model. Therefore, we follow Lai (1998) and Branstetter and Saggi (2011) and make the simplification that the demand for a new product emerges simultaneously in both North and South once it is invented. Nonetheless, it will be interesting to investigate the true effect by incorporating the time lag in further studies.

consumed in region j can be written as:

$$x_{i,t}^j = \frac{\left(p_{i,t}^j\right)^{-\epsilon}}{\left(P_t^j\right)^{1-\epsilon}} E_t^j, \tag{1}$$

where $p_{i,t}^j$ is the price of good i sold in Region j and P_t^j is the aggregate price index in Region j, which is defined as:

$$P_t^j = \left[\int_0^{n_t} (p_{i,t}^j)^{1-\epsilon} \mathrm{d}i\right]^{\frac{1}{1-\epsilon}}. \tag{2}$$

$E_t^j = \int_0^{n_t} p_{i,t}^j x_{i,t}^j \mathrm{d}i$ and $C_t^j = \left[\int_0^{n_t} (x_{i,t}^j)^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}i\right]^{\frac{\epsilon}{\epsilon-1}}$; thus, we can further establish the following identity:

$$E_t^j = P_t^j C_t^j.$$

The identity above shows that the aggregate price index P_t^j can also be understood as the price of the composite good in Region j.

For the second stage optimization, we need to solve the intertemporal consumption optimization problem. The current value Hamiltonian is:

$$\tilde{\mathcal{H}}_t = \ln(C_t^j) + \lambda_t\big(r_t A_t^j + w_t^j L^j + \Pi_t^j - P_t^j C_t^j\big).$$

where λ_t is the co-state variable. After solving this problem, we can derive the growth rate of the consumption of the composite good:

$$\frac{\dot{C}_t^j}{C_t^j} = r_t - \rho - \frac{\dot{P}_t^j}{P_t^j}.$$

Since $E_t^j = P_t^j C_t^j$, thus, the above equation further leads to the Euler Equation:

$$\frac{\dot{E}_t^j}{E_t^j} = r_t - \rho.$$

Under the condition of zero trading cost, each firm will charge the same price for all of its goods regardless of their targeting market: $p_{i,t}^N = p_{i,t}^S = p_{i,t}$. Therefore, the price indices for both regions are also the same, which implies $P_t^N = P_t^S = P_t$. For notational convenience, we drop the superscription j and simply use $p_{i,t}$ to represent the price of goods i and P_t to represent the common price index for both regions at date t whenever necessary. This implies that the aggregate expenditure in the world $E_t = E_t^N + E_t^S$ also grows at the same rate as the regional-specific expenditure:[8]

$$\frac{\dot{E}_t}{E_t} = r_t - \rho. \tag{3}$$

[8] $\frac{\dot{E}^j}{E^j} = r - \rho$, therefore $\dot{E}^j = (r-\rho)E^j$, $\forall j \in \{N, S\}$. $E = E^N + E^S$, therefore, $\dot{E} = \dot{E}^N + \dot{E}^S$. Aggregate the above equation over all $j \in \{N, S\}$, then the result becomes self-evident.

2.2 Production of Differentiated Goods

The differentiated goods are divided into three types according to their producers. $i \in \{N, M, C\}$ represents Northern domestic firms (N, which stands for "*Northern*"), multinational companies (M, which stands for "*Multinational*"), and Southern imitators (C, which stands for "*Copy*"). Hereafter, we refer to them as N Firms, M Firms, and C Firms. N Firms are located in the North, whereas M and C Firms are located in the South. N Firms and M Firms are monopolistic, whereas the market structure faced by C Firms are competitive.

Labor is the only production factor and the Southern labor is assumed to be the numeraire. This implies the Southern wage rate w_t^S equals to 1 for all t, and consequently, the Northern wage rate $w_t^N = w_t$ also represents the relative wage rate between North and South. N Firms hire Northern workers, whereas M Firms and C Firms hire Southern workers. Each variety of differentiated goods, regardless of where its producer is located, will be sold to the whole world through free trade.

2.2.1 Northern Domestic Firms

An N Firm is established once its owner obtains a new "blueprint" from the competitive R&D sector located in the North, which allows it to produce a new variety of differentiated products. IPR protection is fully enforced in the North, and Southern imitators cannot directly imitate these products. Therefore, an N Firm enjoys a global monopolistic status. Assuming that the unit labor requirement in producing differentiated products is 1 in the North, then, the price for N goods sold to Region j can be derived by solving the monopolistic profit maximization problem:

$$\begin{aligned} \max \quad & \pi_{N,t}^j = p_{N,t} x_{N,t}^j - w_t x_{N,t}^j \\ \text{s.t.} \quad & x_{N,t}^j = \frac{(p_{N,t})^{-\epsilon}}{P_t^{1-\epsilon}} E_t^j, \quad j \in \{N, S\}, \end{aligned}$$

where w_t is the Northern wage rate. By solving the above maximization problem, we can obtain the usual mark-up prices for each N Firm:

$$p_{N,t} = \frac{1}{\alpha} w_t, \tag{4}$$

where $\alpha = 1 - \frac{1}{\epsilon} \in (0, 1)$.

Then, the equilibrium output scales of each N Firm for both regions are:

$$x_{N,t} = \frac{\alpha^{\epsilon} w_t^{-\epsilon} E_t}{P_t^{1-\epsilon}}, \tag{5}$$

where $E_t = E_t^N + E_t^S$ is the total expenditure for both North and South at date t.

The profit of a D Firm is therefore

$$\pi_{N,t} = \frac{\alpha^{\epsilon}}{\epsilon - 1} \frac{w_t^{1-\epsilon} E_t}{P_t^{1-\epsilon}}. \tag{6}$$

2.2.2 Multinational Firms

Different from an N Firm, an M Firm is a Northern-originated firm operating in the South and hires Southern workers to produce its differentiated products. The unit labor requirement in the North is 1, whereas it is ζ_t in the South. The subscription t implies the Southern unit labor requirement may change over time. This scenario is different compared with those of previous N-S models formulated by Helpman (1993), Lai (1998), and Dinopoulos and Segerstrom (2010), where the unit labor requirement in the South are all assumed to be constant over time.

Generally, Southern workers tend to be less productive than Northern workers due to lower human capital. Hence, $\zeta_t > 1$ is a reasonable starting point. The reason why some Northern firms continue to shift operation to the less productive South is due to the wage gap between North and South. Although M Firms have to hire more labor to produce the same quantity of products in the South, the wage payment per worker, however, is also lower. Because the unit cost is w_t in the North and ζ_t in the South, therefore, as long as $w_t > \zeta_t$, FDI will take place.

Each M Firm solves the following monopolistic profit-maximization problem to determine its output and employment scales:

$$\begin{aligned} \max \quad & \pi_{M,t}^j = p_{M,t} x_{M,t}^j - \zeta_t x_{M,t}^j \\ \text{s.t.} \quad & x_{M,t}^j = \frac{(p_{M,t})^{-\epsilon}}{P_t^{1-\epsilon}} E_t^j, \quad j \in \{N, S\}. \end{aligned}$$

Solving the above maximization problem and following the notational conventions in Section 2.2.1, we can derive the price and output scale for each M Firm:

$$p_{M,t} = \frac{1}{\alpha} \zeta_t \tag{7}$$

and

$$x_{M,t} = \frac{\alpha^{\epsilon} \zeta_t^{-\epsilon} E_t}{P_t^{1-\epsilon}}. \tag{8}$$

The profit of each M Firm is therefore

$$\pi_{M,t} = \frac{\alpha^\epsilon}{\epsilon - 1} \frac{\zeta_t^{1-\epsilon} E_t}{P_t^{1-\epsilon}}. \tag{9}$$

2.2.3 Southern Imitators

Due to limited IPR protection in the South, Each M Firm faces a non-zero risk of imitation. Once a particular M product is successfully imitated, the associated M Firm will lose its monopoly power due to the competition from the Southern imitators, and the market structure for this industry will become fully competitive, with the price driven to the marginal cost level. In line with Lai (1998) and Gustafsson and Segerstrom (2011), we assume FDI as the only channel of technology transfer. With this assumption, Southern imitation can target M Firms, but not N Firms, which do not operate in the South.

The unit labor requirement for each C Firm is ζ_t, which is the same as that of an M Firm. However, the market structure for C products is competitive; therefore, the price of C products will be driven to the marginal cost level:

$$p_{C,t} = \zeta_t. \tag{10}$$

The equilibrium output scale of each C product is:

$$x_{C,t} = \frac{\zeta_t^{-\epsilon} E_t}{P_t^{1-\epsilon}}. \tag{11}$$

2.3 The R&D sector

Innovation is characterized by the introduction of new products. The competitive R&D sector hires Northern labors as researchers to invent new "blueprints", each representing a new product. The innovation process is characterized by:

$$\dot{n}_t = n_t d_R L_{R,t}^N,$$

or we can rewrite it as

$$\frac{\dot{n}_t}{n_t} = d_R L_{R,t}^N, \tag{12}$$

where d_R is an exogenous productivity parameter and $L_{R,t}^N$ is the number of Northern labor hired as researchers at date t. This functional form of R&D exhibits a spillover effect from the experience gained from past participation in R&D activities, which is essential to the generation of sustained growth.

Based on Equation (12), to produce one new "patent" at date t, $\frac{1}{d_R n_t}$ researchers must be hired. This means the R&D cost is:

$$Q_t = \frac{w_t}{d_R n_t}. \tag{13}$$

By contrast, since the R&D sector is competitive, the value of an innovation equals the present discounted value (PDV) of the N Firm, which obtains and commercializes this patent. Therefore, the value of an innovation is equal to:

$$V_t = \int_t^{\infty} e^{-\int_t^{\tau} r_s \mathrm{d}s} \pi_{N,\tau} \mathrm{d}\tau.$$

By differentiating both sides with respect to t, we can obtain:

$$r_t V_t = \dot{V}_t + \pi_t.$$

The left-hand-side (LHS) of the above equation is the return of selling the firm in the asset market, and the right-hand-side (RHS) is the return of holding the firm, where $\dot{V}_t$ is the capital gains at date t. In equilibrium, $\dot{V}_t = 0$; therefore:

$$V_t = \frac{\pi_{N,t}}{r_t}. \tag{14}$$

The R&D sector features free entry; thus, as long as the value of an innovation exceeds its cost, new R&D firms will keep entering the market. Therefore, in equilibrium, the value of an innovation must equal its cost: $V_t = Q_t$. Substitute Equations (13) and (14) into this equation and we can derive the following free entry condition in the R&D sector:

$$\frac{\pi_{N,t}}{r_t} = \frac{w_t}{d_R n_t}. \tag{15}$$

2.4 FDI and Imitation

For simplicity, we assume zero cost in multinationalization or in conducting FDI. As long as operating in the South generates higher value for a Northern firm, the firm can always choose to shift its production site to the South. Hence, the firm becomes an M Firm without additional cost. Therefore, the FDI decision is endogenously determined by a Northern-originated firm by comparing the potential benefit from lower production cost and the potential hazard of imitation.

The imitation process is governed by an exogenous hazard rate. Once a product is imitated, it will always be produced by the South to satisfy the world demand. This assumption conforms to the theory of Product Cycles, and is in line with previous N-S models such as those of Krugman (1979), Romer (1990), Helpman (1993) and Lai (1998), among others.

Assume that the exogenous imitation rate is μ. By definition, the number of newly-imitated varieties at date t is:

$$\dot{n}_{C,t} = \mu \cdot n_{M,t},$$

where $n_{M,t}$ is the number of varieties produced by M Firms, which have not been imitated yet.

The above equation also implies the definition of μ:

$$\mu = \frac{\dot{n}_{C,t}}{n_{M,t}}. \tag{16}$$

As μ is defined as a hazard rate, the duration Δt between the date of multinationalization (t) and the date of imitation (T) is implicitly assumed as a random variable with exponential distribution of which the Poisson arrival rate is equal to μ. Therefore, the cumulative distribution of an M firm moving to the South at time t and being imitated at time T can be written as:

$$Pr(\Delta t \leq T - t) = \mathscr{F}(t, T) = 1 - e^{-\mu(T-t)}.$$

We can easily derive the density function:

$$Pr(\Delta t = T - t) = \mathscr{F}'_T(t, T) = \mathscr{P}(t, T) = \mu e^{-\mu(T-t)}.$$

Then, we can write the PDV of an M Firm as:

$$V_{M,t} = \int_t^{\infty} \Big(\int_t^T e^{-\int_t^{\tau} r_s \mathrm{d}s} \pi_{M,\tau} \mathrm{d}\tau \Big) \mathscr{P}(t, T) \mathrm{d}T.$$

By differentiating both sides with respect to t, we can obtain:

$$r_t V_{M,t} = \dot{V}_{M,t} + \pi_{M,t} - \mu V_{M,t}.$$

The LHS of the above equation is the return of selling an M Firm in the risk-free asset market, whereas the RHS is the return of holding the M Firm, which consists of the profit flow $\pi_{M,t}$, the capital gains $\dot{V}_{M,t}$, and the expected loss from imitation $\mu V_{M,t}$. In the equilibrium, the capital gains $\dot{V}_{M,t} = 0$. Therefore, the value of an M Firm is:

$$V_{M,t} = \frac{\pi_{M,t}}{r_t + \mu}. \tag{17}$$

The FDI process is endogenous; therefore, as long as the value of operating in the South exceeds that of staying in the North, existing N Firms will conduct FDI to become M Firms. In an equilibrium where some Northern firms choose to remain at home, $V_{M,t} = V_t$. This leads to the no-arbitrage condition of FDI:

$$\frac{\pi_{M,t}}{r_t + \mu} = \frac{\pi_{N,t}}{r_t}. \tag{18}$$

In addition, the endogenous FDI rate, which captures the intensity of FDI activity, is defined as:

$$m_t = \frac{\dot{n}_{S,t}}{n_t}, \tag{19}$$

where $\dot{n}_{S,t}$ is the number of varieties that is starting to be produced in the South at date t, and n_t is the total number of varieties invented at date t.[9]

2.5 Asset and Expenditure

The equilibrium expenditure for North and South, which is required for welfare analysis, is determined endogenously through intertemporal consumption-savings decision. Households in both regions have access to the international capital market; therefore at the aggregate level:

$$\dot{A}_t = w_t \cdot L^N + 1 \cdot L^S + n_{N,t}\pi_{N,t} + n_{M,t}\pi_{M,t} + r_t A_t - E_t.$$

The amount of total asset is equal to the total value of firms; therefore, in the equilibrium we also have:

$$A_t = n_{N,t}V_t + n_{M,t}V_{M,t}.$$

2.6 Labor Market

The population size is L^N in the North and L^S in the South. Each agent is assumed to supply one unit of labor inelastically; thus, the total labor force is also L^N in the North and L^S in the South. There is no growth in population; hence both L^N and L^S are constants. Let $L^N_{N,t}$ be the number of Northern labor force hired as workers to produce N goods, $L^S_{M,t}$ and $L^S_{C,t}$ be the numbers of Southern labor force hired as workers to produce

[9] $\frac{\dot{n}_S}{n}$ means the fraction of newly-multinationalised products out of all the available varieties of products in the world, which captures the intensity of FDI (The Southern imitators can only target on multinationalised products; therefore, the only source of $\dot{n}_S$ is multinationalisation through FDI). Alternatively, we can follow Lai (1998) to define FDI rate as a hazard rate such as $\frac{\dot{n}_S}{n_N}$, which denotes the fraction of newly-multinationalised products out of the products currently produced in the North.

M goods and C goods, respectively, and $L^N_{R,t}$ be the number of Northern labor force hired as researchers. Consequently, the Northern labor market clearing condition is:

$$L^N_{N,t} + L^N_{R,t} = L^N,$$

and the Southern labor market clearing condition is:

$$L^S_{M,t} + L^S_{C,t} = L^S.$$

Moreover, the unit labor requirement in production is 1 in the North and ζ_t in the South; therefore:

$$L^N_{N,t} = n_{N,t}x_{N,t}, \quad L^S_{M,t} = \zeta_t n_{M,t}x_{M,t}, \quad L^S_{C,t} = \zeta_t n_{C,t}x_{C,t},$$

where $n_{i,t}$ is the number of type i varieties and $x_{i,t}$ is the associated equilibrium output scale of each type of variety. $i \in \{N, M, C\}$.

3 Learning-By-Doing

One major difference between our model and those in Lai (1998) and Branstetter and Saggi (2011) is that we consider the horizontal spillover effect of FDI on domestic productivity. In the benchmark model, we assume Southern human capital is accumulated simply along the production of imitated products through the mechanism of LBD. Later, we will change this simple assumption to some more complicated form to make the LBD process consistent with the empirical findings in Smeets and de Vaal (2011) in Section 6.

Due to the weak technological bases and the lack in R&D capability, developing countries generally adopt foreign technologies of the advanced North in their production activities. Therefore, the mechanism of LBD serves as a particularly effective way for the technological followers to enjoy additional productivity gains from the experience of adopting and adjusting foreign technologies in domestic production activities. At any given date, an increase in the aggregate output level of the imitated products will lead to both faster human capital growth and higher steady state human capital level in the South. If we denote the total human capital stock in the South as H_t and the average human capital level for each Southern worker as h_t, the LBD process can be characterized by the following equation:

$$\dot{H}_t = n_{C,t}x_{C,t} - \delta H_t,$$

where

$$H_t = L^S h_t.$$

$n_{C,t}$ is the number of imitated varieties at time t, $x_{C,t}$ is the per-variety output level for imitated products, and $\delta \in (0,1)$ is the human capital depreciation rate, which implies that the learning process is bounded.

The flow term $n_{C,t}x_{C,t}$ is the aggregate output level of imitated products, excluding the output from MNCs. We provide an explanation for such setup.

The assumption that the operations of MNCs do not directly enter the LBD process appears to be slightly counterintuitive, because FDI inflow from the more-advanced regions is believed, at least by policy makers in many developing countries, to benefit economic development in the South, particularly in narrowing the North-South productivity gap through claimed "technology spillovers." We admit that MNCs bring advanced technology to the South. However, the spillovers will not be generated automatically as FDI itself represents a way to internalize the firm-specific knowledge assets, which provides quite effective protection for their key knowledge and ideas from being diffused outside the organization (Görg and Greenaway, 2004). Hence, we assume that the production of knowledge-intensive products within the boundaries of MNCs will not help raise human capital and productivity in the South, until they are successfully imitated.

Second, it appears to be more appropriate to include only the production of *newly-imitated*, rather than the already-imitated products, into the LBD process because knowledge updates in a rapid manner and the production of mature and standardized products may only contribute to human capital marginally. However, this modification makes the analysis of the steady state relationship between IPR and innovation more complicated. Therefore, we take the production of all imitated-products into consideration.

According to the linear technology in producing differentiated products, we can write the aggregate output of imitated products as:

$$n_{C,t}x_{C,t} = \frac{L^S_{C,t}}{\zeta_t},$$

where $L^S_{C,t}$ is the number of employment by Southern imitators and ζ_t is the unit labor requirement in the South.

Moreover, we assume the unit labor requirement ζ_t is determined by the average human capital h_t in the following form:

$$\zeta_t = \eta \cdot h_t^{-\beta}, \tag{20}$$

where η and β are all positive parameters. Subsequently, we can rewrite the LBD process by replacing the aggregate human capital stock H_t in terms of average human capital level h_t:

$$\dot{h}_t = \eta^{-1} \cdot l^S_{C,t} \cdot {h_t}^{\beta} - \delta h_t, \tag{21}$$

where $l^S_{C,t} = \frac{L^S_{C,t}}{L^S}$ is the Southern imitators' share of employment in the South.

To ensure the stationarity of h_t, we need to impose a restriction on the parameter β:

$$\beta \in (0, 1).$$

Then we can solve the steady state level of h_t and ζ_t as:

$$h = (\eta\delta)^{-\frac{1}{1-\beta}} \cdot (l^S_C)^{\frac{1}{1-\beta}}, \tag{22}$$

and

$$\zeta = \eta^{\frac{1}{1-\beta}} \delta^{\frac{\beta}{1-\beta}} \cdot (l^S_C)^{-\frac{\beta}{1-\beta}}. \tag{23}$$

Both the transitional growth rate and the steady state level of Southern human capital are positively determined by the Southern imitators' share of employment (l^S_C), implying that the presence of foreign companies (which is equal to $l^S_M = 1 - l^S_C$) lead to reduced productivity development in the South, owing to the reduction of the extent of knowledge diffusion.

4 Balanced Growth Path

4.1 Steady State Characterization

We focus on the BGP equilibrium, where variables grow at constant rates. Southern labor is the numeraire; therefore, the Southern wage rate is always equal to 1. Under this normalization, the North-South relative wage is equal to the Northern wage rate w_t. In an equilibrium where production activities are dispersed in both North and South, the relative wage must converge to a positive and finite constant w because non-zero demands for labor exist in both regions, and hence, the wage rate in either region does not explode relative to that of the other.

Assume that at time t, the numbers of differentiated varieties produced by N, M, and C Firms are $n_{N,t}$, $n_{M,t}$ and $n_{C,t}$. Define the equilibrium variety shares as $\phi_{N,t} = \frac{n_{N,t}}{n_t}$, $\phi_{M,t} = \frac{n_{M,t}}{n_t}$, and $\phi_{C,t} = \frac{n_{C,t}}{n_t}$ respectively. Given that these varieties are mutually exclusive and cover all the existing varieties, the following properties must hold for each date:

$$\phi_{i,t} \in [0, 1] \ , \qquad \sum_{i \in \{N,M,C\}} \phi_{i,t} = 1, \quad \forall i \in \{N, M, C\}.$$

In the steady state, ϕ_N, ϕ_M and ϕ_C are all constants, and represent stable shares of varieties produced by Northern domestic firms, multinational firms, and Southern imitators.

Let g_t be the innovation rate. In BGP, $g_t = \frac{\dot{n}_t}{n_t} = \frac{\dot{n}_{N,t}}{n_{N,t}} = \frac{\dot{n}_{M,t}}{n_{M,t}} = \frac{\dot{n}_{C,t}}{n_{C,t}} = g$, where g is a constant. Moreover, define $\phi_{S,t} = \phi_{M,t} + \phi_{C,t}$ to represent the share of varieties produced in the South. Owing to the growth rate and the shares of varieties being constants in BGP, the FDI rate $m_t = \frac{\dot{n}_{S,t}}{n_t} = \frac{\dot{n}_{S,t}}{n_{S,t}}\frac{n_{S,t}}{n_t} = g_t \cdot \phi_{S,t}$ must also be a constant in BGP.

The price index P_t will grow at the speed of $n_t^{\frac{1}{1-\epsilon}}$ in BGP. To observe this, substitute Equations (4), (7), and (10) into Equation (2) to obtain the steady state price index:

$$P_t = n_t^{\frac{1}{1-\epsilon}} \left[\alpha^{\epsilon-1} w^{1-\epsilon} \phi_N + \alpha^{\epsilon-1} \zeta^{1-\epsilon} \phi_M + \zeta^{1-\epsilon} \phi_C \right]^{\frac{1}{1-\epsilon}}. \tag{24}$$

w, ζ and ϕ_i are all constants in the steady state; thus, we can infer $P_t \propto n_t^{\frac{1}{1-\epsilon}}$ in BGP. Given that $\epsilon > 1$, P_t is in fact decreasing over time.

Note the total expenditure equals to the total sales of all the differentiated products, which implies:

$$E_t = p_N n_N x_N + p_M n_M x_M + p_C n_C x_C.$$

p_N, p_M and p_C all stop growing in the steady state due to the normalization of wage, and the terms $n_N x_N$, $n_M x_M$ and $n_C x_C$ are the aggregate outputs by firm type. Therefore, they grow at the same speed as that of the sum of labor productivity growth and labor input growth. We assume labor productivity stops growing for both regions, and total labor supply are constants. Hence, we can infer that E_t also stops growing in the steady state. Taking the Euler equation (3) into consideration, we can determine the steady state relationship for r:

$$r = \rho. \tag{25}$$

Although total expenditure E stops growing, the price P_t will keep dropping. This sustains the real consumption of the composite good C_t over time, because $C = \frac{E}{P}$. Moreover, because $E \propto n^0$ and $P \propto n^{\frac{1}{1-\epsilon}}$, therefore, $C \propto n^{\frac{1}{\epsilon-1}}$, which means $\frac{\dot{C}_t}{C_t} = \frac{1}{\epsilon-1} g$. This result implies that innovation serves as the engine for the long-run economic growth for both North and South.

Furthermore, the per-firm output level $x_{i,t} \propto \frac{E_t}{P_t^{1-\epsilon}}$; therefore, the output level of each firm grows at the speed of n_t^{-1} in BGP. With ever-expanding varieties and the fixed total supply of production factor (labor), the output scale for each variety has to drop over time. This indicates that the aggregate output and employment levels for each variety, $n_{i,t}x_{i,t}$ and $L_{i,t}$ with $i \in \{N, M, C\}$, are constants in BGP. The total labor supply in both regions are assumed to be fixed. Thus, in BGP, the amount of labor allocated to conduct R&D is also a constant due to the Northern labor market clearing condition.

In terms of the LBD process, we have already derive the steady state unit labor requirement ζ^L:

$$\zeta^L = \eta^{\frac{1}{1-\beta}} \delta^{\frac{\beta}{1-\beta}} (l_C^S)^{-\frac{\beta}{1-\beta}},$$

where l_C^S is the Southern imitators' share of employment in the steady state, which is determined by g and μ.

In summary, the BGP of this model is characterized by the following time sequence of variables:

$$\left\{g, r, m, w, \zeta, C_t^j, E^j, P_t^j, L_i^j, L_R^N, \phi_i\right\}_{t\to\infty}, \quad j \in \{N, S\}, \quad i \in \{N, M, C\},$$

where g is the innovation rate; r is the interest rate; m is the FDI rate; w is the relative wage between North and South; ζ is the unit labor requirement of production in the South; C_t^j is the total consumption of composite goods in Region j which grows at the rate of $\left(\frac{1}{\epsilon-1}\right)g$; E^j is the total expenditure of Region j which is a constant; P_t^j is the price index in Region j, which grows at the rate of $\left(\frac{1}{1-\epsilon}\right)g$; L_i^j is the total labor employed to produce variety i in Region j; L_R^N is the total labor employed as researchers to conduct R&D and ϕ_i is the share of variety i among the total number of varieties in the world.

4.2 Solving the Steady State

From the definition of imitation rate μ and FDI rate m, we can determine the steady state shares of varieties with the given g, μ and m:

$$\phi_N = \frac{g-m}{g}, \tag{26}$$

$$\phi_M = \frac{m}{g+\mu}, \tag{27}$$

and

$$\phi_C = \frac{\mu}{g} \cdot \frac{m}{g+\mu}. \tag{28}$$

With the given innovation rate g, a strengthening in IPR protection ($\mu \downarrow$) raises the relative share of varieties produced by MNCs to those produced by Southern imitators, because $\frac{n_M}{n_C} = \frac{\phi_M}{\phi_C} = \frac{g}{\mu}$. This is intuitive because stronger IPR protection grants a larger share of Southern industries to the multinational firms by reducing the risk of imitation from Southern imitators.

By contrast, with the given innovation rate g, a larger FDI rate ($m \uparrow$) tends to shift a larger share of products to the South, because $\phi_S = \phi_C + \phi_M = \frac{m}{g}$. Additionally, the condition $m < g$ must hold in the steady state, which means that at any date in the steady state, more inventions are created compared to those becoming multinationalized, or else the number of products that remain in production in the North will shrink over time, contradicting the case where ϕ_N is non-zero in the steady state.

From Equation (5), we can obtain the aggregate output for each variety in the steady state:

$$X_N = n_N x_N = \alpha^\epsilon \phi_N w^{-\epsilon}\chi,\ X_M = n_M x_M = \alpha^\epsilon \phi_M \zeta^{-\epsilon}\chi,\ X_C = n_C x_C = \phi_C \zeta^{-\epsilon}\chi,$$

where $\chi = \frac{n_t E}{P_t^{1-\epsilon}}$ is a variable that shows the combined effect of innovation, world aggregate expenditure, and price index adjustment. χ is a constant in BGP.[10]

Given that the unit labor requirement in the North is 1, and only N products are produced in the North, the number of workers in the North, L_N^N, is equal to the aggregate output of N products, X_N. By contrast, according to Equation (12), if the innovation rate is g, then the amount of labor hired as researchers is equal to $\frac{1}{d_R}g$. Therefore, the labor market clearing condition in the North implies that the sum of employment of workers in producing N products and researchers conducting R&D equals the total Northern labor supply L^N:

$$\alpha^\epsilon \phi_N w^{-\epsilon}\chi + \frac{1}{d_R}g = L^N, \tag{29}$$

which is the Northern labor market clearing condition in BGP.

The unit labor requirement is ζ in the South; therefore, the total amount of employment in the South is equals to $\zeta(X_M + X_C)$. Similarly, the total employment in producing M and C products must be equal to the total supply of labor in the South so as to meet the labor market clearing condition:

$$\big(\alpha^\epsilon \phi_M + \phi_C\big)\zeta^{1-\epsilon}\chi = L^S. \tag{30}$$

The free-entry condition (15) in the R&D sector suggests that the price of an innovation (i.e., the PDV of an N Firm obtaining this innovation, ($\frac{\pi_{N,t}}{r_t}$) must be equal to its R&D

[10]This conclusion is readily observable because E is a constant and $P_t \propto n_t^{\frac{1}{1-\epsilon}}$.

cost. Therefore the steady state free-entry condition can be derived as:

$$\frac{\alpha^{\epsilon}}{\epsilon-1}w^{-\epsilon}\chi = \frac{r}{d_R}. \tag{31}$$

Combining Equations (29), (30) and (31), we can derive:

$$\frac{\phi_N}{\phi_M+\alpha^{-\epsilon}\phi_C}\frac{\omega^{-\epsilon}}{\zeta} = \frac{d_R L^N - g}{d_R L^S}.$$

The FDI no-arbitrage condition implies that in BGP, the PDV of an N Firm ($\frac{\pi_N}{r}$) must also be equal to that of an M Firm ($\frac{\pi_M}{r+\mu}$). From this condition we can derive the productivity-adjusted wage ratio between North and South:

$$\omega = \frac{w}{\zeta} = \Big(\frac{r+\mu}{r}\Big)^{\frac{1}{\epsilon-1}} > 1. \tag{32}$$

Equation (32) implies that the real cost of production must be lower in the South at equilibrium, or no rational Northern firm owners will attempt to multinationalize their products.

Since $\frac{L_M^S}{L_C^S} = \frac{X_M}{X_C} = \frac{\alpha^{\epsilon}\phi_M}{\phi_C}$, and $L_M^S + L_C^S = L^S$, therefore:

$$l_M^S = \frac{L_M^S}{L^S} = \frac{\alpha^{\epsilon}\phi_M}{\alpha^{\epsilon}\phi_M+\phi_C} = \frac{\alpha^{\epsilon}g}{\alpha^{\epsilon}g+\mu}, \qquad l_C^S = \frac{L_C^S}{L^S} = \frac{\phi_C}{\alpha^{\epsilon}\phi_M+\phi_C} = \frac{\mu}{\alpha^{\epsilon}g+\mu}.$$

The two equations imply that with a fixed innovation rate g, the strengthening in Southern IPR protection ($\mu\downarrow$) will increase the employment share of multinational companies and reduce that of the imitators in the South, which is intuitive.

Combining Equations (26), (27) and (28), we can derive the steady state aggregate level of ζ^L in terms of μ and g:

$$\zeta^L = A\cdot\Big(\frac{\alpha^{\epsilon}g+\mu}{\mu}\Big)^{\frac{\beta}{1-\beta}} = A\cdot\Big(\frac{\alpha^{\epsilon}g}{\mu}+1\Big)^{\frac{\beta}{1-\beta}},$$

where $A = \eta^{\frac{1}{1-\beta}}\delta^{\frac{\beta}{1-\beta}}$.

To solve the steady state means to solve jointly the 9-equation system composed of the Euler equation (25), the share of varieties (26), (27) and (28); the two labor market clearing conditions (29) and (30); the free entry condition in the R&D sector (31); the no-arbitrage condition for FDI (32); and the unit labor requirement determination through LBD (35) for 9 unknown variables $\Big\{g, r, m, \phi_D, \phi_M, \phi_C, \omega, \zeta, \chi\Big\}$.[11]

[11] Because χ can be further decomposed into P_t, and $E = E^N + E^S$, therefore a complete solution for the steady state will involve three additional endogenous variables, namely, P_t, E^N and E^S. In this case, we have three additional equations composed of (1) the definition equation of χ, (2) the steady state price index determination equation, and (3) the asset accumulation equation as defined in Section 2.5. In particular, we can obtain the ratio of $\frac{E_t^N}{E_t^S}$, which is helpful for welfare analysis. However, welfare is not the focus of this study; thus, we will leave it for further extensions.

4.3 Analytical Properties

In this section, we show some basic analytical properties of the benchmark model and compare this model with that of Lai (1998).

First, both a lower bound and an upper bound for the steady state innovation rate g exist. The lower bound represents the innovation rate that the North can achieve under autarky. The upper bound represents the innovation rate when the North devotes all of its resources to innovation. In particular, if we denote the growth rate in the autarky as g^A and the upperbound as g^U, then we can derive:

$$g^A = d_R L^N - (\epsilon - 1)\rho,$$

and

$$g^U = d_R L^N.$$

For the derivation, see Appendix Appendix A.

When the Northern economy is opened up with the South, where the production cost is lower, Northern firms can always choose whether to stay in the North or shift to the South to maximize profit. The profit flow in the open environment cannot be lower than the autarky level, and such situation is the same for the return of R&D investment. This further implies that in the open environment, the innovation rate g will be no less than the autarky growth rate g^A. Therefore, g^A is the theoretical lower bound of g under the North-South setup. By contrast, a theoretical upper bound of g also exists when all the Northern labor is allocated in the R&D sector as researchers, whereas all the production tasks are assigned to the South. The upper bound is $g^U = d_R L^N$.

From the Euler equation (25), the steady state interest rate r equals to the time preference:

$$r = \rho,$$

which implies r is independent of g.[12]

By combining Equations (29) and (31), we can determine the steady state share of N products in terms of g and r:

$$\phi_N = \frac{d_R L^N - g}{(\epsilon - 1)r} = \frac{d_R L^N - g}{(\epsilon - 1)\rho}.$$

The equation implies that ϕ_N is always decreasing in g.

[12] In general r is also affected by the innovation rate g. The invariance is the result of the logarithm utility functional form, which specifies a unit intertemporal rate of substitution.

By incoporating the above result into Equation (26), we can determine the steady state FDI rate in terms of g:

$$m = g(1 - \phi_N) = g \cdot \frac{g - [d_R L^N - (\epsilon - 1)\rho]}{(\epsilon - 1)\rho},$$

or

$$m = \frac{g(g - g^A)}{(\epsilon - 1)\rho}. \tag{33}$$

Therefore, it is clear that with $g \in [g^A, g^U]$, the FDI rate m is increasing in g. The intuition behind this result is that an increased FDI rate implies more Northern firms shift their production base to the South, and therefore, less labor is allocated to the production sector in the North at any date. In the equilibrium, the full employment condition implies the reduction of labor allocated to the production sector will cause more labor to be allocated to the R&D sector, which drives up the innovation rate.

From the free-entry condition (31), we can obtain the relationship between χ and w with $r = \rho$:

$$\chi = \alpha^{-\epsilon} \frac{(\epsilon - 1)\rho}{d_R} w^{\epsilon}.$$

From the no-arbitrage condition for FDI, we can determine the relative wage rate after the adjustment in productivity:

$$\omega = \Big(\frac{\rho + \mu}{\rho}\Big)^{\frac{1}{\epsilon - 1}}.$$

Given taht $w = \omega\zeta$, we can determine χ in terms of ζ by eliminating w from the two equations above:

$$\chi = \alpha^{-\epsilon} \frac{(\epsilon - 1)\rho}{d_R} \Big(\frac{\rho + \mu}{\rho}\Big)^{\frac{\epsilon}{\epsilon - 1}} \zeta^{\epsilon}.$$

By incorporating the above result into the Southern labor market clearing condition (30), we can obtain the implied steady state unit labor requirement in the South:

$$\begin{aligned} \zeta^I &= \frac{d_R L^S}{(\epsilon - 1)\rho} \frac{g}{m} \frac{g + \mu}{g + \alpha^{-\epsilon}\mu} \Big(\frac{\rho}{\rho + \mu}\Big)^{\frac{\epsilon}{\epsilon - 1}} \\ &= \frac{d_R L^S}{g - g^A} \frac{g + \mu}{g + \alpha^{-\epsilon}\mu} \Big(\frac{\rho}{\rho + \mu}\Big)^{\frac{1}{\alpha}}. \end{aligned} \tag{34}$$

The superscription I means this is the "Implied" level of unit labor requirement in the South for each combination of given IPR protection μ and observed steady state innovation rate g. Technically, this equation is derived from the Euler equation, North and South labor market clearing conditions, R&D free-entry condition, and FDI no-arbitrage condition, but is independent of the LBD process. We can derive that ζ^I is decreasing in both g and μ (See Appendix Appendix B).

The negative relationship between ζ^I and g implies that if the IPR protection level does not change, rather, an increase in the steady state Northern innovation rate ($g \uparrow$) is observed, then this must be the case where the steady state productivity in the South has been improved ($\zeta \downarrow$). By contrast, the negative relationship between ζ^I and μ implies that if a strengthening in IPR protection occurs in the South ($\mu \downarrow$) despite the unchanging steady state Northern innovation rate, then this must be the case where the steady state productivity level in the South has deteriorated ($\zeta^I \uparrow$).

Next, examine the monotonicity of ζ^L. Given that

$$\zeta^L = A \cdot \Big(\frac{\alpha^\epsilon g}{\mu} + 1\Big)^{\frac{\beta}{1-\beta}}, \tag{35}$$

where $A = \eta^{\frac{1}{1-\beta}} \delta^{\frac{\beta}{1-\beta}} > 0$ and $\beta \in (0, 1)$, then we can observe that ζ^L is increasing in g and decreasing in μ.

As we have obtained the monotonicity properties for both ζ^I and ζ^L, therefore, the steady state g can be pinned down by the intersection of these two curves, and the model is thus solved. ζ^I is increasing in g and ζ^L is decreasing in g. Moreover, with any non-zero μ, ζ^I is in the vicinity of infinity and ζ^L takes a finite value when g is close to the lower bound g^A. Therefore, as long as the value of ζ^L dominates ζ^I when evaluated at the upper bound g^U, then the two curves always cross each other only once within the range (g^A, g^U). Such situation indicates the existence of a unique solution (g, ζ), which is shown in Figure 3:

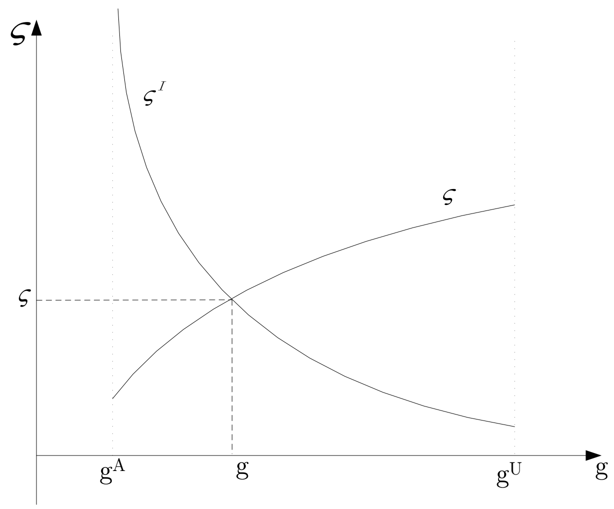

Figure 3: Graphical Representation of the Solution in (ζ, g) Space

With a given value of μ, we can denote ζ^{LA} as the value of ζ^{L} evaluated at $g = g^{A}$, ζ^{LU} as the value of ζ^{L} evaluated at $g = g^{U}$, ζ^{LI} as the value of ζ^{I} evaluated at $g = g^{A}$ and ζ^{IU} as the value of ζ^{I} evaluated at $g = g^{U}$. Consequently, the necessary and sufficient condition of the existence of a solution is:

$$\zeta^{LA} < \zeta^{IA}$$

and

$$\zeta^{LU} > \zeta^{IU}.$$

The first condition automatically holds, because when g is very close to its lower bound g^{A}, ζ^{IA} will move toward infinity, whereas ζ^{LA} takes a finite value. By contrast, if we substitute $g^{U} = d_R L^N$ for Equations (34) and (35), the second condition can be rewritten as:

$$A\Big(\frac{\alpha^{\epsilon} d_R L^N}{\mu} + 1\Big)^{\frac{\beta}{1-\beta}} > \frac{d_R L^S}{(\epsilon-1)\rho}\frac{d_R L^N + \mu}{d_R L^N + \alpha^{-\epsilon}\mu}\Big(\frac{\rho}{\rho+\mu}\Big)^{\frac{1}{\alpha}}.$$

Given that both sides are decreasing in μ, we can assume that μ can be infinitely large and the lower bound of μ is very close to zero. Consequently, it is clear that:

$$A\Big(\frac{\alpha^{\epsilon} d_R L^N}{\mu} + 1\Big)^{\frac{\beta}{1-\beta}} > A$$

and

$$\frac{d_R L^S}{(\epsilon-1)\rho}\frac{d_R L^N + \mu}{d_R L^N + \alpha^{-\epsilon}\mu}\Big(\frac{\rho}{\rho+\mu}\Big)^{\frac{1}{\alpha}} < \frac{d_R L^S}{(\epsilon-1)\rho}.$$

Therefore, the sufficient condition that ensures the existence of a solution is:

$$A > \frac{d_R L^S}{(\epsilon-1)\rho}. \tag{36}$$

4.4 Comparative statics of μ

Next, we examine the effect of strengthening IPR protection in the South in the steady state. Both ζ^{L} and ζ^{I} are decreasing in μ; therefore, the strengthening in IPR protection ($\mu \downarrow$) leads to upward shifts for both curves and results in an unambiguous increase in ζ, as shown in Figure 4.

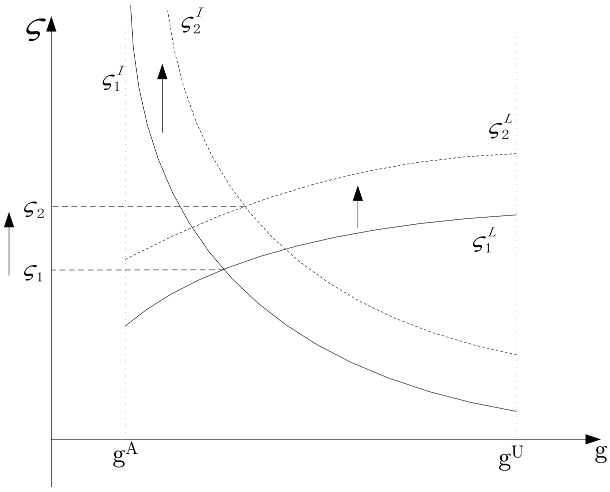

Figure 4: Effects of Stronger IPR on ζ

The two solid lines denoted as ζ_1^I and ζ_1^L represent ζ^I and ζ^L curves before an IPR reform, and the two dash lines denoted as ζ_2^I and ζ_2^L represent the ζ^I and ζ^L curves after the IPR reform. A strengthening in IPR protection unambiguously leads to a higher unit labor requirement in the South ($\zeta \uparrow$) in the new steady state, implying human capital and labor productivity in the South are both reduced with stronger IPR protection. However, the effect on innovation, g, tends to be ambiguous. The effects depend on the response of the two curves ζ^I and ζ^L with respect to the reduced imitation rate μ, as will be shown below.

Define $F(\mu, g) = \ln(\zeta^I)$ and $G(\mu, g) = \ln(\zeta^L)$. Therefore, we can write F and G as:

$$F(\mu, g) = \ln(d_R L^S) - \ln(g - g^A) + \ln(g + \mu) - \ln(g + \alpha^{-\epsilon}\mu) + \frac{1}{\alpha}[\ln(\rho) - \ln(\rho + \mu)],$$

and

$$G(\mu, g) = \ln(A) + \frac{\beta}{1-\beta}[\ln(\alpha^{\epsilon} g + \mu) - \ln(\mu)].$$

The partial derivatives of F and G with respect to g and μ are:

$$F'_g = -\frac{1}{g - g^A} + \frac{1}{g+\mu} - \frac{1}{g + \alpha^{-\epsilon}\mu},$$

$$F'_\mu = \frac{1}{g+\mu} - \frac{\alpha^{-\epsilon}}{g + \alpha^{-\epsilon}\mu} - \frac{1}{\alpha}\frac{1}{\rho+\mu},$$

$$G'_g = \frac{\beta}{1-\beta}\frac{\alpha^{\epsilon}}{\alpha^{\epsilon} g + \mu},$$

$$G'_\mu = \frac{\beta}{1-\beta}\Big(\frac{1}{\alpha^{\epsilon} g + \mu} - \frac{1}{\mu}\Big).$$

By using the implicit function theorem, the derivative of g with respect to μ in the steady state can be expressed as:

$$\frac{\mathrm{d}g}{\mathrm{d}\mu} = -\frac{F'_\mu - G'_\mu}{F'_g - G'_g} = -\frac{\frac{1}{1-\beta}\frac{1}{\alpha^{\epsilon}g+\mu} - \frac{1}{g+\mu} + \frac{1}{\alpha}\frac{1}{\rho+\mu} - \frac{\beta}{1-\beta}\frac{1}{\mu}}{\frac{1}{1-\beta}\frac{\alpha^{\epsilon}}{\alpha^{\epsilon}g+\mu} + \frac{1}{g-g^A} - \frac{1}{g+\mu}}. \quad (37)$$

The denominator is always positive, because $\frac{1}{g-g^A} > \frac{1}{g+\mu}$ holds for all positive g^A and μ. For the numerator, the last term, $-\frac{\beta}{1-\beta}\frac{1}{\mu}$ reaches $-\infty$ when IPR protection is extremely strong ($\mu \to 0$), whereas the remaining terms are all positive given that the solution of g is confined to (g^A, g^U). Therefore, the sign of the numerator is negative when IPR is extremely strong. This implies that $\frac{\mathrm{d}g}{\mathrm{d}\mu} > 0$ when μ is sufficiently small, which means that when IPR protection is already very strong, further strengthening will lead to a lower innovation rate in the steady state.

By contrast, when IPR is weak, the effect of a strengthening can be ambiguous. Examine the numerator again. The term $\frac{1}{1-\beta}\frac{1}{\alpha^\epsilon g+\mu} - \frac{1}{g+\mu} > 0$ always holds, because the conditions $0 < \alpha^\epsilon < 1$, $\frac{1}{1-\beta} > 1$ and $g > 0$ imply $\frac{1}{1-\beta}\frac{1}{\alpha^\epsilon g+\mu}$ dominates $\frac{1}{g+\mu}$ for all $\mu > 0$. The term $\frac{1}{\alpha}\frac{1}{\rho+\mu} - \frac{\beta}{1-\beta}\frac{1}{\mu} > 0$ when $\mu > \frac{\alpha\beta\rho}{1-(1+\alpha)\beta}$. Therefore, if we assume the weakest IPR protection level corresponds to $\mu \to \infty$, then strengthening IPR will always lead to higher innovation rate in the initial stage, since $\frac{\mathrm{d}g}{\mathrm{d}\mu} < 0$ when $\mu \in [\frac{\alpha\beta\rho}{1-(1+\alpha)\beta}, \infty)$.

5 Numerical Solution

5.1 Calibration

Before conducting the steady state comparative static analysis, we calibrate the benchmark model to approximate the real world scenario. We set the return of investment r to 0.07, which reflects the average real return of the U.S. stock market over the 20th century, as determined by Mehra and Prescott (1985). We set α to 0.714, the same value used by Gustafsson and Segerstrom (2011), to reflect a mark-up of approximately 40% for the differentiated products.[13] This implies that the value of $\epsilon = \frac{1}{1-\alpha} = 3.4965$. We set the innovation rate g to 0.05. This value implies a long-run utility growth rate of 2%, which is close to the average real GDP growth in the U.S.[14] We normalize the total Northern labor force to 1. Accordingly, we set Southern labor force to 2.8, which reflects the average ratio of working-age population between high-income and middle-income countries defined by the World Bank's *World Development Index* for the period 1961–2013.

For the market shares of different varieties, only the approximated values can be used due to limited data availability. For the share of imitated products, we estimate based on the counterfeit goods seizure data from the U.S. customs. The share of these counterfeit

[13]This is a number within the range of the average U.S industrial markups estimated in Norrbin (1993) and Basu (1996).
[14]This is because the utility growth rate is equal to $\frac{1}{\epsilon-1}g$.

goods composed about 3% of the total volume of world trade (Jakobsson and Segerstrom, 2012). However, this is only the lower bound of imitation because not all imitated goods are illegal counterfeits. Therefore, we set ϕ_C to 0.1, a value that is roughly three times of the data of illegal products. For the varieties of multinational firms and Northern domestic firms, we assume the ratio between them is approximately 30%. Therefore, we set ϕ_M to 0.2 and ϕ_N to 0.7.

Following Mankiw, Romer and Weil (1992), we assume that human capital depreciates at a speed that is the same as that of the physical capital. We set the human capital depreciation rate δ to 3%, which was used in Mankiw, Romer and Weil (1992). We link the parameter β in our model to the return of human capital. Equation (20) shows that one percent increase in human capital leads to β percent increase in productivity for a Southern worker. If we assume that the return of skill is proportional to the labor productivity, and human capital can be inferred from educational attainments, then β can be interpreted as the return of human capital, a value that is approximately determined in the Mincer's Equation. We set this value to 0.15.

The calibration results are summarized in Table 1.

Table 1: Calibration Results
(Benchmark Model)

Observed	*Value*	*Description*
g	0.05	Innovation rate
r	0.07	Average rate of return of U.S. stock market
ϕ_N	0.70	Share of N products
ϕ_M	0.20	Share of M products
ϕ_C	0.10	Share of C products
Pre-set	*Value*	*Description*
α	0.71	Inferred from a mark-up of approximately 40%
ϵ	3.50	Rate of substitution between varieties
L^N	1.00	Normalized total labor force in the North
L^S	2.80	Normalized total labor force in the South
δ	0.03	Human capital depreciation rate
β	0.15	Return of human capital
Calibrated	*Value*	*Description*
ρ	0.07	Subjective discount rate
d_R	0.17	R&D productivity parameter
η	4.49	Human capital scaling parameter

5.2 Simulation

We use the calibrated parameter values for simulation with μ ranging from 0.2 (weak IPR) to 0 (extremely high IPR). The main results are summarized in Figure 13.

We focus on the effect of enhancing Southern IPR protection on economic growth rate, FDI rate, Southern labor productivity, relative wage between North and South, and the shares of different types of varieties, respectively.

Figure 5 depicts the relationship between IPR protection in the South and long-run economic growth. As expected, when the current level of IPR protection is relatively low (i.e., when μ is large), an incremental strengthening in IPR protection leads to higher long-run economic growth. However, when the current IPR protection level reaches a certain threshold, a further enhancement will lead to a slowdown in the long-run economic growth. Similarly, such a relationship also exists between IPR protection and FDI rate, as revealed in Figure 6.

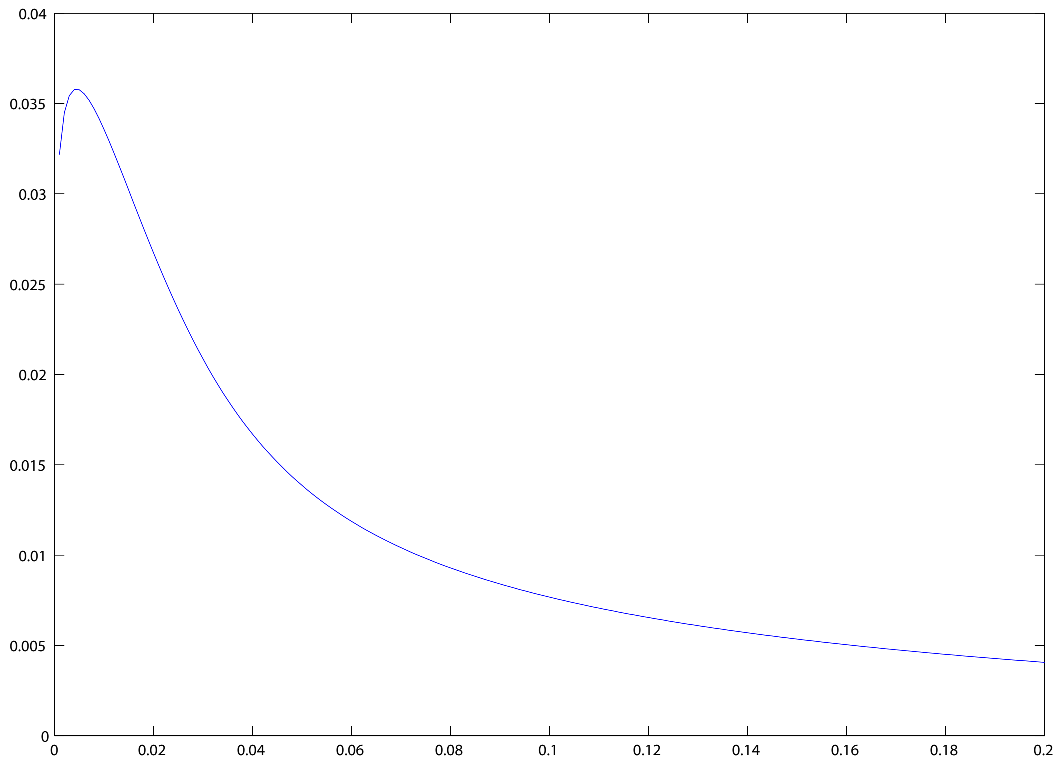

Figure 5: IPR Protection and Economic Growth

(Benchmark Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is.

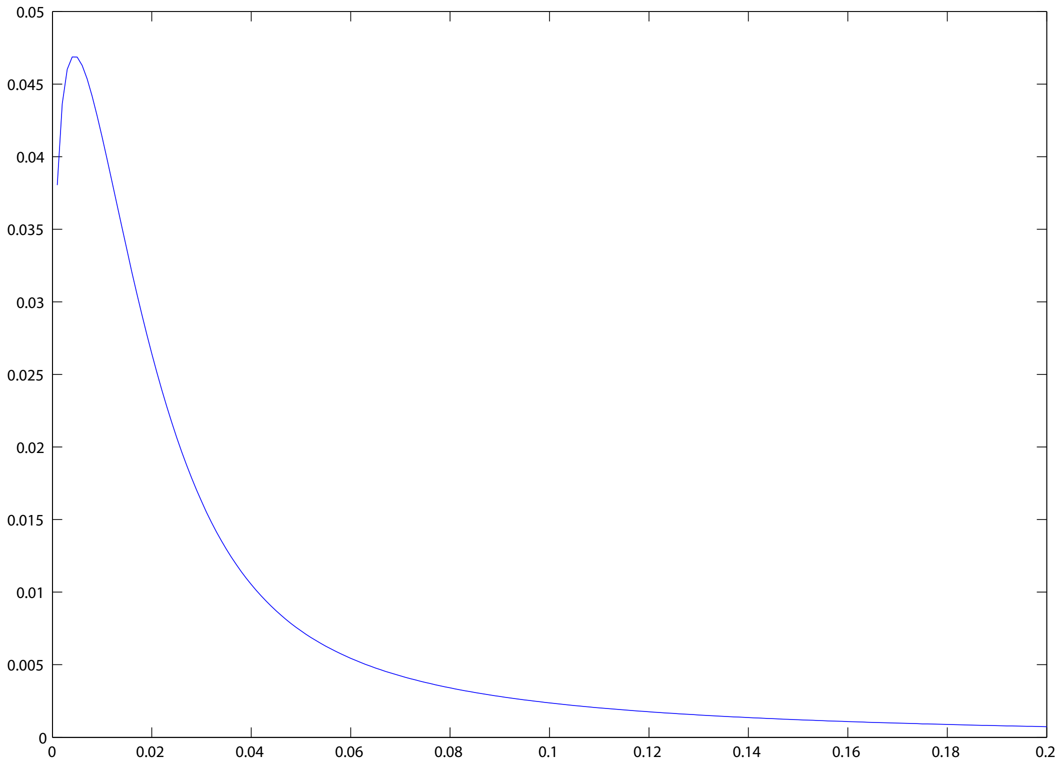

Figure 6: IPR Protection and FDI Rate
(Benchmark Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is. FDI rate is defined as the fraction of product varieties that are newly introduced to the South in the total number of varieties in the world during unit time intervals.

Such a pattern reflects the key trade-offs between technology transfer and knowledge diffusion in determining the production shift effect: a strengthened IPR protection prolongs the expected monopoly duration for the MNCs, and therefore raises the value of MNCs and encourages technology transfer through FDI. This positively affects the production shift effect because more resources in the North can be allocated to the R&D sector. However, a strengthened IPR in the South diminishes the knowledge diffusion in the South, and therefore reduces Southern human capital, which in turn raises the cost that MNCs face *at any given wage rate*. The increase in cost discourages FDI, and hence negatively affects the production shift effect because the Northern firms choose to remain in the North for an prolonged period on average. As a result, the resource supply for R&D is reduced. Therefore, the overall effect can be ambiguous and non-monotonic, depending on the current level of IPR protection. When IPR protection is weak, the technology transfer effect dominates, and the net production shift effect is positive. This leads to an increase in both innovation rate and FDI rate, and consequently, the world economic growth is promoted. However, when IPR protection is sufficiently strong, the knowledge diffusion effect dominates, and the net production shift effect become negative. This leads to a decrease in both innovation rate and FDI rate; hence, the world economic growth is lowered.

The effect of foreign presence on Southern productivity is always negative, as shown in Figure 7. This finding echoes the empirical evidences of negative horizontal FDI spillovers, as discussed in Section 1. The key mechanism underlying this pattern is the LBD process, in which the average human capital level h is positively correlated with the imitation rate μ in the steady state. Because the foreign presence l_M^S is negatively correlated with μ, therefore the relationship between l_M^S and h is also negative.

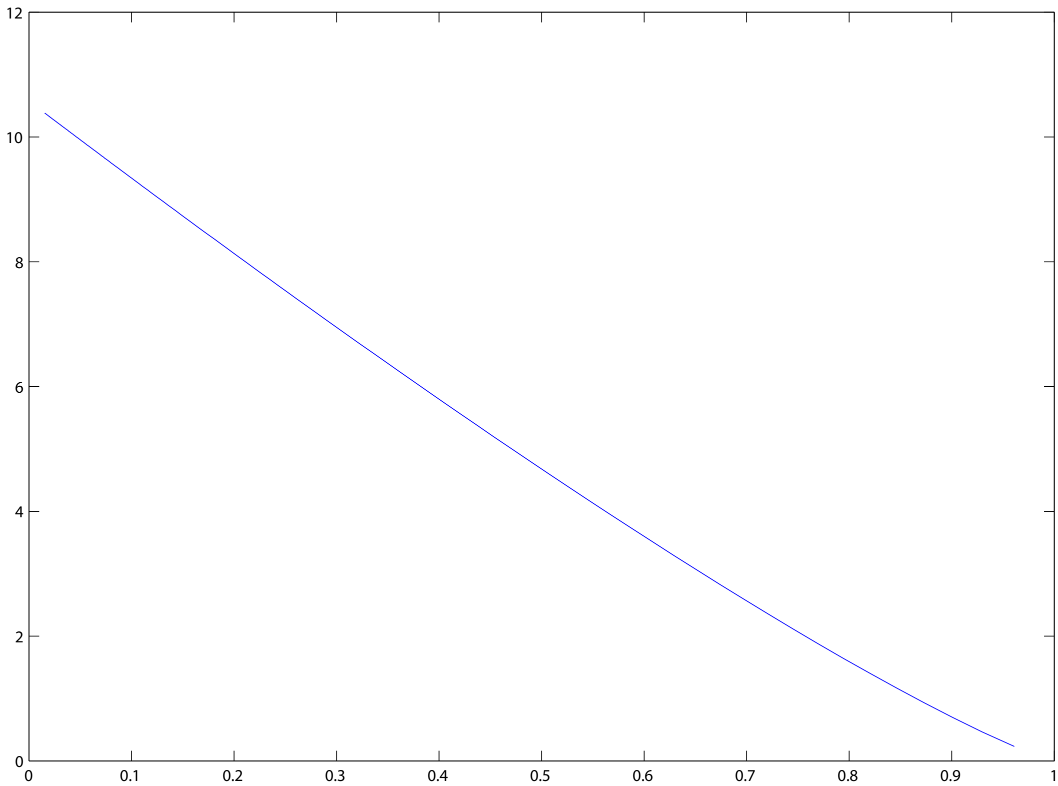

Figure 7: Foreign Presence and Southern Human Capital
(Benchmark Model)

Notice: The horizontal axis is foreign presence defined as the fraction of labor hired by the MNCs in the South: $l_M^S \equiv \frac{L_M^S}{L^S}$. The vertical axis is the Southern average human capital h.

Figure 8 reveals that the wage gap between North and South is also non-monotonic. When IPR protection is weak, strengthening IPR protection encourages FDI, which increases the demand for Southern labor. Although strong IPR may also stifle knowledge diffusion and subsequently reduce the productivity of Southern labor, this negative effect is dominated. Figure 13 shows that the increase in the unit labor requirement is only marginal when IPR is weak ($\mu \uparrow$). Hence, the North-South wage gap is narrowed in the initial stage. However, once IPR protection reaches a certain level, its negative effect on Southern labor productivity becomes considerably intensified, which discourages FDI. Consequently, the demand for Southern labor is reduced. This results in the re-widening of the North-South wage gap.

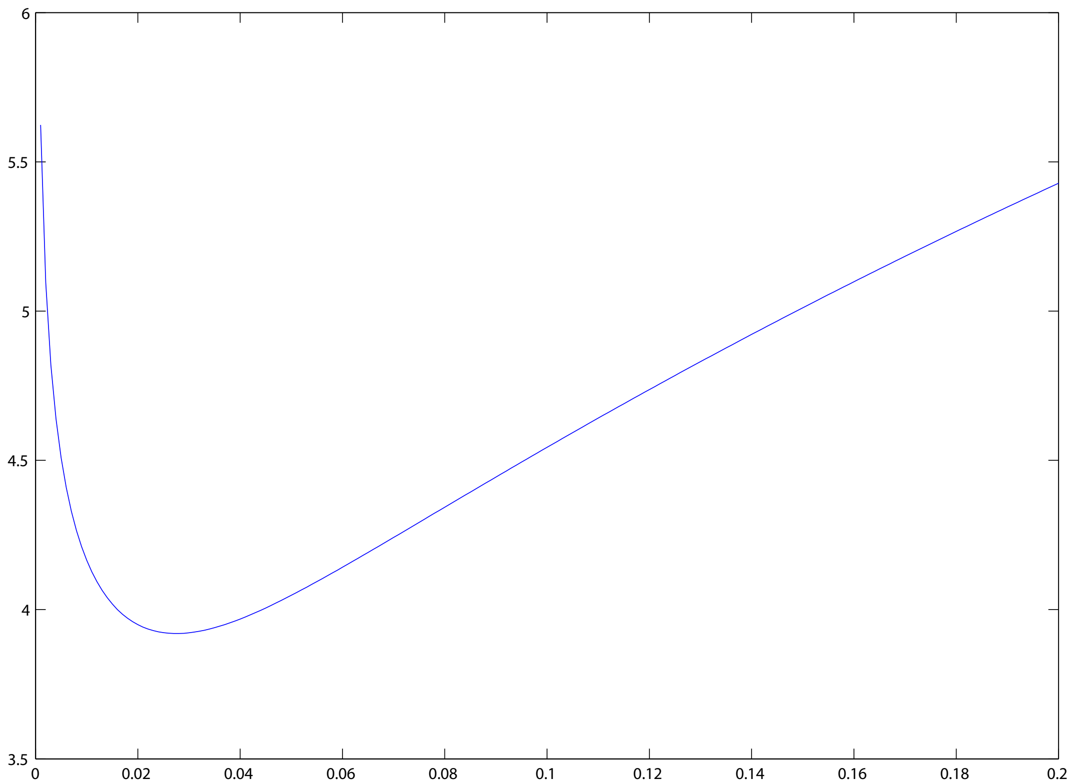

Figure 8: IPR Protection and North-South Wage Gap
(Benchmark Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is. The vertical axis is the North-South relative wage $w \equiv \frac{w^N}{w^S}$.

With regard to the global division of labor in manufacturing differentiated products, the effect of strengthening IPR in the South is also non-monotonic and dependent on the current level of IPR protection, See Figure 9.

When the IPR protection is weak, the Northern share decreases, whereas the Southern share increases. This result is intuitive, because strengthening IPR protection encourages

FDI when IPR protection is weak, which increases the MNCs' share. The increase in the Southern imitators' share is the less intuitive result. Such result is produced by the extremely fast speed of FDI inflow as stimulated by an enhancement in IPR protection during a time when it is weak. As a result, Southern imitators have a larger "pool" to imitate from. Therefore, although the imitators' share unambiguously decreases with the IPR being strengthened *in the South*, their share *in the world* will increase when IPR protection is weak. By contrast, when IPR protection becomes sufficiently strong, further enhancement reinforces the Northern share and reduce both the MNCs' share and Southern imitators' share.

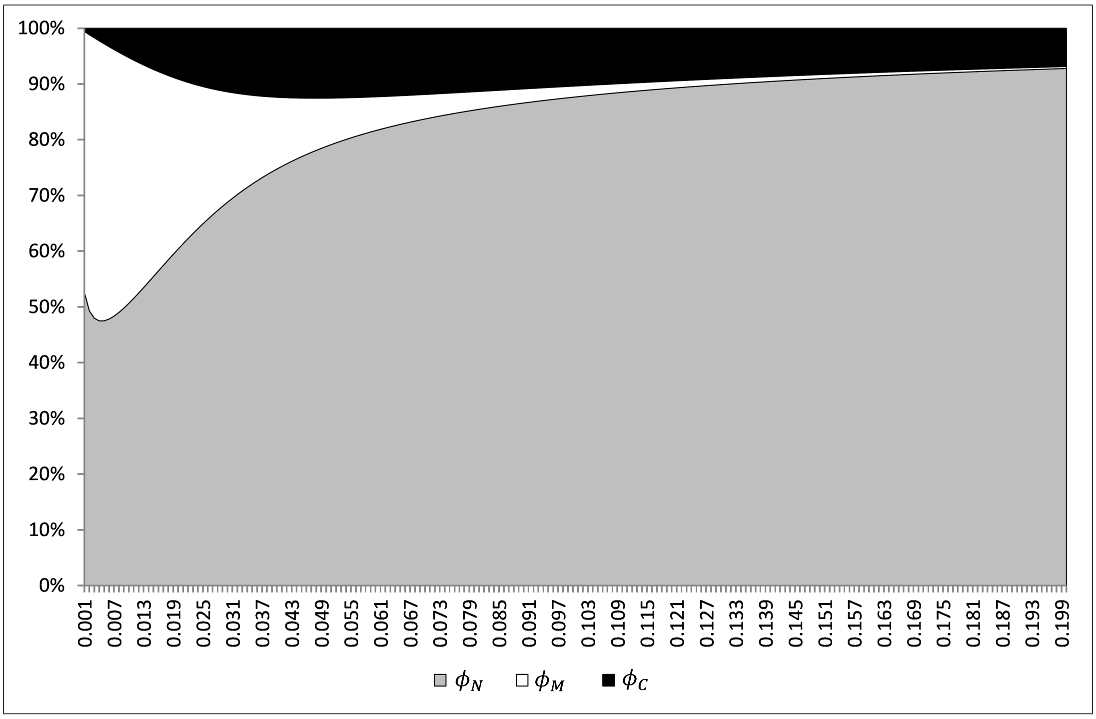

Figure 9: IPR Protection and Shares of Varieties

(Benchmark Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is. ϕ_i represents the fraction of varieties produced by firm with type i in the total number of world varities $\phi_i \equiv \frac{n_i}{n}$.

The results shown above are different from those of Lai (1998) specific to a case where the current IPR protection in the South is sufficiently strong. Lai (1998) suggested that stronger IPR protection in the South always leads to higher economic growth rate and a narrower North-South wage gap. Although our result is consistent with his prediction when Southern IPR protection is moderate if not weak, the direction is reversed when the extent of IPR protection reaches a certain threshold: further strengthening of an established stringent level of IPR protection reduces world economic growth and widens the North-South wage gap. The key difference is that we take the consequence of IPR on Southern development into consideration: strengthening IPR protection depresses imitation and increases the employment share of MNCs. MNCs can effectively protect their firm-specific assets within the organization; thus, the knowledge diffusion is lowered from a social point of view. Lowered knowledge diffusion leads to a smaller output level for imitated products, and reduces the human capital in the South through the mechanism of LBD. An extremely low level of human capital may discourage future FDI, because it generates a large negative effect on the localization advantage for overseas operation, according to the OLI paradigm. This negative effect, however, is not mentioned in any of the existing models under the North-South Product Cycles framework.

The setup of the LBD process is important to our model. Therefore, we perform a comparative static analysis to show how the changes in the key structural parameter in the LBD process β can affect the previously obtained result.

5.3 Comparative Statics of β

We conduct the comparative static analysis using the following strategy. First, we keep all the other pre-set parameters and observed variables unchanged, but change the values of β. Second, with the updated values, we conduct a re-calibration of d_R and η. Third, with the new set of structural parameters, we simulate the effect of μ on the key endogenous variables again, and compare the differences.

Figure 10 exhibits the effect of IPR protection on long-run economic growth with different values of β, the return to human capital. The solid line represents the benchmark case when β is set to the moderate value of 0.15. The long-dashed line represents the case when $\beta = 0.5$, which means that the return of human capital is relatively high. The short-dashed line represents the case when $\beta = 0.01$, which means that the return of human capital is extremely low. Figure 10 reveals that the return of human capital affects the choice of an optimal level of IPR protection, which is aimed at maximizing the long-run economic growth. A higher return of human capital implies that the LBD is more effective: the experience gained from one additional unit of production generates more reductions in the unit labor requirement. This indicates the increase in the negative effect of IPR protection on productivity becomes larger for any steady state. Therefore, the growth-maximizing level of IPR protection also drops to a weaker level. By contrast,

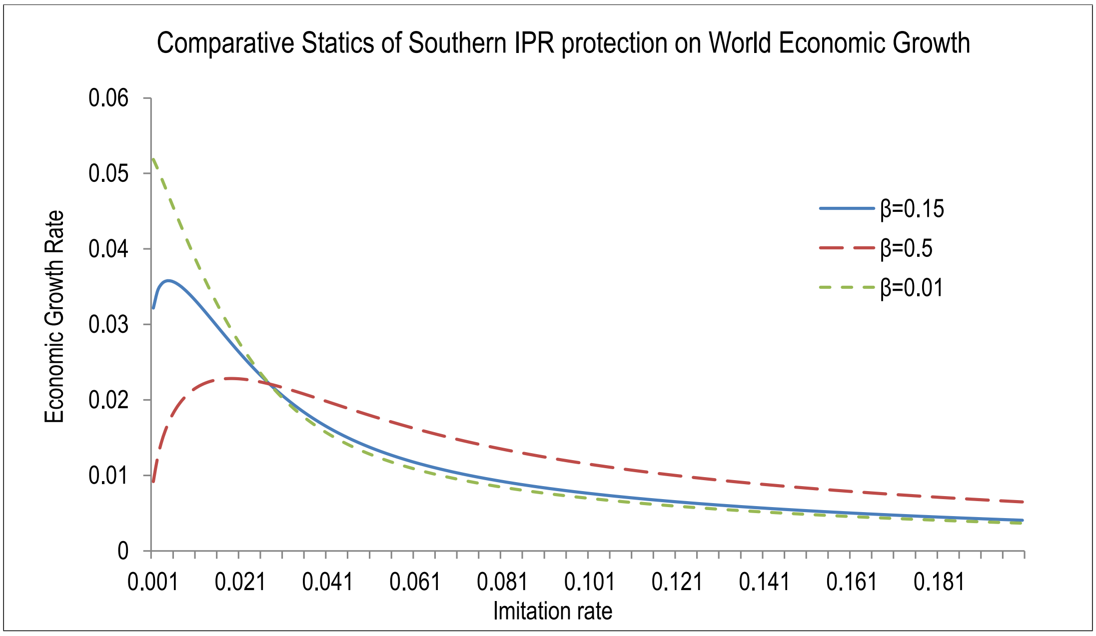

Figure 10: Effects of IPR Protection on Long-Run Economic Growth

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The vertical axis is the long-run economic growth which equals to $\frac{1}{\epsilon-1}g$, where g is the steady state innovation rate.

when the return of human capital is exceptionally small, which means that the human capital generated in the LBD process has a very slight effect on workers' productivity, then the negative effect of IPR protection on knowledge diffusion becomes almost negligible. Therefore, we can expect the growth-maximizing level of IPR protection to be at a very strong level. When the learning effect is absent, then the growth-maximizing level of IPR protection lies at the strongest level ($\mu = 0$). This is exactly the result obtained by Lai (1998).

The growth-maximizing level of IPR protection is summarized in Table 2. The result implies that currently, the Southern IPR protection level has not yet reached the growth-maximizing level.

Table 2: Growth-Maximizing IPR

Case	*Optimal imitation rate*	*Maximum growth rate*
$\beta = 0.01$	≈ 0	0.052
$\beta = 0.15$	0.004	0.036
$\beta = 0.50$	0.019	0.023
	Current imitation rate	*Current growth rate*
	0.025	0.020

It is also important to examine the effect of IPR on the North-South wage gap w when β changes. Figure 11 exhibits the effects of IPR protection on the North-South wage gap and Table 3 summarizes the critical values of IPR protection at which the smallest North-South wage gap is attained. The patterns show that when the return of human capital is large (the case when $\beta = 0.5$), the IPR protection level, which produces the narrowest North-South gap will be at a weak level ($\mu = 0.076$). When the return of human capital is very low (the case when $\beta = 0.01$), the IPR protection level, which creates the narrowest North-South gap will be at a very strong level ($\mu = 0.002$). Indeed, if no learning effect takes place ($\beta = 0$), strengthening IPR will lead to a monotonic decrease in North-South wage gap, which is exactly the case in the study of Lai (1998). Moreover, based on the benchmark case ($\beta = 0.15$), the current IPR protection level 0.025 is already stronger than the critical value 0.028. This implies that keeping strengthening IPR protection at the current level will lead to the widening of the North-South wage gap.

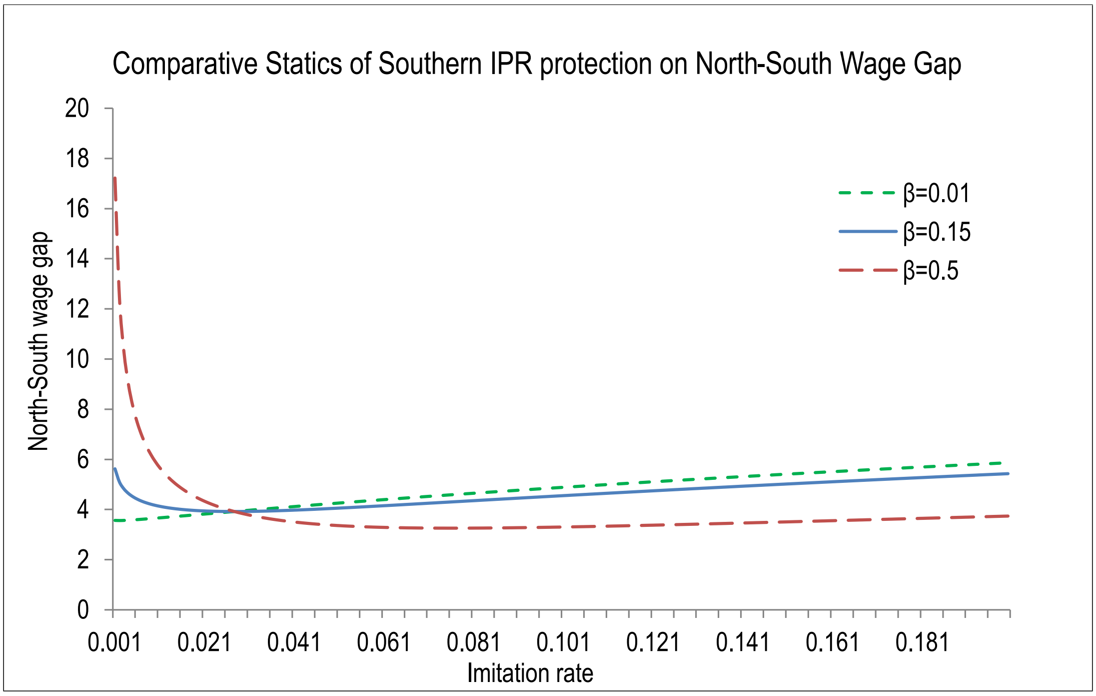

Figure 11: Effects of IPR Protection on North-South Wage Gap

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The vertical axis is the steady state North-South wage gap.

Table 3: Growth-maximizing IPR

Case	*Optimal imitation rate*	*Smallest wage gap*
$\beta = 0.01$	0.002	3.56
$\beta = 0.15$	0.028	3.92
$\beta = 0.50$	0.076	3.26
	Current imitation rate	*Current wage gap*
	0.025	≈ 3.92

6 Extension

One of the predictions generated by our benchmark model is that the increase in foreign presence always causes the Southern human capital h to decrease in the steady state, which is consistent with the empirical findings of negative horizontal spillovers in studies such as Aitken and Harrison (1999) and Konings (2001). Because foreign presence will always increase as IPR protection strengthens, therefore this prediction also implies that Southern human capital, or equivalently, Southern labor productivity, will always decrease when IPR protection is enhanced. However, such a prediction is inconsistent with the empirical findings by Smeets and de Vaal (2011), which suggests when the current IPR protection is weak, the horizontal FDI spillovers are positive. Negative horizontal spillovers occur only when IPR protection is sufficiently strong. Therefore, we extend our benchmark model to address such a phenomenon.

Compared to the benchmark model, we re-define the LBD process: only the aggregate output level of *newly-imitated* products contributes to human capital accumulation, rather than the aggregate output level of *all the historically-imitated* products:

$$\begin{aligned} \dot{H}_t &= \dot{n}_{C,t} x_{C,t} - \delta H_t \\ &= \mu \frac{L^S_{M,t}}{\zeta_t} \alpha^{-\epsilon} - \delta H_t, \end{aligned}$$

where $\dot{n}_C = \mu n_M$, $X_M = n_M x_M = \zeta L^S_M$, and $\frac{x_C}{x_M} = \frac{1}{\alpha^\epsilon}$.

This setup implies that the contribution of imitation on human capital is *immediate* rather than *lasting*. This is based on the assumption that the repetitive production of the "old" products only contributes marginally to productivity advancement because the knowledge contained by these products has already been exhausted at some early stages.

With the definition of h_t unchanged, now the LBD process becomes:

$$\dot{h}_t = \eta^{-1}\alpha^{-\epsilon} \cdot \mu l_{M,t}^S \cdot {h_t}^\beta - \delta h_t. \tag{38}$$

Equation (38) is quite different from the benchmark LBD process (21): the direct effect of foreign presence (measured by the employment share of Southern labor by MNCs, l_M^S) on human capital accumulation is positive, but the magnitude of the effect depends on the imitation rate μ. We can show l_M^S is decreasing in imitation rate μ; therefore, we have a trade-off in strengthening IPR is created between the processes of encouraging a deeper penetration of foreign presence in the local economy and reducing the extent of spillovers from imitation, which represent the two competing forces in determining the Southern labor productivity.

To pin down the steady state, we explain the solution using the graphical approach. Again, the steady state is determined by the ζ^I and ζ^L curve. Although the ζ^I curve is the same as that of the benchmark model as shown in Equation (34), the ζ^L curve, in the extended model becomes:

$$\zeta^{L'} = A\Big(\alpha^\epsilon \frac{1}{\mu} + \frac{1}{g}\Big)^{\frac{\beta}{1-\beta}}, \tag{39}$$

where $A = \eta^{\frac{1}{1-\beta}}\delta^{\frac{\beta}{1-\beta}}$, which is the same as that of the benchmark notation.

In this regard, the monotonicity properties of $\zeta^{L'}$ are quite different from those of ζ^L in the sense $\zeta^{L'}$ is decreasing in both g and μ. When evaluated at $g = g^A$, the condition $\zeta^{IA} > \zeta^{LA}$ always holds. We also impose the restriction $\zeta^{IU} < \zeta^{LU}$ to ensure the existence of a solution. One sufficient condition to ensure the latter restriction is that:

$$\zeta^{IU} = \frac{d_R L^S}{(\epsilon-1)\rho} \frac{d_R L^N + \mu}{d_R L^N + \alpha^{-\epsilon}\mu} \Big(\frac{\rho}{\rho+\mu}\Big)^{\frac{1}{\alpha}} < A\Big(\alpha^\epsilon \frac{1}{\mu} + \frac{1}{d_R L^N}\Big)^{\frac{\beta}{1-\beta}} = \zeta^{L'U}$$

for all possible μ.

ζ^{IU} reaches its maximum when $\mu = 0$ and $\zeta^{L'U}$ reaches its minimum when $\mu = \infty$; therefore the sufficient condition becomes:

$$A > \frac{(d_R L^N)^{\frac{\beta}{1-\beta}} d_R L^S}{(\epsilon-1)\rho}. \tag{40}$$

The above condition indicates that A must be sufficiently large.

We calibrate the extended model once more using the same observable endogenous variables and pre-set parameters. The calibration results for the extended model are shown in Table 4.

Table 4: Calibration Results
(Extended Model)

Observed	*Value*	*Description*
g	0.05	Innovation rate
r	0.07	Average rate of return of U.S. stock market
ϕ_N	0.70	Share of N products
ϕ_M	0.20	Share of M products
ϕ_C	0.10	Share of C products
Pre-set	*Value*	*Description*
α	0.71	Inferred from a mark-up of approximately 40%
ϵ	3.50	Rate of substitution between varieties
L^N	1.00	Normalized total labor force in the North
L^S	2.80	Normalized total labor force in the South
δ	0.03	Human capital depreciation rate
β	0.15	Return of human capital
Calibrated	*Value*	*Description*
ρ	0.07	Subjective discount rate
d_R	0.17	R&D productivity parameter
η	2.86	Human capital scaling parameter

The simulation result for the extended model is summarized in Figure 14. Compare Figure 14 and Figure 13, we can observe that while the movements for the other endogenous variables are quite similar to that of the benchmark model, the extended model generates contrasting results for the response of the unit labor requirement (ζ) with IPR protection being strengthened. In the benchmark model, stronger IPR protection always lead to higher unit labor requirement (lower labor productivity) in the South, but stronger IPR protection will actually lead to lower unit labor requirement (higher labor productivity) in the South when IPR protection is at a low level. The driving force behind this change lies in the LBD process, in which all the imitated products make contribution in the benchmark model, but only the newly-imitated products make contribution in the extended model. While the foreign presence (l_M^S which is decreasing in μ) in the South always harms the productivity development in the South by reducing the output scale of the imitation sector in the benchmark case, it may help to raise productivity depending at a high level of μ (low IPR protection) in the extended case, where only newly-imitated products enter the LBD process. Stronger IPR protection increases the inflow of technology transfer by MNCs, but limits the extent of spillover from these transfer by reducing imitation. Therefore the overall effect on human capital and labor productivity depends, much analogous to the trade-off between a larger pool (more FDI inflow) and a thinner pipe (weaker spillover effect for any given level of FDI inflow).

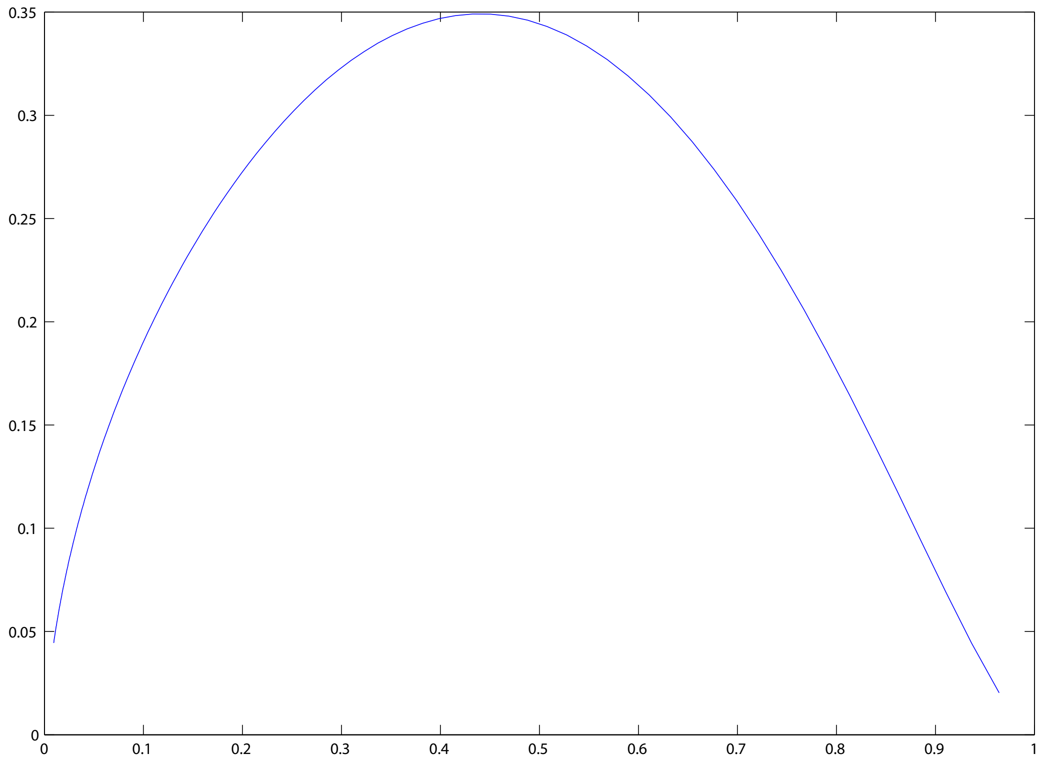

Figure 12: Foreign Presence and Southern Human Capital
(Extended Model)

Notice: The horizontal axis is foreign presence defined as the fraction of labor hired by the MNCs in the South: $l_M^S \equiv \frac{L_M^S}{L^S}$. The vertical axis is the Southern average human capital h.

Figure 12 highlights the relationship between foreign presence and Southern human capital in the extended model. Compared to the benchmark case where more foreign presence always leads to lower Southern human capital, as is shown in Figure 7, the relationship is non-monotonic in the extended model with the shape of an inverted-U. When the current foreign presence is small, an incremental rise will lead to higher Southern human capital, or labor productivity. However, when the foreign presence reaches a certain threshold, a further enhancement will on the contrary lead to a reduction in Southern human capital and lower the Southern labor productivity. The underlying force that drives such a trade-off is that in the benchmark model, FDI also makes contribution to Southern human capital by providing a larger inflow of new products for imitation. This positive facade from FDI does not exist in the benchmark model.

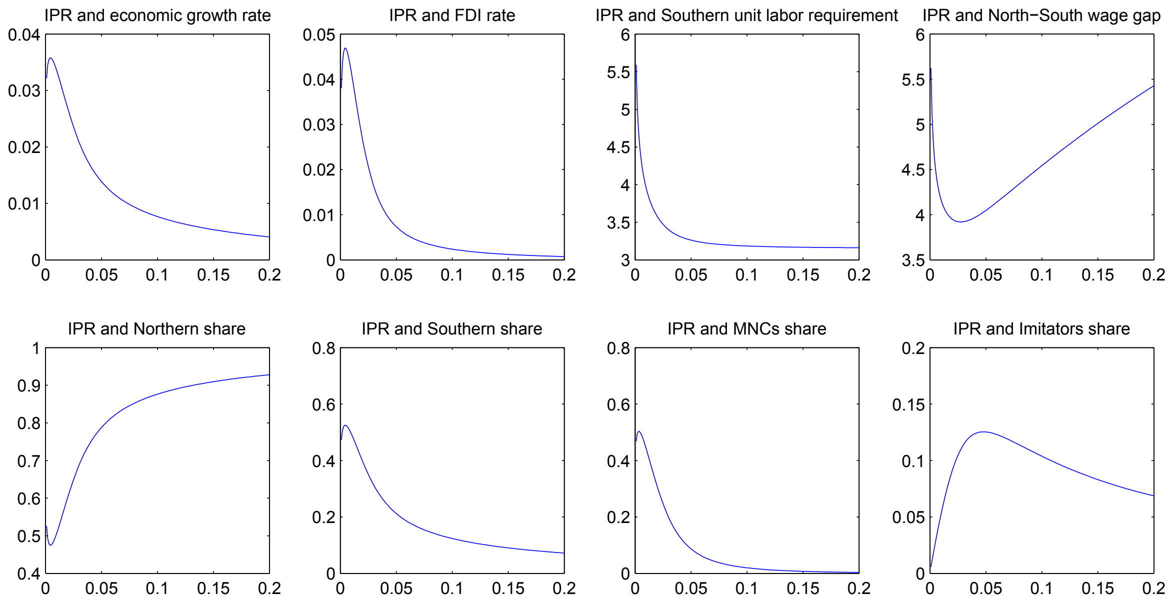

Figure 13: A Summary of Simulation Results

(Benchmark Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is.

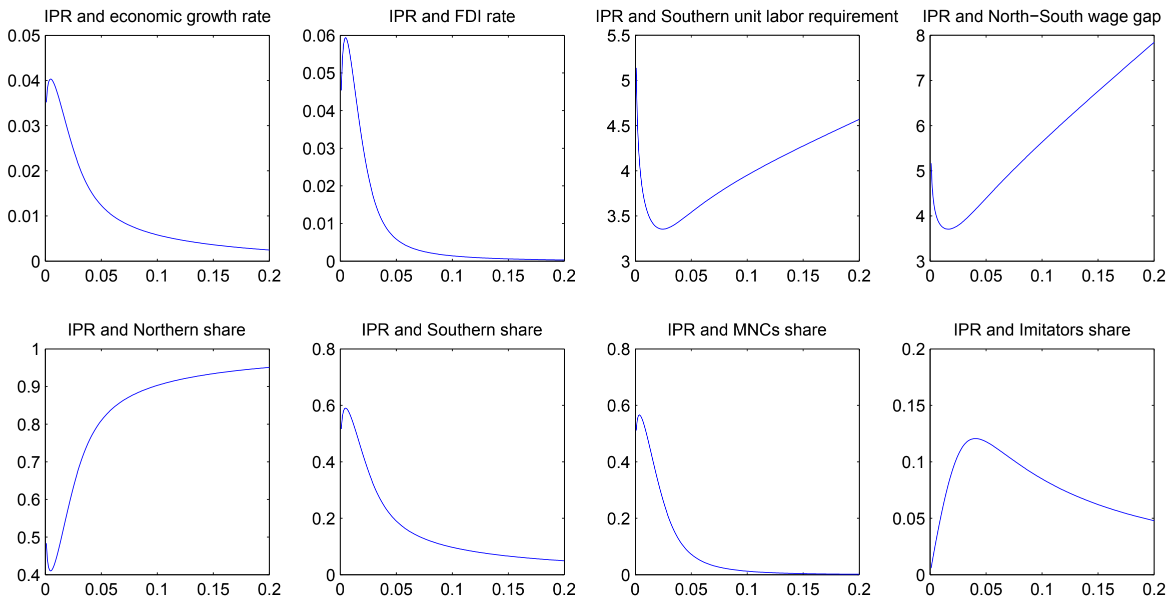

Figure 14: A Summary of Simulation Results

(Extended Model)

Notice: The horizontal axis is the imitation rate μ, which can be viewed as an-inverse measure of IPR protection. The closer to zero, the stronger the IPR protection is.

7 Concluding Remarks

Whether a global IPR harmonization benefits the bulk of developing countries remain one of the most controversial topics in both economic studies and international relations. Generally, IPR supporters emphasize the dynamic gains from a stronger IPR regime in stimulating innovation, which leads to faster growth pace for both North and South in the long run. This point of view is supported by studies embracing FDI as the technology transfer channel, such as Lai (1998) and Branstetter and Saggi (2011), where the long-run economic growth rate and innovation rate are ultimately determined by the positive "production shift effect" from FDI. However, these studies did not consider the effect of foreign capital on the labor productivity in the South, which affects future FDI decisions through the changes in the localization advantage. Based on the few empirical evidence supporting positive intra-industry spillovers from FDI, but several identifying negative intra-industry spillovers from FDI, we propose a theoretical framework where the LBD process over the imitated products serves as the mechanism through which the presence of foreign companies can generate negative spillovers on Southern labor productivity. A stronger IPR protection enhances the status of MNCs in the South, which in turn leads to lower human capital and higher production cost in the South for both existing MNCs and Northern firms preparing to engage overseas operations in the future. Our model suggests that the effect of IPR protection on global economic growth in the long run depends on its current level. When IPR is weak, strengthening IPR protection will lead to higher economic growth in the future. However, when IPR protection has already reached a certain level, strengthening IPR protection will lead to lower economic growth in the future. An inverted-U relationship exists between Southern IPR protection and global economic growth. Our model is under the framework of the North-South product cycles. Therefore, it can be viewed as an open economy complement to the existing studies that focus on the inverted-U relationship between IPR protection and economic growth in closed setups.

Nevertheless, our model has several limitations. First, the transitional dynamics are rather difficult to obtain.[15] We cannot analyze the welfare consequences along the tran-

[15] The North-South models such as Grossman and Helpman (1991) and Lai (1998) usually do not exhibit transitional properties, but just jump to the steady state. However, these models are rather sensitive in terms of transitional properties. For example, Mondal and Ranjan Gupta (2009) made a slight change in the R&D process in Grossman and Helpman (1991), and obtained transitional dynamics. when the LBD process is involved, the transitional dynamics may also exist. However, such an investigation will be beyond the scope of this study, and we will leave it for further researches.

sitional path without a full characterization of the transitional dynamics. Additionally, the stability properties of the system is also unclear. Due to the computational difficulty of this model, the Second, this model exhibits the scale effect. We can remove the scale effect by restricting the externality in the R&D process in a way similar to those of Gustafsson and Segerstrom (2011) and Jakobsson and Segerstrom (2012). However, under this modification, the long-run economic growth will be unaffected by the IPR policies and driven only by population growth only. These disadvantages are common in the North-South product cycle models where growth is driven by the expansion of the variety of differentiated products and where FDI serves as the technology transfer channel, such as Lai (1998) Branstetter and Saggi (2011), and Mondal and Gupta (2008). More efforts are required in further studies.

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