A North-South Model of Intellectual Property Rights Protection and Skill Accumulation

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Abstract

This paper examines how stronger intellectual property rights (IPR) protection in the south affects the processes of R&D investment, technology transfer and skill accumulation. It finds that stronger IPR protection has only a temporary impact on the innovation rate while it has a negative impact on the long-run imitation rate. In the north, the impact on the process of skill accumulation is negative and increases the within-country wage inequality. In the south, the impact is ambiguous and depends on the externality that skill accumulation generates on the process of education. In addition, the paper shows that skills play a crucial role in attracting FDI inflows, and strengthening IPR protection may be ineffective in attracting technological knowledge when the level of local skill is low.

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1 Introduction

Probably one of the most striking results on globalization and growth is that strengthening the protection of intellectual property rights (IPR) in developing countries has the effect of reducing the flow of knowledge transmission (Helpman, 1993; Lai, 1998; Yang and Maskus, 2001; and Glass and Saggi, 2002).

Recently, a new vintage of papers has revisited this issue by adding many other aspects of globalization to the basic framework. Focusing on the huge increase in outsourcing of the late four decades, Glass (2004) finds that an increase in the intensity of imitation decreases the rate of innovation and the extent of outsourcing, while increasing the relative wage of the south. A similar result has been reached by Dinopoulos and Segerstrom (2005). In their model, globalization corresponds to an exogenous increase in the size of the population of the south. Without foreign direct investment (FDI), they find that strengthening IPR protection leads to a permanent increase in the relative wage of the north, to a decrease in the long-run rate of imitation, but to only a short-run decrease in the rate of innovation. In the presence of FDI results are reversed and lead to the conclusion that in order to attract FDI, developing countries must make IPR safer. This will both rise their relative wage rate and attract technology from abroad.

Glass and Wu (2005) build a general equilibrium, R&D-based endogenous growth model with the aim of seeing if the difference in the type of innovation might alter the consequences of IPR protection. In their model, an exogenous decrease in the imitation intensity, in a setting in which FDI is costless and innovation takes the form of quality improvements, discourages FDI and reduces the innovative effort of developed countries. On the contrary, when innovation takes the form of an ever-expanding variety of horizontally differentiated products, stronger southern IPR protection encourages FDI and spurs investment in R&D.

Even though this matter has been dealt with extensively, the study of globalizing IPR protection has not yet analyzed the relationship between the strength of IPR protection in developing countries, skill accumulation and within-country wage inequality. A weak technology absorptive capacity has been recognized as perhaps the main problem facing developing countries that want to get nearer to the technological frontier. One the one hand, Benhabib and Spiegel (1994; 2005) find empirical evidence that human capital and technological progress are complementary factors in the process of growth and development, and that the adoption of advanced technologies is often restricted by the availability of particular skills in people. On the other, Maskus (2000) points out that the relationship between IPR protection and the level of economic development is U-shaped, so that low level of IPR protection might be growth-improving for economies at an early stage of economic development[1]. In such a case, imitation turns out to be more effective than innovation

[1]Chen and Puttitanun (2005) develop a model to study how the trade-off between innovation and imitation may affect a developing country's choice of IPR. In their model the country's IPR crucially depends on its level

in bridging the technology gap, so that human capital is what matters for developing economies to be able to absorb and adapt foreign knowledge and catching-up with an ever-moving technological frontier.

In this paper, I explore the role played by IPR in enhancing the long-run rate of innovation and giving incentives to private agents in developing countries to acquire skills and education to enable them absorb and implement foreign technological knowledge. The key assumption is that in the south skilled workers perform R&D tasks with the main goal of absorbing foreign technology and adopting it to replicate existing northern firm's product. With respect to the standard literature, this paper introduces two further important modifications. First, the model does not present scale problems in the balanced-growth path (BGP) and generates a non-explosive long-run rate of growth. Second, the industry strategic setup is such that all industry leaders find it optimal to charge the same markup over their own marginal cost, independent of where the previous industry leader resides.

In the absence of FDI, I find that stronger IPR induce no change in the long-run innovation rate, hurt the rate of technology transfer, and increase the relative unskilled wage of the north. In terms of human capital accumulation and within-country wage inequality, I find that strengthening IPR protection in the south leads to a fall in the northern supply of skilled labor and to an increase in the within-country wage inequality. In the south, the balanced-growth equilibrium effect is twofold and has both microeconomic and macroeconomic implications. At the industry level, stronger IPR regimes generate an increase in the productivity of skilled workers that reduces the demand for skilled labor and reduces the R&D employment per industry. At the aggregate level, the impact depends on the externality that skill accumulation generates in the process of education.

In presence of FDI, I find that no northern producer will be willing to engage in FDI when the level of local skill is very low and the cost of human capital is very high. In this case, strengthening IPR protection is ineffective in attracting foreign technology through FDI. On the contrary, when local skill is high and its cost is sufficiently low, stronger IPR protection turns out to be a useful tool in attracting foreign technology through FDI. Specifically, I find that strengthening IPR protection reduces the flow of technology coming from the imitation of imported products while the total impact on the that coming from FDI is ambiguous.

The paper develops as follows. Section 2 presents a two country (north-south) innovation-based endogenous growth model in the spirit of Grossman and Helpman (1991) and Glass and Saggi (2002), where both innovation and imitation are rent-seeking activities. Section 3 analyzes the BGP effects of strengthening IPR protection in the south. Section 4 provides an extension of the basic model by introducing a new source of technology transfer acting through FDI. Finally,

of development in a non-monotonic way. They provide empirical evidence confirming both the positive impact of IPR on innovations in developing countries and the presence of a U-shaped relationship between IPR and economic development.

Section 5 concludes.

2 The model

In this section I construct a quality-ladder endogenous growth model in the spirit of Grossman and Helpman (1991) in which two countries, developed north and developing south, trade in final goods. At each instant of time t, there is a continuum of final goods indexed by $z \in [0,1]$, that potentially can be produced in an unlimited number of vertically differentiated qualities. Firms are distinguished by the quality j of the products they produce, where higher values of j denote higher quality levels. I assume that the quality jump separating the product of quality j from the one of quality $j-1$ is constant and equals $\lambda > 1$, and that at time $t = 0$, the state-of-the-art quality product in each industry is $j = 0$, so the base quality is simply $\lambda^0 = 1$.

Both countries engage in R&D which requires skilled labor as a primary input. Since the north is more productive in conducting innovation, I assume that only the northern R&D firms are capable of raising the quality level of existing product lines while in the southern country R&D is carried out exclusively to imitate northern products. When a Developing Country succeeds in acquiring knowledge from abroad, the next step is to absorb and implement it. In such a process, IPR protection may play a crucial role since it may restrict the range of the economic area the new knowledge can be applied to and make the use of new discoveries more expensive.

Firms maximize profits and consumers maximize utility. The model generates a balanced-growth path (BGP) where the pace of technological progress is driven only by innovation.

2.1 Preferences

In each country $i = \{N, S\}$, the economy consists of a continuum of $\ell_i(t)$ of identical dynastic households. Each individual lives for a period of time $T > 0$, and the demographic dynamics are such that at every moment the number of births at time t equals the number of deaths at $t + T$. Assuming that the growth rate of the population is $g = \beta - \delta > 0$, where β denotes the birth rate and δ denotes the death rate, the dynamics of the population imply $\beta \cdot \ell_i(t) = \delta \cdot \ell_i(t+T)$. Since $\ell_i(t+T) = \ell_i(t)\, e^{gT}$, it is possible to solve this expression in terms of β and δ, yielding $\beta = ge^{gT} / \left(e^{gT} - 1\right)$ and $\delta = g / \left(e^{gT} - 1\right)$.

Individuals choose from a continuum of products indexed by $z \in [0,1]$, where products are available in an unlimited number of quality levels indexed by j. The generic representative household maximizes the logarithmic intertemporal utility function

$$\max_{q_i} U_i(0) \equiv \int_0^{\infty} \ell_i(0)\, e^{-(\rho-g)t} \log u(t)\, dt \tag{1}$$

subject to the constraints:

$$
\begin{aligned}
\log u(t) &\equiv \int_0^1 \log\left[\Sigma_j \lambda^j q_i(j,z,t)\right] dz && (2)\\
E_i(t) &= \int_0^1 \left[\Sigma_j p_i(j,z,t)\, q_i(j,z,t)\right] dz && (3)\\
W_i(t) + A_i(t) &= \int_t^{\infty} E_i(t) \cdot e^{g\tau} e^{-[R(\tau)-R(t)]} d\tau && (4)\\
\ell_i(0) &> 0; \quad \rho > g
\end{aligned}
$$

Eq. [1] is the discounted utility of the representative household, where $u(t)$ denotes the instantaneous utility and ρ is the subjective discount rates. Eq. [2] is the Dixit-Stiglitz consumption index, where λ^j is the quality level of a product improved j times after $t = 0$, and $q_i(j,z,t)$ is the consumption of quality j of product z at time t. Eq. [3] is the static budget constraint which assumes that at each instant of time t, the per capita expenditure of the representative household, $E_i(t)$, must equates to the value of all final goods consumed, where $p_i(j,z,t)$ is the price of quality j of product z at time t. Finally, Eq. [4] is the intertemporal budget constraint, where $W_i(t)$ denotes the household's discounted wage income at time t and $A_i(t)$ is the present value of the household's financial assets at time t (which must equal the discounted value of consumption, where $R(t) \equiv \int_0^t r(\tau)\, d\tau$ is the market discount factor with $dR(t)/dt = r(t)$ denoting the instantaneous interest rate at time t).

Following Grossman and Helpman (1991), it is possible to divide this problem into three steps. Firstly, every household maximizes Eq. [2] subject to the static constraint [3]. According to the Cobb-Douglas specification of the Dixit-Stiglitz index [2], only those goods with the lowest price per unit of quality are purchased by consumers. This budget allocation leads to an overall demand function for each top-quality product of the form

$$
q(z,t) = \frac{c(t)}{p(z,t)} \tag{5}
$$

where $c(t) \equiv E_N(t)\,\ell_N(t) + E_S(t)\,\ell_S(t)$ is the global consumption expenditure at time t.

Secondly, every household faces an intertemporal optimization problem in which the logarithmic preferences in Eq. [1] must be maximized subject to the intertemporal budget constraint [4]. Since the intertemporal felicity function [1] is additively separable in the logarithmic of spending, the optimal intertemporal spending path for the representative dynasty is given by the Euler equation

$$
\frac{\dot{E}_i(t)}{E_i(t)} = r(t) - \rho \tag{6}
$$

According to Eq. [6], the per capita consumption expenditure grows over time if and only if the market interest rate, $r(t)$, exceeds the subjective discount rate, ρ.

2.1.1 Skill accumulation and training

In the last step, individuals address the concern of skill accumulation and training. Assume that each household has an identical aptitude for learning[2] and restrict the analysis to an economy in a balanced-growth path where w_L^i and w_H^i are constant over time, and where $r(t) = \rho$ for all t. Individuals can immediately start earning the going wage rate for unskilled labor, w_L^i, or become students, acquire an education that lasts for a period of time of length, D_i, and earn the going market wage rate for skilled labor, w_H^i. If we define the share of population that chooses to remain unskilled by ψ_i, then at each instant of time t, $(1-\psi_i)\,\ell_i(t)\,T$ individuals choose to become educated, while the remaining $\psi_i \ell_i(t)\,T$ choose to become unskilled workers. In order to separate the subpopulation that is training from the one that is already employed as skilled workers, it suffices to consider that in each country the skilled workers are the older individuals, so that, at each instant t, a fraction $(1-\psi_i)\,\ell_i(t)\,D_i$ of individuals is out of the labor force attending school, while the remaining $(1-\psi_i)\,\ell_i(t)\,(T-D_i)$ is doing jobs requiring skills. Accordingly, the total population can be split in the following way:

$$\psi_i \ell_i(t) + (1-\psi_i)\,\ell_i(t)\,\frac{D_i}{T} + (1-\psi_i)\,\ell_i(t)\,\frac{T-D_i}{T} = \ell_i(t)$$

Education is an activity that transforms students into skilled workers after a lapse of time D_i. I follow Findlay and Kierzkowski (1983) in assuming that the process of learning is an activity governed by a production function, $h_i(D_i)$ (with $h_i'(\cdot) > 0$ and $h_i''(\cdot) < 0$), which measures the efficiency with which the education system turns the time spent at school into skills. I also assume that the investment in human capital by households takes into account the externalities induced by education, in the sense that the amount of skills embodied in educated workers is now directly related to the average stock of human capital, $\left(\frac{H_i(t)}{\ell_i(t)}\right)^{\phi}$, where $\phi \in [0,1)$ is an exogenous parameter measuring the strength with which the average stock of human capital generates positive externalities in the process of skill accumulation.

As a result, while the income of an unskilled worker simply equals the marginal value product of one unit of unskilled labor w_L^i, the income of a skilled worker equals the marginal value product of one efficiency unit of skill, $w_H^i h_i(D_i)\left(\frac{H_i(t)}{\ell_i(t)}\right)^{\phi}$. To choose the optimal D_i, individuals compare the present value of lifetime earnings as an unskilled worker with the present value of the income that they could gain by becoming skilled workers. This entry condition reads

$$\int_t^{t+T} e^{-[R(\tau)-R(t)]} w_L^i \, d\tau \leq \int_{t+D_i}^{t+T} e^{-[R(\tau)-R(t)]} w_H^i h_i(D_i) \left(\frac{H_i(t)}{\ell_i(t)}\right)^{\phi} d\tau \qquad (7)$$

[2]In this model I rule out any possible heterogeneity among economic agents by assuming that each individual has the same ability to learn and apply what is learnt. For an alternative approach with heterogeneous agents see Dinopoulos and Segerstrom (1999).

where the left-hand side of Eq. [7] is the opportunity cost of education – represented by the discounted wage income of an individual employed as an unskilled worker – and the right-hand side is the lifetime income of an individual who devotes a period of time $D_i > 0$ to acquiring skills without earning an income and then earns $w_H^i h_i(D_i)\left(\frac{H_i(t)}{\ell_i(t)}\right)^{\phi}$ from time $t + D_i$ to time $t + T$.

In a BGP equilibrium, Eq. [7] will hold with equality, so that there exists an optimal time spent at school such that the marginal benefit from extending the time in education equals the marginal opportunity cost of the extra time spent in education. The optimal time spent in school, $\bar{D}_i$, is therefore given by the first order condition

$$1 - e^{-\rho\left(T - \bar{D}_i\right)} = \frac{\rho h_i\left(\bar{D}_i\right)}{h_i'\left(\bar{D}_i\right)} \tag{8}$$

As the left-hand side of [8] is decreasing in $\bar{D}_i$ and the right-hand side is increasing, the optimal time of schooling is in the range $\bar{D}_i \in (0, T)$. Observe that the optimal $\bar{D}_i$ does not depend on the equilibrium wage rates, so that the individual's incentive to invest in education is only affected by the parameters governing the demographic structure of each population.

Given $\bar{D}_i$, equilibrium in the educational sector requires that the net benefit from education must be zero. In the long-run then, the equilibrium relative wage will be the solution of Eq. [7]

$$\omega_i \equiv \frac{w_H^i}{w_L^i} = \frac{\sigma_i}{\left(h_i\left(\bar{D}_i\right)\right)^{1/(1-\phi)}\left(B_i\left(\bar{D}_i\right)(1-\psi_i)\right)^{\phi/(1-\phi)}} \tag{9}$$

where $\sigma_i \equiv \left(1 - e^{-\rho T}\right)/\left(e^{-\rho\bar{D}_i} - e^{-\rho T}\right) > 1$ and $B_i\left(\bar{D}_i\right) \equiv \left(T - \bar{D}_i\right)/T < 1$ are both functions of $\bar{D}_i$. According to Eq. [9], the skill premium ω_i is a function of the efficiency of the education system, $h_i(\cdot)$, of the share of the population that chooses to remain unskilled, ψ_i, of the optimal time spent in education, $\bar{D}_i$, and of all the parameters included in σ_i.[3] In terms of the elasticity, η, a change of ψ_i generates a change of ω equal to

$$\eta_{\omega,\psi} = \frac{\phi}{1-\phi}\frac{\psi_i}{1-\psi_i}$$

with the result that when $\phi = 0$, the process of human capital accumulation does not affect the quantity of skills embodied in each skilled worker or the size of the skill premium. Eq. [9] turns out to be independent of the share of the population that chooses to remain unskilled, ψ_i, while, when ϕ approaches 1, an increase in the share of the population that chooses to remain unskilled generates a progressive increase in the skill premium.

At equilibrium, the supply of unskilled labor reads

$$L_i(t) = \psi_i \ell_i(t) \tag{10}$$

[3] This feature stems from the assumption that individuals are identical in their ability to learn. Dinopoulos and Segerstrom (1999) adopt a different setup where each individual knows his or her own ability and where the productivity of training is a linear function of the worker's ability.

whereas the supply of skilled labor (i.e. human capital stock) is

$$H_i(t) = \left(h_i\left(\bar{D}_i\right) B_i\left(\bar{D}_i\right)(1-\psi_i)\right)^{1/(1-\phi)} \ell_i(t) \tag{11}$$

Note that when $\phi = 0$, the supply of skilled workers turns out be a linear function of the share of the population that chooses to remain unskilled, ψ_i. On the contrary, when ϕ approaches 1, the supply of skilled workers is no longer a linear function of ψ_i, with the result that it can either explode (for $h_i\left(\bar{D}_i\right) B_i\left(\bar{D}_i\right)(1-\psi_i) < 1$) or converge to zero (for $h_i\left(\bar{D}_i\right) B_i\left(\bar{D}_i\right)(1-\psi_i) > 1$).

2.2 Production

In the absence of transnational corporations (TNC), only two types of profit-making firms are active at equilibrium: (i) northern leaders producing the state-of-the-art product after they have successfully improved the quality level of an existing brand, which I denote by n_N; and (ii) southern firms which succeed in replicating the technology needed to produce the state-of-the-art good, which I denote by n_N. Each southern firm has a constant marginal cost of production equal to w_L^S while each northern firm has a constant marginal cost equal to w_L^N. In the remainder of the paper, I restrict attention to analyzing the *narrow-gap* case occurring when $w_L^S < w_L^N < \lambda w_L^S$.[4] At each instant, these types of firm must exhaust all the possibilities for profitable enterprise (i.e., $n_N + n_S = 1$).

To become the industry leader, each firm must first be successful in the R&D race. Analyze first the situation in which a northern firm wins an R&D race. Once an innovation has been developed, the discoverer enjoys a quality lead over the previous industry leader. Since the price elasticity of demand is equal to one, in this model innovation is always non-drastic and northern producers have to compete as price-setting oligopolists and use a limit-pricing strategy to capture the entire industry market. The competitor can be a northern firm (if the product one step below on the quality ladder has not been imitated) or a southern firm (if that product has been imitated). In order to simplify the analysis, I assume that maintaining unused production plants is costly and that, once a firm has exited the market, there are positive costs for reentering the market.

Consider the case in which the producer of the product one step below on the quality ladder is a northern firm. With the previous industry leader charging a price equal to its marginal cost w_L^N, the northern industry leader is able to capture the entire market by setting a price that does not exceed λw_L^N. This price is the Nash equilibrium price since the leader has no incentive to

[4]This assumption allows me to analyze the strengthening IPR protection in the south in a model with product cycles à la Vernon (1966). Notice that in the alternative case of a model with a *wide gap*, targeting Southern industries should be not profitable for Northern R&D firms. In fact, when $w^N > \lambda w^S$, the optimal price strategy for northern firms would be to set a price equal to λ times the previous industry leader's marginal cost, w^S. But since $w^N > \lambda w^S$, the profit function would be negative and would discourage northern enterprises from financing R&D projects which target Southern products.

deviate from this limit-pricing strategy. Indeed, the leader would not wish to rise its price; if it did, consumers would prefer to purchase the product one step below on the quality ladder. At the same time, the leader would not wish to reduce its price since the industry demand function is unit elastic.

Consider now the case in which the producer of the product one step below on the quality ladder is a southern firm. With the previous industry leader charging a price equal to its marginal cost w_L^S, the northern industry leader is able to capture the entire industry market by setting a price that does not exceed λw_L^S. As maintaining unused production facilities is costly, for the southern rival it is profit-maximizing to exit the market immediately rather than pricing at marginal cost. Once the rival has exited the market, the leader deviates from the previous limit-pricing strategy by raising its price to λw_L^N. This price is the Nash equilibrium price since the leader has no incentive to deviate from it. On the one hand, the presence of positive costs for reentering the market ensure that it is not profitable for the rival to re-start production of the obsolete product.[5] On the other, the unitary elasticity of the industry demand does not allow the leader to raise or reduce its price.

As a result, pricing at λw_L^N is the only type of pricing strategy for a northern industry leader, regardless of where the previous industry leader is based. By charging $p_N = \lambda w_L^N$, each northern industry leader makes sales $q_N = c(t)/\lambda w_L^N$ and earns an instantaneous flow of profits

$$\pi_N(t) = \left(1 - \frac{1}{\lambda}\right) c(t) \tag{12}$$

Analyze now the situation in which a southern firm wins an R&D race. In this case, the technology in use in such an industry is first absorbed and then adapted by the firm, which starts competing with the former industry leader. This firm is always a northern firm since it is not profitable for southern firms to target those products currently produced by other southern firm. Thus, by pricing at anything less than the northern rival's marginal cost, w_L^N, the imitator is capable of capturing the whole market. Once again, the presence of positive costs for staying in the industry implies that it is profit-maximizing for the rival to exit the market immediately rather than pricing at marginal cost. Therefore, once the rival has exited the market, the leader will find it optimal to raise its price to λw_L^S. This constitutes a Nash equilibrium since the southern leader has no incentive to deviate from it. By charging $p_S = \lambda w_L^S$, each southern industry leader makes sales $q_S = c(t)/\lambda w_L^S$ and earns an instantaneous flow of profits

$$\pi_S(t) = \left(1 - \frac{1}{\lambda}\right) c(t) \tag{13}$$

[5] As Dinopoulos and Segerstrom (2005) point out, by reentering the previous industry leader may at best earns positive profits insofar as the current industry leader reverts to limit-pricing. To break ties, I follow Howitt (1999) by considering those steady-state solutions where the previous industry leaders prefer to exit the industry and decide to stay out forever.

According to Eqs. [12] and [13], the instantaneous profits earned by both northern and southern quality leaders are an increasing function of the exogenous quality jump λ, and worldwide aggregate expenditure $c(t)$. In the rest of the paper I focus on the BGP property of the model by using the unskilled wage rate of the south as the numeraire (i.e., $w_L^S = 1$).

2.3 Research and development

Both innovation and imitation are industry-specific R&D races requiring skilled labor. Any northern firm investing resources in R&D at intensity ι for a time interval dt, will succeed in creating a new generation of final good with probability $\iota(z,t)\,dt$ and will fail with probability $(1-\iota(z,t)\,dt)$. To achieve such an innovation intensity ι, the firm must invest $a_N \chi(t)\,\iota(z,t)$ units of skilled workers per unit of time, where $\chi(t)$ denotes the difficulty of conducting R&D. Specifically, I assume that the level of R&D difficulty, $\chi(t)$, increases with the level of the industry-wide cumulative R&D investment, according to the *temporary effects on growth* (TEG) approach suggested by Segerstrom (1998), and governed by differential equation

$$\frac{\dot{\chi}(t)}{\chi(t)} = \xi \iota(t) \tag{14}$$

where $\xi > 0$ is a time invariant exogenous parameter and $\iota(t)$ is the rate of innovation of the overall economy. According to Eq. [14], as the global economy grows due to innovation, $\chi(t)$ increases as well and innovating becomes more difficult. As in Jones (1995), this approach implies both a scale invariant long-run rate of growth proportional to the growth rate of population and that R&D policies do not have permanent growth effects[6].

Denoting the expected discounted flow of profits of a firm winning the R&D race in industry z by $v_N(z,t)$ and the cost of setting up a research lab by $a_N w_H^N \chi(t)\,\iota(z,t)\,dt$, every firm will choose the optimal level of research intensity such that,

$$v_N(z,t) \begin{cases} \leq a_N w_H^N \chi(t) & if \quad \iota = 0 \\ = a_N w_H^N \chi(t) & if \quad \iota > 0 \end{cases} \tag{15}$$

Free entry condition in Eq. [15] makes each firm evaluate the expected value of market entry compared to the cost.[7]

[6]For further discussion of the implications of the scale effects property for the first vintage of R&D-based endogenous growth models, see in particular Jones (1999), Dinopoulos and Thompson (1999) and Dinopoulos and Sener (2004).

[7]In this model I do not take into account the issue of the "leader" and "follower" in the innovation sector (see Grossman and Helpman (1991) for details). Nor do I distinguish between productivities in firm's research labs, so that any firm financing R&D projects will devote the same quantity of resources to achieving the same probability of success.

As regards the global rate of imitation, I treat imitative R&D as a risky venture similar to innovation, where southern research firms enter the market freely, hire skilled workers, and try to implement the state-of-the-art technology of a certain product line. Once the firm succeeds in acquiring the technology embodied in a northern product, research consists in absorbing the foreign technology and using it to achieve business goals. In this sense, imitation requires a lot of specific skills such as managerial talent, abilities to adapt existing knowledge, and business acumen.

Denoting the Poisson arrival rate of imitation in industry z for a time interval dt by $m(z,t)$, any firm will succeed in adopting and imitating with a probability of $m(z,t)\,dt$ and will fail with a probability of $(1-m(z,t)\,dt)$. Specifically, to achieve a level of imitation of $m(z,t)$, each firm must invest $a_S\chi(t)\,m(z,t)$ units of skilled workers per unit of time. The presence of $\chi(t)$ in the imitation technology captures the idea that as the global economy grows and innovation become more difficult, the process of technology adoption also becomes more complex.

In order to introduce the effect of the stronger IPR protection in the south, I assume that the cost of imitation is increased by a stronger IPR regime in the south. In particular, I denote the strength with which IPR are enforced in the south by $\mu > 0$.[8] Such a definition, together with the extent of constant returns to scale technology in the R&D sector, implies that the cost of setting up a research lab in the south is $a_S\chi(t)\,w_H^S(1+\mu)\,mdt$. Denoting the expected discounted flow of profits of a southern industry leader by $v_S(z,t)$, every southern research firm will choose its research intensity such that,

$$v_S(z,t)\begin{cases}\leq a_S\chi(t)\,w_H^S(1+\mu) & if \quad m=0\\ = a_S\chi(t)\,w_H^S(1+\mu) & if \quad m>0\end{cases} \tag{16}$$

In country $\iota = \{N, S\}$ the cost of R&D is the same across industries, so the free entry conditions [15] and [16] imply that $v_i(z,t) = v_i(t)$ and that at each instant firms devote the same number of skilled workers to R&D. As a result, in the rest of the paper I will focus on a symmetric equilibrium where ι and m are per industry intensities of research in, respectively, innovation and imitation activities.

2.4 The stock market

In each country there is a stock market channeling consumer saving to risky in R&D firm. As the returns to engaging R&D are independently distributed across firms and industries and capital is perfectly mobile across countries, investors can completely offset the industry-specific risk simply by holding a diversified portfolio of stocks. Over the time interval dt, every northern firm's shareholders will earn a dividend equal to the profit flow $\pi_N(t)\,dt$ but will suffer a depreciation equal to

[8] Yang and Maskus (2001) provide another possible role for IPR. In their model IPR are used for reducing the transaction costs associated with technology transfer. In this model I rule out such a role.

$dv_N(t) = \dot{v}_N(t)\,dt$. Moreover, the Walrasian nature of the stock market requires that the expected rate of return of a stock issued by successful R&D firms must equal the riskless rate of return $r(t)$, which, in turn, implies that the following capital market non-arbitrage condition must hold:

$$\frac{\dot{v}_N(t)}{v_N(t)} + \frac{\pi_N(t)}{v_N(t)} = r(t) + \iota + m \tag{17}$$

Plugging Eqs. [12] and [15] into Eq. [17], and observing that in equilibrium $\frac{\dot{v}_N(t)}{v_N(t)} = \frac{\dot{\chi}(t)}{\chi(t)} = \xi\iota(t)$, yields the northern R&D condition

$$\frac{(1-1/\lambda)\,y(t)}{r(t) + \iota(1-\xi) + m} = a_N w_H^N x(t) \tag{18}$$

where $x(t) \equiv \chi(t)/\ell_N(t)$ denotes the northern population-adjusted degree of complexity that I take as a measure of relative R&D difficulty, and $y(t) \equiv c(t)/\ell_N(t)$ is the northern population-adjusted global consumption expenditure at time t. Eq. [18] governs the incentive of northern firms to devote resources to innovation. The left-hand side is the expected discounted flow of profits from commercializing an innovation, while the right-hand side is simply the cost of innovating.

In the south, similar reasoning shows that

$$\frac{\dot{v}_S(t)}{v_S(t)} + \frac{\pi_S(t)}{v_S(t)} = r(t) + \iota \tag{19}$$

Plugging Eqs. [13] and [16] into Eq. [19], and observing that in equilibrium $\frac{\dot{v}_S(t)}{v_S(t)} = \frac{\dot{\chi}(t)}{\chi(t)} = \xi\iota$, gives the southern R&D condition

$$\frac{(1-1/\lambda)\,y(t)}{r(t) + \iota(1-\xi)} = a_S x(t)\, w_H^S (1+\mu) \tag{20}$$

Eq. [20] is similar to Eq. [18] and governs the incentive of southern firms to devote resources to imitation. The left-hand side is the expected discounted flow of profits from imitating an imported product, while the right-hand side is simply the cost of imitation.

2.5 The product measures

At each instant the flow into each country equals the flow out; i.e. $mn_N = \iota n_S$. Since this section relies exclusively on trade as the only channel through which technology transfers between countries, in the BGP equilibrium the north's share of world manufacturing is constant and equal to

$$n_N = \frac{\iota}{m + \iota} \tag{21}$$

According to Eq. [21], n_N is an increasing function of the rate of innovation ι and a decreasing function of the rate of imitation m. In such a setup, stronger IPR protection in the south enhances the international redistribution of industries that makes the share of the north in the total number of industries, n_N, change through variations in both ι and m. In the remainder of the paper, I will refer to this as the redistribution effect.

2.6 The factor markets

Factor markets are perfectly competitive. As already mentioned, the manufacturing sector employs only unskilled labor and the R&D sector employs only skilled workers. In the north, $q_N(t)\,n_N$ units of unskilled labor are hired by manufacturing firms, while $\iota\chi(t)$ units of skilled labor are hired by R&D firms. Equating these two factor demand functions to the supply of unskilled and skilled workers (Eqs. [10] and [11] respectively), the following labor-market full-employment conditions are obtained

$$n_N \frac{y(t)}{\lambda w_L^N} = \psi_N \tag{22}$$

$$a_N \iota x(t) = \left(h_N\left(\bar{D}_N\right) B_N\left(\bar{D}_N\right)(1-\psi_N)\right)^{1/(1-\phi)} \tag{23}$$

Note that the left-hand side of Eq. [23] is the economy-wide skilled labor demand, which is also a measure of the aggregate stock of human capital in the north.

Similarly, in the south $q_S(t)(1-n_N)$ units of unskilled labor are hired in the manufacturing sector, while $n_N(1+\mu)\,m\chi(t)$ units of skilled labor are employed in R&D. The labor-market full-employment conditions for the south are

$$(1-n_N)\frac{y(t)}{\lambda} = \psi_S \frac{\ell_S(t)}{\ell_N(t)} \tag{24}$$

$$n_N(1+\mu)\, m a_S x(t) = \left(h_S\left(\bar{D}_S\right) B_S\left(\bar{D}_S\right)(1-\psi_S)\right)^{1/(1-\phi)} \frac{\ell_S(t)}{\ell_N(t)} \tag{25}$$

The left-hand side of Eq. [25] stands for the economy-wide skilled labor demand of the south, which crucially depends on northern production n_N. In contrast to Eq. [23], then, in the south the aggregate stock of human capital positively depends on trade. An increase in the share of northern production, n_N, positively affects the aggregate stock of southern human capital because it enlarges the set of potentially imitable products.

2.7 The BGP equilibrium

In this section I will focus on a BGP equilibrium of the model where the allocation of all resources to various activities remains fixed over time, where all markets clear, and where firms invest in R&D. Let me first demonstrate that the BGP innovation rate is constant over time. According to Eq. [14], the difficulty of R&D increases with the cumulative R&D effort. As R&D starts off being equally difficult in all industries, the existence of a balanced-growth path requires that x does not change in the BGP. Because relative R&D difficulty equals $x(t) = \chi(t)/\ell_N(t)$, a balanced-growth equilibrium requires the long-run innovation rate[9] to be equal to

$$\iota = \frac{g}{\xi} \tag{26}$$

As mentioned above, the long-run rate of innovation given by Eq. [26] is proportional to the rate of population growth, $g > 0$, and inversely proportional to the R&D difficulty parameter $\xi > 0$. Plugging Eq. [26] into Eq. [21] shows that the BGP share of northern manufacturing in global production only depends on the long-run rate of imitation

$$n_N = \frac{g}{g + \xi m} \tag{27}$$

Substituting the BGP innovation rate (Eq. [26]) and the BGP product measure (Eq. [27]), into research equations (Eqs. [18] and [20]) and labor market full-employment conditions (Eqs. [22], [23], [24] and [25]), the resulting expressions form a system of six equations in six unknowns: the northern population-adjusted global consumption expenditure y, the relative R&D difficulty x, the rate of imitation of northern firms' products m, the northern unskilled wage w_L^N, the northern supply of unskilled labor ψ_N, and the southern supply of unskilled labor ψ_S.

Finally, using Eq. [9] to substitute for the skill premium, the BGP equilibrium system can be reduced to the following pair of equations (see Appendix A for details)

$$x^{1-\phi} = \frac{\frac{g+\xi m}{g\left(\rho+\frac{g}{\xi}(1-\xi)+m\right)}}{\frac{\left(a_N\frac{g}{\xi}\right)^{1-\phi}}{h_N(D_N)B_N(D_N)}\frac{g+\xi m}{g\left(\rho+\frac{g}{\xi}(1-\xi)+m\right)} + \frac{a_N\sigma_N}{(\lambda-1)\left(a_N\frac{g}{\xi}\right)^{\phi}h_N\left(\bar{D}_N\right)}} \tag{28}$$

$$x^{1-\phi} = \frac{\frac{\ell_S}{\ell_N}\frac{g+\xi m}{\xi m\left(\rho+\frac{g}{\xi}(1-\xi)\right)}}{\frac{\ell_S}{\ell_N}\frac{g+\xi m}{\xi m\left(\rho+\frac{g}{\xi}(1-\xi)\right)}\frac{\left((1+\mu)ma_S\frac{g}{g+\xi m}\frac{\ell_N}{\ell_S}\right)^{1-\phi}}{h_S(D_S)B_S(D_S)} + \frac{(1+\mu)a_S\sigma_S}{(\lambda-1)\left((1+\mu)ma_S\frac{g}{g+\xi m}\frac{\ell_N}{\ell_S}\right)^{\phi}h_S\left(\bar{D}_S\right)}} \tag{29}$$

where [28] and [29] are both expressions giving the long-run combinations of the northern population-adjusted R&D difficulty x, and the long-run rate of imitation m, that are consistent with a firm's profit-maximizing behavior, the absence of arbitrage opportunities, and market-clearing in the unskilled labor market of both countries.[10] Notice that only Eq. [29] directly depends on μ, while Eq. [28] indirectly depends on μ through the redistribution effect, the population-adjusted R&D complexity x, and the BGP rate of imitation m. Figure 1 illustrates the balanced-growth path of the model where NN stands for northern BGP research condition [28] and SS stands for southern BGP research condition [29].

[9] Indeed, since relative R&D difficulty equals $x(t) = \chi(t)/\ell_N(t)$, a balanced-growth equilibrium requires that $\dot{x}/x = \dot{\chi}/\chi - g = 0$. Eq. [26] follows straightforwardly from [14].

[10] In Eq. [29], the ratio ℓ_S/ℓ_N is exogenously given and does not vary over time since both populations are supposed to grow at the same constant rate of growth, g.

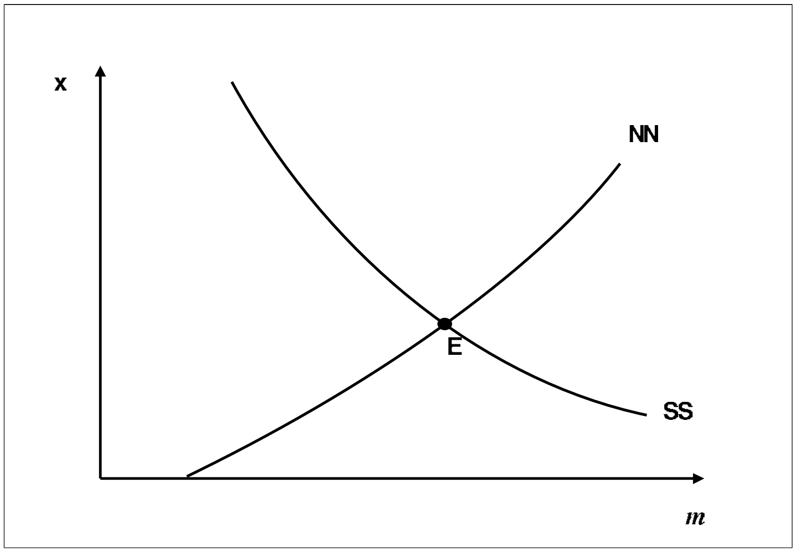

Figure 1: The balanced-growth equilibrium

In contrast to Helpman (1993), Lai (1998) and Glass and Saggi (2002), I have shown that a BGP equilibrium exists without scale effects with the following characteristics:

Proposition 1 *Under the TEG specification of the R&D difficulty index, a unique balanced-growth path exists in which:* (*a*) *the long-run rate of innovation is positive and exogenously defined by Eq. (26);* (*b*) *both the relative R&D difficulty index* x*, and the long-run rate of imitation* m*, are constant over time; and* (*c*) *the supply of skilled labor in the north and the south are determined endogenously by Eqs. [23] and [25].*

Proof. See Appendix A ■

Given the BGP pair (x, m), the remaining endogenous variables of the model are completely determined recursively. Moreover, because of the TEG specification adopted, any policy affecting both x and m, only results in temporary changes in the long-run innovation rate, ι. Thus, a full analysis of the long-run effect of changes in x would require a complete analysis of the transitional dynamics of the model that are beyond the scope of this paper.

3 Strengthening IPR protection

In this section, I investigate the impact of strengthening IPR protection in the south on the BGP incentive of individuals to invest in R&D and accumulate skills, and on the within-country wage inequality. A permanent increase in μ affects both the long-run rate of imitation, m, and the relative R&D complexity, x. Starting from the balanced-growth path, E, the southern balanced-growth

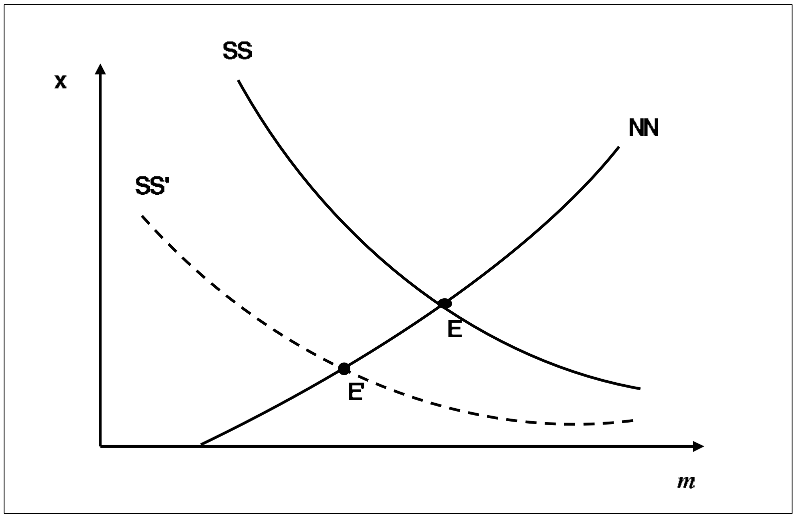

Figure 2: comparative statics

condition, SS, shifts to the left and converges to the new balanced-growth path equilibrium, E' (see Figure. 2). The long-run effects of strengthening IPR protection in the south are summarized in the following proposition:

Proposition 2 *For economies in a balanced-growth path, strengthening IPR protection in the south:* (a) *induces only a temporary fall in the rate of innovation,* ι*;* (b) *induces a permanent decrease in the population-adjusted R&D difficulty index,* x*;* (c) *induces a permanent fall in the BGP rate of imitation,* m*; and* (d) *widens the gap between the unskilled of the north and the south,* w_L^N/w_L^S*.*

Proof. see appendix B ■

Proposition 2 echoes the current literature in arguing that strengthening IPR protection in developing countries slows down R&D investment and growth. In addition, this model sheds new light on the balanced-growth equilibrium effects of strengthening IPR protection, on skill accumulation and the within-country wage inequalities.

Proposition 3 *For economies in a balanced-growth path, strengthening IPR protection in the south implies:* (a) *a decrease in R&D employment in the north at both industry-wide and aggregate level as well as a permanent increase in wage inequality;* (b) *a permanent decrease in the industry-wide R&D employment in the south; and* (c) *an increase or a decrease in economy-wide R&D employment as well as wage inequality in the south that crucially depends on the size of the externality parameter* ϕ*;*

Proof. see appendix B ■

The economic intuitions underlying Propositions 2 and 3 are simple to explain. Differentiating Eq. [27] with respect to μ, shows that the redistribution effect goes in favor of the north and reads

$$\frac{dn_N}{d\mu} = -\frac{g\xi}{(g+\xi m)^2}\frac{dm}{d\mu} > 0 \tag{30}$$

According to Eq. [30], the permanent increase in μ generates a redistribution of industry from the south to the north that raises the demand for northern unskilled workers and reduces the demand for southern unskilled labor. This, in turn, increases the unskilled wage in the north and reduces the unskilled wage in south, so widening the gap in the relative unskilled wage rate of the north (w_L^N/w_L^S). In the north, the rise in the unskilled wage rate shrinks the skill premium and discourages households from investing in skill accumulation. The reduced supply of skilled labor pushes the northern skilled wage, w_H^N, upward with the result that R&D firms are forced to reorganize their investment plans. As the skill premium gradually rises to restore the equilibrium in Eq. [7], the cost of R&D rises as well by discouraging R&D investment and making the innovation rate fall temporarily. To restore the BGP pace of technological progress given by Eq. [26], the skilled wage has to increase by more than the increase in the unskilled wage.[11] As a result, in the new BGP, E', the northern economy experiences a permanent fall in the supply of skilled labor (i.e. ψ_N increases), and a permanent increase in the wage inequality (i.e. ω_N increases).

In the south, the redistribution effect goes in the opposite direction, encouraging investment in education. In addition, the rise in μ increases the opportunity cost of investing in R&D. It has a positive impact on the southern skilled labor demand because of a resource wasting effect described by Glass and Saggi (2002). In order to maintain the rate of imitation unchanged, firms must invest in a larger amount of skilled labor. The resource wasting effect, then, reinforces the redistribution effect and generates an increase in the skill premium that encourages more people to acquire skills. Finally, there is a third effect offsetting the previous ones and that is due to the reduction in the relative R&D difficulty, x. The permanent fall in x produces a productivity gain due to a reduction in the absolute R&D difficulty, implying that less skilled labor needs to be devoted to R&D activities to maintain the BGP innovation rate constant. Following Segerstrom (1998), I refer to this negative external effect of the marginal innovation as the intertemporal R&D spillover effect. The intertemporal R&D spillover effect compresses the skilled labor demand and has the effect of reducing the BGP skill premium.

The redistribution effect is a general equilibrium effect, whereas the remaining two effects have only industry-specific implications. At industry level, the BGP impact is negative and leads to a reduction in the amount of skilled labor employed by each industry z.[12] At aggregate level, the

[11] As emphasized in Section 2.1.1, the reaction of the skill premium to changes in the share of unskilled workers crucially depends on ϕ. More specifically, for $\phi \in (0, 1)$, any increase in ψ_i generates a permanent increase in the skill premium whose magnitude is measure by the elasticity $\eta_{\omega,\psi}$.

[12] See Appendix B for the analytical details of this outcome.

final result of strengthening IPR protection on the long-run pace of skill accumulation is positive if, and only if, the redistribution effect is capable of more than offsetting the reduction of the industry-wide skilled labor employment. In Appendix B, I show that this result crucially depends on whether the parameter governing the externality affecting the process of skill accumulation ϕ is larger or smaller than a given threshold ϕ^*. When $\phi \in (\phi^*, 1)$, the redistribution effect more than offsets the reduction in the industry-wide skilled labor employment and the south records a permanent increase in the supply of skilled labor (i.e. ψ_S falls) as well as a permanent decrease in the wage inequality (i.e. ω_S falls). On the contrary, when $\phi \in [0, \phi^*)$, the opposite result holds and the south records a permanent fall in the supply of skilled labor (i.e. ψ_S increases) and a permanent increase in the wage inequality (i.e. ω_S increases).

4 Foreign direct investment

The model presented in Section 2 studies the effects of stronger IPR protection in the presence of only one channel of technology transmission. A natural extension of the model is to analyze how the results change in the presence of another channel of technology transfer, namely FDI.

Compared to the model of Section 2, two additional types of profit-making firms are now active in equilibrium: northern firms that have been successful in becoming TNCs, denoted by n_F, and southern firms that successfully imitate the TNC's products, denoted by n_{SF}. At each instant t, these four types of firms must exhaust all the possibilities for profitable enterprises $n_N + n_F + n_{SN} + n_{SF} = 1$, where n_{SN} is now the market measure of products produced by southern firm that successfully imitate imported northern products.

4.1 Transnational corporations and the incentive to invest abroad

To become a TNC, a northern firm must first adapt its production process for the south. In contrast to Lai (1998), Glass (2004) and Glass and Wu (2005), I assume that adapting the production for the south is costly and requires southern skilled labor. Undertaking FDI intensity F for a time interval dt leads to success with probability Fdt and to a failure with probability $1 - Fdt$, and entails an adaptation cost equal to $a_F \chi(t) F w_H^S dt$, where a_F is the labor requirement of adaptation (with $a_S > a_F$).

Let $v_F(t)$ denote the expected discounted flow of profits when engaging in FDI (which also measures the value of a northern producer becoming a TNC). An equilibrium with positive FDI requires

$$v_F(t) - v_N(t) \begin{cases} \leq a_F \chi(t) w_H^S \ if \ F = 0 \\ = a_F \chi(t) w_H^S \ if \ F > 0 \end{cases} \tag{31}$$

where $v_F(t) - v_N(t)$ is the expected capital gain from becoming a TNC. Using Eq. [15] to substitute for $v_N(t)$, a BGP with both innovation and FDI requires Eq. [31] to hold with

$$v_F(t) = a_F \chi(t) w_H^S (1+\theta)$$

where $\theta \equiv a_N w_H^N / a_F w_H^S$ is the cost of innovation relative to adaptation that I take as a measure of the relative R&D cost in the north.

Upon successful adaptation, the northern firm becomes a TNC and starts producing in the south at a marginal cost lower than w_L^N but higher than that faced by pure southern producers. I follow Markusen (1995) and Glass and Saggi (2002) and assume that the unit unskilled-labor requirement for each TNC is $\zeta > 1$, and that this cost difference is the consequence of logistical difficulties due to several factors (such as the distance, the lack of familiarity with the southern economic environment, and other cultural, country-specific factors). Moreover, I assume that there is an exogenous probability, M, that the TNC's product is imitated by a southern firm.[13]

As a consequence, by charging price $p_F = \lambda$, each TNC makes sales $q_F = c(t)/\lambda$ and earns an instantaneous profit flow

$$\pi_F(t) = \left(1 - \frac{\zeta}{\lambda}\right) c(t) \tag{32}$$

In contrast to Eq. [12], instantaneous profit flow in Eq. [32] decreases in the production cost gap $\zeta > 1$. Therefore, for given c and λ, the instantaneous flow of profits earned by TNC is lower than that earned by northern firms.

Stock market evaluation gives the following capital market no-arbitrage equation

$$\frac{(1-\zeta/\lambda)\, y(t)}{\rho + \iota(1-\xi) + M} = a_F x(t) w_H^S (1+\theta) \tag{33}$$

which can be combined with that of a northern firm to give

$$\frac{\lambda - \zeta}{\lambda - 1} \frac{\theta}{\theta + 1} = \frac{\rho + \iota(1-\xi) + M}{\rho + \iota(1-\xi) + m} \tag{34}$$

Eq. [34] the a key equation of the model since it governs the incentive for northern firms to engage in FDI. The first term on the left-hand side is the relative profit flow of a TNC, whereas the right-hand side is the relative effective discount rate which measures the degree to which TNC profits are deflated relative to the profits of northern firms due to differences in exposure to imitation.

Condition [34] is needed for both free-entry conditions [17] and [33] to hold simultaneously. It also pins down the relative R&D cost θ and relates the relative skilled-wage of the north $\frac{w_H^N}{w_H^S}$ to both relative profit $\frac{\lambda-\zeta}{\lambda-1}$ and relative effective discount rate $\frac{\rho+\iota(1-\xi)+M}{\rho+\iota(1-\xi)+m}$. Provided that producing

[13] This assumption allows me to bring the paper closer to those of Lai (1998), Glass (2004), Dinopoulos and Segerstrom (2005) and Glass and Wu (2005), and also to interpret M as a policy variable that captures the strength with which TNCs' intellectual assets are enforced.

in the south is more costly for northern firms (i.e. $\zeta > 1$), becoming a TNC will be profitable for northern firms only if they face a lower risk of imitation M. Indeed, the cost disadvantage of TNC reduces profits and discourages northern firms from engaging in FDI insofar as the risk of imitation faced by TNCs, M, is larger than that faced by northern firms, m. If the relative cost θ were not to adjust when M started being sufficiently lower than m to attract FDI from abroad, the intensity of FDI would be infinite and northern manufacturing would disappear in the long-run. Therefore, in order to get a BGP with both innovation and FDI, Eq. [34] suggests that as northern firms are increasingly moving their production locations from the north to the south, the relative R&D cost of the north, θ, must decrease to restore the equilibrium. Thus, if a lower imitation rate M were to induce more northern firms to engage in adaptive R&D, an increase in the cost of adaptation would re-establish the equilibrium.

Eq. [34] also highlights the importance of the relative cost θ in attracting FDI. Suppose there are two country in the south where the imitation risk faced by TNC, M, is identical, but where the relative R&D cost of the north θ, differs. Other things equal, northern firms would find it more attractive to invest in the lower cost country than in the higher cost country. In terms of Eq. [34], the left-hand side is greater than the right-hand side, implying that the reduced risk of imitation more than offsets the reduction in profits due to FDI, $\frac{\lambda-\zeta}{\lambda-1}$. Thus, even though two southern countries offer the same strength in protecting IPR, FDI will concentrate in the country where θ is lower; and since individuals are identical in their ability to learning, cross-country differences in relative R&D cost θ are the result of a more efficient education system (measured by differences in the function $h_i(\cdot)$ or by differences in the externality parameter, ϕ). This outcome helps us understand why, despite the dramatic worldwide increase in the strength of IPR protection, the bulk of FDI inflows has been directed to only a limited number of countries (see also UNCTAD (2005)).[14]

4.2 Labor markets

In the north resource constraints remain unchanged, while in the south they change in such a way as to include TNCs' activities. More specifically, Eq. [24] changes to include the new market measures n_F and n_{SF}. At each instant t, $q_F(t)\, n_F$ units of unskilled workers are employed by TNC and $q_{SF}(t)\, n_{SF}$ units of unskilled workers are employed by those southern firms that have been able to displace a TNC from the market.

Once a southern firm has been successful in imitating a TNC's product, it starts producing

[14]Such an analysis has found empirical support at both cross-country and country specific level. Noorbakhsh et al. (2002), for instance, analyzed the determinants of FDI location into 36 developing countries during the period 1984-94 and found that the level of human capital is one of the most important determinants of FDI inflows. In the same vein, Dasgupta et al. (1996) and Kumar (1990) found similar results for some Asian developing economies such as China, Malaysia, Indonesia and India.

at a marginal cost equal to one. With the TNC charging a price equal to the marginal cost ζ, the southern firm is able to capture the entire industry market by setting a price that does not exceed ζ. Since maintaining unused production facilities is costly, the TNC can not do better than exits the market immediately rather than pricing at marginal cost. Thus, using the same strategic considerations as in Section 2.3, each southern firm of type n_{SF} charges price $p_{SF} = \lambda$, makes sales $c(t)/\lambda$, and earns a profit as given by Eq. [13].

As all the firms producing in the south have the same flow of sales, the unskilled labor full-employment condition does not change and is still given by Eq. [24]. However, the skilled-labor full-employment condition in Eq. [25] changes to include the mass of skilled workers doing adaptive R&D, $n_N a_F F x$, and becomes

$$n_N x \left(a_S m (1+\mu) + a_F F\right) = h_S \left(\bar{D}_S\right) B_S \left(\bar{D}_S\right) (1-\psi_S) \frac{\ell_S(t)}{\ell_N(t)} \tag{35}$$

As in the model in the previous section, any increase in n_N increases the aggregate stock of skills of the economy.

4.3 The BGP equilibrium

Let us now analyze the BGP equilibrium properties of the model. The flow into production by TNC must equal the flow of TNC driven out of business because of both innovation and imitation: $F n_N = (\iota + M) n_F$. The flow into the pure southern production because of imitation must equal the flow of southern firms driven out business by innovation: $m n_N = \iota n_{SN}$, and $M n_F = \iota n_{SF}$. Finally, the flow into northern production must equal the flow out due to both imitation and FDI; i.e. $\iota(1 - n_N) = (m + F) n_N$. Rearranging this equilibrium condition, it is easy to verify that a BGP equilibrium requires

$$F n_N = \iota - (\iota + m) n_N \tag{36}$$

Repeating the reasoning of Section 2.7, shows that even in the presence of TNC the BGP innovation rate is constant and is given by Eq. [26]. Thus, adding TNC does not change the rate at which firms innovate over time. Using Eq. [9] to substitute for the skill premium, the relative R&D cost becomes

$$\theta = \frac{a_N}{a_F} \frac{\sigma_N \left(h_N \left(\bar{D}_N\right)\right)^{-1/(1-\phi)} \left(B_N \left(\bar{D}_N\right)(1-\psi_N)\right)^{-\phi/(1-\phi)}}{\sigma_S \left(h_S \left(\bar{D}_S\right)\right)^{-1/(1-\phi)} \left(B_S \left(\bar{D}_S\right)(1-\psi_S)\right)^{-\phi/(1-\phi)}} w_L^N \tag{37}$$

which only depends on the proportion of unskilled workers within the employed population in both the north and the south.

Plugging the BGP innovation rate (Eq. [26]), equilibrium condition (Eq. [36]), and the relative R&D cost (Eq. [37]), into the no-arbitrage conditions given by Eqs. [17], [19] and [34], and the labor market full-employment conditions in Eqs. [22], [23], [24] and [35], the resulting expressions form a system of seven equations in seven unknowns: the northern population-adjusted global consumption expenditure y; the relative R&D difficulty, x; the rate of imitation of northern firms' products, m; the relative manufacturing cost of the north, w_L^N; the share of northern products in the total volume of products, n_N; the northern supply of unskilled labor, ψ_N; and the southern supply of unskilled labor, ψ_S. Substituting Eqs. [19] and [34] into Eq. [17], and solving the resulting expression for the rate of imitation of imported products gives

$$m^* = \frac{(1+\mu)\frac{a_S}{a_F}}{(1+\mu)\frac{a_S}{a_F}\frac{(\lambda-\zeta)/(\lambda-1)}{\rho+(1-\xi)(g/\xi)+M} - \frac{1}{\rho+(1-\xi)(g/\xi)}} - (\rho + (g/\xi)(1-\xi)) \tag{38}$$

According to Eq. [38], the BGP imitation rate of northern products negatively depends on μ and positively on M.[15] This means that, as the south reduces the risk of imitation of TNC and increases FDI inflows, it also slows down the rate at which imported products are imitated by local firms. This result is not surprising and relies on the fact that the presence of TNC increases the cost of R&D in the south. By contrast, the negative effects of μ on m^* follow the same reasoning of Section 3 faithfully.

Finally, using the [9] to substitute for the skill premium in the remaining equations, the BGP system can be reduced to the following pair of BGP equations[16]

$$x^{1-\phi} = \frac{\frac{(\lambda-1)\frac{\ell_S}{\ell_N}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}}{\frac{(1+\mu)a_S\sigma_S}{\left(B_S\left(\bar{D}_S\right)\right)^{1/(1-\phi)}\left(h_S\left(\bar{D}_S\right)(\Psi n_N+\Gamma)\right)^{\phi/(1-\phi)}} + \frac{(\lambda-1)\frac{\ell_S}{\ell_N}(\Psi n_N+\Gamma)^{1-\phi}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}} \tag{39}$$

and

$$x^{1-\phi} = \frac{n_N\Lambda - (1-n_N)(\Psi n_N+\Gamma)^{\phi/(1-\phi)}}{n_N\Lambda(\Psi n_N+\Gamma)^{1/(1-\phi)} - (1-n_N)(\Psi n_N+\Gamma)^{\phi/(1-\phi)}} \tag{40}$$

where Λ, Ψ, and Γ are all exogenously given (see Appendix C).

Eq. [39] is the BGP imitative R&D condition while Eq. [40] is the BGP FDI condition. Both curves increase in (n_N, x) space and intersect for $n_N \in (0,1)$.[17] Thus, a BGP equilibrium with the following characteristics exists.

Proposition 4 *When the relative R&D cost is not too high, there exists a unique balanced-growth path in which:* (*a*) *the long-run rate of innovation is positive and exogenously defined by Eq. (26);* (*b*) *both FDI and imitation are active channels of technology transfer; and* (*c*) *both aggregate stocks*

[15] This statement can easily be checked by considering the first derivative with respect to μ and M. For details see Appendix C.

[16] For the analytical details and the proof of the existence of the steady-state equilibrium, see Appendix C.

[17] For the sake of completeness, the system also has an intersection when $n_N \geq 1$. As I am interested only in those solutions for which n_N lies within the interval $(0, 1)$, I will not discuss this outcome.

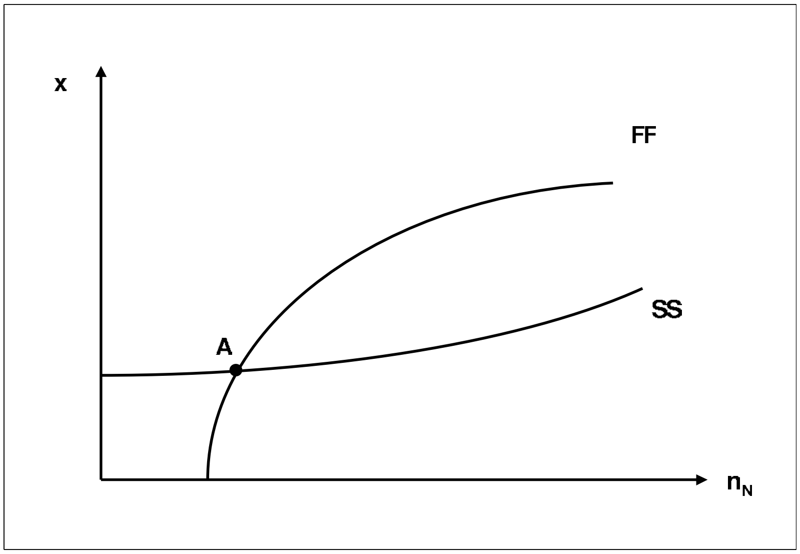

Figure 3: The BGP equilibrium with FDI

of skills in the north and the south are determined endogenously by the full-employment conditions [23] and [35].

Proof. see Appendix C. ■

The BGP equilibrium is represented by point A of Figure 3. The label "SS" stands for BGP imitation condition [39] and the label "FF" stands for BGP FDI condition [40]. As in Section 3, the remaining endogenous variables are completely determined recursively.

Let us now study the BGP impact of an increase in the level of IPR protection. From Eq. [38] I know that strengthening IPR protection generates a reduction in the stream of technology transfer occurring through imported products. As regards FDI technology transfer, differentiating Eq. [36] with respect to μ gives:

$$\frac{dF}{d\mu} = -\left(\frac{dm}{d\mu} + \frac{g}{\xi n_N^2}\frac{dn_N}{d\mu}\right)$$

which turns out to be ambiguous for any $\phi \in (0,1)$ because of the presence of the $\frac{dn_N}{d\mu}$ term on the right-hand side.[18]

Observe that this finding does not neglect the use of IPR as a tool to attract technology through FDI. What is more plausible is that the effectiveness of stronger IPR regimes is fairly industry specific, with the consequence that IPR are more effective in attracting FDI in those industrial environment where imitation is relatively less difficult for competent people. Nevertheless, devel-

[18] More specifically, the sign of $\partial n_N/\partial\mu$ is ambiguous and turns out to depend on both starting n_N and the size of the exogenous parameters. For details, see Appendix D.

oping countries might affect the geographical distribution of FDI by pursuing policies that raise the level of local skill.

5 Conclusions

In this paper I have studied the effect of strengthening IPR protection on the rate of innovation, the rate of technological transfer, and the incentives to skills accumulation, in an open-economy, R&D-based growth model. I found that a stronger IPR regime in the south has only a temporary effect on the worldwide innovation rate, whereas it undoubtedly hurts the rate of technology transfer via a permanent fall in the long-run rate of imitation.

In the north, strengthening IPR protection in the south leads to a permanent decrease in the local level of skill due to a reduction in individuals' incentive to acquire education, and generates an increase in the northern skill premium that, in turn, exacerbates the domestic wage inequality. In the south, the balanced-growth equilibrium effect of strengthening IPR protection is twofold and has both microeconomic and macroeconomic implications. The microeconomic effects are negative and lead to a reduction in the industry-wide R&D employment, whereas the macroeconomic effects are positive and turn out to depend on the externality that skill accumulation generates on the process of education. When the externality is higher than a threshold, more IPR protection in the south increases the BGP stock of skills and reduces the within-country wage inequality. On the contrary, when the externality is lower than the threshold, stronger IPR protection scales down the BGP stock of skills and increases the within-country wage inequality.

In an extension of the model, I have also shown that when two different sources of technology transfer (imitation and FDI) are present in the BGP, skills play a crucial role in attracting inflow FDI, and strengthening IPR protection in the south may be ineffective in attracting technological knowledge to those economic systems in which the level of local skills is low and the cost of the existing human capital is too expensive to encourage northern producers to adapt their technology for the south. Whenever local skills are affordable, I found that strengthening IPR protection shrinks the flow of technology from imitation of imported products while generates mixed effects for that from FDI.

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A Proof of Proposition 1

I first demonstrate that the BGP equilibrium exists for $\phi \in [0,1)$. After substitution, the BGP system consists of the six equations

$$\frac{(1-1/\lambda)\, y}{\rho+\iota\,(1-\xi)+m} = a_N x \omega_N w_L^N \tag{41}$$

$$\frac{(1-1/\lambda)\, y}{\rho+\iota\,(1-\xi)} = (1+\mu)\, a_S x \omega_S \tag{42}$$

$$\frac{g}{g+\xi m}\frac{y}{\lambda w_L^N} = \psi_N \tag{43}$$

$$a_N x \iota = \left(h_N\left(\bar{D}_N\right) B_N\left(\bar{D}_N\right)(1-\psi_N)\right)^{1/(1-\phi)} \tag{44}$$

$$\frac{\xi m}{g+\xi m}\frac{y}{\lambda} = \psi_S \frac{\ell_S}{\ell_N} \tag{45}$$

$$a_N\,(1+\mu)\, m x \frac{g}{g+\xi m} = \left(h_S\left(\bar{D}_S\right) B_S\left(\bar{D}_S\right)(1-\psi_S)\right)^{1/(1-\phi)} \frac{\ell_S(t)}{\ell_N(t)} \tag{46}$$

Firstly, I plug Eqs. [43] and [44] into Eq. [41], and Eqs. [45] and [46] into Eq. [42]. Secondly, I solve the resulting expressions for $x^{1-\phi}$ and substitute Eq. [9] for ω_i, $i \in \{N,S\}$. The result is the two BGP conditions [28] and [29]. Next, I differentiate [28] and [29] with respect to x and m and get

$$\left.\frac{dx}{dm}\right|_N = \frac{(\lambda-1)(\rho-g)\,\xi^2\left(\frac{g}{\xi}a_N\right)^{\phi-1}(\Gamma_N)^2\,\sigma_N}{\left((\lambda-1)(g+\xi m)+(\xi\rho+(1-\xi)\,g+m)\,\Gamma_N\sigma_N\right)^2}\frac{x^\phi}{1-\phi} > 0$$

and

$$\left.\frac{dx}{dm}\right|_S = -\frac{g^2(\lambda-1)\left(a_S\,(1+\mu)\frac{gm}{g+\xi m}\frac{\ell_N}{\ell_S}\right)^{\phi-1}\Gamma_S x^\phi}{m\,(g+\xi m)\left(g\,(\lambda-1)+(\xi\rho+(1-\xi)\,g)\,\Gamma_S\sigma_S\right)} < 0$$

Because both Eqs. [28] and [29] are monotonic functions in (m,x) space, a unique intersection of the two curves in the positive orthant exists.

B Proof of Propositions 2 and 3

In this appendix, I provide a formal proof of the results stated in Propositions 2 and 3. Differentiation of Eqs. [28] and [29] with respect to the two endogenous variables $\{m,x\}$ and the institutional parameter μ yields

$$B \cdot \begin{bmatrix} \frac{dm}{d\mu} \\ \frac{dx}{d\mu} \end{bmatrix} = \begin{bmatrix} 0 \\ -\frac{m(g+\xi m)}{g(1+\mu)} b_{21} \end{bmatrix}$$

where

$$B = \begin{bmatrix} b_{11} & (1-\phi)\, x^{-\phi} \\ b_{21} & (1-\phi)\, x^{-\phi} \end{bmatrix}$$

and

$$b_{11} = -\frac{(\lambda-1)(\rho-g)\,\xi^2 \left(\frac{g}{\xi} a_N\right)^{\phi-1} \left(B_N\left(\bar{D}_N\right) h_N\left(\bar{D}_N\right)\right)^2 \sigma_N}{\left((\lambda-1)(g+\xi m) + (\xi(\rho-g)+g+m)\, B_N\left(\bar{D}_N\right) h_N\left(\bar{D}_N\right) \sigma_N\right)^2} < 0 \tag{47}$$

$$b_{21} = \frac{g^2(\lambda-1)(1-\phi)\, B_S\left(\bar{D}_S\right) h_S\left(\bar{D}_S\right) \left(\frac{gm}{g+\xi m}\frac{\ell_N}{\ell_S} a_S (1+\mu)\right)^{\phi-1}}{m(g+\xi m)\left(g(\lambda-1) + (\xi(\rho-g)+g)\, B_S\left(\bar{D}_S\right) h_S\left(\bar{D}_S\right) \sigma_S\right)} > 0 \tag{48}$$

The Jacobian matrix is invertible with a strictly negative determinant equal to

$$|B| = \frac{1-\phi}{x^{\phi}}\left[b_{11} - b_{21}\right] < 0$$

I now define two auxiliary matrices

$$B_m \equiv \begin{bmatrix} 0 & (1-\phi)\, x^{-\phi} \\ -\frac{m(g+\xi m)}{g(1+\mu)} b_{21} & (1-\phi)\, x^{-\phi} \end{bmatrix}$$

and

$$B_x \equiv \begin{bmatrix} b_{11} & 0 \\ b_{21} & -\frac{m(g+\xi m)}{g(1+\mu)} b_{21} \end{bmatrix}$$

with determinants

$$|B_m| \equiv \frac{1-\phi}{x^{\phi}} \frac{m(g+\xi m)}{g(1+\mu)} b_{21} > 0$$

and

$$|B_x| \equiv -\frac{m(g+\xi m)}{g(1+\mu)} b_{21} b_{11} > 0$$

Using the Cramer rule, I get the following comparative statics

$$\frac{dm}{d\mu} = \frac{|B_m|}{|B|} = \frac{m(g+\xi m)\, b_{21}}{g(1+\mu)(b_{11}-b_{21})} < 0 \tag{49}$$

and

$$\frac{dx}{d\mu} = \frac{|B_x|}{|B|} = -\frac{m x^{-\phi}(g+\xi m)\, b_{11} b_{21}}{g(1+\mu)(1-\phi)(b_{11}-b_{21})} < 0 \tag{50}$$

which demonstrate points a) and b) of Proposition 2.

To demonstrate points a) and b) of Proposition 3, Eqs. [23] and [25] must be differentiated with respect to μ. The BGP impact on the economy-wide R&D employment, $1-\psi_N$, is negative since

$$\frac{d\psi_N}{d\mu} = -\frac{(1-\phi)\left(a_N\left(g/\xi\right)\right)^{1-\phi} x^{-\phi}}{h_N\left(\bar{D}_N\right)B_N\left(\bar{D}_N\right)}\frac{dx}{d\mu} > 0$$

while its impact on the economy-wide R&D employment in the south is not clear and equals

$$\frac{d\psi_S}{d\mu} = -\frac{(1-\phi)\left(\frac{a_S g(1+\mu)}{g+\xi m}\frac{\ell_N}{\ell_S}\right)^{1-\phi}(mx)^{-\phi}}{h_S\left(\bar{D}_S\right)B_S\left(\bar{D}_S\right)}\left[x\frac{dm}{d\mu} + m\left(\frac{x}{1+\mu}+\frac{dx}{d\mu}\right)\right]$$

It is easy to see that the effect of more IPR protection in the south on ψ_S depends on the sign of the expression between brackets.

Lemma 1 *: There exists a $\phi^* \in (0,1)$, such that for $\phi > \phi^*$ the following inequality*

$$x\frac{dm}{d\mu} + m\left(\frac{x}{1+\mu}+\frac{dx}{d\mu}\right) > 0$$

holds and the BGP impact of a stronger IPR regime generates an increase in the BGP aggregate R&D employment in the south.

Proof. The function $T(\phi)$ is defined as

$$T(\phi) \equiv x\frac{m(g+\xi m)b_{21}}{g(1+\mu)(b_{11}-b_{21})} + m\left(\frac{x}{1+\mu} - \frac{mx^{-\phi}(g+\xi m)b_{11}b_{21}}{g(1+\mu)(1-\phi)(b_{11}-b_{21})}\right)$$

where Eqs. [49] and [50] has been used to substituted for $\frac{dm}{d\mu}$ and $\frac{dx}{d\mu}$, respectively. The function $T(\phi)$ is monotonic when $\phi \in [0,1)$, with $T'(\phi) < 0$. When $\phi = 0$, b_{11} and b_{21}become (see Eqs. [47] and [48])

$$\check{b}_{11} = -\frac{(\lambda-1)(\rho-g)\xi^3\left(B_N\left(\bar{D}_N\right)h_N\left(\bar{D}_N\right)\right)^2\sigma_N}{ga_N\left((g+\xi m)(\lambda-1)+B_N\left(\bar{D}_N\right)h_N\left(\bar{D}_N\right)\sigma_N\left(\xi\rho+(1-\xi)g+m\right)\right)^2} < 0$$

and

$$\check{b}_{21} = \frac{g(\lambda-1)B_S\left(\bar{D}_S\right)h_S\left(\bar{D}_S\right)}{m^2 a_S(1+\mu)\left(g(\lambda-1)+B_S\left(\bar{D}_S\right)h_S\left(\bar{D}_S\right)\sigma_S\left(\xi(\rho-g)+g\right)\right)}\frac{\ell_S}{\ell_N} > 0$$

In order to simplify the analysis, I analyze the sign of $T(\phi=0)$ in the limit as the difference between the subjective discount rate and the growth rate of population becomes trivial (i.e., $\rho \to g$) and $\mu = 0$. Using these tricks, $T(\phi=0)$ is strictly negative and

$$T(\phi=0) = -\frac{m^2 x\xi}{g} < 0$$

When $\phi \to 1$, b_{11} and b_{21} become

$$\hat{b}_{11} = -\frac{(\lambda-1)(\rho-g)\xi^2(\Gamma_N)^2\sigma_N}{\left((\lambda-1)(g+\xi m)+(\xi\rho+(1-\xi)g+m)\Gamma_N\sigma_N\right)^2} < 0$$

and

$$\hat{b}_{21} = 0$$

By continuity of $T(\phi)$ on the left of $\phi = 1$, the impact on the BGP of imitation is nil (i.e., $\frac{dm}{d\mu} = 0$) and the objective function reduces to

$$T(\phi = 1) = \frac{mx}{1+\mu} > 0$$

which is strictly positive. ■

Point b) of Proposition 1 also establishes that strengthening IPR protection in the south generates a permanent decrease in the industry-wide R&D employment. The industry-wide R&D technology of Section 2.3 can be summarized by

$$m(z) = \frac{\vartheta(z)\frac{\ell_t^S}{\ell_t^N}}{(1+\mu)x} \tag{51}$$

where $\vartheta(z)$ stands for the industry-wide stock of human capital in the zth industry.

Differentiating Eq. [51] with respect to μ yields

$$\frac{dm}{d\mu}\frac{x(1+\mu)}{m} + \frac{dx}{d\mu}\frac{1+\mu}{x} = \frac{d\vartheta}{d\mu}\frac{1}{m\vartheta} - x \tag{52}$$

Since $\frac{dm}{d\mu} < 0$ and $\frac{dx}{d\mu} < 0$, Eq. [52] holds if, and only if, $\partial\vartheta/\partial\mu < 0$. This result demonstrates the point b of Proposition 3.

Finally, in order to demonstrate point d) of Proposition 3, I differentiate Eq. [9] with respect to μ and get

$$\frac{d\omega_i}{d\mu} = \frac{\phi}{1-\phi}\frac{\sigma_i B_i\left(\bar{D}_i\right)}{\left(h_i\left(\bar{D}_i\right)B_i\left(\bar{D}_i\right)(1-\psi_i)\right)^{1/(1-\phi)}}\frac{d\psi_i}{d\mu}$$

which turns out to be positive for the north and negative for the south for $\phi \in (\phi^*, 1)$.

C Proof of proposition 4

This appendix provides a formal proof of the existence of a BGP equilibrium in the extent to which TNC are active in the equilibrium. The BGP system is formed by the following seven equations

$$\frac{(1-1/\lambda)y}{\rho + (g/\xi)(1-\xi) + m} = a_N x \omega_N w_L^N \tag{53}$$

$$\frac{(1-1/\lambda)y}{\rho + (g/\xi)(1-\xi)} = (1+\mu)a_S x \omega_S \tag{54}$$

$$\frac{\lambda-\zeta}{\lambda-1} = \frac{\rho + (g/\xi)(1-\xi) + M}{\rho + (g/\xi)(1-\xi) + m}\left(1 + \frac{a_F\omega_S}{a_N\omega_N}\frac{1}{w_L^N}\right) \tag{55}$$

$$\frac{n_N}{\lambda w_L^N} y = \psi_N \tag{56}$$

$$a_N x \left(g/\xi\right) = \left(h_N \left(\bar{D}_N\right) B_N \left(\bar{D}_N\right) \left(1 - \psi_N\right)\right)^{1/(1-\phi)} \tag{57}$$

$$\frac{1 - n_N}{\lambda} y = \psi_S \frac{\ell_S}{\ell_N} \tag{58}$$

$$\left(\left(a_S \left(1 + \mu\right) - a_F\right) n_N m + \left(1 - n_N\right) \left(g/\xi\right) a_F\right) x = \left(h_S \left(\bar{D}_S\right) B_S \left(\bar{D}_S\right) \left(1 - \psi_S\right)\right)^{\frac{1}{1-\phi}} \frac{\ell_S(t)}{\ell_N(t)} \tag{59}$$

First, I reduce the dimension of the system by substituting for w_L^N and y Eqs. [56] and [57]. The resulting equations are

$$\frac{\left(\lambda - 1\right) \psi_N}{\left(\rho + \left(g/\xi\right)\left(1 - \xi\right) + m\right) n_N} = a_N x \omega_N \tag{60}$$

$$\frac{\left(\lambda - 1\right) \psi_S \frac{\ell_S}{\ell_N}}{\left(\rho + \left(g/\xi\right)\left(1 - \xi\right)\right)\left(1 - n_N\right)} = \left(1 + \mu\right) a_S x \omega_S \tag{61}$$

and

$$\frac{1 - n_N}{n_N} = \frac{\psi_S a_N \omega_N}{\psi_N a_F \omega_S} \left(\frac{\lambda - \zeta}{\lambda - 1} \frac{\rho + \left(g/\xi\right)\left(1 - \xi\right) + M}{\rho + \left(g/\xi\right)\left(1 - \xi\right) + m} - 1\right) \tag{62}$$

Inserting Eqs. [61] and [62] into Eq. [60] gives the following expression that implicitly gives the BGP rate of imitation of imported products

$$\frac{\rho + \left(g/\xi\right)\left(1 - \xi\right) + m^*}{\rho + \left(g/\xi\right)\left(1 - \xi\right)} = \left(1 + \mu\right) \frac{a_S}{a_F} \left(\frac{\rho + \left(g/\xi\right)\left(1 - \xi\right) + m^*}{\rho + \left(g/\xi\right)\left(1 - \xi\right) + M} \frac{\lambda - \zeta}{\lambda - 1} - 1\right) \tag{63}$$

where m^* is the solution of Eq. [63].

Differentiation with respect to μ gives

$$\frac{dm^*}{d\mu} = -\frac{\frac{a_S}{a_F}\left(\rho + \left(1 - \xi\right)\left(g/\xi\right)\right)\left(\rho + \left(1 - \xi\right)\left(g/\xi\right) + M\right)^2}{\left(\frac{a_S}{a_F}\frac{\lambda - \zeta}{\lambda - 1}\left(\rho + \left(1 - \xi\right)\left(g/\xi\right)\right)\left(1 + \mu\right) - \rho - \left(1 - \xi\right)\left(g/\xi\right) - M\right)^2} < 0$$

and differentiation with respect to M gives

$$\frac{dm^*}{dM} = \frac{\lambda - \zeta}{\lambda - 1} \frac{\left(\rho + \left(1 - \xi\right)\left(g/\xi\right)\right)^2 \left(\left(1 + \mu\right)\frac{a_S}{a_F}\right)^2}{\left(\left(\left(1 + \mu\right)\frac{a_S}{a_F}\left(\frac{\lambda - \zeta}{\lambda - 1}\right) - 1\right)\left(\rho + \left(1 - \xi\right)\left(g/\xi\right)\right) - M\right)^2} > 0$$

Eq. [63] replaces Eq. [60] in the computation of the other endogenous variables. Given m^*, Eqs. [57] and [59] can be simplified as follows

$$\psi_N = 1 - a_N \left(\frac{\Gamma}{a_F}\right)^{1-\phi} x^{1-\phi} \tag{64}$$

$$\psi_S = 1 - (\Psi n_N + \Gamma)^{1-\phi} x^{1-\phi} \tag{65}$$

where

$$\Psi \equiv \frac{(a_S(1+\mu) - a_F)\, m^* - (g/\xi)\, a_F}{\left(h_N(\bar{D}_N)\, B_N(\bar{D}_N)\right)^{1/(1-\phi)}} \ and\ \Gamma \equiv \frac{(g/\xi)\, a_F}{\left(h_N(\bar{D}_N)\, B_N(\bar{D}_N)\right)^{1/(1-\phi)}}$$

with $\partial\Psi/\partial\mu > 0$

Putting Eqs. [64] and [65] into Eq. [9] gives

$$\omega_N = \frac{\sigma_N}{\left(B_N(\bar{D}_N)\right)^{1/(1-\phi)} \left(h_N(\bar{D}_N)\, a_N \left(\frac{\Gamma}{a_F}\right)^{1-\phi}\right)^{\phi/(1-\phi)} x^{\phi}}$$

$$\omega_S = \frac{\sigma_S}{\left(B_S(\bar{D}_S)\right)^{1/(1-\phi)} \left(h_S(\bar{D}_S)(\Psi n_N + \Gamma)\right)^{1/(1-\phi)} x^{\phi}} \tag{66}$$

and

$$\frac{\omega_S}{\omega_N} = \frac{\sigma_S}{\sigma_N} \left(\frac{\Gamma}{a_F}\right)^{\phi} \left(\frac{B_N(\bar{D}_N)}{B_S(\bar{D}_S)}\right)^{1/(1-\phi)} \left(\frac{h_N(\bar{D}_N)\, a_N}{h_S(\bar{D}_S)(\Psi n_N + \Gamma)}\right)^{\phi/(1-\phi)} \tag{67}$$

Finally, putting Eqs. [64], [65], [66] and [67], into Eqs. [61] and [62], I get the pair of BGP equations

$$\frac{(\lambda - 1)\left(1 - (\Psi n_N + \Gamma)^{1-\phi} x^{1-\phi}\right) \frac{\ell_S}{\ell_N}}{(\rho + (g/\xi)(1-\xi))(1 - n_N)} = \frac{(1+\mu)\, a_S \sigma_S x^{1-\phi}}{\left(B_S(\bar{D}_S)\right)^{1/(1-\phi)} \left(h_S(\bar{D}_S)(\Psi n_N + \Gamma)\right)^{\phi/(1-\phi)}} \tag{68}$$

$$\frac{1 - n_N}{n_N} = \frac{1 - (\Psi n_N + \Gamma)^{1-\phi} x^{1-\phi}}{1 - \Psi x^{1-\phi}} \frac{\Lambda}{(\Psi n_N + \Gamma)^{\phi/(1-\phi)}} \tag{69}$$

where

$$\Lambda = \frac{a_N}{a_F} \frac{\sigma_S}{\sigma_N} \left(\frac{B_N(\bar{D}_N)}{B_S(\bar{D}_S)}\right)^{1/(1-\phi)} \left(\frac{h_N(\bar{D}_N)\, a_N \left(\frac{\Gamma}{a_F}\right)^{1-\phi}}{h_S(\bar{D}_S)}\right)^{\phi/(1-\phi)} \left(\frac{\lambda - \zeta}{\lambda - 1} \frac{\rho + (g/\xi)(1-\xi) + M}{\rho + (g/\xi)(1-\xi) + m^*} - 1\right)$$

with $\partial\Lambda/\partial\mu > 0$.

Rearranging terms, it is possible to rewrite Eqs. [68] and [69] as

$$x^{1-\phi} = \frac{\frac{(\lambda-1)\frac{\ell_S}{\ell_N}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}}{\frac{(1+\mu)a_S\sigma_S}{\left(B_S(\bar{D}_S)\right)^{1/(1-\phi)}\left(h_S(\bar{D}_S)(\Psi n_N+\Gamma)\right)^{\phi/(1-\phi)}} + \frac{(\lambda-1)\frac{\ell_S}{\ell_N}(\Psi n_N+\Gamma)^{1-\phi}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}}$$

$$x^{1-\phi} = \frac{n_N \Lambda - (1 - n_N)(\Psi n_N + \Gamma)^{\phi/(1-\phi)}}{n_N \Lambda (\Psi n_N + \Gamma)^{1/(1-\phi)} - (1 - n_N)(\Psi n_N + \Gamma)^{\phi/(1-\phi)}}$$

which can be plotted in (n_N, x) space.

D Comparative statics analysis with FDI

In this Appendix I provide a an analytical demonstration of the intractability of the comparative statics of the model in the presence of FDI. Rewrite the BGP equilibrium system on page 23 as

$$x^{1-\phi} - f_S\left(n_N, \mu\right) = 0$$

$$x^{1-\phi} - f_F\left(n_N, \mu\right) = 0$$

where

$$f_S\left(n_N, \mu\right) \equiv \frac{\frac{(\lambda-1)\frac{\ell_S}{\ell_N}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}}{\frac{(1+\mu)a_S\sigma_S}{\left(B_S\left(\bar{D}_S\right)\right)^{1/(1-\phi)}\left(h_S\left(\bar{D}_S\right)(\Psi n_N+\Gamma)\right)^{\phi/(1-\phi)}} + \frac{(\lambda-1)\frac{\ell_S}{\ell_N}(\Psi n_N+\Gamma)^{1-\phi}}{(\rho+(g/\xi)(1-\xi))(1-n_N)}}$$

and

$$f_F\left(n_N, \mu\right) \equiv \frac{n_N\Lambda - \left(1-n_N\right)\left(\Psi n_N + \Gamma\right)^{\phi/(1-\phi)}}{n_N\Lambda\left(\Psi n_N + \Gamma\right)^{1/(1-\phi)} - \left(1-n_N\right)\left(\Psi n_N + \Gamma\right)^{\phi/(1-\phi)}}$$

Total differentiation gives

$$\left(1-\phi\right)x^{-\phi} - \frac{\partial f_S}{\partial n_N}dn_N - \frac{\partial f_S}{\partial \mu}d\mu = 0$$

$$\left(1-\phi\right)x^{-\phi} - \frac{\partial f_F}{\partial n_N}dn_N - \frac{\partial f_F}{\partial \mu}d\mu = 0$$

or in matrix form:

$$\begin{bmatrix} \left(1-\phi\right)x^{-\phi} & -\frac{\partial f_S}{\partial n_N} \\ \left(1-\phi\right)x^{-\phi} & -\frac{\partial f_F}{\partial n_N} \end{bmatrix} \cdot \begin{bmatrix} \frac{dx}{d\mu} \\ \frac{dn_n}{d\mu} \end{bmatrix} = \begin{bmatrix} \frac{\partial f_S}{\partial \mu} \\ \frac{\partial f_F}{\partial \mu} \end{bmatrix}$$

The determinant of the Jacobian on the left-hand side reads

$$D_P \equiv \left(1-\phi\right)x^{-\phi}\left(\frac{\partial f_S}{\partial n_N} - \frac{\partial f_F}{\partial n_N}\right)$$

Observe that $\frac{\partial f_S}{\partial n_N} > 0$ and $\frac{\partial f_F}{\partial n_N} > 0$ for any $n_N \in (0,1)$. However, as shown by Figure 3, there exists a $n_N^* \in (0,1)$ such that $\frac{\partial f_F}{\partial n_N} > \frac{\partial f_S}{\partial n_N}$ for $n_N \in (0, n_N^*)$ and $\frac{\partial f_F}{\partial n_N} \leq \frac{\partial f_S}{\partial n_N}$ for $n_N \in [n_N^*, 1)$. As a result, the sign of D_P is not clear-cut and crucially depends on starting n_N.

To simplify the analysis, I perform the comparative statics by assuming $\phi = 0$ and $\ell_S = \ell_N$. Using the Cramer's rule yields

$$\frac{dx}{d\mu} = \frac{1}{D_P}\left(\frac{\partial f_F}{\partial n_N}\frac{\partial f_S}{\partial \mu} - \frac{\partial f_S}{\partial n_N}\frac{\partial f_F}{\partial \mu}\right)$$

and

$$\frac{dn_N}{d\mu} = \frac{(1-\phi)\, x^{-\phi}}{D_P} \left(\frac{\partial f_S}{\partial \mu} - \frac{\partial f_F}{\partial \mu} \right)$$

where

$$\frac{\partial f_F}{\partial \mu} = -\frac{(\lambda - 1)\, B_S\left(\bar{D}\right)\left(\left(\frac{g}{\xi}(1-\xi)+\rho\right) a_S (1-n_N)\, \sigma_S + (\lambda-1)\, B_S\left(\bar{D}\right) n_N \frac{\partial \Psi}{\partial \mu}\right)}{\left(\left(\frac{g}{\xi}(1-\xi)+\rho\right)(1+\mu)\, a_S (1-n_N)\, \sigma_S + (\lambda-1)\, B_S\left(\bar{D}\right)(\Gamma + n_N \Psi)\right)^2} < 0$$

and

$$\begin{aligned} \frac{\partial f_S}{\partial \mu} &= \frac{n_N \frac{\partial \Lambda}{\partial \mu}}{n_N (\Gamma + n_N \Psi)\, \Lambda - (1-n_N)} + \\ &\quad - \frac{n_N \left(n_N \Lambda(\mu) - (1-n_N)\right)\left((\Gamma + n_N\Psi) \frac{\partial \Lambda}{\partial \mu} + n_N \Lambda \frac{\partial \Psi}{\partial \mu}\right)}{\left(n_N (\Gamma + n_N \Psi)\, \Lambda - (1-n_N)\right)^2} \\ &\lesseqgtr 0 \end{aligned}$$

The sign of $\frac{\partial f_S}{\partial \mu}$ is ambiguous and turns out to depend on both exogenous parameters and starting n_N. Observe that $\frac{\partial f_S}{\partial \mu}$ is non-monotonic for $n_N \in (0,1)$. Taking limit yields

$$\lim_{n_N \to 0} \frac{\partial f_S}{\partial \mu} = 0 \qquad \textit{and} \qquad \lim_{n_N \to 1} \frac{\partial f_S}{\partial \mu} = -\frac{1}{(\Gamma + \Psi)^2} \frac{\partial \Psi}{\partial \mu} < 0$$

This means that the sign of $\frac{\partial f_S}{\partial \mu}$ depends on starting n_N and might change with it. For instance, for values of n_N approaching 0 the comparative statics analysis leads to:

$$\frac{dx}{d\mu} = -\frac{1}{D_P} \left(\frac{\partial f_S}{\partial n_N} \frac{\partial f_F}{\partial \mu} \right) > 0$$

and

$$\frac{dn_N}{d\mu} = -\frac{(1-\phi)\, x^{-\phi}}{D_P} \left(\frac{\partial f_F}{\partial \mu} \right) < 0$$

while, for values of n_N approaching 1, results are ambiguous and read

$$\frac{dx}{d\mu} = \frac{1}{D_P} \left(\frac{\partial f_F}{\partial n_N} \frac{\partial f_S}{\partial \mu} - \frac{\partial f_S}{\partial n_N} \frac{\partial f_F}{\partial \mu} \right) \lesseqgtr 0$$

and

$$\frac{dn_N}{d\mu} = \frac{(1-\phi)\, x^{-\phi}}{D_P} \left(\frac{\partial f_S}{\partial \mu} - \frac{\partial f_F}{\partial \mu} \right) \lesseqgtr 0$$

Moreover, for values on n_N in the range $(0,1)$, the model is intractable and results turn out to depends on the size of the exogenous parameters (i.e., ρ, g, ξ, μ, M, λ, a_N, a_S and a_F).