Intellectual Property Rights and Skills Accumulation: A North-South Model of FDI and Outsourcing

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ABSTRACT

This study investigates the effects of stronger intellectual property rights (IPR) protection in the South on innovation, skills choice, wage inequality and patterns of production based on a North-South general-equilibrium model with foreign direct investment (FDI) and international outsourcing. We find that stronger IPR protection in the South raises the extent of outsourcing and reduces the extent of FDI. This raises the proportion of Southerners being unskilled and mitigates wage inequality in the South. In the North, stronger Southern IPR protection raises the proportion of Northerners being skilled and wage inequality. The effects of international specialization, R&D cost and Northern population are also examined.

Keywords: FDI; Outsourcing; Quality ladder; Skill; Wage inequality.

JEL Classification: F12; F23; O31.

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1. INTRODUCTION

It is quite obvious that foreign direct investment (FDI) and international outsourcing are now very common on a global scale. When considering the production of part of their goods abroad as a means of saving costs, firms can produce goods abroad either through multinationals or by licensing foreign firms to produce them on their behalf. Over the years, these phenomena have led to economists devoting considerable interest in the causes and effects of international specialization.[1]

In this paper, we examine the effects of global production on innovation, wage inequality and patterns of production based on a North-South product-cycle general-equilibrium model, within which final-good producers are based in the North, but the firms can choose either to carry out the entire production of the goods in the North or to allow the goods to be produced in the South (a foreign country) through FDI or international outsourcing. The North-South product-cycle model was originally introduced by Vernon (1966) and subsequently extended by Segerstrom et al. (1990) and Grossman and Helpman (1991a, 1991b), with the literature relating to this model essentially following two major lines of research. The first research line focuses on the examination of the impact of FDI on imitation activity in developing countries (Helpman, 1993; Lai, 2001; Glass and Saggi, 2002); the second research line investigates the effects of increased international outsourcing of production on innovation, wages and patterns of production (Glass and Saggi, 2001).[2] Thus, in prior studies where the product-cycle model is adopted, there has clearly been a tendency to study FDI and international outsourcing activities as separate issues, thereby ignoring

[1] Grossman and Helpman (2003) investigate the trade-off between FDI and outsourcing based on the assumption that final-good producers can manufacture the goods by themselves or through specific investment governed by imperfect contracts. Antras and Helpman (2004) go on to develop a model within which firms can choose between engaging in FDI or domestic/international outsourcing based on a model with heterogeneous firms.

[2] One of the earlier theoretical studies of the effects of outsourcing is provided by Feenstra and Hanson (1996a) who assume that the final goods are produced from a continuum of intermediate goods using different proportions of skilled and unskilled workers.

the fact that firms can choose to undertake their production in foreign countries based on both FDI and outsourcing.

In this study, we allow firms to choose between FDI and outsourcing when carrying out production in the South. There are two major differences between FDI and outsourcing strategies. First, conducting FDI activity incurs higher governance costs (Williamson, 1985; Grossman and Helpman, 2003).[3] A Northern firm needs to recruit Southern skilled workers to manage or monitor its production process in the South. Second, Lai et al. (2009) argue that the major disadvantage of outsourcing is the possibility of the leakage of production secrets due to the incompleteness of contracts. Without properly managing or monitoring its production process in the South and given that outsourcing is plagued with contractual difficulties in the absence of perfect contracting, outsourcing is subject to the risk of imitation.[4] However, the risk of imitation will be reduced if intellectual property rights (IPR) protection in the South is strengthened.[5]

The other feature which distinguishes this paper from the extant literature is that we allow for the heterogeneity among the agents by endogenizing skills choice. All Northerners are assumed to be skilled and work in the R&D sector or production sector, whereas Southerners can choose to either remain unskilled or become skilled. Unskilled Southerners work in the production sector while skilled Southerners work in the FDI sector. The heterogeneity of Southerners allows us to study the effects of strengthening IPR protection and global production on wage inequality in the South

[3] Tomiura (2007) finds that firms involving in FDI activity are more productive than foreign outsourcers based on the firm-level data of 118,300 firms across all manufacturing industries in Japan. Although FDI requires higher fixed entry costs, it brings in higher gross profits for firms.

[4] The 2003 survey of the Shared Services and Business Process Outsourcing Association (SBPOA) reports that 33% of respondents agree that a lack of control and loss of internal knowledge are the main concerns when making an outsourcing decision.

[5] Previous literature examining the effects of stronger Southern IPR protection also tends to separate FDI and outsourcing activities. The impact of strengthening IPR protection on FDI decision is studied by Lai (1998), Glass and Saggi (2002), Glass and Wu (2007) and Parello (2008) while its effect on outsourcing decision is examined by Yang and Maskus (2001) and Glass (2004).

and the international wage dispersion of skilled workers.[6]

We find that stronger Southern IPR protection increases the extents of outsourcing and Southern production while reducing the extents of FDI and Northern production. Our result outlining the reduced extent of FDI caused by stronger Southern IPR protection is different from Lai (1998) and Glass and Wu (2007) who show that stronger IPR protection will increase the extent of FDI. In addition, the result of the lower extent of Northern production is also different from Glass and Saggi (2002) and Parello (2008) who demonstrate that stronger Southern IPR protection will raise the extent of Northern production.[7] This is because by assuming that firms only engage in Northern production and FDI (outsourcing) strategy, previous studies are not able to detect the behavior that firms will switch between FDI and outsourcing strategies when there is an increased Southern IPR protection.

We also examine the effects of international specialization, the cost of R&D and Northern population. We find that increasing incentives for outsourcing (such as the lower labor intensity for outsourcing) will increase the extent of outsourcing and the demand for unskilled Southerners, thereby reducing the proportion of Southerners becoming skilled and the extent of FDI. Similar effects will be caused by a reduction in the cost of R&D. On the other hand, increasing incentives for FDI (such as the lower labor intensity for FDI) will cause reversed effects on the proportion of Southerners being skilled and the extents of FDI and outsourcing.

In order to address the issue about the effects on the Northern wage inequality, we then consider an economy with heterogeneous Northerners. Our results show that those changes inducing greater demand for Southern unskilled workers (such as

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[6] The heterogeneity of workers is also assumed by Lai (1995) in an examination of the effects of the labor supply on the global distribution of income.

[7] We also find that stronger Southern IPR protection will raise the R&D difficulty and this result is different from Parello (2008) who finds that strengthening IPR protection will reduce the R&D difficulty due to lower R&D employment.

stronger Southern IPR protection) will raise wage inequality in the North and reduce wage inequality in the South, along with an increase in the international wage dispersion of skilled workers. On the other hand, changes inducing a reduction in cost of FDI, which increases the extent of FDI and the demand for Southern skilled workers, will cause reversed effects on the Northern and Southern wage inequalities, ultimately lowering the international wage dispersion of skilled workers.

Section 2 develops the model and determines the balanced-growth-path (BGP) equilibrium. Section 3 examines how strengthening IPR protection, international specialization, cost of R&D and Northern population affect innovation, skills choice, wages and patterns of production. An economy with heterogeneous Northerners is considered in Section 4. The final section concludes.

2. THE MODEL

We begin with a description of a product-cycle model with endogenous innovation and skills (human capital) accumulation in the spirit of Romer (1990), Grossman and Helpman (1991a, 1991b) and Dinopoulos and Segerstrom (1999). In our model, there exist a developed Northern country (*N*) and a developing Southern country (*S*). Within each country, $i = \{N, S\}$, the economy is comprised of $L_i(t)$ households at time *t*. Given the birth rate, θ, and the death rate, δ, in both countries, the growth rate of the population, g, is equal to $(\theta - \delta)$. Assuming that the lifespan of each individual is *T*, the population dynamics imply that that $\theta L_i(t) = \delta L_i(t+T)$ and $L_i(t+T) = L_i(t)e^{gT}$.[8] This indicates that the number of births at time *t* equals the number of deaths at time *t*+*T*. Thus, we can express $\theta = \frac{ge^{gT}}{e^{gT}-1}$ and $\delta = \frac{g}{e^{gT}-1}$.

2.1. Consumers

[8] This implicitly assumes that for $t < T$, $L_i(t)$ includes those who have lived for less than *T* periods. For example, when $t = 0$, $\psi L_i(0)$ consumers are born and $\delta L_i(0)$ consumers die immediately after the economy starts.

Consumers can choose from a continuum of products $z \in [0,1]$ available at different quality levels (j). The quality increment between a quality 'j' product and a quality 'j-1' product is constant and equal to $\lambda > 1$. Thus, each product of quality j provides quality λ^j. All products begin at time t=1 with the quality level j=0 and the base quality $\lambda^0 = 1$.

The representative household in country i is faced with a lifetime utility of:

$$U_i(0) = \int_0^\infty L_i(0) e^{-(\rho-g)t} \log u_i(t)\, dt;\;\; L_i(0) > 0;\; \rho > g\,, \quad (1)$$

where ρ denotes the subjective discount factor. The instantaneous utility is:

$$\log u_i(t) = \int_0^1 \log[\textstyle\sum_j \lambda^j q_{ij}(z,t)]\, dz\,, \quad (2)$$

where $q_{ij}(z,t)$ is the household consumption in country i for quality level j of product z at time t.

The total expenditure for all products with different quality levels under price $p_{ij}(z,t)$ is:

$$E_i(t) = \int_0^1 \left[\textstyle\sum_j p_{ij}(z,t) q_{ij}(z,t)\right] dz\,. \quad (3)$$

The representative household will maximize the lifetime utility subject to the following aggregate intertemporal budget constraint:

$$W_i(t) + A_i(t) = \int_t^\infty L_i(0)[E_i(t) + g_G] e^{g\tau} e^{-[R(\tau)-R(t)]} d\tau, \quad (4)$$

where $W_i(t)$ denotes the sum of discount wage income of those households from country i, $A_i(t)$ represents the value of assets that the household holds at time t and $g_G \geq 0$ is a lump-sum tax in every period. The cumulative interest rate, up to time t, is given by $R(t) = \int_0^t r(\tau) d\tau$, where $r(\tau)$ is instantaneous interest rate at time τ.

The optimization problem can be solved by three steps. In the first step, consumers allocate expenditure at each point for each product across available quality levels. Based on the utility specification set in Eq. (2), consumers will choose the quality which gives the lowest adjusted price, $\frac{p_{j(z,t)}}{\lambda^j}$. That is, consumers are willing to pay λ for a single quality level improvement in a product.

In the second step, consumers allocate expenditures across products at each point in time, and because the elasticity of substitution between any two products is constant at unity, expenditure across all products will be the same. Therefore, the global demand function for product z of quality j is $q_j(z,t) = E(t)/p_j(z,t)$, where $E(t) = E_N(t)L_N(t) + E_S(t)L_S(t)$ is the global expenditure at time t. In the equilibrium, only the highest quality level available will sell.

In the final step, consumers allocate lifetime wealth across time by maximizing Eq. (1) subject to the intertemporal budget constraint in Eq. (4). This yields the optimal expenditure path for the representative agent in each country:

$$\frac{\dot{E}_i(t)}{E_i(t)} = r(t) - \rho \,. \tag{5}$$

In order to ensure the existence of the balanced-growth-path equilibrium, we focus on a steady state where $r(t) = \rho$ holds.

2.2. Skills accumulation

All Northerners are skilled workers who spend all of their time at work to earn the wage rate w_N^H. Agents in the South can choose to remain unskilled and earn the wage rate, w_S^L, which is normalized to 1, or choose the time period (D_S) spent in schools for skills training; on completion of their education, they will receive the skilled wage rate w_S^H per unit of effective labor.

It is widely accepted within the literature on human capital that important determinants of the accumulation of human capital include public investments in education and time spent in schools. We therefore consider human capital formation as being dependent on these two important determinants. Public educational investment is supported by the tax revenue and we assume that government runs a balanced budget.[9] The total Southern public educational investment in period t is $G_S(t) = g_G L_S(t)$. Let ϕ_S denote the proportion of the unskilled population in the South. The remaining $(1-\phi_S)L_S(t)$ individuals either attend schools for skill training or work as skilled workers. All skilled Southerners are eligible for public subsidy. Thus, the subsidy received by each Southern skilled worker is $g_S = \frac{G_S(t)}{(1-\phi_S)L_S(t)}$.[10]

The income of an unskilled worker equals the unskilled wage rate multiplied by one unit of unskilled labor while the income of a skilled worker equals the skilled wage rate multiplied by one efficiency unit of skilled labor. Thus, individuals choose to receive education if:

$$\int_t^{t+T} e^{-[R(\tau)-R(t)]}\, w_S^L d\tau \leq \int_{t+D_S}^{t+T} e^{-[R(\tau)-R(t)]} w_S^H h_S(D_S) {g_S}^{\gamma} d\tau\,, \tag{6}$$

where $\gamma \in (0,1)$ is the elasticity of skills accumulation with respect to the public educational investment. The skills production function of the amount of time spent in schools is represented by $h_S(D_S) = A_S {D_S}^{\beta_S}$, where $A_S > 0$ is the productivity of skills production and $\beta_S \in (0,1)$ is the elasticity of human capital accumulation with respect to the time spent in schools. Therefore, $h_S(D_S){g_S}^{\gamma}$ represents one efficiency unit of skilled labor.[11]

In an equilibrium where skilled and unskilled workers coexist in the South, Eq. (6) holds with equality. The optimal time spent in schools $(\bar{D}_S)$ is determined by the following equation:

$$\rho h_S(\bar{D}_S) = \left(1 - e^{-\rho(T-\bar{D}_S)}\right) h_S'(\bar{D}_S). \tag{7}$$

[9] Since Northerners are all skilled workers, we first assume that Northern government does not levy tax. This assumption will be relaxed in Section 4.

[10] Since human capital depreciates over time, for those Southerners who have started working, the public educational subsidy provides on-the-job training for them in order to keep the level of their human capital unchanged.

[11] The Cobb-Douglas formation of the human capital accumulation function has been widely used in the literature; see, for example, Glomm and Ravikumar (1992) and Chen (2005, 2006).

Eq. (7) indicates that $\bar{D}_S$ is dependent on the skill production function $h_S(\bar{D}_S)$.

From Eqs. (6) and (7), wage inequality (measured by the wage of skilled workers divided by the wage of unskilled workers) in the South can be expressed as:

$$\frac{w_S^H}{w_S^L} = w_S^H = \frac{\sigma_S(\bar{D}_S)(1-\phi_S)^\gamma}{h_S(\bar{D}_S)g_G{}^\gamma} \ , \tag{8}$$

where $\sigma_S(\bar{D}_S) = \frac{1-e^{-\rho T}}{e^{-\rho\bar{D}_S}-e^{-\rho T}} > 1$.

The supply of unskilled labor (L_S^L) is:

$$L_S^L(t) = \phi_S L_S(t) \, . \tag{9}$$

In the subpopulation of Southerners who choose to become skilled, the working agents are those born between period $(t-T)$ and $(t-\bar{D}_S)$:

$$\int_{t-T}^{t-\bar{D}_S} \theta\,(1-\phi_S)L_S(\tau)d\tau = (1-\phi_S)B_S(\bar{D}_S)L_S(t),$$

where $B_S(\bar{D}_S) = \left(e^{g(T-\bar{D}_S)}-1\right)/(e^{gT}-1) < 1$. Then the supply of effective skilled Southern labor (L_S^H) is:

$$L_S^H(t) = \psi_S L_S(t) \, , \tag{10}$$

where $\psi_S = (1-\phi_S)B_S(\bar{D}_S)h_S(\bar{D}_S)g_S{}^\gamma = B_S(\bar{D}_S)h_S(\bar{D}_S)g_G{}^\gamma(1-\phi_S)^{1-\gamma}$.

2.3. Producers

Innovation occurs only in the North. Northern firms engage in R&D activity and produce cutting-edge quality products through innovation. A Northern firm in industry z which is engaged in innovation intensity $\iota_R(z,t)$, for a time interval, dt, will achieve one level of quality improvement in the final product, with probability $\iota_R(z,t)dt$. In order to achieve this, $a_R\iota_R(z,t)X(t)dt$ units of labor will be required at a total cost of $w_N^H a_R\iota_R(z,t)X(t)dt$, where $X(t)$ denotes R&D difficulty. Based on the *semi-endogenous growth* approach, as proposed by Segerstrom (1998), we assume that R&D difficulty grows in line with innovation intensity.[12] That is, $\frac{\dot{X}(t)}{X(t)} =$

[12] This is referred as the *temporary effects on growth* approach in Segerstrom (1998).

$\xi\iota_R(t)$ with $0 < \xi < 1$, wherein this assumption takes into account the concept whereby innovations can be discovered more easily will be achieved earlier in time.

After succeeding in innovating a higher-level quality product, a Northern firm can undertake its production in the North or carry out its production in the South, lowering its costs through FDI or outsourcing by hiring unskilled Southern workers to carry out this production. Let v_N denote the expected discounted value of a Northern firm that has discovered a new product. A Northern firm will select its research intensity such that the expected gains from innovation do not exceed the costs, with equality being achieved when innovation occurs with positive intensity:

$$v_N \leq w_N^H a_R X,\ \iota_R > 0 \Leftrightarrow v_N = w_N^H a_R X\ . \tag{11}$$

Previous literature tends to use the hiring costs of Southern labor and Northern labor to represent the set-up costs of FDI and outsourcing, respectively.[13] The same setting is used in this paper. Following Parello (2008), we assume that in order to undertake its production in the South through FDI, a Northern firm needs to hire skilled Southern workers to manage its production process in the South.[14] Engaging in FDI intensity $\iota_F(z,t)$ for a time interval, dt, will require $a_F\iota_F(z,t)X(t)dt$ units of labor at a cost of $w_S^H a_F\iota_F(z,t)X(t)dt$, with a probability of success of $\iota_F(z,t)dt$. Let $(v_F - v_N)$ represent capital gains from undertaking production in the South through FDI. A Northern firm will choose its FDI intensity such that the expected gains from FDI do not exceed the costs, with equality being achieved when FDI occurs with positive intensity:

$$v_F - v_N \leq w_S^H a_F X, \iota_F > 0 \Leftrightarrow v_F - v_N = w_S^H a_F X. \tag{12}$$

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[13] FDI is assumed to require Southern labor in Glass and Saggi (2002) and Parello (2008) while outsourcing is assumed to require Northern labor in Glass and Saggi (2001).

[14] Although outsourcing may also incur governance costs, these costs are smaller than those incurred by FDI. To simplify the model, we assume that only FDI incurs governance costs. However, one can obtain the same results qualitatively by assuming that outsourcing faces with lower governance costs.

Althernatively, Northern firms can choose to license Southern firms to carry out their production processes on a contractual basis. Following the literature, we assume that in order to undertake its production in the South through outsourcing, a Northern firm needs to hire some Northern workers to carry out the paperwork involved in setting up the contracts. Engaging in outsourcing intensity $\iota_O(z,t)$ for a time interval, dt, will require $a_O\iota_O(z,t)X(t)dt$ units of labor at a cost of $w_N^H a_O\iota_O(z,t)X(t)dt$, with a probability of success of $\iota_O(z,t)dt$.[15]

$$v_O - v_N \leq w_N^H a_O X,\ \iota_O > 0 \Leftrightarrow v_O - v_N = w_N^H a_O X\ . \tag{13}$$

Eqs. (11) to (13) together imply that along the BGP equilibrium:

$$\frac{\dot{X}(t)}{X(t)} = \frac{\dot{v}_N(t)}{v_N(t)} = \frac{\dot{v}_F(t)}{v_F(t)} = \frac{\dot{v}_O(t)}{v_O(t)} = \xi\iota_R(t). \tag{14}$$

Assume old technologies which designs have been improved are available internationally. Thus, Southern firms are able to produce final goods by using old technologies. Firms are assumed to confront a Bertrand competition. Since Northern firms which produce through the use of state-of-the-art technologies possess a one quality level lead over the closest rivals, they will charge the price $p = \lambda$ (and make a sale $q = E/\lambda$) to just prevent their closest rivals from earning positive profits. We assume that one unit of labor is needed for one unit of the final product. The cost of firms completing the final production in the North is w_N^H. The instantaneous profits for them are:[16]

$$\pi_N = E\left(1 - \frac{w_N^H}{\lambda}\right). \tag{15}$$

Firms undertaking production in the South (either through FDI or outsourcing) can save costs by hiring unskilled Southern workers to produce goods, leading to marginal costs of $w_S^L = 1$. The instantaneous profits are therefore:

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[15] It should be noted that our model setting induces that $w_N^H a_O X < w_S^H a_F X$, which implies that the paperwork costs involved in outsourcing are less than the management costs involved in FDI.

[16] In order to guarantee a positive profit of π_N, we need $1 < w_N^H < \lambda$. As we will see later, this condition will be guaranteed by Eq. (31).

$$\pi = E\left(1 - \frac{1}{\lambda}\right). \tag{16}$$

The reward for successful innovation by a Northern firm is:

$$v_N = \frac{\pi_N}{\rho + (1-\xi)\iota_R}. \tag{17}$$

The reward for a firm successfully carrying out its production in the South through FDI is:

$$v_F = \frac{\pi}{\rho + (1-\xi)\iota_R}. \tag{18}$$

If a Northern firm chooses to outsource in the South, it faces the risk of imitation which is denoted by ε.[17] Thus, the reward for a firm successfully undertaking its production in the South through outsourcing is:

$$v_O = \frac{\pi}{\rho + (1-\xi)\iota_R + \varepsilon}. \tag{19}$$

2.4. The BGP equilibrium and factor markets

As noted earlier, the focus of our analysis is on the BGP equilibrium, along which the growth rate in R&D difficulty is equal to the population growth rate. This allows us to derive the long-run innovation rate, which is expressed as:

$$\iota_R = \frac{g}{\xi}. \tag{20}$$

Let n_N and n_S, respectively, denote the proportions of products produced completely in the North (the extent of Northern production) and in the South (the extent of Southern production). Similarly, let n_F and n_O respectively represent the proportions of the goods for which production is carried out through FDI (the extent of FDI) and outsourcing (the extent of outsourcing). The sum of these product measures should be one:

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[17] In order to simplify our analysis, we assume that only outsourcing is subject to an imitation risk. We can also assume that there is an imitation risk for a Northern firm which chooses to carry out its production in the South through FDI. However, assuming that FDI faces with a lower risk of imitation will generate the same results qualitatively.

$$n_N + n_F + n_O + n_S = 1. \quad (21)$$

Along the BGP equilibrium, the flows into FDI, outsourcing activities and Southern production equal the flows out of them:

$$\iota_F n_N = \iota_R n_F, \quad (22)$$

$$\iota_O n_N = (\iota_R + \varepsilon) n_O, \quad (23)$$

$$\varepsilon n_O = \iota_R n_S. \quad (24)$$

We define two stationary variables as the adjusted level of R&D difficulty, $x = X/L_S$, and the adjusted global expenditure, $\hat{E} = E/L_S$. Since Northern labor can be used for R&D, outsourcing and production, the labor-market clearing condition for the North is:

$$a_R \iota_R x + a_O \iota_O x n_N + n_N \frac{\hat{E}}{\lambda} = \frac{L_N}{L_S}. \quad (25)$$

We assume that once the product is imitated, the Southern firms are able to carry out the entire production and earn zero profits. That is, they charge a price equal to the cost of production. The labor-market clearing conditions for the South indicate that:

$$a_F \iota_F x n_N = \psi_S, \quad (26)$$

$$(n_F + n_O + \lambda n_S) \frac{\hat{E}}{\lambda} = \phi_S. \quad (27)$$

Substituting Eqs. (11)-(13), (15) and (16) into Eqs. (17)-(19), we obtain:

$$\hat{E}\left(1 - \frac{w_N^H}{\lambda}\right) = [\rho + (1 - \xi)\iota_R] w_N^H a_R x, \quad (28)$$

$$\frac{\hat{E}}{\lambda}(w_N^H - 1) = [\rho + (1 - \xi)\iota_R] w_S^H a_F x, \quad (29)$$

$$\frac{\hat{E}}{\lambda}(w_N^H - 1) = \mu w_N^H x, \quad (30)$$

where $\mu = [\rho + (1 - \zeta)\iota_R] a_O + \varepsilon(a_O + a_R)$.

The economy is described by Eqs. (7), (8) and (20)-(30) with thirteen variables $\{w_N^H, w_S^H, \bar{D}_S, \phi_S, x, \hat{E}, n_N, n_F, n_O, n_S, \iota_R, \iota_F, \iota_O\}$. Using Eqs. (28)-(30), we can derive the wage rates as:

$$w_N^H = \frac{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R}{\mu + [\rho + (1-\xi)\iota_R]a_R} > 1, \tag{31}$$

$$w_S^H = \frac{\mu}{[\rho + (1-\xi)\iota_R]a_F} w_N^H. \tag{32}$$

Eq. (32) implies that the international wage dispersion of skilled workers is:

$$w^H = \frac{w_N^H}{w_S^H} = \frac{[\rho + (1-\xi)\iota_R]a_F}{\mu}. \tag{33}$$

Combining Eqs. (21)-(30), the equilibrium can be reduced to the following two equations in x and n_S:

$$n_S = \frac{1 - \frac{\psi_S}{a_F x \iota_R} + \frac{(\lambda-1)\left(a_R x \iota_R - \frac{L_N}{L_S}\right)}{x\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}}{\frac{\varepsilon + i_R}{\varepsilon} - \frac{a_O x \iota_R(\iota_R + \varepsilon)(\lambda - 1)}{\varepsilon x\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}}, \tag{34}$$

$$n_S = \frac{\varepsilon}{x(\lambda\varepsilon + i_R)}\left\{\frac{\phi_S(\lambda-1)}{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R} - \frac{\psi_S}{a_F \iota_R}\right\}. \tag{35}$$

Eqs. (34) and (35) are respectively represented by the NL and SL locus in Figure 1. Note that Eq. (34) indicates that n_S and x are positively correlated while Eq. (35) implies that there is a negative relationship between n_S and x. As shown in Appendix A, there exists a unique BGP equilibrium. Once one derives the solution of $\{x, n_S\}$, the remaining endogenous variables can be solved accordingly.

<Figure 1 is inserted about here>

3. IPR PROTECTION, FDI AND OUTSOURCING

In order to attract Northern firms to carry out their production in the South, the South can make efforts to improve its economic environment. Strengthening IPR protection is one way to attract Northern firms to conduct outsourcing activities. Besides, such improvements in the economic environment can be also represented by reductions in the labor intensity for outsourcing and the labor intensity for FDI.

We first examine the effects of stronger IPR protection which lowers the imitation risk (ε). Due to the complexity of the model, the theoretical analysis of the effects on the patterns of trade may not be able to provide clear results; thus, we resort to a numerical analysis and calibrate the parameter values used in the model. For the benchmark model, the per capita real GDP growth rate is set at $g = 2\%$. The discount factor $\rho = 0.06$ is chosen to generate a 6% real interest rate. Following Glass and Saggi (2001), we set the one-stage quality improvement at $\lambda = 2$, and the labor intensities for R&D and outsourcing at $a_R = 2$ and $a_O = 1$. The labor intensity for FDI is set at $a_F = 1.8$ to make the extent of Northern production (n_N) roughly equal to 50%.[18] The parameter of the growth rate in R&D difficulty (ξ) is assigned to 0.99 and the risk of imitation (ε) is set to 0.01 in order to generate enough international wage dispersion of skilled workers and wage inequality in the South. We normalize the initial Northern population to 1 and set the ratio of the Northern population to Southern population (L_N/L_S) to 1, but will allow this ratio to vary to examine its impact.

The skills accumulation depends on the quantity of education (D_S) and the quality of education (g_G). Following Dinopoulos and Segerstrom (1999), we assume that each agent has a working life of 40 years which is normalized to one in the model ($T = 1$), and an "unskilled" high-school graduate becomes skilled worker by spending 4 years in college. Thus, we calibrate $\beta_S = 0.1$ to match the value that skilled workers spend about 10% of working life on skills training and 90% of working life on work. The parameter A_S is set to 1.08 so that less than 5% of Southern workers are skilled workers. Compared to the quantity of education, the quality of education has a much smaller effect on earnings (Card and Krueger, 1996; Krueger and Lindahl, 2001), so we set $\gamma = 0.02$. Public investment in education (g_G) is set at 1.1 which is 36% of adjusted global expenditure.

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18 We follow Glass and Saggi (2001) to match the extent of Northern production at 50%.

Based on our parameterization of the benchmark model, 1.36% of Southern workers will spend 8.87% of their time on education in order to become skilled workers. The wage rate in the North is 1.43 while the wage rate for skilled workers in the South is 1.19. Thus, the international wage dispersion of skilled workers is 1.20. The resultant adjusted global expenditure is 3.03 and adjusted R&D difficulty is 5.03. The respective extents of Northern production, FDI, outsourcing and Southern production are 49.56%, 6.27%, 29.55% and 14.63%. The benchmark values are presented in Table 1, which summarizes the effects of various events on the key macroeconomic variables in our model; these events are described in the following sub-sections.

<Table 1 is inserted about here>

A reduction in ε by 1% raises the extent of outsourcing because outsourcing becomes more attractive to firms. There will be a reduction in the extent of FDI as a result of an increase in the demand for Southern unskilled production workers. A lower imitation risk will reduce the extent of Southern production while a higher extent of outsourcing will raise the extent of Southern production. Our numerical results indicate that overall, the extent of Southern production will increase. As illustrated in Figure 1, a lower ε shifts both NL and SL locus upward and results in a higher extent of Southern production. The extent of Northern production will decrease while the adjusted level of R&D difficulty will increase. Consequently, there will also be a reduction (increase) in FDI (outsourcing) intensity to restore the steady-state condition. We summarize the results on globalization production decisions as follows.

Effects of Strengthening Southern IPR Protection on Production. Along the balanced-growth path, strengthening IPR protection in the South is in favor of outsourcing over FDI. It raises the extents of outsourcing and Southern production while reducing the extents of FDI and Northern production.

The shift of production to the South will reduce the Northern wage rate. As a result of a decrease for the demand of Southern skilled workers, wage inequality in the South will be reduced, leading to a rise in the international wage dispersion of skilled workers. The lower wage rate for Southern skilled workers will lead to a lower proportion of the population in the South becoming skilled. These results are summarized in Proposition 1.[19]

Proposition 1. An increase in IPR protection in the South (or a reduction in the labor intensity for outsourcing) reduces the Northern and Southern wage rates for skilled workers, raises the North-South wage gap among skilled workers and increases the proportion of Southern unskilled workers.

3.1. Labor intensities for outsourcing and FDI

A reduction in the labor intensity for outsourcing (a_O) will cause the same effects on wage inequality, international wage dispersion of skilled workers and skill choice for Southerners as strengthening IPR protection (see Proposition 1). Table 1 also reveals that it also causes similar effects on the extents of FDI, outsourcing and Southern production, the adjusted level of R&D difficulty as well as FDI and outsourcing intensities. However, the extent of Northern production will increase.

A decrease in a_F by 1% increases the incentives for FDI, which raises the extent of FDI. Both the extents of outsourcing and Southern production will decrease because Northern firms will switch from outsourcing strategy to FDI. Overall, the extent of Northern production will decrease. The demand for Southern skilled workers becomes higher, which in turn, leads to an increase in wage inequality in the South. This

[19] Because it is quite easy to prove Propositions 1 and 2 by taking the derivatives of Eqs. (31)-(33) and (A4) with respect to ε, a_O and a_F, we do not provide the proofs in the paper; they are, however, available upon request.

increase in the Southern wage inequality lowers the international wage dispersion of skilled workers. Our findings on wage rates are summarized as follows:

Proposition 2. A fall in the labor intensity for FDI raises the Southern wage rate for skilled workers, reduces the North-South wage gap among skilled workers, and increases the proportion of Southern skilled workers. However, it does not affect the Northern wage rate.

3.2. Labor intensity for R&D

We go on to examine the effects of a reduction in the labor intensity for R&D (a_R). A decrease in a_R increases the incentives for R&D activity and raises the adjusted level of R&D difficulty. The lower labor intensity for R&D raises the extents of Northern production and outsourcing since more Northern labor is available for Northern production and outsourcing. The increase in the demand for Northern labor leads to a rise in the Northern wage rate. There will be a resultant increase in the demand for unskilled Southerners, which lowers wage inequality in the South and increases the international wage dispersion of skilled workers. With a decrease in the proportion of skilled Southerners, the extent of FDI will decrease.

3.3. Labor supply

Finally, we investigate the impact of a decrease in the Northern population (L_N). Because Northern labor supply does not directly affect the incentives for innovations, FDI and outsourcing, the wage rates in both the North and the South are unaffected. Thus, there is also no change in the international wage dispersion of skilled workers. With no change in the incentives for skills accumulation, the proportion of skilled Southerners remains the same. Nevertheless, a reduction in the Northern labor supply implies that less labor can be devoted to innovation and production in the North. This will lead to a reduction in the adjusted level of R&D difficulty, a smaller extent of Northern production and a greater extent of FDI.

Although a lower Northern labor supply will shift production from the North to the South, which will, in turn, raise the extent of outsourcing, it also has the effect of reducing the extent of outsourcing because outsourcing requires Northern labor. The former will dominate the latter, such that there will an increase in the extent of outsourcing. We summarize the results in the following proposition.[20]

Proposition 3. A reduction in the Northern labor supply will result in a corresponding reduction in the adjusted level of R&D difficulty, along with a reduction in the extent of Northern production and increases in the extents of FDI, outsourcing and Southern production. Both the FDI and outsourcing intensities will increase. However, wage rates in the North and the South and the proportion of Southern workers being skilled will be unaffected.

4. HETEROGENEOUS NORTHERNERS

There has been considerable debate on the pros and cons of international production for the North. Those advocating such international production argue that it can reduce the costs of production, while its opponents argue that it leads to an increase in the Northern wage inequality. Despite numerous empirical studies in this field, very few theoretical studies have set out to explain the linkage between the two issues. In order to address this, we extend our basic model to allow for heterogeneity among Northerners.

Like Southerners, Northerners can choose to remain unskilled and earn the wage rate w_N^L or to spend a time period D_N in school for skills training and receive the skilled wage rate w_N^H on completion of their skills education. Let ϕ_N represent the proportion of population remaining unskilled in the North. Each Northerner needs to

[20] The proof of Proposition 3 is provided in the Appendix B.

pay $g_G > 0$ for tax in every period and we assume that Northern government runs a balanced budget. The total Northern public investment in education is $G_N(t) = g_G L_N(t)$, which implies that such investment amounts to $g_N = \frac{G_N(t)}{(1-\phi_N)L_N(t)}$ for each skilled Northerner. Northerners will choose to receive skills training if:

$$\int_t^{t+T} e^{-[R(\tau)-R(t)]} w_N^L d\tau \leq \int_{t+D_N}^{t+T} e^{-[R(\tau)-R(t)]} w_N^H h_N(D_N) {g_N}^{\gamma} d\tau , \quad (36)$$

where the function $h_N(D_N) = A_N {D_N}^{\beta_N}$ with $A_N > 0$ and $\beta_N \in (0,1)$.

The optimal time spent in schools $(\bar{D}_N)$ is chosen by:

$$\rho h_N(\bar{D}_N) = \left(1 - e^{-\rho(T-\bar{D}_N)}\right) h_N'(\bar{D}_N). \quad (37)$$

Wage inequality in the North is therefore:

$$w_N = \frac{w_N^H}{w_N^L} = \frac{\sigma_N(\bar{D}_N)(1-\phi_N)^{\gamma}}{h_N(\bar{D}_N){g_G}^{\gamma}} , \quad (38)$$

where $\sigma_N(\bar{D}_N) = \frac{1-e^{-\rho T}}{e^{-\rho \bar{D}_N} - e^{-\rho T}}$.

We define $B_N(\bar{D}_N) = \left(e^{g(T-\bar{D}_N)} - 1\right)/(e^{gT} - 1)$. The supply of unskilled labor (L_N^L) is therefore:

$$L_N^L(t) = \phi_N L_N(t),$$

and the supply of effective skilled labor (L_N^H) is:

$$L_N^H(t) = \psi_N L_N(t),$$

where $\psi_N = h_N(\bar{D}_N) B_N(\bar{D}_N) {g_G}^{\gamma} (1-\phi_N)^{1-\gamma}$.

Northern unskilled workers are employed in manufacturing of new products, whereas Northern skilled workers are engaged in R&D investment and outsourcing activities. Thus, Eq. (17) becomes:

$$\pi_N = E\left(1 - \frac{w_N^L}{\lambda}\right). \quad (39)$$

Note that the instantaneous profit for firms carrying out FDI or outsourcing (Eq. (16)) remains the same.

It should be noted that Eqs. (11)-(13) and (17)-(21) remain unchanged, as do the steady-state conditions in Eqs. (22) to (24) and the labor market clearing conditions for the South in Eqs. (26) to (27). The labor market clearing conditions for the skilled and unskilled Northern labor are:

$$a_R \iota_R x + a_O \iota_O x n_N = \psi_N \frac{L_N}{L_S}. \tag{40}$$

$$n_N \frac{\hat{E}}{\lambda} = \phi_N \frac{L_N}{L_S}. \tag{41}$$

The setting for the South remains the same. As compared with the benchmark model in Section 2, we have three new variables $\{w_N^L, \overline{D}_N, \phi_N\}$ and three more equations (Eqs. (37), (38) and one more equation for the Northern labor market).

As shown in Appendix C, in equilibrium, the extent of FDI (n_F) can be expressed in terms of n_S, the proportion of Southern population being unskilled (ϕ_S) can be expressed as a function of ϕ_N while the adjusted expenditure ($\hat{E}$) can be expressed in terms of ϕ_N and n_S. Then the market clearing conditions for Northern and Southern unskilled workers become can be expressed by n_S and ϕ_N:

$$n_S = \frac{\varepsilon}{\varepsilon + a_R}\left[1 - n_F(n_S) - \frac{\lambda \phi_N L_N}{\hat{E}(\phi_N, n_S) L_S}\right]. \tag{42}$$

$$n_S = \frac{\varepsilon}{\lambda\varepsilon + a_R}\left[\frac{\lambda \phi_S(\phi_N)}{\hat{E}(\phi_N, n_S)} - n_F(n_S)\right]. \tag{43}$$

Figure 2 illustrates the equilibrium where Eq. (42) is represented by the NN locus and Eq. (43) is represented by SS locus.[21] Since stronger IPR protection will shift both the NN and SS locus upward, the extent of Southern production increases while the change of the fraction of unskilled Northerners is not clear. To conduct numerical analysis, we set $\beta_N = 0.12$ which is higher than β_S so that Northerners will spend a longer period in schools than Southerners.[22] We assign $A_N = 1.32$ and $A_S = 1$, so

[21] See Appendix C for the details about deriving the BGP equilibrium and Appendix D for the calculations of the slopes of NN and SS locus.

[22] This parameter setting produces D_N=10.46%, which is higher than D_S=8.87%.

that about 24.81% of Northerners and 1.38% of Southerners are skilled workers.[23] This will also generate the result that wage inequality is lower in the North than in the South. The remaining parameters are set at the same values as those in the benchmark model. The equilibrium values of the key variables are presented in Table 2.

<Figure 2 is inserted about here>

Table 2 shows that stronger IPR protection policy raises the extents of outsourcing and Southern production while reducing the extents of FDI and Northern production. Both the fraction of unskilled Northerners and the wage rate for unskilled Northerners will decrease due to the shift of production from the North to the South. The higher supply of skilled Northerners will reduce the wage rate for skilled Northerners. Overall, wage inequality will be higher in the North. On the other hand, an increase in the fraction of unskilled Southerners will reduce wage inequality in the South. The international wage dispersion for skilled workers will increase.

<Table 2 is inserted about here>

Table 2 also indicates that a reduction in a_O will cause similar effects on wage inequalities for the North and the South and the international wage dispersion for skilled workers as those caused by stronger IPR protection.[24] However, a reduction in the labor intensity for FDI will generate the reversed effects on the wage inequalities for the North and the South and the international wage dispersion for skilled workers. This is because it increases the demand for Southern skilled workers while reducing

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23 The parameterization used by Dinopoulos and Segerstrom (1999) guarantees that the proportion of the labor force becomes skilled is less than 25% in both developed and developing countries.

24 The empirical studies of Feenstra and Hanson (1996a, 1996b) find that the reduction in the wages of unskilled workers (and the increase in the relative wages between skilled and unskilled workers) in the U.S. during the 1980's can be explained by the increase in the outsourcing of production activities. On the other hand, using the data of 29 developing countries over the period 1982-2000, Khalifa and Mengova (2010) show that there exists skill abundance threshold, below which production is outsourced to developing countries and the relationship between outsourcing and wage inequality is negative in these developing countries.

the demand for Northern skilled workers.[25]

A decrease in the labor intensity for R&D reduces wage inequality in the North and raises the extent of outsourcing since more skilled Northerners are available for outsourcing. With more Northerners choosing to become unskilled, the extent of Northern production will increase. The increase in the extent of outsourcing leads to a reduction in the extent of FDI. The demand for Southern skilled workers is therefore reduced, which lowers the wage rate for Southern skilled workers. Therefore, the international wage dispersion for skilled workers will increase.

If there is a decrease in Northern population, there will be a corresponding increase in wage inequality in the North, since it raises the wage rate for skilled Northerners, while leaving the wage rate for unskilled Northerners unchanged. With lower labor resources devoted to production in the North, there will be an increase in the extent of FDI, which thereby raises the demand for skilled workers in the South. Wage inequality in the South will increase, leaving the international wage dispersion of skilled workers unchanged.

A comparison between Tables 1 and 2 reveals that the effects on adjusted R&D difficulty and patterns of production arising from increasing globalization, R&D cost and the Northern population, are all similar to those in the benchmark model, with one exception: a decrease in the level of Northern population reduces the proportion of Southern unskilled workers in the presence of heterogeneous Northern workers.[26]

5. CONCLUSION

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[25] The empirical study of Aitken et al. (1996) finds that FDI activity is associated with higher wages only for foreign-owned firms. The higher levels of FDI will cause a higher relative wage ratio in the South. The recent study of Herzer et al. (2012) shows that increase in inward FDI contributes to widening income inequality in Latin America economies.

[26] In Appendix E, we perform a sensitivity analysis to check the robustness of our results in Tables 1 and 2. In particular, we allow λ, ξ, γ and g_G to decrease or increase from their benchmark values by 5%. The results indicate that our main finding that stronger IPR protection in the South is in favor of outsourcing over FDI is robust. Furthermore, its effects on wage inequalities and the fraction of Southerner (Northerners) being skilled remain the same qualitatively.

In this paper, we develop a North-South general-equilibrium model to investigate the effects of strengthening IPR protection on innovation, skills choice, wage inequality, and patterns of production. Our results illustrate that strengthening IPR protection in the South will raise the extents of outsourcing and Southern production, along with corresponding reductions in the extents of FDI and Northern production. The Northern wage inequality will increase since firms will shift their production from the North to the South. The Southern wage inequality will decrease as a result of the increase in the demand for Southern unskilled production workers. We also examine the effects of increasing globalization, R&D cost and the Northern population.

We conclude this study with the suggestion that our model can be extended and applied to a variety of issues, and by pointing out two specific directions which would appear to be ripe for future study. First, in addition to products produced through outsourcing, Southern firms can also imitate products produced through FDI or products completely produced in the North. Second, the outsourcing contracts could also be endogenized. By designing elaborate contracts, Northern firms could avoid the loss of profits caused by contract default.

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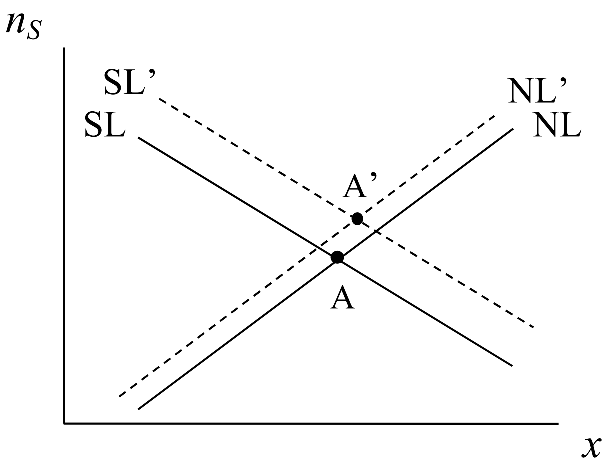

Figure 1. Adjusted R&D difficulty and Southern production

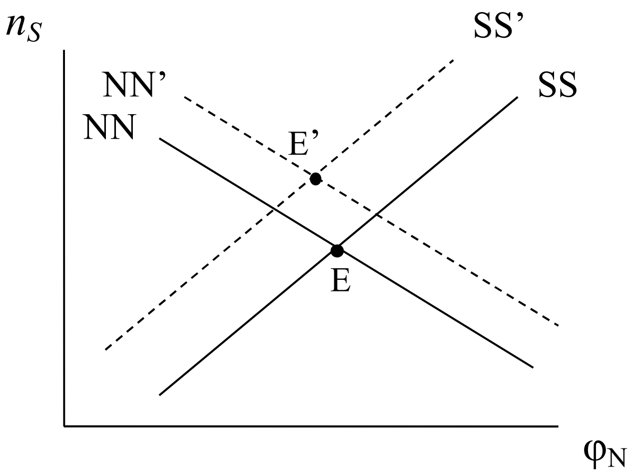

Figure 2. Northern skilled labor and Southern production

Table 1 Numerical results

Variables	Equilibrium Values	Measures of Exogenous Shifts				
		ε down 1%	a_O down 1%	a_F down 1%	a_R down 1%	L_N down 1%
Panel A: Effects on Wage Rates						
w_N^H	1.4283	-0.0571	-0.1339	0.0000	0.1343	0.0000
w_S^H	1.1889	-0.3895	-0.9111	1.0101	-0.0877	0.0000
w^H	1.2013	0.3337	0.7844	-1.0000	0.2222	0.0000
Panel B: Other Effects						
ϕ_S	0.9864	0.2450	0.5074	-0.9022	0.0593	0.0000
x	5.0399	0.0407	0.0279	0.7165	0.5233	-0.5815
n_N	0.4956	-0.0029	0.1997	-0.4314	0.0770	-0.5952
n_F	0.0627	-17.4389	-36.1584	64.1117	-4.7070	0.5849
n_O	0.2955	2.8178	4.9059	-8.6118	0.5814	0.5849
n_S	0.1463	1.7897	4.9059	-8.6118	0.5814	0.5849
ι_F	0.0026	-17.4365	-36.2857	64.8227	-4.7830	1.1872
ι_O	0.0180	2.4804	4.6967	-8.2159	0.5040	1.1872

Note: All figures refer to the percentage changes in the key variables from their benchmark values (presented in column 2) as a result of each exogenous shift.

Table 2 Heterogeneous Northerners

Variables	Equilibrium Values	Measures of Exogenous Shifts				
		ε down 1%	a_O down 1%	a_F down 1%	a_R down 1%	L_N down 1%
Panel A: Effects on Wage Rates						
w_N^H	1.5429	-0.0474	-0.1194	-0.0169	0.1305	0.0104
w_N^L	1.4283	-0.0571	-0.1339	0.0000	0.1343	0.0000
w_N	1.0802	0.0097	0.0144	-0.0169	-0.0038	0.0104
w_S^H	1.2843	-0.3798	-0.8968	0.9930	-0.0915	0.0104
w^H	1.2013	0.3337	0.7844	-1.0000	0.2222	0.0000
Panel B: Other Effects						
ϕ_N	0.7519	-0.1603	-0.2391	0.2780	0.0632	-0.1722
ϕ_S	0.9862	0.2417	0.5059	-0.8914	0.0624	-0.0073
x	4.6676	0.0337	0.0151	0.7244	0.5246	-0.5860
n_N	0.4958	-0.0042	0.1991	-0.4264	0.0785	-0.5983
n_F	0.0632	-17.0400	-35.6969	62.7441	-4.8871	1.1040
n_O	0.2950	2.7884	4.8948	-8.5176	0.6125	0.5143
n_S	0.1460	1.7605	4.8948	-8.5176	0.6125	0.5143
ι_F	0.0026	-17.0366	-36.8246	63.4410	-4.9617	1.7125
ι_O	0.0180	2.4524	4.6864	-8.1258	0.5336	1.1193

Note: All figures refer to the percentage changes in the key variables from their equilibrium values (presented in column 2) as a result of each exogenous shift.

APPENDIX A

BGP Equilibrium

First note that $\bar{D}_S$ and ι_R are respectively determined by Eqs. (7) and (20). Using Eqs. (28)-(30), we can derive:

$$\hat{E} = \frac{x\lambda\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}{\lambda - 1}, \tag{A1}$$

$$w_N^H = \frac{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R}{\mu + [\rho + (1-\xi)\iota_R]a_R} > 1, \tag{A2}$$

$$w_S^H = \frac{\mu}{[\rho + (1-\xi)\iota_R]a_F} w_N^H. \tag{A3}$$

From Eq. (8), we can compute the proportion of unskilled Southerners:

$$\phi_S = 1 - \left[\frac{h_S(\bar{D}_S) g_G{}^{\gamma} w_S^H}{\sigma_S(\bar{D}_S)}\right]^{\frac{1}{\gamma}}, \tag{A4}$$

where w_S^H is given by Eq. (A3).

Combining Eqs.(22) and (26) gives us:

$$n_F = \frac{\psi_S}{a_F \iota_R x}. \tag{A5}$$

Then substitution Eqs. (21), (24), (A1) and (A5) into the market clearing condition of Northern labor (Eq. (25)), we can derive Eq. (34):

$$n_S = \frac{1 - \dfrac{\psi_S}{a_F x \iota_R} + \dfrac{(\lambda - 1)\left(a_R x \iota_R - \frac{L_N}{L_S}\right)}{x\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}}{\dfrac{\varepsilon + i_R}{\varepsilon} - \dfrac{a_O x \iota_R(\iota_R + \varepsilon)(\lambda - 1)}{\varepsilon x\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}}. \tag{A6}$$

Substitution Eqs. (24), (A1) and (A5) into the market clearing condition of Southern unskilled labor (Eq. (27)) gives us Eq. (35):

$$n_S = \frac{\varepsilon}{x(\lambda\varepsilon + i_R)}\left\{\frac{\phi_S(\lambda - 1)}{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R} - \frac{\psi_S}{a_F \iota_R}\right\}. \tag{A7}$$

Note that Eq. (34) indicates that n_S and x are positively correlated while Eq. (35) implies that there is a negative relationship between n_S and x.

From Eqs. (A6) and (A7), we can derive the unique solution of x:

$$x = \frac{(\lambda\varepsilon + i_R)\frac{L_N}{L_S} + \frac{\psi_S}{a_F}\theta_1 - \phi_S\theta_2}{(\lambda\varepsilon + i_R)\left\{a_R\iota_R + \frac{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R}{\lambda - 1}\right\}}, \tag{A8}$$

where $\theta_1 = a_O(\varepsilon + i_R) + \frac{\varepsilon\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}{i_R}$ and $\theta_2 = \frac{a_O(\varepsilon + i_R)(\lambda - 1)}{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R} - (\varepsilon + i_R)$.

Substituting the solution of x in Eqs. (A7) and (A1), we can get n_S and $\hat{E}$. Using Eqs. (24), (21), (22) and (23), we can derive $n_O = \iota_R n_S/\varepsilon$, $n_N = 1 - n_O - n_F - n_S$, $\iota_F = \iota_R n_F/n_N$ and $\iota_O = (\iota_R + \varepsilon)n_O/n_N$. Thus, we have completely solved the model and showed that there exists a unique solution.

APPENDIX B

Proof of Proposition 4

Note that Eqs. (20), (A2), (A3) and (A4) indicate that ι_R, w_N^H, w_S^H and ϕ_S do not depend on L_N. This implies that w_N^H is also independent of L_N. Using Eq. (A8) to differentiate x with respect to L_N, we obtain:

$$\frac{\partial x}{\partial L_N} = \frac{(\lambda\varepsilon + i_R)}{L_S(\lambda\varepsilon + i_R)\left\{a_R\iota_R + \frac{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R}{\lambda - 1}\right\}} > 0. \tag{B1}$$

Eq. (A5) indicates that

$$\frac{\partial n_F}{\partial L_N} = \frac{-\psi_S}{a_F\iota_R x^2}\frac{\partial x}{\partial L_N} < 0. \tag{B2}$$

From Eq. (A7), we can get that

$$\frac{\partial n_S}{\partial L_N} = \frac{-\varepsilon}{x^2(\lambda\varepsilon + i_R)}\left\{\frac{\phi_S(\lambda - 1)}{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R} - \frac{\psi_S}{a_F\iota_R}\right\}\frac{\partial x}{\partial L_N} < 0. \tag{B3}$$

Then

$$\frac{\partial n_O}{\partial L_N} = \frac{\iota_R}{\varepsilon}\frac{\partial n_S}{\partial L_N} < 0. \tag{B4}$$

Eqs. (B2)-(B4) implies that:

$$\frac{\partial n_N}{\partial L_N} = -\left(\frac{\partial n_F}{\partial L_N} + \frac{\partial n_S}{\partial L_N} + \frac{\partial n_O}{\partial L_N}\right) > 0. \tag{B5}$$

Differentiating ι_F and ι_O with respect to L_N, we have:

$$\frac{\partial \iota_F}{\partial L_N} = \frac{\iota_R}{n_N^2}\left(n_N \frac{\partial n_F}{\partial L_N} - n_F \frac{\partial n_N}{\partial L_N}\right) < 0. \tag{B6}$$

$$\frac{\partial \iota_O}{\partial L_N} = \frac{\iota_R + \varepsilon}{n_N^2}\left(n_N \frac{\partial n_O}{\partial L_N} - n_O \frac{\partial n_N}{\partial L_N}\right) < 0. \tag{B7}$$

Eqs. (B1)-(B7) indicate that a decrease in L_N lowers x and n_N, and raises n_F, n_O, n_S, ι_F and ι_O.

APPENDIX C

Equilibrium of the Model of Heterogeneous Northerners

First note that $\bar{D}_N$ is determined by Eq. (37). Substituting Eqs. (11)-(13), (16) and (39) into Eqs. (17)-(19), we have:

$$\hat{E}\left(1 - \frac{w_N^L}{\lambda}\right) = [\rho + (1-\xi)\iota_R] w_N^H a_R x, \tag{C1}$$

$$\frac{\hat{E}}{\lambda}(w_N^L - 1) = [\rho + (1-\xi)\iota_R] w_S^H a_F x, \tag{C2}$$

$$\frac{\hat{E}}{\lambda}(w_N^L - 1) = \mu w_N^H x. \tag{C3}$$

Note that ι_R is solved by Eq. (20). Using Eqs. (C1)-(C3), we can further derive:

$$w_N^H = \frac{\hat{E}(\lambda - 1)}{x\lambda\{\mu + [\rho + (1-\xi)\iota_R]a_R\}}, \tag{C4}$$

$$w_N^L = \frac{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R}{\mu + [\rho + (1-\xi)\iota_R]a_R}, \tag{C5}$$

$$w_S^H = \frac{\mu}{[\rho + (1-\xi)\iota_R]a_F} w_N^H. \tag{C6}$$

Combining Eqs. (8), (38) and (C6), we can express ϕ_S as a function of ϕ_N:

$$\phi_S(\phi_N) = 1 - \Gamma(1 - \phi_N), \tag{C7}$$

where $\Gamma = \left\{\frac{\sigma_N(\bar{D}_N)\mu w_N^L h_S(\bar{D}_S)}{\sigma_S(\bar{D}_S)[\rho + (1-\xi)\iota_R]a_F h_N(\bar{D}_N)}\right\}^{\frac{1}{\gamma}}$.

The steady-state conditions in Eqs. (22) to (24) remain unchanged, as do the labor market clearing conditions for the South in Eqs. (26) to (27). From Eq. (40), we can express x as a function of ϕ_N and n_S:

$$x(\phi_N, n_S) = \frac{\varepsilon \psi_N(\phi_N) L_N}{[\varepsilon a_R + a_O(\varepsilon + i_R)n_S]\iota_R L_S}. \tag{C8}$$

Using Eqs. (38), (C5) and (C8), we can express $\hat{E}$ in terms of ϕ_N and n_S:

$$\hat{E}(\phi_N, n_S) = \frac{\sigma_N(\overline{D}_N)x(\phi_N, n_S)\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}(1-\phi_N)^\gamma}{(\lambda - 1)h_N(\overline{D}_N)g_G{}^\gamma}. \tag{C9}$$

Eqs. (C4), (C.5) and (C9) imply that the Northern wage inequality can be represented as a function of ϕ_N and n_S:

$$w_N(\phi_N, n_S) = \frac{\hat{E}(\phi_N, n_S)(\lambda - 1)}{x\lambda\{\lambda\mu + [\rho + (1-\xi)\iota_R]a_R\}}. \tag{C10}$$

Combining Eqs. (22), (26) and (C10) and definitions of ψ_N and ψ_S, we can derive n_F as a function of n_S:

$$n_F(n_S) = \frac{[\varepsilon a_R + a_O(\varepsilon + i_R)n_S]\iota_R L_S h_S(\overline{D}_S)B_S(\overline{D}_S)\Gamma^{1-\gamma}}{\varepsilon a_F \iota_R L_N h_N(\overline{D}_N)B_N(\overline{D}_N)}. \tag{C11}$$

Substituting Eqs. (21), (24), (C9) and (C11) into labor market clearing conditions for unskilled Northerners and Southerners (Eqs. (41) and (27)), we have:

$$n_S = \frac{\varepsilon}{\varepsilon + a_R}\left[1 - n_F(n_S) - \frac{\lambda\phi_N L_N}{\hat{E}(\phi_N, n_S)L_S}\right]. \tag{C12}$$

$$n_S = \frac{\varepsilon}{\lambda\varepsilon + a_R}\left[\frac{\lambda\phi_S(\phi_N)}{\hat{E}(\phi_N, n_S)} - n_F(n_S)\right]. \tag{C13}$$

Note that Eq. (C12) shows that ϕ_N and n_S are negatively correlated while Eq. (C13) implies that ϕ_N and n_S are positively correlated. The equilibrium ϕ_N and n_S can be derived by using Eqs. (C12) and (C13). Therefore, substituting the ϕ_N and n_S into Eqs. (C4)-(C10), we can compute w_N^H, w_N^L, w_S^H, w_N, $\hat{E}$, ϕ_S and x. Using Eqs. (24), (21), (22) and (23), we can derive $n_O = \iota_R n_S/\varepsilon$, $n_N = 1 - n_O - n_F - n_S$, $\iota_F = \iota_R n_F/n_N$ and $\iota_O = (\iota_R + \varepsilon)n_O/n_N$. Thus, we have completely solved the model and showed that there exists a unique solution.

APPENDIX D

Slopes of NN and SS locus

Substituting Eqs. (C7)-(C9), and (C11) and the definition of ψ_N into Eq. (C12), we have:

$$n_S = \frac{\alpha_2(1-\alpha_1 \varepsilon a_R i_R) - \varepsilon a_R i_R \dfrac{\phi_N L_N}{(1-\phi_N)L_S}}{\dfrac{\phi_N L_N}{(1-\phi_N)L_S} a_O(\varepsilon + \iota_R)\iota_R + \alpha_2\left[\alpha_1 a_O(\varepsilon+\iota_R)\iota_R + 1 + \frac{\iota_R}{\varepsilon}\right]}, \quad \text{(D1)}$$

where $\alpha_1 = \frac{L_S h_S(\bar{D}_S)B_S(\bar{D}_S)\Gamma^{1-\gamma}}{L_N a_F \varepsilon \iota_R h_N(\bar{D}_N)B_N(\bar{D}_N)}$ and $\alpha_2 = \frac{L_N \varepsilon B_N(\bar{D}_N)\sigma_N(\bar{D}_N)\{\lambda\mu+[\rho+(1-\xi)\iota_R]a_R\}}{L_S(\lambda-1)}$.

Using Eq. (D1), we can obtain $dn_S/d\phi_N < 0$. This implies that n_S and ϕ_N are negatively correlated from the perspective of the market clearing condition for Northern unskilled labor.

Substituting Eqs. (C7)-(C9) and (C11) into Eq. (C13), we have:

$$n_S = \frac{\varepsilon a_R i_R[1-(1-\phi_N)(\Gamma+\alpha_1\alpha_2)]}{(1-\phi_N)\left\{\alpha_2\left[\alpha_1 a_O(\varepsilon+\iota_R)\iota_R + \lambda + \frac{\iota_R}{\varepsilon}\right] + \Gamma a_O(\varepsilon+\iota_R)\iota_R\right\} - a_O(\varepsilon+\iota_R)\iota_R}. \quad \text{(D2)}$$

From Eq. (D2), we can obtain $dn_S/d\phi_N > 0$. This implies that n_S and ϕ_N are positively correlated from the perspective of the market clearing condition for Southern unskilled labor.

APPENDIX E

Table E1 Sensitivity analysis: homogeneous Northerners

Variables	Benchmark Model	Effects of stronger IPR protection (ε decreases 1%)							
		λ down 5%	λ up 5%	ξ down 5%	ξ up 5%	γ down 5%	γ up 5%	g_G down 5%	g_G up 5%
Panel A: Effects on Wage Rates									
w_N^H	-0.0571	-0.0530	-0.0610	-0.0564	-0.0578	-0.0571	-0.0571	-0.0571	-0.0571
w_S^H	-0.3895	-0.3854	-0.3934	-0.3850	-0.3937	-0.3895	-0.3895	-0.3895	-0.3895
w^H	0.3337	0.3337	0.3337	0.3298	0.3373	0.3337	0.3337	0.3337	0.3337
Panel B: Other Effects									
ϕ_S	0.2450	0.0524	1.1359	0.1720	0.3408	0.2031	0.2898	0.2326	0.2574
x	0.0407	0.1893	-0.5875	0.1046	-0.0499	0.0740	0.0054	0.0505	0.0308
n_N	-0.0029	-0.0913	0.4033	-0.0552	0.0722	-0.0242	0.0196	-0.0091	0.0033
n_F	-17.4389	-17.3947	-17.0751	-17.3077	-17.5342	-18.3097	-16.6388	-17.4470	-17.4308
n_O	2.8178	0.9609	15.3343	2.0066	3.9951	2.3765	3.3139	2.6874	2.9497
n_S	1.7897	-0.0487	14.1809	0.9866	2.9552	1.3527	2.2807	1.6606	1.9202
ι_F	-17.4365	-17.3192	-17.4083	-17.2620	-17.5937	-18.2899	-16.6552	-17.4395	-17.4335
ι_O	2.4804	0.7185	14.4906	1.7365	3.5647	2.0621	2.952	2.3567	2.6055

Note: All figures refer to the percentage changes in the key variables from their equilibrium values as a result of stronger IPR protection.

Table E2 Sensitivity analysis: heterogeneous Northerners

Variables	Benchmark Model)	Effects of stronger IPR protection (ε decreases 1%)							
		λ down 5%	λ up 5%	ξ down 5%	ξ up 5%	γ down 5%	γ up 5%	g_G down 5%	g_G up 5%
Panel A: Effects on Wage Rates									
w_N^H	-0.0474	-0.0468	-0.0385	-0.0479	-0.0466	-0.0483	-0.0465	-0.0474	-0.0474
w_N^L	-0.0571	-0.0530	-0.0610	-0.0564	-0.0577	-0.0571	-0.0571	-0.0571	-0.0571
w_N	0.0097	0.0062	0.0225	0.0085	0.0111	0.0088	0.0106	0.0097	0.0097
w_S^H	-0.3798	-0.3792	-0.3709	-0.3765	-0.3826	-0.3807	-0.3789	-0.3798	-0.3798
w^H	0.3337	0.3337	0.3337	0.3298	0.3373	0.3337	0.3337	0.3337	0.3337
Panel B: Other Effects									
ϕ_N	-0.1603	-0.0966	-0.3768	-0.1486	-0.1741	-0.1537	-0.1667	-0.1603	-0.1603
ϕ_S	0.2417	0.0499	1.0955	0.1773	0.3220	0.2179	0.2648	0.2417	0.2417
x	0.0337	0.1852	-0.5793	0.0923	-0.0450	0.0535	0.0146	0.0337	0.0337
n_N	-0.0042	-0.0923	0.3853	-0.0526	0.0619	-0.0164	0.0076	-0.0042	-0.0042
n_F	-17.0400	-17.1404	-16.1625	-16.9517	-17.0888	-17.9206	-16.2333	-17.0400	-17.0400
n_O	2.7884	0.9363	14.9516	2.0594	3.7846	2.5311	3.0474	2.7884	2.7884
n_S	1.7605	-0.0730	13.8021	1.0388	2.7468	1.5057	2.0169	1.7605	1.7605
ι_F	-17.0366	-17.0638	-16.4842	-16.9080	-17.1401	-17.9071	-16.2396	-17.0366	-17.0366
ι_O	2.4524	0.6951	14.1314	1.7865	3.3657	2.2083	2.6984	2.4524	2.4524

Note: All figures refer to the percentage changes in the key variables from their equilibrium values as a result of stronger IPR protection.