

NORTH-SOUTH TRADE, UNEMPLOYMENT AND GROWTH: WHAT'S THE ROLE OF LABOR UNIONS?

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Abstract: We construct a North-South product-cycle model of trade with fully-endogenous growth in which both countries experience unemployment due to union wage bargaining. We show that the existence of labor unions matters for trade liberalization to have any effect on Northern innovation and worldwide growth. We find that unilateral Northern trade liberalization reduces growth and increases unemployment in both countries, while unilateral Southern trade liberalization has the opposite effects. For empirically plausible parameter values, bilateral trade liberalization by equal amounts increases growth and reduces unemployment in both countries. Stronger Northern labor unions hurt both countries by reducing growth and increasing unemployment. However, stronger Southern labor unions exert a positive growth effect for both countries, while decreasing Northern unemployment and increasing Southern unemployment.

Keywords: endogenous growth, labor unions, unemployment, trade liberalization, product cycle

JEL classification: O31, F16, F43, J51

1 Introduction

The impact of trade liberalization on long-run economic growth still remains a controversial issue and hence a matter of ongoing interest for both theoretical and empirical research (Segerstrom 2011, Estevadeordal and Taylor 2008). While being convenient for modeling purposes, the early literature's focus on the effects of switching from autarky to free trade can be analytically misleading and empirically misspecified, as forcefully argued by Baldwin and Forslid (1999, pp. 798-799).

The alternative is to investigate the question by considering marginal reductions in trade barriers, that is, incremental trade liberalization. Indeed, a small body of literature has taken up this approach, but mostly used symmetric North-North settings and exclusively assumed perfectly competitive labor markets [see for example Dinopoulos and Syropoulos (1997), Baldwin and Forslid (1999), Dinopoulos and Segerstrom (1999), and Naito (2012)]. The focus of this literature on North-North settings and flexible wages is surprising given the well-established integration of the South with the North and the importance of labor unions and wage bargaining in both regions. Recently, Dinopoulos and Segerstrom (2007) and Grieben and Şener (2009) have studied the growth effects of incremental trade liberalization using asymmetric North-South models. However, these models also consider flexible wages and full employment, putting aside the role of labor unions. Hence the question of how trade liberalization affects growth and unemployment in a North-South setting with unionized labor markets and wage bargaining remains open to investigation, which is precisely the question we intend to take up in this paper.

Our focus on unionized labor markets is motivated by the fact that labor unions and, more importantly, collective wage bargaining are prevalent features of many developed and developing countries' labor markets. Although the unionization rates have shown a downward trend since the 1980s for most OECD countries, the coverage of collective bargaining has remained relatively stable, around or above 70% for most continental European countries (Nickell et al. 2005, pp. 6-7). In addition, the coordination of wage bargaining, which captures the extent to which the negotiating parties take into account the possible negative employment effects of the bargained wage rate, has decreased in most OECD countries (see Nickell 2005, p.7). In the developing world, unions are also an important aspect of the labor market. Pal (2010, p. 500) reports that 34.1% of non-agricultural workers in India were organized in labor unions in 2005. Martin and Brady (2007, p. 569) report union membership rates of 25.2% and 39.1% for Brazil and Russia, respectively, in 2000. Yao and Zhong (2012) report a dramatic increase in unionization in China since 2003, with the union membership rate reaching 53% of urban workers by the end of 2009.

Our setting is a North-South growth model of trade that features wage bargaining and unemployment. The model's growth and tariff structure follows closely Grieben and Şener (2009). The North is engaged in innovation and the South is engaged in imitation. The endogenous Northern innovation rate coupled with fixed innovation size determines the world-wide economic growth rate. Both countries impose ad-valorem tariffs on imported goods from abroad. Our main departure is to incorporate unions and wage bargaining in both the Northern and the Southern labor markets. Wage setting by unions coupled with a rigid outside option for workers results in involuntary Northern and Southern unemployment.

New results emerge with this set up. Adding wage bargaining breaks the tariff-neutrality result of Grieben and Sener (2009), which implies that tariff reductions have no effect on the rates of innovation and imitation. In particular, we find that innovation and imitation respond to trade liberalization, and the effects crucially depend on which country cuts its tariffs. Unilateral Northern trade liberalization reduces both the Northern innovation rate and the Southern imitation rate, whereas unilateral Southern trade liberalization exerts the opposite effects. When trade liberalization takes place bilaterally, the rates of innovation and imitation both increase. With regards to unemployment, we find that unilateral Northern trade liberalization increases the Northern and Southern unemployment rates, whereas unilateral Southern and bilateral trade liberalization decrease both countries' unemployment rates. Finally, we find that both Southern unilateral and bilateral trade liberalization boost Southern and Northern welfare, whereas Northern unilateral trade liberalization reduces Northern welfare with an ambiguous impact on Southern welfare. To sum up, we find adverse effects from Northern trade liberalization but favorable effects from Southern and bilateral trade liberalization.

Our model is also linked to the trade and labor markets literature. One strand of this literature uses static settings, where unemployment is generated by either wage bargaining, search frictions or efficiency wages, but economic growth is absent by construction.¹ A second strand explores the role of unions in again static trade models but without unemployment.² A third strand uses dynamic endogenous growth settings with trade and unemployment, but labor unions are not incorporated.³ Hence, this literature too

¹ See e.g. Felbermayr et al. (2011a), Davis and Harrigan (2011), Boughol (2011), Helpman and Itskhoki (2010), Egger and Kreickemeier (2009), Eckel and Egger (2009), Dutt et al. (2009), Davidson et al. (1999), and Matusz (1996). This literature assumes structurally identical countries and symmetric cuts in trade costs.

² See e.g. Lommerud et al. (2009, 2012), Bastos and Kreickemeier (2009), Zhao (2001), and Naylor (1999).

³ Şener (2001) considers a symmetric North-North setting in which unemployment arises due to time-consuming job matching rather than labor unions. Arnold (2002) constructs an asymmetric North-South model with search frictions and studies the impact of increased Southern imitation – rather than the impact of tariff cuts. Grieben (2004) and Şener (2006) construct two-country models of trade that feature country asymmetries and also unemployment due to wage rigidities. However, they focus on the effects of labor market policies and technology

does not address the question of how tariff cuts affect growth and unemployment with wage bargaining by unions.

Empirically, our results are consistent with the findings of Felbermayr et al. (2011b) that an increase in trade openness tends to reduce long-run structural unemployment in both a sample of 20 OECD countries and in a larger sample including developing countries, and that the effects mostly materialize via affecting TFP. Our results are also in line with the empirical finding of Hasan et al. (2012) that a decrease in tariffs and non-tariff barriers tends to reduce urban unemployment in Indian states with high employment share in net export sectors. Moreover, our results highlight the need for (hitherto missing) empirical research on the growth and unemployment effects of *unilateral* trade liberalization in a North-South context controlling for the presence of unions.

Finally, we also contribute to the literature on the growth and unemployment effects of labor unions, which so far has been confined to closed-economy settings.⁴ We show that stronger Northern labor unions (as measured by their bargaining power, or their reference wage in the bargaining process) reduce Northern innovation, Southern imitation, and increase both Northern and Southern unemployment. Stronger Southern labor unions reduce Southern imitation and increase Southern unemployment, while they increase Northern innovation and decrease Northern unemployment.

The remainder of this paper is organized as follows: section 2 presents all elements of the model and the steady-state equilibrium. Section 3 analyzes the effects of trade liberalization, changes in labor market institutions, and presents the model's numerical implementation. Section 4 concludes.

2 The Basic Model

In our model the world economy consists of a continuum of industries. Northern entrepreneurs participate in industry-specific R&D races to innovate higher quality products. Successful innovators manufacture their top quality products using Northern labor and become global monopolists. Northern technologies can be imitated by Southern firms with lower production costs. With each Southern imitation success, industry production shifts from the North to the South. Further Northern innovation moves the corresponding industry back to the North. Consequently, the North exports newly-invented goods, and the South exports

shocks instead of tariff cuts.

⁴ Mortensen (2005) finds that an increase in the labor union's bargaining power reduces economic growth, whereas the results in Palokangas (1996, 2004) and Lingens (2003) suggest that stronger labor unions can actually raise economic growth.

imitated products (“product-cycle trade”).⁵ The governments in both regions impose ad-valorem tariffs on imported products. Trade is balanced in equilibrium. We remove the scale effect on innovation by introducing R&D difficulty, the level of which is determined endogenously by the Rent Protection Activities (RPAs) of Northern producers.⁶ In both countries, a centralized labor union bargains with local firms over the wage rate of production workers. The labor unions’ objective is to maximize the expected excess wage income over a given reference income set e.g. by the level of local unemployment benefits. The unions will bargain for wage rates that are higher than the hypothetical competitive wage levels, respectively, and both countries experience unemployment.

2.1 Household Behavior

The world economy consists of two countries, the North and the South, indexed by $i \in \{N, S\}$, respectively. Each country has a fixed number of identical households, normalized to one. Let N_{0i} denote the population size and also the labor force size of country i at time zero. The number of household members in both countries grows at the common rate $n > 0$; thus, the population size in country i at time t equals $N_{ti} = N_{0i}e^{nt}$. The representative household maximizes the per-capita utility function

$$F_i(t) = \int_0^\infty N_{0i} e^{-\rho t} \log f_i(t) dt \quad \text{for } i = N, S, \quad (1)$$

where $\rho > n$ is the subjective discount rate. The function $\log f_i(t)$ stands for the instantaneous logarithmic utility function of each household member and is given by

$$\log f_i(t) \equiv \int_0^1 \log \left[\sum_j \lambda^{j(\omega,t)} x_i(j, \omega, t) \right] d\omega \quad \text{for } i = N, S, \quad (2)$$

where $\lambda > 1$ is the size of each quality improvement, $j(\omega, t)$ is the number of successful innovations in industry $\omega \in [0, 1]$ up to time t , and $x_i(j, \omega, t)$ is the per-capita demand for a product of quality j in industry ω at time t . Hence, product quality starts at $\lambda^0 = 1$ in any industry ω and improves at discrete steps with each successful innovation, which is governed by a stochastic process to be explained later.

The household optimization process consists of two steps. The first step is to allocate consumption

⁵ Different versions of product-cycle trade have recently been proposed: in Gustafsson and Segerstrom (2010), product cycles are one-way only from North to South, where manufacturing of imitated products never moves back to the North. In Şener and Zhao (2009), the Northern stage of production is skipped altogether for some products, such that Northern newly invented goods are immediately produced in the South only (“iPod cycle”). Puga and Trefler (2010) introduce incremental innovation in Southern low-wage countries (like resolving product-line bugs), which generates trade equilibria that allow for new products being first produced in the South.

⁶ See Grieben and Şener (2009, pp. 1043-44) for definition and examples of RPAs, as well as further references. For recent examples of RPAs that draw some media attention, see http://en.wikipedia.org/wiki/Apple_Inc._litigation.

expenditure across products to maximize $f_i(t)$ for given product prices. Since products in a typical industry ω differ only in their quality, and λ units of quality j are a perfect substitute for one unit of quality $j + 1$, households purchase in each industry only the product with the lowest quality-adjusted price. In addition, since products enter (2) symmetrically, each household spreads its consumption expenditure evenly across product lines. It thus follows that per-capita demand for each industry's product is $x_i(\omega, t) = c_i(t)/p(t)$ where c_i is per-capita consumption expenditure in country i , and $p(t)$ is the price of the purchased good.

Given the static demand functions, the second step is to determine the consumption expenditure path over time. This involves maximizing $\int_0^\infty N_{0i} e^{-\rho t} \log c_i(t) dt$ for $i = N, S$, subject to the intertemporal budget constraint $\dot{B}_i(t) = W_i(t) + r(t)B_i(t) - c_i(t)$, where $B_i(t)$ denotes the per-capita stock of financial assets owned by the household, $W_i(t)$ is the household's per-capita expected wage income and $r(t)$ is the instantaneous rate of return in the global market. The expected wage component $W_i(t)$ accounts for unemployment which will arise for Northern and Southern workers. A household's members engage in income sharing, thereby eliminating the individual consumption uncertainty. The solution to this dynamic optimization problem gives the "Keynes-Ramsey rule"

$$\dot{c}_i(t)/c_i(t) = r(t) - \rho \quad \text{for } i = N, S. \quad (3)$$

At the steady-state equilibrium, c_i will be constant; thus $r(t) = \rho$. Since we focus on steady-states and consider structurally-identical industries, we henceforth drop the time index t and the industry index ω .

2.2 *Labor and Activities*

Labor is the only factor of production and is immobile across countries. In the North, the labor force consists of specialized and general-purpose workers, with the fixed proportion of the former given as $s_N \in (0, 1)$ and that of the latter given as $1 - s_N$. In the North, there are three types of activities: innovation, manufacturing of final goods, and rent protection. General-purpose workers can be employed in innovation or goods production, whereas specialized workers (lawyers, lobbyists) are only employed in Rent Protection Activities (RPAs). These activities are undertaken by incumbent firms to deter the innovation or imitation efforts targeted at their products.⁷ In the South, there is only one type of labor that

⁷ RPAs are first introduced in a closed economy endogenous growth setting by Dinopoulos and Syropoulos (2007). Grieben and Şener (2009) discuss the empirical evidence on RPAs in a North-South context. Our labor assignment follows Dinopoulos and Syropoulos (2007) and Grieben and Şener (2009). As is discussed in the latter paper, its advantage is that it yields fully-endogenous growth (in the sense that the steady-state growth rate depends on all parameters of the model) with a parsimonious structure by creating a link between the innovation rate and the Northern wage rate for specialized relative to general-purpose workers in the simplest possible way.

can be used in manufacturing of final goods or imitative R&D. There are no Southern RPAs since neither Southern nor Northern firms find it profitable to imitate goods that have already been imitated by a Southern firm.

2.3 *Product Markets*

There is a continuum of structurally-identical industries indexed by $\omega \in [0,1]$. In each industry, Northern entrepreneurs participate in R&D races to discover the technology of producing next-generation products, whose quality is $\lambda > 1$ times higher than the current-generation product. Whenever a higher quality product is discovered in the North, a new R&D race starts and the technology of producing the previous-generation product becomes common knowledge to all firms in the global economy. In the global product markets, firms engage in Bertrand price competition to offer the lowest quality-adjusted price given their state of technology and regional labor costs. In both the North and the South, workers are represented by a labor union, respectively, and wages are determined by decentralized wage bargaining to be discussed later. We denote the Northern wage rate of general-purpose labor as w_L and the Southern wage rate as w_S . In both countries, production of one unit of final goods requires one unit of general-purpose labor, regardless of the quality level of the manufactured goods. The governments of both regions impose ad-valorem tariffs on imported goods, which are redistributed in a lump-sum fashion to local consumers for simplicity. We denote by $\tau_N \geq 0$ the tariff rate imposed by the North and by $\tau_S \geq 0$ the tariff rate imposed by the South.

For each industry, there are two possible structures at any point in time. Whenever a Northern entrepreneur discovers a next-generation product, the resulting structure is a *Northern industry*, in which the Northern quality leader competes in both markets with Southern followers who have access to the previous-generation technology. Whenever the technology of producing a current-generation product is imitated by a Southern firm, the resulting structure is a *Southern industry*, in which the Southern quality leader competes in both markets with the Northern quality leader.⁸

Consider first the profits of firms in a Northern industry. In the Northern market, the Southern followers face an ad-valorem tariff rate τ_N . By pricing at marginal cost and accounting for the Northern tariff rate, the followers can offer their goods to Northern consumers at a price $w_S(1 + \tau_N)$. In this case, the

⁸ Northern followers' unit cost is w_L whereas the Southern followers' unit cost is w_S . Northern followers cannot compete with Southern followers in the Southern market if $w_L(1 + \tau_S) > w_S$. Moreover, Northern followers cannot compete with Southern followers in the Northern market provided $w_L > (1 + \tau_N)w_S$. We impose this latter stronger condition and later discuss its parametric implications, given that both wage rates are endogenous.

Northern quality leader charges the limit price $p_N^N = \lambda w_S(1 + \tau_N) - \varepsilon$ with $\varepsilon \rightarrow 0$ and drives the Southern followers out of the market.⁹ The profits of the Northern quality leader from sales in the Northern market are:

$$\pi_N^N = \frac{c_N N_N}{\lambda w_S(1 + \tau_N)} [\lambda w_S(1 + \tau_N) - w_L].$$

In the Southern market, the Northern quality leader faces an ad-valorem tariff rate τ_S . Under marginal cost pricing, the Southern followers can offer a price of w_S . To capture the Southern market, the Northern quality leader must set its price such that the price faced by the Southern consumers does not exceed λw_S . This implies that the Northern leader charges the limit price $p_N^S = \lambda w_S - \varepsilon$ with $\varepsilon \rightarrow 0$, of which the Northern firm receives only $\lambda w_S/(1 + \tau_S)$. The profits of the Northern quality leader from exports are:

$$\pi_N^S = \frac{c_S N_S}{\lambda w_S} \left(\frac{\lambda w_S}{1 + \tau_S} - w_L \right).$$

For $\pi_N^S > 0$, we need $\tau_S < (\lambda w_S/w_L) - 1$, which we maintain. Hence total profits from sales of Northern monopolists are:

$$\pi_N^P = \pi_N^N + \pi_N^S = c_N N_N \left[1 - \frac{w_L}{\lambda w_S(1 + \tau_N)} \right] + c_S N_S \left(\frac{1}{1 + \tau_S} - \frac{w_L}{\lambda w_S} \right). \quad (4)$$

Consider now the profits of firms in a Southern industry. In the Southern market, the Northern leader firm face an ad-valorem tariff rate τ_S . By pricing at marginal cost and accounting for the Southern tariff rate, the Northern leader can offer its goods to Southern consumers at a price $w_L(1 + \tau_S)$. In this case, the Southern quality leader charges the limit price $p_S^S = w_L(1 + \tau_S) - \varepsilon$ with $\varepsilon \rightarrow 0$ and drives the Northern leader out of the market. The profits of the Southern quality leader from sales in the Southern market are:

$$\pi_S^S = \frac{c_S N_S}{w_L(1 + \tau_S)} [w_L(1 + \tau_S) - w_S].$$

In the Northern market, the Southern quality leader faces an ad-valorem tariff rate τ_N . Under marginal cost pricing, the Northern leader can offer a price of w_L . To capture the Northern market, the Southern quality leader must set its price such that the price faced by the Northern consumers does not exceed w_L .

⁹ We assume that follower firms face zero capacity maintenance costs. Thus, they impose a constant threat to enter the market, forcing the quality leader firm to engage in limit pricing during its entire tenure.

This implies that the Southern leader charges the limit price $p_S^N = w_L - \varepsilon$ with $\varepsilon \rightarrow 0$, of which the Southern firm receives only $w_L/(1+\tau_N)$. The profits of the Southern quality leader from exports are:

$$\pi_S^N = \frac{c_N N_N}{w_L} \left(\frac{w_L}{1+\tau_N} - w_S \right).$$

$\pi_S^N > 0$ is ensured by our above assumption $(1 + \tau_N)w_S < w_L$. Hence total profits from sales of Southern monopolists are:

$$\pi_S = \pi_S^S + \pi_S^N = c_S N_S \left[1 - \frac{w_S}{w_L(1+\tau_S)} \right] + c_N N_N \left(\frac{1}{1+\tau_N} - \frac{w_S}{w_L} \right). \quad (5)$$

While Northern quality leaders earn monopoly profits, they simultaneously expend resources for RPAs. For this purpose, each Northern incumbent hires Northern specialized labor at a wage rate of w_H . The cost of performing X units of RPAs is $w_H \gamma X$, where γ is the unit labor requirement of such activities. Hence, a Northern incumbent's profit flow net of rent protection costs then equals:

$$\pi_N = \pi_N^P - w_H \gamma X. \quad (6)$$

2.4 Innovation and Imitation Decisions

In the North, there are sequential and stochastic R&D races in each industry $\omega \in [0,1]$ to discover the next-generation product. The R&D technology is identical across Northern firms. The instantaneous probability of innovation success (the Poisson arrival rate) by firm k is given as

$$i_k(\omega) = R_k(\omega) / \left[R(\omega)^{1-\varepsilon} D(\omega)^\varepsilon \right] \quad \text{with} \quad \dot{D}(\omega) = n_N \delta X(\omega) \quad \text{and} \quad \varepsilon \in (0,1), \quad (7)$$

where $R_k(\omega)$ represents the innovation intensity of a typical Northern entrepreneur k targeting industry ω , $R(\omega) = \sum_k R_k(\omega)$ is the industry-wide innovation intensity, and $D(\omega)$ measures the difficulty of conducting R&D in industry ω at time t . The R&D technology in (7) implies that there are constant returns to scale in R_k for the individual Northern entrepreneur. According to (7), R&D difficulty D is modeled as a stock variable,¹⁰ where n_N is the proportion of industries located in the North, $X(\omega)$ is the flow of RPAs

¹⁰ Modeling R&D difficulty as a stock variable, rather than as a flow variable as in Dinopoulos and Syropoulos (2007), better captures the persistence of the institutional and legal framework surrounding intellectual property rights protection. Moreover, the flow approach would have the implausible implication that R&D difficulty is zero in Southern industries, since successful Southern imitators do not invest in RPAs. This would redirect all Northern innovative R&D expenditure to Southern industries, leaving incumbent Northern firms unchallenged.

undertaken by the Northern incumbent in industry ω at time t , and δ measures the effectiveness of these RPAs. The equation of motion for $D(\omega)$ in (7) implies that whenever an industry is registered as a Northern industry – the probability of which is equal to n_N in equilibrium – each individual Northern incumbent undertakes RPAs which increase the stock of R&D difficulty in that particular industry by $\delta X(\omega)$. For a constant steady-state innovation rate, R&D difficulty must grow at the same rate as the labor force, hence $\dot{D}(\omega) = nD(\omega)$ is required. From this and (7), we obtain the steady-state stock of R&D difficulty:

$$D(\omega) = n_N \delta X(\omega) / n. \quad (8)$$

Since innovation success is independently distributed across firms and industries, the Poisson arrival rate for innovation at the industry level (which is ‘the’ Northern innovation rate) equals

$$\iota(\omega) = \sum_k \iota_k(\omega) = \frac{R(\omega)}{R(\omega)^{1-\varepsilon} D(\omega)^\varepsilon} = \left[\frac{R(\omega)}{D(\omega)} \right]^\varepsilon, \quad (9)$$

where $\varepsilon < 1$ captures the degree of diminishing returns to R&D at the industry level. A higher level of ε implies a weaker diminishing-returns effect.¹¹ Entrepreneurs participating in R&D races hire general-purpose labor to perform R&D. The cost of conducting R_k units of R&D activity is $w_L a_t R_k$, where a_t is the unit labor requirement of innovative R&D. Imposing the usual free-entry assumption for R&D races, expected profits from R&D are competed away, and the maximization problem yields

$$\max_{R_k(\omega)} \frac{v_N R_k(\omega)}{R(\omega)^{1-\varepsilon} D(\omega)^\varepsilon} - w_L a_t R_k(\omega) \quad \Rightarrow \quad v_N = w_L a_t D(\omega)^\varepsilon R(\omega)^{1-\varepsilon}, \quad (10)$$

where v_N is the firm value of a successful Northern innovator.

In the South, firms invest in R&D in each industry with a Northern leader firm to imitate the current state-of-the-art product. The successful imitator can drive its (Northern) competitor out of the global market and enjoy temporary monopoly power. The instantaneous probability of imitation success (Poisson arrival rate) by firm k is given as

¹¹ See Dinopoulos (1994, p. 6, fn. 8) for justification of decreasing returns to scale in R&D at the aggregate level. We generalize his specification by including R&D difficulty D that is required to remove the scale effect from the model. Alternative decreasing-returns-to-scale specifications are used in Davidson and Segerstrom (1998), Lundborg and Segerstrom (2002), and Gustafsson and Segerstrom (2010). As is discussed at length in Davidson and Segerstrom (1998), constant-returns-to-scale R&D technologies can lead to equilibria that violate intuitive stability conditions and have implausible comparative-static properties.

$$\mu_k(\omega) = M_k(\omega) / \left[M(\omega)^{1-\varepsilon} D(\omega)^\varepsilon \right], \quad (11)$$

where $M_k(\omega)$ represents the imitation intensity of a typical Southern entrepreneur k targeting industry ω , and $M(\omega) = \sum_k M_k(\omega)$ is the industry-wide imitation intensity. We assume that R&D difficulty D applies equally well as imitation difficulty, i.e. RPAs that deter innovation can simultaneously deter imitation. The Poisson arrival rate for imitation at the industry level (henceforth ‘the’ Southern imitation rate for simplicity) equals

$$\mu(\omega) = \sum_k \mu_k(\omega) = \frac{M(\omega)}{M(\omega)^{1-\varepsilon} D(\omega)^\varepsilon} = \left[\frac{M(\omega)}{D(\omega)} \right]^\varepsilon. \quad (12)$$

Hence, Southern imitation activity also features constant returns to scale at the individual firm level, but decreasing returns to scale at the aggregate level. Since Southern entrepreneurs target only Northern industries, the economy-wide Southern imitation rate is given as $m \equiv \mu n_N$.

The cost of conducting M_k units of imitative activity in the South is $w_S a_\mu M_k$, where a_μ is the unit labor requirement of imitative R&D. Under free entry into imitation, expected profits from imitative R&D are competed away, and the maximization problem yields

$$\max_{M_k(\omega)} \frac{v_S M_k(\omega)}{M(\omega)^{1-\varepsilon} D(\omega)^\varepsilon} - w_S a_\mu M_k(\omega) \Rightarrow v_S = w_S a_\mu D(\omega)^\varepsilon M(\omega)^{1-\varepsilon}. \quad (13)$$

2.5 The Stock Market

The savings of consumers in both countries are channeled to firms investing in innovative or imitative R&D by means of a global stock market. Given the structural symmetry across industries, we henceforth drop the industry index ω . Over a small time period dt , the stockholders of a Northern quality leader operating in a Northern industry receive dividend payments $\pi_N dt$. With probability $(\iota + \mu)dt$, successful innovation or imitation takes place and the Northern firm is driven out of the market. The stockholders face the risk of a complete capital loss of size v_N . With probability $1 - (\iota + \mu)dt$, neither Northern innovation nor Southern imitation takes place, and the Northern firm experiences a capital gain $\dot{v}_N dt$. Consumers can engage in complete diversification of their asset portfolio to eliminate the industry-specific risk of unsuccessful R&D efforts. In an arbitrage-free asset market equilibrium, the expected return from a stock issued by the Northern firm must equal the return of a risk-free asset that pays the market interest rate on an investment of equal size during the same time period:

$$\pi_N dt - v_N (\iota + \mu) dt + \dot{v}_N [1 - (\iota + \mu) dt] dt = r v_N dt. \quad (14)$$

Solving (14) for v_N and imposing $dt \rightarrow 0$ yields the value of a Northern quality leader as

$$v_N = \frac{\pi_N}{r + \iota + \mu - (\dot{v}_N/v_N)}. \quad (15)$$

Over a small time period dt , stockholders of a Southern imitator operating in a Southern industry receive dividend payments $\pi_S dt$. With probability ιdt , successful innovation by a Northern firm takes place which drives the Southern firm out of business and implies a complete capital loss of size v_S . With probability $1 - \iota dt$, Northern innovation does not take place, and the Southern firm experiences a capital gain $\dot{v}_S dt$. Similar to (14), the no-arbitrage condition for Southern imitators implies:

$$\pi_S dt - v_S \iota dt + \dot{v}_S (1 - \iota dt) dt = r v_S dt. \quad (16)$$

Solving (16) for v_S and imposing $dt \rightarrow 0$ yields the value of a successful Southern imitator as

$$v_S = \frac{\pi_S}{r + \iota - (\dot{v}_S/v_S)}. \quad (17)$$

2.6 Optimal Rent Protection Decision by Northern Incumbents

Substituting D from (8) into (9) and (12), we derive $\iota(X) = \left(\frac{Rn}{n_N \delta X}\right)^\varepsilon$ and $\mu(X) = \left(\frac{Mn}{n_N \delta X}\right)^\varepsilon$, which shows that in any particular industry ω , an increase in industry-specific RPAs X reduces both ι and μ in this industry ω , and thus diminishes the threat of replacement faced by the incumbent Northern leader firm, respectively. The incumbent avoids the capital loss v_N and realizes the change in its valuation \dot{v}_N by the extent of the decline in ι and μ per unit of time. Each unit of RPA costs $w_H \gamma$ per unit of time. When choosing the optimal level of X , the Northern incumbent weighs the marginal gains against the marginal costs. Formally, the firm chooses X to maximize the expected returns on its stocks

$$\left(\pi_N^P - w_H \gamma X \right) dt - v_N [\iota(X) + \mu(X)] dt + \dot{v}_N dt \left\{ 1 - [\iota(X) + \mu(X)] dt \right\},$$

where (6) is used for π_N and the expressions for $\iota(X)$ and $\mu(X)$ are from above. Setting the derivative of the expected return with respect to X to zero, using $d\iota(X)/dX = -\varepsilon\iota/X < 0$ and $d\mu(X)/dX = -\varepsilon\mu/X < 0$, and taking limits as $dt \rightarrow 0$, we derive the first order condition for the optimal X as:

$$X = \varepsilon v_N (\iota + \mu) / (w_H \gamma). \quad (18)$$

Intuitively, the optimal level of RPAs X increases with the firm value v_N (since there is more at stake) and the replacement rate due to innovation ι and imitation μ (the instantaneous probability of full capital loss at each point in time). The optimal level of X increases with ε , the effectiveness by which RPAs reduce ι and μ , and it decreases with the unit cost of RPAs $w_H\gamma$. Using (18) together with (6) and (4) in (15) gives the discounted Northern firm value as

$$v_N = \frac{c_N N_N \left[1 - \frac{w_L}{\lambda w_S (1 + \tau_N)} \right] + c_S N_S \left(\frac{1}{1 + \tau_S} - \frac{w_L}{\lambda w_S} \right)}{r + (1 + \varepsilon)(\iota + \mu) - \dot{v}_N / v_N}. \quad (19)$$

2.7 *Balanced Trade*

We impose a balance-of-trade (BOT) condition to determine the relative consumer expenditure levels for both countries. More specifically, the BOT implies that the value of exports net of tariffs must be equal between the North and the South. In our continuum-of-industries setting, this gives:

$$n_N \frac{c_S N_S}{w_S \lambda} \cdot \frac{w_S \lambda}{1 + \tau_S} = (1 - n_N) \frac{c_N N_N}{w_N} \cdot \frac{w_N}{1 + \tau_N}.$$

The LHS (RHS) denotes the value of Northern (Southern) exports net of tariffs. To determine n_N , the industry share located in the North, we note that Northern entrepreneurs capture industry leadership from Southern firms at a rate of $\iota(1 - n_N)$, while Southern firms capture industry leadership from Northern firms at a rate of μn_N . Constancy of industry shares in the steady state requires $\iota(1 - n_N) = \mu n_N$, which implies

$$n_N = \iota / (\iota + \mu). \quad (20)$$

By using (20) and defining the relative Southern population size as $\eta_S \equiv N_S / N_N$, the above BOT condition can be rewritten as

$$\frac{c_N}{c_S} = \frac{\iota \eta_S (1 + \tau_N)}{\mu (1 + \tau_S)} \quad \text{BOT}. \quad (21)$$

The relative North-South consumption expenditure c_N/c_S is increasing in $\iota/\mu = n_N/(1 - n_N)$, since an increase in the relative proportion of Northern industries $n_N/(1 - n_N)$ raises the relative size of Northern exports, thereby increasing the relative Northern income available for consumption. c_N/c_S is increasing in τ_N , since a higher Northern import tariff decreases the value of Southern exports net of tariffs by decreasing the profit margins of Southern exporters. Thus, the relative Southern income available for consumption decreases, implying a rise in c_N/c_S . All arguments are reversed for the case of an increase in τ_S , which

reduces c_N/c_S .

2.8 Labor Markets Part 1: Equilibrium Conditions

To close our model, we derive the labor market equilibria. In both countries, decentralized wage bargaining can lead to labor-union induced unemployment. The Northern general-purpose labor market equilibrium requires that $(1 - s_N - u_N)N_N = L_N$ is always fulfilled, where $u_N \equiv U_N/N_N$ denotes the Northern unemployment rate, U_N is the total number of Northern unemployed workers, and L_N is Northern employment. Similarly, the Southern labor market equilibrium requires that $(1 - u_S)N_S = L_S$ is always fulfilled, with u_S and L_S denoting Southern unemployment rate and employment, respectively.

The Northern demand for manufacturing labor is $n_N Q_N \equiv n_N \{c_N N_N / [(1 + \tau_N) \lambda w_S] + c_S N_S / (\lambda w_S)\}$, where Q_N is the total quantity produced per Northern industry. The Northern R&D labor demand is, using (9), $a_i R = a_i D t^{\frac{1}{\varepsilon}}$; hence the Northern general-purpose labor market equilibrium (LABN) condition is

$$L_N = \frac{n_N}{\lambda w_S} \left(\frac{c_N N_N}{1 + \tau_N} + c_S N_S \right) + a_i D t^{\frac{1}{\varepsilon}} = (1 - s_N - u_N) N_N \quad \mathbf{LABN.} \quad (22)$$

Obviously, the Northern bargained wage rate w_L does not affect Northern general-purpose labor demand directly (indirect effects are coming through w_L affecting t and μ , as will be explained later). The reason is that due to global Bertrand price competition, product prices are proportional to the marginal cost of the lowest-cost competitors, which happen to be the Southern producers with marginal cost w_S . Northern RPA labor demand is $n_N \gamma X$, hence the Northern specialized labor market equilibrium condition is

$$n_N \gamma X = s_N N_N. \quad (23)$$

The Southern demand for manufacturing labor is $(1 - n_N) Q_S \equiv (1 - n_N) \{c_S N_S / [w_L (1 + \tau_S)] + c_N N_N / w_L\}$, where Q_S is the total quantity produced per Southern industry. The Southern imitative R&D labor demand is, using (12), $n_N a_\mu M = n_N a_\mu D \mu^{\frac{1}{\varepsilon}}$; hence the Southern labor market equilibrium (LABS) condition is

$$\frac{1 - n_N}{w_L} \left(c_N N_N + \frac{c_S N_S}{1 + \tau_S} \right) + n_N a_\mu D \mu^{\frac{1}{\varepsilon}} = (1 - u_S) N_S \quad \mathbf{LABS.} \quad (24)$$

Similar to the LABN condition before, the Southern bargained wage rate w_S does not affect Southern labor demand directly. Indirect effects are coming through w_S affecting μ and t , as will be explained later.

2.9 Labor Markets Part 2: Wage Bargaining

We first discuss the determination of the Northern general-purpose wage rate w_L . There is decentralized wage bargaining between any new incumbent Northern firm and a centralized labor union who bargains on behalf of Northern general-purpose workers. The sequence of events is as follows. **First**, when an entrepreneur firm enters the R&D race, it employs general-purpose workers at the going wage rate w_L to perform R&D services. There is nothing to bargain between entrepreneurs and R&D workers due to free entry in R&D races and thus zero expected profits. **Second**, if the entrepreneur becomes successful in innovating, it has to bargain with the production workers before any production starts. This is because there are positive expected monopoly profits and workers are represented by a labor union. In the meanwhile, the previously employed R&D workers of the successful innovator can find employment (either in a new R&D firm or in a producing firm which may as well be the successful innovator) or they can become unemployed. When bargaining, the prospective production workers take the industry-wide innovation rate as given since it is beyond control of a single firm.¹² **Third**, after the wage bargaining is settled, the firm decides about the level of manufacturing employment and starts production.¹³ The bargained wage rate, although determined individually between a single firm and the labor union, will be the same across all firms because they face a symmetric problem and have identical bargaining power. It is derived from the Nash maximand

$$\Omega_N = \left(\frac{W_N}{r} - \bar{W}_N \right)^\alpha (v_N - \bar{v}_N)^{1-\alpha} \rightarrow \max_{w_L} \quad (25)$$

$\alpha \in [0,1[$ is the relative bargaining power of the Northern labor union, and $W_N \equiv (w_L - \underline{w}_N)^\theta [(1 - s_N - u_N)N_N]^\chi$ is the expected excess-wage income received by the Northern union members. \underline{w}_N denotes the Northern reservation wage level, and excess wage and employment levels are evaluated by the elasticities of the underlying utility function of the labor union, respectively.¹⁴ \underline{w}_N can be given various

¹² The same is true with respect to the economy-wide unemployment rate which will be derived as a function of the aggregate innovation rate. The individual firm's innovation rate is also exogenous to the bargaining process since for producing firms the act of innovation is a past event. Due to the standard Arrow inertia effect, the successful innovator no longer invests in R&D in its own industry. Segerstrom (2007) suggests a model without this property.

¹³ Since the Northern firms' production labor demand (22) does not (directly) depend on w_L , there is no pass-through of higher Northern production costs to product prices, which would reduce consumption and hence the individual Northern firm's general-purpose labor demand. Thus, in our setting it does not matter whether the firm is granted the "right to manage" employment ex-post or ex-ante wage bargaining.

¹⁴ The underlying labor union's objective is a Stone-Geary type utility function $U(w_L, L_N) = (w_L - \underline{w}_N)^\theta (L_N)^\chi$, where $\theta \geq 0$ and $\chi \geq 0$ represent, respectively, the union's preference for excess wages and employment, cf. Mezzetti and

interpretations: it could either represent disutility in work effort, or the level of unemployment benefits, or a minimum wage rate set and credibly enforced by the government. In any case, \underline{w}_N serves as the natural reference point for the labor union.¹⁵ \bar{W}_N is the workers' discounted per-period income during the negotiations on w_L or during a strike – their ‘*inside option*’ (and *not* what they would get if they unilaterally quit the negotiations without agreement – their ‘*outside option*’¹⁶), and \bar{v}_N is the discounted Northern firm's profits during the negotiation or a strike. We assume that employed workers do not have any income during wage negotiations (i.e., we abstract from any strike funds of the labor union). Moreover, possible one-time redundancy payments to those workers just laid off do not matter in this respect since they are not paid under the condition that the bargaining process takes another period, hence $\bar{W}_N = 0$. Similarly, $\bar{v}_N = 0$ since Northern firms cannot manufacture without agreement on w_L . Using these identities in (25), and substituting for v_N from (19) simplifies the bargaining problem to

$$\Omega_N = \left\{ \frac{(w_L - \underline{w}_N)^\theta [(1 - s_N - u_N) N_N]^\chi}{r} \right\}^\alpha \left\{ \frac{c_N N_N \left[1 - \frac{w_L}{\lambda w_S (1 + \tau_N)} \right] + c_S N_S \left(\frac{1}{1 + \tau_S} - \frac{w_L}{\lambda w_S} \right)}{r + (1 + \varepsilon)(\iota + \mu) - \dot{v}_N / v_N} \right\}^{1-\alpha} \rightarrow \max!_{w_L} \quad (26)$$

The first order condition is

$$\frac{\alpha \theta}{w_L - \underline{w}_N} \left\{ c_N N_N \left[1 - \frac{w_L}{\lambda w_S (1 + \tau_N)} \right] + c_S N_S \left(\frac{1}{1 + \tau_S} - \frac{w_L}{\lambda w_S} \right) \right\} = (1 - \alpha) \left[\frac{c_N N_N}{\lambda w_S (1 + \tau_N)} + \frac{c_S N_S}{\lambda w_S} \right], \quad (27)$$

which implies that the increase in the firm's profits extraction by the labor union through a marginal increase in $w_L - \underline{w}_N$, evaluated by the union's share α in Ω_N and the union's excess wage preference θ (LHS), must equal the increase in the firms' production costs by this marginal increase in $w_L - \underline{w}_N$,

Dinopoulos (1991, p. 82).

¹⁵ Lingens (2003) takes as the union's reference wage the competitive wage rate derived from a hypothetical situation with no wage bargaining. This requires truly heroic rationality of labor unions since the competitive wage rate cannot be observed in such a setting, while this is not true for the various interpretations of \underline{w}_N we suggest. In the trade literature with unions (e.g., Mezzetti and Dinopoulos 1991, Zhao 2001), the union's reference wage is derived from a second sector that is perfectly competitive and non-unionized. This modeling renders the reference wage a real and observable option but complicates the analysis and removes unemployment from the model.

¹⁶ Palokangas (2004, p. 205, fn. 6), with reference to Binmore et al. (1986, p. 186-187), points out that taking the expected income outside the firm as the union's reference point would not be correct since it “[...] *is not in line with the microfoundations of the alternating offers game*”. Instead, it is “[...] *appropriate to identify the reference income with the income streams accruing to the parties in the course of the dispute*”. The outside option for the workers (unemployment benefits, wage income elsewhere) if the firm and the labor union fail to agree on a wage rate is an irrelevant alternative and “[...] *has no effect on the bargain, provided the bargain gives both parties more than they could get elsewhere*” (Layard et al. 2005, p. 100).

evaluated by the firm's share $1 - \alpha$ in Ω_N (RHS).¹⁷ For the remainder of the paper, we normalize $\theta \equiv 1$ without loss of generality. By using the BOT condition (21) in (27) and simplifying terms, we find the negotiated Northern general-purpose wage rate as an increasing function of α :

$$w_L = \frac{\alpha \lambda w_S [\iota(1 + \tau_N) + \mu]}{\iota + \mu(1 + \tau_S)} + (1 - \alpha) \underline{w}_N \quad \forall \alpha \in [0, 1[, \quad \text{given } \frac{\lambda w_S [\iota(1 + \tau_N) + \mu]}{\iota + \mu(1 + \tau_S)} \equiv w_L^{\max} > \underline{w}_N. \quad (28)$$

w_L^{\max} is the maximum wage rate that would apply for $\alpha \rightarrow 1$, which leaves zero profits for Northern incumbent firms. For the rest of the paper we maintain $w_L^{\max} > w_L > \underline{w}_N$.

The determination of the Southern wage rate w_S is modeled symmetrically. The bargaining problem between any Southern entrepreneur that was successful in imitating the Northern state-of-the-art production technology and the centralized Southern labor union is

$$\Omega_S = \left\{ \frac{(w_S - \underline{w}_S)^\theta [(1 - u_S) N_S]^\chi}{r} \right\}^\beta \left\{ \frac{c_N N_N \left(\frac{1}{1 + \tau_N} - \frac{w_S}{w_L} \right) + c_S N_S \left[1 - \frac{w_S}{w_L(1 + \tau_S)} \right]}{r + \iota - \dot{v}_S / v_S} \right\}^{1 - \beta} \rightarrow \max_{w_S}! \quad (29)$$

Here, (17) and (5) have been used to substitute for v_S , $\beta \in [0, 1[$ is the relative bargaining power of the Southern labor union, and \underline{w}_S is the Southern reservation wage level. Using again $\theta \equiv 1$ and the BOT condition (21), the solution of (29) is the following Southern wage rate as an increasing function of β :

$$w_S = \frac{\beta w_L [\iota + \mu(1 + \tau_S)]}{\iota(1 + \tau_N) + \mu} + (1 - \beta) \underline{w}_S \quad \forall \beta \in [0, 1[, \quad \text{given } \frac{w_L [\iota + \mu(1 + \tau_S)]}{\iota(1 + \tau_N) + \mu} \equiv w_S^{\max} > \underline{w}_S. \quad (30)$$

w_S^{\max} is the maximum wage rate that would apply for $\beta \rightarrow 1$, and we maintain $w_S^{\max} > w_S > \underline{w}_S$.

The Northern general-purpose wage rate w_L is an increasing function of the Southern wage rate w_S and vice versa, since higher trading partner's production costs raise the own leader firms' limit prices and profits, which magnifies the pie that can be shared with the own country's labor union, respectively. For the special case $\underline{w}_S = 0$, the subsequent analysis greatly simplifies. Since this sharpens the intuition of the main analytical results, we make this assumption for now and relax it later when implementing our model numerically in section 3.3. Using $\underline{w}_S = 0$, (28) and (30) can be solved for the wage rates

$$w_L = \frac{(1 - \alpha) \underline{w}_N}{1 - \alpha \beta \lambda}, \quad (31)$$

¹⁷ The second derivative of (26) with respect to w_L is negative, hence the f.o.c. is also sufficient for a maximum.

$$w_S = \frac{\beta[\iota + \mu(1 + \tau_S)](1 - \alpha)\underline{w}_N}{[\iota(1 + \tau_N) + \mu](1 - \alpha\beta\lambda)}. \quad (32)$$

To ensure $w_L > 0$, we require $\alpha\beta\lambda < 1$, while $\beta\lambda > 1$ is necessary to ensure $w_L > \underline{w}_N$. Together, we need to impose the parametric restriction $1 < \beta\lambda < 1/\alpha$ to get a positive Northern general-purpose wage rate w_L exceeding the Northern reservation wage \underline{w}_N , such that the presence of a Northern labor union is justified from a union's perspective.¹⁸ Under this restriction, the wage rates have the following intuitive properties: ceteris paribus, both w_L and w_S are increasing in α , β , and \underline{w}_N . That is, the trade link ensures that workers of both countries benefit in terms of wages not only from labor standards in their own country, but also from those in the trade partner country. Furthermore, w_L is independent of tariffs provided $\underline{w}_S = 0$, while w_S is increasing in τ_S and decreasing in τ_N . Ceteris paribus (i.e., for given ι and μ), there are two main channels by which tariff changes affect w_S . First, an increase in τ_N reduces the export sales revenues of Southern imitators, which reduces the size of the profit pie to be shared with Southern workers in the bargaining process. Second, an increase in τ_S raises the degree of Southern protectionism and hence the price charged in the domestic market by Southern imitators, which increases the size of the profit pie to be shared with Southern workers.

We can use the results (31) and (32) to verify the parametric restrictions $w_S(1 + \tau_N) < w_L$, which implies that Northern follower firms cannot compete with Southern follower firms in either the Southern or the Northern market, and $w_L < \lambda w_S/(1 + \tau_S)$, which implies that Northern firms make positive export profits. This yields the following feasible range of the Southern labor union's bargaining power:

$$\beta^{\min} \equiv \frac{[\iota(1 + \tau_N) + \mu](1 + \tau_S)}{\lambda[\iota + \mu(1 + \tau_S)]} < \beta < \frac{\iota(1 + \tau_N) + \mu}{(1 + \tau_N)[\iota + \mu(1 + \tau_S)]} \equiv \beta^{\max}.$$

It follows that the feasible wage rate for Northern general-purpose workers relative to Southern workers is

$$\frac{w_L}{w_S} = \frac{\iota(1 + \tau_N) + \mu}{\beta[\iota + \mu(1 + \tau_S)]} \in \left(1 + \tau_N, \frac{\lambda}{1 + \tau_S}\right). \quad (33)$$

By how much can λ be increased to yield realistic North-South wage differences, as suggested by

¹⁸ We later verify numerically that the bargained wage rates in both countries exceed the hypothetical competitive wage rates w_N^{comp} and w_S^{comp} , respectively, further justifying the existence of labor unions ex post. For the general case $\underline{w}_S > 0$, Referees' Appendix R.3 shows that $\alpha\beta\lambda < 1$ is still necessary to ensure both $w_L > 0$ and $w_S > 0$, while $\beta\lambda > 1$ and $\alpha\lambda > 1$ become sufficient (but not necessary) conditions to ensure $w_N > \underline{w}_N$ and $w_S > \underline{w}_S$, respectively.

Gustafsson and Segerstrom (2010)?¹⁹ As can be seen in (33), the upper bound of this wage gap is essentially determined by λ , which is closely related to the price marginal-cost ratio that is $\lambda w_S(1+\tau_N)/w_L$ for products newly-invented by Northern firms. Standard estimates of this ratio are within the range [1.05, 1.4], see Şener and Zhao (2009, p. 107) giving reference to Basu (1996) and Norrbin (1993). More recent evidence suggests that price marginal-cost ratios for modern consumer electronics goods can be substantially larger.²⁰ This justifies to consider at least the upper bound 1.4 of the standard range, which would imply $\lambda = 1.94$ for our benchmark in Table 1. For our numerical simulation in section 3.3, we use $\lambda = 2$. Hence, our model can produce substantial North-South wage gaps, although this is not our main focus.

2.10 Steady-State Equilibrium

We choose Southern consumption expenditure as the numéraire, $c_S \equiv 1$, and solve the model for an interior steady-state equilibrium where the endogenous variables $c_N, u_N \in (0, 1 - s_N), u_S \in (0, 1), \iota, \mu, n_N, w_S, w_L$, and w_H are non-negative and remain constant. $\pi_N^P, \pi_S, X, D, R, M, v_N$, and v_S are also non-negative and grow at a common rate of $n > 0$, and $r = \rho$.

First note that with $c_S \equiv 1$, (21) gives c_N as a function of ι and μ only, and (20) determines n_N as a function of ι and μ only. We use $c_S \equiv 1$, (8) and (23) to derive $D = \delta s_N N_N / (n\gamma)$, and rewrite the Northern general-purpose labor market equilibrium condition (22) in Northern per-capita terms as

$$\frac{n_N}{\lambda w_S} \left(\frac{c_N}{1 + \tau_N} + \eta_S \right) + \iota^{\frac{1}{\epsilon}} A_\iota = 1 - s_N - u_N,$$

where $A_\iota \equiv a_\iota \delta s_N / (n\gamma)$ is the effective resource requirement per unit of innovative R&D. Using (20) to substitute for n_N , (32) to substitute for w_S , and (21) with $c_S \equiv 1$ to substitute for c_N allows to rewrite the Northern unemployment rate as a function of ι and μ only:

¹⁹ Gustafsson and Segerstrom calibrate their model to US-Mexican data (ibid, p. 105) and generate a North-South wage ratio w_N/w_S of 2.21. They argue that standard Schumpeterian product-cycle models cannot produce such large wage differences. The reason that their model can produce such large North-South wage differentials is that it features one-way product cycles, which does not have the equilibrium requirement that $w_S > w_N/\lambda$.

²⁰ See Kraemer et al. (2011), Xing and Detert (2011), and Linden et al. (2009). For example, Kraemer et al. report a retail price for the iPhone 4 in 2010 of \$549 and total production costs (including profits for US and foreign intermediate products' suppliers, in addition to labor costs, of which only \$10 are for assembling in China) of \$228. For the benchmark parameters in Table 1, this gives $\lambda w_S(1+\tau_N)/w_L = 549/228 = 2.40$, implying $\lambda = 3.33$.

$$u_N = 1 - s_N - \frac{\iota \eta_S [\iota(1 + \tau_N) + \mu] (1 - \alpha \beta \lambda)}{(\iota + \mu) \lambda \beta (1 - \alpha) \underline{w}_N \mu (1 + \tau_S)} - \iota^{\frac{1}{\varepsilon}} A_\iota \quad \mathbf{LABN}(u_N, \iota, \mu). \quad (34)$$

Since we impose $w_L > w_L^{comp}$ (to be validated by our numerical simulation in section 3.3), it follows $u_N > 0$ for all feasible $\alpha \in]0, 1/(\beta\lambda)[$.²¹ Similarly, we use $D = \delta s_N N_N / (n\gamma)$ and $c_S \equiv 1$ to rewrite the Southern labor market equilibrium condition (24) in Northern per-capita terms as

$$\frac{1 - n_N}{w_L} \left(c_N + \frac{\eta_S}{1 + \tau_S} \right) + n_N \mu^{\frac{1}{\varepsilon}} A_\mu = (1 - u_S) \eta_S,$$

where $A_\mu \equiv a_\mu \delta s_N / (n\gamma)$ is the effective resource requirement per unit of imitative R&D. Using (20) to substitute for n_N , (31) to substitute for w_L , and (21) with $c_S \equiv 1$ to substitute for c_N allows to rewrite u_S as a function of ι and μ only:

$$u_S = 1 - \frac{(1 - \alpha \beta \lambda) [\iota(1 + \tau_N) + \mu]}{(\iota + \mu) (1 - \alpha) \underline{w}_N (1 + \tau_S)} - \frac{\iota \mu^{\frac{1}{\varepsilon}} A_\mu}{(\iota + \mu) \eta_S} \quad \mathbf{LABS}(u_S, \iota, \mu). \quad (35)$$

Since we impose $w_S > w_S^{comp}$ (to be validated by our numerical simulation in section 3.3), it follows $u_S > 0$ for all feasible $\beta \in]0, 1/(\alpha\lambda)[$.

Next, we substitute v_N from (10) into (18), use (8) to substitute for D , (20) to substitute for n_N , (31) to substitute for w_L , and $A_\iota \equiv a_\iota \delta s_N / (n\gamma)$. This gives the Northern specialized-labor wage rate as an increasing function of ι only:

$$w_H = \varepsilon (1 - \alpha) \underline{w}_N A_\iota^{\frac{1}{\varepsilon}} / [(1 - \alpha \beta \lambda) s_N]. \quad (36)$$

It remains to determine the steady-state values of ι and μ . Setting (19) equal to (10), using (9) to substitute for R , using (8) and (23) to substitute for D and X , respectively, using $r = \rho$, $\dot{v}_N / v_N = n$, $A_\iota \equiv a_\iota \delta s_N / (n\gamma)$, (21) to substitute for c_N , $c_S \equiv 1$, (31) to substitute for w_L , (32) to substitute for w_S , and dividing by N_N yields, after simplifying, the free-entry in innovation (FEIN) condition²²

²¹ The competitive wage rate w_N^{comp} is the wage rate that clears the Northern general-purpose labor market under no bargaining. Any higher bargained wage rate $w_L > w_N^{comp}$, which justifies ex post the existence of a labor union, raises R&D and production costs by more than it raises revenues (the latter indirectly through affecting w_S). This reduces R&D incentives of Northern entrepreneurs. The resulting decrease in ι reduces R&D and production labor demand (the latter by reducing n_N , inter alia) in the North, which implies $u_N > 0$ in equilibrium.

²² Since $A_\iota \rightarrow \infty$ for $n \rightarrow 0$, it follows from (37) that a positive steady-state innovation rate is not compatible with zero population growth. In our model, RPAs lead to accumulation of R&D difficulty stock over time. Thus,

$$\frac{\overbrace{\eta_S \cdot \frac{\iota(1+\tau_N)+\mu}{\mu(1+\tau_S)} \cdot \left(1-\frac{1}{\beta\lambda}\right)}^{=\pi_N^r/N_N}}{\rho+(1+\varepsilon)(\iota+\mu)-n} = \frac{(1-\alpha)\underline{w}_N A_\iota \cdot \iota^{\frac{1-\varepsilon}{\varepsilon}}}{1-\alpha\beta\lambda} \quad \mathbf{FEIN}(\iota, \mu). \quad (37)$$

The LHS of (37) gives the discounted innovative R&D benefits per capita, and the RHS of (37) gives innovative R&D costs per capita. To find the slope of the FEIN curve, we collect the μ and ι terms on the LHS of (37) and totally differentiate. We find that the LHS of the resulting expression is unambiguously decreasing in μ . It is also decreasing in ι provided that the following holds:

$$\left[\left(2-\frac{1}{\varepsilon}\right)\iota(1+\tau_N)+\left(1-\frac{1}{\varepsilon}\right)\mu\right]\left[\rho+(1+\varepsilon)(\iota+\mu)-n\right] < \iota\left[\iota(1+\tau_N)+\mu\right](1+\varepsilon). \quad (38)$$

It is easily verified that for all $\varepsilon \leq 0.5$, the inequality (38) is true. In other words, for sufficiently decreasing returns to scale in R&D, the FEIN(ι, μ) curve is unambiguously downward sloping in (ι, μ) space.²³

Similarly, using (5) in (17) together with $r = \rho$ and $\dot{v}_S/v_S = n$, setting this equal to (13), using (12) to substitute for M , using (8) and (23) to substitute for D and X , respectively, $A_\mu \equiv a_\mu \delta s_N / (n\gamma)$, (21) to substitute for c_N , $c_S \equiv 1$, (31) to substitute for w_L and (32) to substitute for w_S , and dividing by N_N yields, after simplifying, the free-entry in imitation (FEIM) condition

$$\frac{\overbrace{\eta_S \cdot \left[1 + \frac{\iota}{\mu(1+\tau_S)}\right] \cdot (1-\beta)}^{=\pi_S/N_N}}{\rho+\iota-n} = w_S A_\mu \mu^{\frac{1-\varepsilon}{\varepsilon}} \Leftrightarrow$$

$$\frac{\eta_S \cdot \frac{\iota(1+\tau_N)+\mu}{\mu(1+\tau_S)} \cdot \left(\frac{1}{\beta}-1\right)}{\rho+\iota-n} = \frac{(1-\alpha)\underline{w}_N}{1-\alpha\beta\lambda} \cdot A_\mu \mu^{\frac{1-\varepsilon}{\varepsilon}} \quad \mathbf{FEIM}(\iota, \mu). \quad (39)$$

supporting a positive and constant innovation rate requires expanding resources for R&D, which in turn requires $n > 0$. However, if we introduce a constant depreciation rate $\sigma > 0$ for R&D difficulty, a positive steady-state innovation rate would be compatible with $n = 0$. Instead of (7), the equation of motion for R&D difficulty would be given by $\dot{D}(\omega) = n_N \delta X(\omega) - \sigma D(\omega)$. With $n = 0$, setting $\dot{D} = 0$ and using (23) would imply a constant R&D difficulty $D = s_N N_N \delta / (\sigma\gamma)$ and positive steady-state growth.

²³ We rule out an upward-sloping FEIN to ensure intuitive stability in the sense of Davidson and Segerstrom (1998), and to rule out implausible comparative-static results. See that paper for further discussion. A formal stability analysis is beyond the scope of this paper. See, however, Martensen (2012) for necessary and sufficient stability conditions for a simplified version of this model (with exogenous Southern imitation and a competitive Southern labor market).

The LHS of (39) captures the discounted imitative R&D benefits per Northern capita, and the RHS captures the imitative R&D costs per Northern capita. To find the slope of the FEIM curve, we again collect the μ and ι terms on the LHS of (39) and totally differentiate. We find that the LHS of the resulting expression is unambiguously decreasing in μ . Numerical simulations show that it is also decreasing in ι for a wide range of plausible parameter values. Thus, the FEIM curve is also downward sloping in the (ι, μ) space. Dividing (37) by (39) gives the relative profitability (RP) condition

$$\frac{(\rho + \iota - n) \left(1 - \frac{1}{\beta\lambda}\right)}{[\rho + (1 + \varepsilon)(\iota + \mu) - n] \left(\frac{1}{\beta} - 1\right)} = \frac{a_\iota \left(\frac{\iota}{\mu}\right)^{\frac{1-\varepsilon}{\varepsilon}}}{a_\mu \left(\frac{\iota}{\mu}\right)} \quad \mathbf{RP}(\iota, \mu), \quad (40)$$

which equates the relative innovation-imitation benefits to the relative innovation-imitation costs. To find the slope of the RP curve, we collect the μ and ι terms on the LHS of (40) and totally differentiate. We find that the LHS of the resulting expression is increasing in μ iff

$$\frac{(1 - \varepsilon)(\rho - n)}{\varepsilon\mu} + (1 + \varepsilon) \cdot \frac{(1 - \varepsilon)\frac{\iota}{\mu} + 1 - 2\varepsilon}{\varepsilon} > 0, \quad (41)$$

which again is fulfilled for any $\varepsilon \leq 0.5$. Our numerical simulations show that the LHS of the resulting expression is declining in ι for a wide range of plausible parameter values, such that the RP curve is upward sloping in (ι, μ) space.²⁴ The simulations also show that a unique steady-state equilibrium in the positive quadrant exists for a wide range of parameters around a reasonable benchmark (the choice of benchmark parameters is discussed below in section 3.3). Figure 1 shows the RP and FEIN curves that jointly pin down the steady-state values of ι^* and μ^* for the special case $\underline{w}_S = 0$, and also shows the effects of unilateral Northern trade liberalization ($\tau_N \downarrow$) to be discussed below in section 3.1.

Insert here Figure 1

The remaining endogenous variables are determined recursively for given ι^* and μ^* in the following order. w_H^* follows from (36), u_N^* follows from (34), u_S^* follows from (35), w_S^* follows from (32), n_N^* follows from (20), c_N^* follows from (21) for given $c_S \equiv 1$, v_N^* follows from (19) for given $r = \rho$ from (3) and $\dot{v}_N/v_N = n$, π_N^{P*} follows from (4), π_S^* follows from (5), v_S^* follows from (17) for given $r = \rho$ and $\dot{v}_S/v_S = n$, X^* follows from (18), D^* follows from (8), R^* follows from (9), and M^* follows from (12).

²⁴ We used Mathematica version 8 to run the simulations. The source code and the details of the simulations are relegated to a Mathematica Appendix, which is available on the authors' web sites (<http://www1.union.edu/senerm/> and <http://www.vwl.uni-wuerzburg.de/lehrstuehle/vwl2/team/lehrstuhlvertretung/research/>).

Finally, as we show in Appendix R.1, Northern per-capita steady-state welfare can be expressed as

$$F_N = \frac{1}{\rho} \left[\frac{\iota \log(\lambda)}{\rho} + (1 - n_N) \log \left(\frac{c_N}{p_S^N} \right) + n_N \log \left(\frac{c_N}{p_N^N} \right) \right], \quad (42)$$

which consists of static and dynamic components. The dynamic welfare component is $\iota \log \lambda$. In the continuum of industries, quality improvements arrive at a rate of ι , and each improvement raises the consumer's utility by $\log \lambda$. The static welfare component is the logarithm of purchased goods summed over industries. In a fraction $1 - n_N$ of industries, the Northern consumer faces a price of $p_S^N = w_L$ and purchases c_N / p_S^N units. In the remaining fraction n_N of industries, she faces a price of $p_N^N = \lambda w_S (1 + \tau_N) > p_S^N$ and buys c_N / p_N^N units.^{25, 26} Similarly, Southern per-capita steady-state welfare can be expressed as

$$F_S = \frac{1}{\rho} \left[\frac{\iota \log(\lambda)}{\rho} + (1 - n_N) \log \left(\frac{c_S}{p_S^S} \right) + n_N \log \left(\frac{c_S}{p_N^S} \right) \right], \quad (43)$$

where $c_S \equiv 1$ and $p_S^S = w_L (1 + \tau_S) < p_N^S = \lambda w_S$.

3 Comparative Analysis

3.1 Trade Liberalization

Unilateral Northern trade liberalization for $w_S = 0$ does not affect the RP curve (40), but decreases the LHS of FEIN (37).²⁷ For any given μ , a decrease in ι is required to restore FEIN. Hence this curve shifts down as illustrated in Figure 1 above, and the steady-state values of both ι and μ decline. Since the common steady-state utility growth rate is derived from (2) as $g^* = \dot{f}_N / f_N = \dot{f}_S / f_S = \iota^* \log \lambda$, this implies that unilateral Northern trade liberalization reduces Northern innovation and worldwide economic growth.

²⁵ $p_N^N > p_S^N$ follows from (33) for the entire feasible range of β .

²⁶ Combining (21) for $c_S \equiv 1$, (31), and (34) reveals that for given ι and μ , Northern per-capita consumption expenditure is declining in u_N (and rising in w_L): $c_N = \frac{(1 - s_N - u_N - \iota^{\frac{1}{\epsilon}} A_i)(\iota + \mu)(1 + \tau_N) \lambda \beta w_L}{\iota(1 + \tau_N) + \mu}$. This explains how unemployment ceteris paribus reduces F_N , although it does not show up directly in (42).

²⁷ The Mathematica Appendix shows that in the general case $w_S > 0$, a reduction in τ_N turns the more general version of the RP curve slightly counterclockwise, while all effects discussed below remain qualitatively unchanged.

A lower τ_N exerts multiple effects on innovative R&D profitability. First, it directly reduces the price received by the Northern innovator from sales in the North $\lambda w_S(1 + \tau_N)$. This decreases π_N and thus innovative R&D profitability. Second, a lower τ_N reduces c_N and thus the total sales of the Northern innovator in the Northern market. This decreases π_N and thus innovative R&D profitability. Finally, a lower τ_N exerts no effect on w_L but reduces the North-South relative wage w_L/w_S . This increases the price marginal-cost ratio of the Northern firm in both markets, increasing π_N and also innovative R&D profitability.²⁸ The net effect follows from (37), which is a fall in innovative R&D profitability.

Restoring FEIN requires a fall in ι , which works its effect via multiple channels. First, a lower ι implies lower innovative R&D costs due to the decreasing-returns-to-scale technology. Second, it decreases the total domestic sales of Northern firms by decreasing c_N . Third, a lower ι exerts no effect on w_L but increases the price marginal-cost ratio for Northern innovators in both markets by decreasing w_L/w_S . The net effect is an increase in R&D profitability to reestablish equilibrium.

The downward shift in FEIN implies a movement down the RP curve. More specifically, when ι declines, the profitability of innovative R&D increases by more than the profitability of imitative R&D, given that condition (41) is fulfilled. In other words, the profitability of imitation relative to innovation falls; hence, a decrease in μ is required to restore RP.

From (34) it follows that a decrease in τ_N affects u_N in three ways. First, one direct impact of a lower τ_N is to increase the Southern firms' export profits π_S^N , and hence the Southern bargained wage rate w_S for given ι and μ . This raises the product prices of Northern firms and reduces the total quantity produced per Northern industry Q_N , which reduces Northern production labor demand as seen in (22).²⁹ A second impact of a lower τ_N is to reduce the Northern innovation rate ι , which directly reduces Northern R&D labor demand and also indirectly reduces Northern production labor demand (by reducing the share of Northern firms n_N). A third impact of a lower τ_N is to reduce the Southern imitation rate μ , which implies an increase in Northern production labor demand by raising n_N . Further second-order effects work through the impact of changes in ι and μ on w_S and c_N .³⁰ Our numerical simulations in section 3.3 reveal that for

²⁸ In the Southern market, the innovator's price marginal-cost ratio is $[\lambda w_S/(1 + \tau_S)]/w_L$. In the Northern market, the innovator's price marginal-cost ratio is $\lambda w_S(1 + \tau_N)/w_L$.

²⁹ There are two additional effects on Northern production employment that cancel out: a decrease in τ_N increases Q_N by reducing the Northern firms' limit price $\lambda w_S(1 + \tau_N)$ on the Northern market for given w_S , which exactly offsets the decline in c_N that is dictated by the BOT condition (21) for $c_S \equiv 1$.

³⁰ For example, if ι/μ decreases, this would reduce Q_N by decreasing c_N , see (21), and by increasing w_S , see (32),

plausible parameter values, the negative employment effects dominate, such that a decline in τ_N raises u_N^* .

From (35) it follows that unilateral Northern trade liberalization affects the Southern unemployment rate u_S in three ways. First, the decrease in c_N explained before also reduces the total quantity produced per Southern industry Q_S . This reduces Southern production labor demand as seen in (24). A second effect works through the decline in ι . This reduces Southern imitative R&D labor demand by lowering the share of Northern industries that imitation can target, but it also increases the share of Southern industries $1 - n_N$ and hence increases Southern production labor demand. A third impact of a lower τ_N is to reduce the Southern imitation rate μ , which directly reduces Southern imitative R&D labor demand and also indirectly reduces Southern production labor demand (by reducing $1 - n_N$). Further second-order effects again work through the impact of changes in ι and μ on w_S and c_N . Our numerical simulations in section 3.3 reveal that for plausible parameter values, the net effect of a decline in τ_N is to increase u_S^* .

Unilateral Southern trade liberalization for $w_S = 0$ again does not affect the RP curve (40), but increases the LHS of FEIN (37).³¹ An increase in ι for any given μ is required to restore FEIN. Hence this curve shifts upward (opposite to Figure 1 above), and the steady-state values of both ι and μ increase. Thus, unilateral Southern trade liberalization raises Northern innovation and worldwide economic growth.

A lower τ_S exerts multiple effects on innovative R&D profitability. First, it directly raises the net price received by the Northern innovator from exports $\lambda w_S / (1 + \tau_S)$. This increases π_N and thus innovative R&D profitability. Second, a lower τ_S raises c_N and thus the total sales of the Northern innovator in the Northern market. This increases π_N and thus innovative R&D profitability. Finally, a lower τ_S exerts no effect on w_L but increases the North-South relative wage w_L / w_S . This reduces the price marginal-cost ratio of the Northern firm in both markets, decreasing π_N and also innovative R&D profitability. The net effect follows from (37), which is an increase in innovative R&D profitability.

Restoring FEIN requires an increase in ι , which works its effects through the same channels identified in the case of a decline in τ_N , but in the opposite direction. In short, a higher ι reestablishes equilibrium by decreasing innovative R&D profitability by more than imitative R&D profitability, given that condition (41) is fulfilled. The upward shift in FEIN implies a movement up the RP curve; hence an increase in μ is required to restore RP.

which would reduce Northern production labor demand further.

³¹ The Mathematica Appendix shows that in the general case $w_S > 0$, a reduction in τ_S turns the more general version of the RP curve slightly clockwise, while all effects discussed below remain qualitatively unchanged.

From (34) it follows that unilateral Southern trade liberalization affects u_N in four ways. First, for given levels of ι and μ , a decrease in τ_S increases c_N , as required by the BOT condition (21). Second, a decrease in τ_S reduces w_S , as given in (32). Both effects raise Q_N and hence the demand for Northern production labor. Third, a lower τ_S raises ι , which directly increases Northern R&D labor demand and also indirectly increases Northern production labor demand (by raising the share of Northern firms n_N). Fourth, a lower τ_S raises μ , which implies a decrease in Northern production labor demand by reducing n_N . Further second-order effects again work through the impact of changes in ι and μ on w_S and c_N . Our numerical simulations in section 3.3 reveal that for plausible parameter values, the positive employment effects dominate, such that a decline in τ_S reduces u_N^* .

From (35) it follows that unilateral Southern trade liberalization affects u_S in four ways. First, for given ι and μ , a lower τ_S reduces p_S^S and thereby increases Southern aggregate output Q_S and Southern labor demand for production. Second, this effect is reinforced by the resulting increase in c_N that is required by the BOT condition (21), given $c_S \equiv 1$. A third effect works through the increase in ι . This raises Southern imitative R&D labor demand by increasing the share of Northern industries that imitation can target, but it also decreases the share of Southern industries $1 - n_N$ and hence the demand for Southern production labor. Fourth, a lower τ_S leads to an increase in μ , which directly raises Southern imitative R&D employment, and it also indirectly increases Southern production employment by raising $1 - n_N$. Further second-order effects again work through the impact of changes in ι and μ on w_S and c_N . Our numerical simulations in section 3.3 reveal that for plausible parameter values, the net effect of a decline in τ_S is to reduce u_S^* .

Finally, we analyze **bilateral trade liberalization** that takes the form of a simultaneous decline in both τ_N and τ_S by the same amount (i.e., $d\tau_N = d\tau_S \equiv d\tau < 0$), while we allow for different tariff levels across countries. Provided that $\tau_S - \tau_N < \mu/\iota$ holds *ex ante*,³² which comprises equal tariff levels $\tau_S = \tau_N$ as a special case, $d\tau < 0$ raises the LHS of the FEIN condition (37), such that the FEIN curve shifts upward, while the RP curve for $\underline{w}_S = 0$ is again not (and for $\underline{w}_S > 0$ not significantly) affected. Hence, both ι^* and μ^* unambiguously increase. Our numerical analysis below shows that for plausible parameter values, both u_N^* and u_S^* decline. Summarizing the main arguments, we have derived our

³² The only term in (37) that contains tariff rates is $[\iota(1 + \tau_N) + \mu]/[\mu(1 + \tau_S)]$. For $\mu/\iota = \tau_S - \tau_N$, this becomes $1/(\tau_S - \tau_N)$. Hence in this knife edge case, $d\tau < 0$ would leave the FEIN condition unaffected. However, our numerical simulations show that the condition $\tau_S - \tau_N < \mu/\iota$ is clearly fulfilled for all feasible parameter values, see Table 1.

Proposition 1: *Starting from a unique steady-state equilibrium with an interior solution we find the following permanent effects:*

- (a) *Northern unilateral trade liberalization reduces Northern innovation, worldwide economic growth, and Southern imitation, and it increases both Northern and Southern unemployment rates;*
- (b) *Southern unilateral trade liberalization raises Northern innovation, worldwide economic growth, and Southern imitation, and it decreases both Northern and Southern unemployment rates;*
- (c) *for all empirically plausible parameter values, bilateral trade liberalization by equal amounts raises Northern innovation, worldwide growth, and Southern imitation, and it reduces both Northern and Southern unemployment rates.*

Our analysis generates a number of new insights. First, we find that changes in tariff rates either by the North or the South affect the equilibrium rates of innovation and imitation. This differs from Grieben and Şener (2009, Proposition 2, p. 1055) who use a similar set up but consider competitive wages. They find that innovation and imitation rates are neutral to tariff adjustments (the “tariff-neutrality” result). Hence, we conclude that wage bargaining plays a crucial role for tariffs to have any effect on Northern innovation and Southern imitation rates. What is the intuition? In the presence of wage bargaining, Northern wages do not respond to changes in tariffs as shown in equation (31).³³ Hence, any revenue gains by Northern innovators from higher Northern tariffs (or lower Southern tariffs) do not translate into higher Northern wages. The lack of this direct cost-increasing impact, along with other general equilibrium effects, implies that a higher Northern tariff rate (or a lower Southern tariff rate) can actually raise R&D profitability and thereby lead to faster innovation. In the case of competitive wages, any profit-increasing impact of tariff changes are mitigated by increased Northern wages. More specifically, higher Northern wages along with other general equilibrium effects completely nullify any revenue gains by innovator firms emanating from tariff changes, leaving innovative R&D profitability and the innovation rate the same.³⁴

Second, we find that in our North-South setting, unilateral Northern tariff hikes can actually lead to higher growth. This differs from Dinopoulos and Segerstrom (1999) who find that lower Northern tariffs boost growth in a similar set up but with competitive wages and a symmetric North-North structure. What

³³ This reasoning also extends to the more general case of $w_s > 0$. The interdependency of wages given in (28) and (30) implies that tariff effects on w_L are mitigated by their opposite effects on w_S , and vice versa.

³⁴ In Appendix A, we provide the technical details regarding the responses of Northern and Southern wages in the competitive wage version of our model.

explains the stark difference? In Dinopoulos and Segerstrom, tariffs imposed by the home country do not help the country's quality leader to get an edge in the domestic market. This is because in this symmetric setting, successful home innovators compete with home country followers in the domestic market, and tariff rates do not affect the extent of mark-up pricing in this market. The primary impact of lower tariffs is associated with foreign market sales. Lower tariffs in the foreign country raise the export revenues of innovators and thereby increase the rewards from innovative R&D. In our North-South set up, successful Northern innovators compete with one-step down potential Southern producers. Thus, Northern innovators' mark-up rates are functions of the South's marginal cost of production and also the North's tariff rates. In particular, home country tariffs (in this case Northern tariffs) can raise the mark-up rate charged by home producers in the domestic market. This is the standard rent-shifting mechanism of home tariffs to domestic suppliers, which shows up as the primary force in our North-South setting but is muted in a symmetric North-North setting. Hence, we conclude that our North-South structure coupled with wage bargaining sets the scene to give rise to the result that higher Northern tariffs lead to more Northern innovative R&D.

Third, our results suggest that bilateral (i.e., simultaneous Northern and Southern) trade liberalization, as it took place e.g. in the Uruguay round 1986-1993 under the GATT, will yield positive growth (and employment) effects if the developing South's tariff cuts are sufficiently large relative to those of the developed North. Estevadeordal and Taylor (2008, pp. 14-15) report evidence along these lines for the period 1975-2000: 22 developed countries lowered their tariff rates from about 10% to about 5% on average, whereas 63 developing countries lowered their tariff rates from about 35% to about 15% on average.³⁵ Hence if empirical evidence is able to establish positive growth effects from bilateral trade liberalization during that period, our results would be fully in line with this. We should note though that the existing empirical specifications fail to distinguish between the effects of unilateral and bilateral tariff cuts. Hence they do not examine the questions of whether the country origin of the tariff cut matters for growth. We therefore think that existing empirical work can neither confirm nor reject our surprising growth result for unilateral Northern trade liberalization.³⁶

³⁵ Estevadeordal and Taylor find a significant positive (transitional) growth effect of reducing import tariffs for capital and intermediate goods (but not for consumption goods, which is the focus of our model) in the "Great Liberalization" period of the 1990s. Note that their group of "liberalizers" includes only three developed countries but 39 developing countries. Rodrik (1994) also provides evidence on a significant wave of unilateral trade liberalization of many developing countries since the early 1980s.

³⁶ A general problem of the empirical literature is to identify the growth effects of trade *policy* liberalization, see e.g. the comments of Rodríguez (2007) on Wacziarg and Welch (2008), or the comments of Noguer and Siscart (2005, p. 457) on their own study. Another issue relevant for our purpose is that empirical studies such as DeJong and Ripoll (2006), who find that growth is decreasing in tariffs for countries with high income, use data consisting of a

3.2 Labor Unions' Power

An increase in the Northern union's bargaining power α raises the RHS of FEIM (39), given $\beta\lambda > 1$, such that a decrease in μ is required for any given ι to restore the FEIM condition. Hence, the FEIM curve in Figure 1 is shifting down, while the RP curve for the special case $\underline{w}_S = 0$ (for the general case $\underline{w}_S > 0$) is not (significantly) affected, and both ι and μ decrease unambiguously. An increase in the Northern reservation wage level \underline{w}_N has qualitatively the same effects.

As we explained earlier, an increase in α or \underline{w}_N directly raises the Northern bargained wage rate w_L , and indirectly raises the Southern bargained wage rate w_S . The rise in the wage levels are of equal proportion; thus, the relative wage w_L/w_S remains the same for given ι and μ , as seen in (33). It follows that the price marginal-cost ratio of Northern firms in both markets and hence π_N remain unchanged. However, due to the rise in w_L , innovative R&D costs increase. The FEIN curve shifts downward and the equilibrium level of ι declines. As before, the decrease in ι implies a fall in the profitability of imitative R&D relative to innovative R&D, which triggers the reduction in μ via a downward movement along the RP curve.

As can be seen in (34) and (35), for given ι and μ , both u_N and u_S are increasing in α and \underline{w}_N . This is because higher wages w_S and w_L imply higher product prices and reduce both Northern and Southern per-capita output levels Q_N and Q_S , decreasing production labor demand in both countries. The decline in μ and ι reduce both countries' R&D labor demand, but have an ambiguous net effect on the North-South distribution of industries, and thus on both countries' production labor demand. Our numerical analysis below shows that for plausible parameter values, both u_N and u_S increase with α and \underline{w}_N .

An increase in the Southern union's bargaining power β increases both the LHS and RHS of (37). The net effect is an increase in R&D profitability if and only if $1/\lambda^2 > \alpha\beta^2$, a condition which holds for a large set of parameters. Hence, assuming this condition holds, for any given μ , an increase in ι is required to restore the FEIN condition, and the FEIN curve in Figure 1 shifts up. In addition, the LHS of (40) rises, which also requires an increase in ι for any given positive μ to restore the RP condition, and the RP curve turns counterclockwise in Figure 1. While ι increases unambiguously, the net effect on μ is in general

single import tariff rate per country and period that is derived by using import shares as weights. Since by far most trade is among Northern developed countries, one mostly captures the positive growth effect of North-North trade liberalization. This is well established in Schumpeterian growth theory (see e.g. Dinopoulos and Segerstrom, 1999), but it does not allow to draw any conclusions about the effects of trade liberalization in a North-South context. See Billmeier and Nannicini (2009, pp. 469-473) for further criticism on DeJong and Ripoll (2006).

ambiguous.

The intuition for the curve shifts is as follows. A higher β directly raises the Southern bargained wage rate w_S , and indirectly raises the Northern bargained wage rate w_L . The rise in w_S is proportionately larger than the rise in w_L ; thus, the relative wage w_L/w_S declines, as seen in (33).³⁷ These wage changes exert competing effects on innovative R&D profitability. First, the higher w_L raises innovative R&D costs. Second, the fall in w_L/w_S increases the price marginal-cost ratio of Northern firms in both markets. The net impact on innovative R&D profitability is positive if and only if $1/\lambda^2 > \alpha\beta^2$ holds. With respect to the RP condition (40), we observe that a higher β increases the relative innovation-imitation profitability by increasing the mark-up rates of Northern firms and reducing those of Southern firms. This effect materializes by the decline in North-South relative wage w_L/w_S . Restoring the RP condition requires an increase in ι for a given level of μ . This implies a counterclockwise shift of the RP curve.

As can be seen in (34) and (35), for given ι and μ , both u_N and u_S are increasing in β . This is because higher wages w_S and w_L imply higher product prices and reduce both Northern and Southern per-capita output levels Q_N and Q_S , decreasing production labor demand in both countries. The decline in μ and the increase in ι further reduce Southern labor demand in production (by reducing $1 - n_N$) and imitative R&D, such that u_S rises. By raising n_N and increasing Northern R&D labor demand, the decline in μ and the increase in ι work towards reducing Northern unemployment. Our numerical analysis below shows that for plausible parameter values, the net effect is a decline in u_N . We finally note that an increase in the Southern reservation wage level \underline{w}_S has qualitatively the same effects as an increase in β . Summarizing the main arguments, we have derived our

Proposition 2: *Starting from a unique steady-state equilibrium with an interior solution we find the following permanent effects:*

- (a) *an increase in the Northern labor union's bargaining power α or the reservation wage level \underline{w}_N reduces Northern innovation, worldwide economic growth, and Southern imitation, and it increases both Northern and Southern unemployment rates;*
- (b) *an increase in the Southern labor union's bargaining power β or the reservation wage level \underline{w}_S raises Northern innovation and worldwide economic growth, decreases Southern imitation, reduces the Northern unemployment rate, and it increases the Southern unemployment rate.*

³⁷ Our numerical simulations in Table 1 below reveal that this is still true for the more general case $\underline{w}_S > 0$.

3.3 Numerical Simulation of the Steady-State Equilibrium

We now numerically simulate the model to demonstrate the existence of an interior equilibrium for reasonable parameter values. We also use the simulations to resolve the ambiguities on the net growth, unemployment and welfare effects of policies.

The choice of our benchmark parameter values as shown in Table 1 below is justified as follows: The size of innovations, $\lambda = 2$, implies a reasonable price marginal-cost ratio $\lambda w_S(1 + \tau_N)/w_L \approx 1.4$ of Northern innovative firms as we argued before. The subjective discount rate ρ is set at 0.07 to reflect a real interest rate of 7 percent, consistent with the average real return on the US stock market over the past century as calculated by Mehra and Prescott (1985). The use of this value is further justified by Jones and Williams (2000, p. 73). The population growth rate $n = 0.01$ is calculated as the annual rate of population growth of middle-income (2008 GNI per capita between \$976 and \$11,905) and high-income (2008 GNI per capita \$11,906 or more) countries between 1990 and 2008, as defined by the World Bank (2009). The ratio of Southern to Northern population $\eta_S = N_S/N_N$ is set at 3.93, which is calculated as the ratio of the working age population in middle-income countries to that in high-income countries, again following the World Bank (2009). For the degree of decreasing returns to R&D, we follow the choice $\varepsilon = 0.5$ of Gustafsson and Segerstrom (2010), who justify this by referring to the range [0.1, 0.6] reported by Kortum (1993, p. 452). The choice $\underline{w}_N = 0.55$ produces a reasonable Northern replacement ratio \underline{w}_N/w_L of around 40-50%, which is within the range for EU countries reported for 1999 by Nickell et al. (2005, p. 5, Table 2). Tariff rates $\tau_N = 0.1$ and $\tau_S = 0.2$ are chosen such that tariff cuts of 5% points lead to average Northern and Southern import tariff rates as documented by Estevadeordal and Taylor (2008). The proportion of specialized labor s_N is set at 0.01 to generate a wage differential w_H/w_L that is significantly greater than 1. It is reasonable to assume that specialized lobbyists/lawyers are in low supply and earn more than the general-purpose workers. The remaining parameters (A , A_μ , α , β , and \underline{w}_S) are chosen with the objective in mind to generate reasonable values for endogenous variables, in particular to generate unemployment rates³⁸ around 10%, and a growth rate $g = \ln \lambda$ around 2%, which is the average U.S. GDP per capita growth rate from 1950 to 1994 reported in Jones (2005).

Insert here Table 1

We note the following seven main findings from the numerical analysis of Table 1: first, all results

³⁸ Given our framework, the relevant figure for Southern developing countries is the urban unemployment rate, which is typically significantly larger than the rural one. For example, Liu (2012) estimates for 2002 an urban unemployment rate in China of 9.5%.

from Propositions 1 and 2 are confirmed for the special case $\underline{w}_S = 0$ and also for the more general case $\underline{w}_S > 0$. Second, bilateral trade liberalization by equal amounts raises North-South wage inequality w_N/w_S . Third, the growth effects of unilateral and bilateral trade liberalization translate into welfare effects of the same direction, with the only exception that a reduction in τ_N may increase Southern per-capita welfare F_S despite its negative innovation effect (i.e. the net positive static welfare effects can dominate in this case). Fourth, with wage bargaining and for all tariff levels considered, the values for ι , μ , F_N , and F_S are always below the corresponding values obtained with perfectly competitive labor markets, thereby reflecting efficiency costs of wage bargaining. Fifth, more Northern union power (increase in α or \underline{w}_N) forces both Northern manufacturing and R&D workers into unemployment, which reduces ι , c_N , and F_N . Sixth, qualitatively the exact opposite results are obtained in the case of more Southern union power (increase in β or \underline{w}_S , the latter not shown in Table 1 but available in our Mathematica Appendix). Seventh, while bilateral trade liberalization improves Southern welfare under both unionized and competitive labor markets, this is true for Northern welfare only in the case with unions. In other words, the *mere existence* of unionized labor markets switches the impact of bilateral tariff cuts on Northern welfare from negative to positive. This is mostly due to the dynamic (growth) gains from trade that are not realized with competitive wage setting (see Appendix A for details).

4 Conclusions

This is a first paper to analyze the growth, unemployment and welfare effects of unilateral and bilateral trade liberalization in a North-South general-equilibrium framework with unionized labor markets in both countries. Our findings make a case for unilateral trade liberalization by the South (based on growth, employment and welfare considerations), but not by the North. Our results challenge the mainstream view as highlighted by Krugman (1997, p. 113) that, putting the optimal tariff argument aside, which has almost no relevance in real world trade negotiations, “*the economist’s case for free trade is essentially a unilateral case: a country serves its own interests by pursuing free trade regardless of what other countries may do*”. We demonstrate that the case for unilateral trade liberalization may not have much support in a dynamic growth framework with asymmetric countries and unionized labor markets. However, we show that bilateral trade liberalization can be beneficial for both countries in terms of growth, long-run welfare, and employment. We emphasize that the growth gains from bilateral trade liberalization are obtained just because of the existence of labor unions, i.e. these gains are not realized with perfectly competitive labor markets where the “tariff neutrality” result from Grieben and Şener (2009) applies. Our analysis therefore qualifies the standard theoretical arguments suggesting positive

growth effects of trade liberalization, as exemplified by Dinopoulos and Segerstrom (1999) in a North-North setting with competitive labor markets. Moreover, our results point to the need for empirical research to isolate the impact of *unilateral* trade liberalization between developed and developing countries, and to account for labor market imperfections at the same time. Finally, we demonstrate how the North can benefit in terms of growth, long-run welfare and employment from having stronger labor unions in the South.

It is important to recognize four limitations of our model. First, the model assumes collective wage bargaining. Hence, our results for the North are more relevant for e.g. continental European countries than for the US. Second, the model assumes that the South is sufficiently close in terms of technical knowledge and workers' education such that it is able to copy Northern state-of-the-art technologies. Hence, our results are more relevant for e.g. East Asian emerging markets than for poor LDCs. Third, our model features a continuum of symmetric industries and hence is not designed to make any predictions about tariff changes across industries. Fourth, and most importantly, our model does not attempt to explain existing tariff levels in the world. Standard arguments for why observed developing countries' tariff rates exceed those of developed countries include a poorly developed taxation system in the former (such that Southern governments need to rely on tariff revenues to finance public expenditures), and a late entry of most developing countries into GATT negotiation rounds. We also do not model political economy arguments for tariffs that might influence Northern and Southern governments (often affected by mercantilistic attitudes) much more than the growth and unemployment effects we emphasize. Therefore, it would be misleading to draw a normative conclusion that the North would unequivocally benefit from raising its tariffs on Southern imports. Strategic negotiation considerations (i.e. the fear of Southern retaliation) may prevent Northern governments from doing so. Indeed, our model shows that the North does prefer bilateral trade liberalization over the status quo.

Appendix A: Steady-State Equilibrium with Competitive Wage Rates

We can derive the competitive wage rates w_L^{comp} and w_S^{comp} as a function solely in ι and μ , that is, the levels of w_L and w_S that would prevail if there were no wage bargaining, and if the competitive wage rates were exceeding the reservation wage levels in both countries, respectively. From (10) we get $w_L = v_N/(a_t D^\epsilon R^{1-\epsilon})$. Using (19) together with $r = \rho$ and $\dot{v}_N/v_N = n$ to substitute for v_N , using (9) to substitute for R , (8) and (23) to substitute for D , $A_t \equiv a_t \delta s_N/(n\gamma)$, (21) to substitute for c_N , $c_S \equiv 1$, simplifying and solving this free-entry in innovation (FEIN) condition for w_L^{comp} yields

$$w_L^{comp} = \frac{\eta_S [\iota(1 + \tau_N) + \mu]}{\mu(1 + \tau_S) [\rho + (1 + \varepsilon)(\iota + \mu) - n] A_\iota \iota^{\frac{1-\varepsilon}{\varepsilon}} + \frac{\eta_S}{\lambda w_S^{comp}} [\iota + \mu(1 + \tau_S)]}. \quad (\text{A.1})$$

From (13) we get $w_S = v_S / (a_\mu D^\varepsilon M^{1-\varepsilon})$. Using (17) and (5) together with $r = \rho$ and $\dot{v}_S / v_S = n$ to substitute for v_S , using (12) to substitute for M , (8) and (23) to substitute for D , $A_\mu \equiv a_\mu \delta s_N / (n\gamma)$, (21) to substitute for c_N , $c_S \equiv 1$, simplifying and solving this free-entry in imitation (FEIM) condition for w_S^{comp} yields

$$w_S^{comp} = \frac{\eta_S [\iota + \mu(1 + \tau_S)]}{(1 + \tau_S)(\rho + \iota - n) A_\mu \mu^{\frac{1}{\varepsilon}} + \frac{\eta_S}{w_L^{comp}} [\iota(1 + \tau_N) + \mu]}. \quad (\text{A.2})$$

From (A.1) and (A.2), the following competitive wage rates can be derived:

$$w_L^{comp} = \frac{(\lambda - 1)\eta_S [\iota(1 + \tau_N) + \mu]}{(1 + \tau_S) \left\{ \lambda \mu [\rho + (1 + \varepsilon)(\iota + \mu) - n] A_\iota \iota^{\frac{1-\varepsilon}{\varepsilon}} + \mu^{\frac{1}{\varepsilon}} (\rho + \iota - n) A_\mu \right\}}, \quad (\text{A.3})$$

$$w_S^{comp} = \frac{(\lambda - 1)\eta_S [\iota + \mu(1 + \tau_S)]}{\lambda(1 + \tau_S) \left\{ \mu [\rho + (1 + \varepsilon)(\iota + \mu) - n] A_\iota \iota^{\frac{1-\varepsilon}{\varepsilon}} + \mu^{\frac{1}{\varepsilon}} (\rho + \iota - n) A_\mu \right\}}. \quad (\text{A.4})$$

Since competitive wage rates ensure full employment by definition, we set $u_N = 0$ and $w_S = w_S^{comp}$ in the LABN equation from the main text:

$$\frac{n_N}{\lambda w_S^{comp}} \left(\frac{c_N N_N}{1 + \tau_N} + c_S N_S \right) + a_\iota \iota^{\frac{1}{\varepsilon}} D = (1 - s_N) N_N.$$

Using (20) to substitute for n_N , (A.4) to substitute for w_S^{comp} , (21) to substitute for c_N , $c_S \equiv 1$, (8) and (23) to substitute for D , and the definition $A_\iota \equiv a_\iota \delta s_N / (n\gamma)$ yields, after simplifying, a LABN equation that is independent of tariffs:

$$\frac{\iota \left\{ [\rho + (1 + \varepsilon)(\iota + \mu) - n] A_\iota \iota^{\frac{1-\varepsilon}{\varepsilon}} + (\rho + \iota - n) A_\mu \mu^{\frac{1-\varepsilon}{\varepsilon}} \right\}}{(\lambda - 1)(\iota + \mu)} + A_\iota \iota^{\frac{1}{\varepsilon}} = 1 - s_N. \quad \mathbf{LABN}(\iota, \mu) \quad (\text{A.5})$$

Finally, we set $u_S = 0$ and $w_L = w_L^{comp}$ in the LABS equation from the main text:

$$\frac{1 - n_N}{w_L^{comp}} \left(c_N N_N + \frac{c_S N_S}{1 + \tau_S} \right) + n_N a_\mu \mu^{\frac{1}{\varepsilon}} D = N_S.$$

Using (20) to substitute for n_N , (A.3) to substitute for w_L^{comp} , (21) to substitute for c_N , $c_S \equiv 1$, (8) and (23) to

substitute for D , and the definition $A_\mu \equiv a_\mu \delta_{S_N} / (n\gamma)$ yields, after simplifying, a LABS equation that is also independent of tariffs:

$$\frac{\lambda\mu[\rho + (1 + \varepsilon)(\iota + \mu) - n]A_\mu t^{\frac{1-\varepsilon}{\varepsilon}} + (\rho + \iota - n)A_\mu \mu^{\frac{1}{\varepsilon}}}{(\lambda - 1)(\iota + \mu)} + \frac{\iota A_\mu \mu^{\frac{1}{\varepsilon}}}{\iota + \mu} = \eta_S. \quad \text{LABS}(\iota, \mu) \quad (\text{A.6})$$

For a wide range around our benchmark parameters, both LABN and LABS curves are downward sloping in (ι, μ) space, see the Mathematica Appendix. These curves determine a unique steady-state equilibrium that is not affected by tariff changes. Hence with competitive wage rates, while leaving the rest of the framework unchanged, the rates of innovation and imitation, ι^{comp} and μ^{comp} , are independent of tariff rates, such that the tariff neutrality result of Grieben and Şener (2009, Proposition 2, p. 1055) is reestablished.

Any profit-increasing tariff changes (e.g., an increase in τ_N that raises the profits from Northern domestic sales, or a decrease in τ_S that raises the profits from Northern exports) are mitigated by a corresponding increase in w_L^{comp} . This effect along with the resulting general-equilibrium effects associated with changes in w_L^{comp} , w_S^{comp} , and c_N^{comp} completely nullify the initial positive tariff stimulus, and similarly for profit-decreasing tariff changes. With dynamic gains from trade liberalization being absent, only the static welfare effects on F_N^{comp} and F_S^{comp} remain, as reported in Table 1.

With wage bargaining in both countries, the independency of w_L from tariffs as given in (31) disables one of the adjustment channels relevant for the case of competitive labor markets. This reasoning also extends to the more general case of $\underline{w}_S > 0$.

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Table 1: Numerical steady-state equilibrium with $\underline{w}_S > 0$

Benchmark parameters: $\lambda = 2$, $\rho = 0.07$, $n = 0.01$, $\eta_S = 3.93$, $\alpha = 0.76$, $\beta = 0.51$, $\underline{w}_N = 0.55$, $\underline{w}_S = 0.2$, $s_N = 0.01$, $A_t = 75$, $A_\mu = 335$, $\varepsilon = 0.5$, $\tau_N = 0.1$, $\tau_S = 0.2$ (normalization: $c_S \equiv 1$)

Endogenous variables	Benchmark	$\tau_N = 0.05$	$\tau_S = 0.15$	$\tau_N = 0.05$ $\tau_S = 0.15$	$\alpha = 0.762$	$\underline{w}_N = 0.56$	$\beta = 0.512$
l	0.0306	0.0303	0.0314	0.0311	0.0303	0.0301	0.0308
μ	0.0896	0.0894	0.0910	0.0907	0.0894	0.0893	0.0885
n_N	0.2542	0.2530	0.2568	0.2556	0.2530	0.2524	0.2582
w_L	1.1785	1.1710	1.1987	1.1909	1.1857	1.1889	1.1928
w_S	0.7715	0.7759	0.7605	0.7646	0.7759	0.7778	0.7813
w_L/w_S	1.5274	1.5093	1.5762	1.5574	1.5281	1.5285	1.5268
\underline{w}_N/w_L	0.4667	0.4697	0.4588	0.4618	0.4639	0.4710	0.4611
w_H	2.0562	2.0182	2.1757	2.1357	2.0193	2.0377	2.1187
u_N	0.0886	0.0997	0.0529	0.0644	0.0999	0.1047	0.0810
u_S	0.1007	0.1070	0.0748	0.0812	0.1071	0.1098	0.1109
c_N	1.2280	1.1645	1.2990	1.2319	1.2199	1.2164	1.2540
$s_{R\&D} \equiv t^{\frac{1}{\varepsilon}} A_t$	0.0700	0.0687	0.0741	0.0727	0.0687	0.0682	0.0712
$s_M \equiv 1 - s_N - u_N - s_{R\&D}$	0.8314	0.8216	0.8630	0.8529	0.8214	0.8171	0.8378
$g = \text{dlog} \lambda$	0.0212	0.0210	0.0218	0.0216	0.0210	0.0209	0.0214
F_N	3.5860	3.0100	4.3721	3.7975	3.3715	3.2781	3.7250
F_S	-0.9447	-0.9353	-0.4996	-0.4896	-1.0693	-1.1235	-1.0888
w_L^{comp}	1.0688	1.0553	1.1152	1.1012			
w_S^{comp}	0.7026	0.7026	0.7095	0.7095			
t^{comp}	0.0332	0.0332	0.0332	0.0332			
μ^{comp}	0.0954	0.0954	0.0954	0.0954			
c_N^{comp}	1.2524	1.1955	1.3069	1.2475			
F_N^{comp}	5.5978	5.2388	5.7188	5.3598			
F_S^{comp}	0.8008	0.9349	0.7650	0.8991			

Notes: Here we provide the main results of our simulations using Mathematica. We analyze the variation of only one labor market parameter at a time. All conditions for the existence of a unique interior steady-state equilibrium (see Referees' Appendix R.3) are fulfilled throughout. In general, the benchmark parameters are in line with the recent related theoretical growth literature that employs numerical simulations, e.g. Dinopoulos and Segerstrom (1999), Jones (2002), Lundborg and Segerstrom (2002), Şener (2006, 2008), Segerstrom (2007), and Impullitti (2010). $s_{R\&D}$ is the Northern share of labor employed in R&D. s_M is the Northern share of labor employed in manufacturing. The negative Southern welfare is due to the logarithmic utility function and the choice of numéraire $c_S \equiv 1$, and hence is unproblematic.

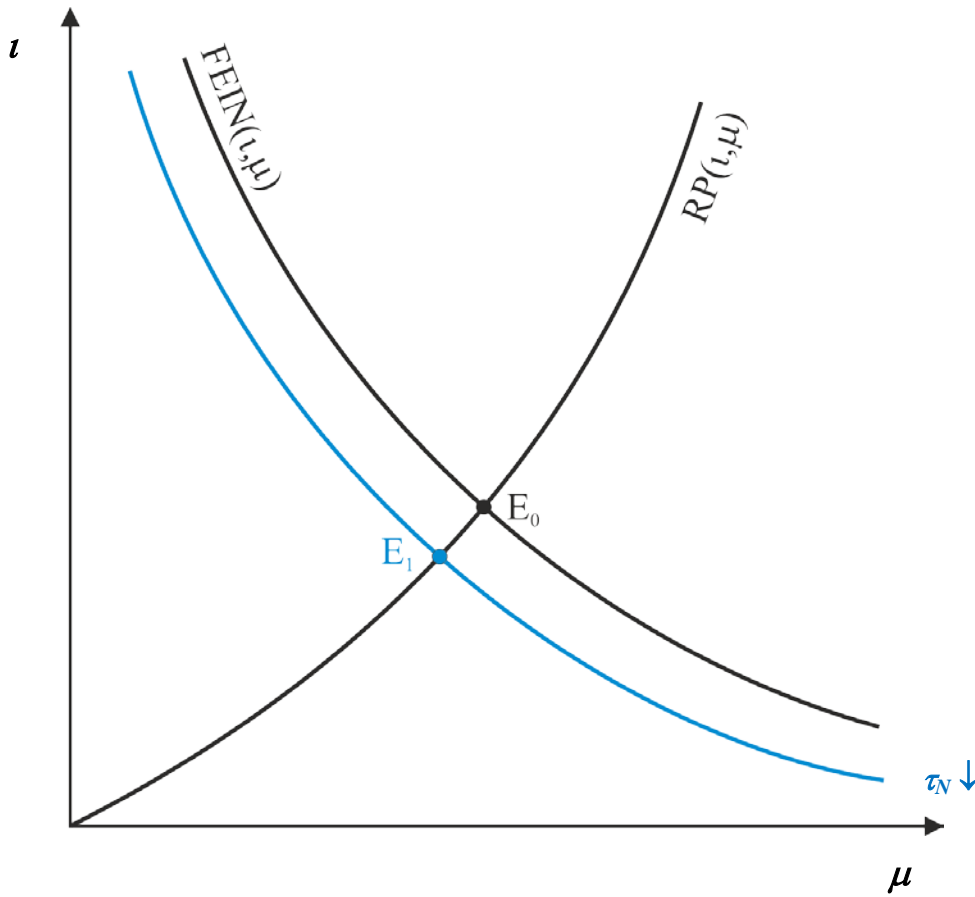


Figure 1: Steady-state equilibrium and unilateral Northern trade liberalization for $\underline{w}_S = 0$

Referees' Appendix (not for publication)

Appendix R.1: Derivation of Steady-State Welfare

To derive the expression (42) for Northern steady-state welfare, we first consider the instantaneous utility function per household member (2), and use the fact that only goods with the lowest quality-adjusted price are consumed (which allows to drop the sum Σ_j). We then replace the per-capita Northern unit-elastic demand function $x_N(j, \omega, t)$ by c_N/p_N^N and c_N/p_S^N for the products of Northern and Southern industries, respectively. This yields

$$\log f_N(t) = \int_0^{1-n_N} \log \left[\lambda^{j^*(\omega, t)} \frac{c_N}{p_S^N} \right] d\omega + \int_{1-n_N}^1 \log \left[\lambda^{j^*(\omega, t)} \frac{c_N}{p_N^N} \right] d\omega, \quad (\text{R.1})$$

where $j^*(\omega, t)$ stands for the quality level of the state-of-the-art product in industry ω at time t . We then use the property $\int_0^1 \log \lambda^{j(\omega, t)} d\omega = t \log \lambda$ of the stochastic Poisson process (see Grossman and Helpman, 1991, p. 97), which simplifies (R.1) to

$$\log f_N(t) = t \log(\lambda) + (1-n_N) \log \left(\frac{c_N}{p_S^N} \right) + n_N \log \left(\frac{c_N}{p_N^N} \right). \quad (\text{R.2})$$

Substituting (R.2) into the intertemporal utility function (1), and evaluating the integral, yields (42) as the expected discounted utility of a representative Northern citizen over an infinite horizon. Differentiating (R.2) with respect to time t gives the steady-state utility growth rate $g^* = \dot{f}_N/f_N = t^* \log \lambda$. The expected discounted utility of a representative Southern citizen (43) is derived in the same way, and the same steady-state growth rate $g^* = \dot{f}_S/f_S = t^* \log \lambda$ applies for the South.

Additional Reference for the Appendix R.1

Grossman, Gene and Helpman, Elhanan (1991): *Innovation and Growth in the Global Economy*. MIT Press, Cambridge, MA.

Appendix R.2: Numerical Simulation with Zero Southern Reservation Wage

Table 1A: Numerical steady-state equilibrium with $\underline{w}_S = 0$

Benchmark parameters: $\lambda = 2$, $\rho = 0.07$, $n = 0.01$, $\eta_S = 3.93$, $\alpha = 0.75$, $\beta = 0.55$, $\underline{w}_N = 0.85$, $\underline{w}_S = 0$, $s_N = 0.01$, $A_t = 50$, $A_\mu = 400$, $\varepsilon = 0.5$, $\tau_N = 0.1$, $\tau_S = 0.2$ (normalization: $c_S \equiv 1$)

Endogenous variables	Benchmark	$\tau_N = 0.05$	$\tau_S = 0.15$	$\tau_N = 0.05$ $\tau_S = 0.15$	$\alpha = 0.76$	$\underline{w}_N = 0.86$	$\beta = 0.552$
l	0.0292	0.0290	0.0297	0.0295	0.0289	0.0290	0.0303
μ	0.0852	0.0844	0.0880	0.0872	0.0836	0.0844	0.0834
n_N	0.2550	0.2559	0.2520	0.2529	0.2567	0.2559	0.2668
w_L	1.2143	1.2143	1.2143	1.2143	1.2439	1.2286	1.2355
w_S	0.7483	0.7576	0.7245	0.7334	0.7662	0.7569	0.7617
w_L/w_S	1.6228	1.6029	1.6760	1.6556	1.6235	1.6231	1.6221
\underline{w}_N/w_L	0.7000	0.7000	0.7000	0.7000	0.6833	0.7000	0.6880
w_H	2.5811	2.5553	2.6700	2.6438	2.5935	2.5872	2.8416
u_N	0.0867	0.0939	0.0621	0.0694	0.1004	0.0934	0.0471
u_S	0.1079	0.1196	0.0671	0.0792	0.1302	0.1188	0.1188
c_N	1.2333	1.1827	1.2668	1.2148	1.2443	1.2386	1.3107
$s_{R\&D} \equiv l^{\frac{1}{\varepsilon}} A_t$	0.0425	0.0421	0.0440	0.0435	0.0417	0.0421	0.0460
$s_M \equiv 1 - s_N - u_N - s_{R\&D}$	0.8608	0.8541	0.8839	0.8771	0.8479	0.8545	0.8969
$g = d \log \lambda$	0.0202	0.0201	0.0206	0.0205	0.0200	0.0201	0.0210
F_N	3.2378	2.7399	3.8200	3.3214	2.9749	3.1103	3.9732
F_S	-1.3507	-1.4167	-0.7082	-0.7734	-1.7335	-1.5365	-1.4380
w_L^{comp}	1.0930	1.0794	1.1405	1.1264			
w_S^{comp}	0.6752	0.6752	0.6817	0.6817			
l^{comp}	0.0313	0.0313	0.0313	0.0313			
μ^{comp}	0.0918	0.0918	0.0918	0.0918			
c_N^{comp}	1.2275	1.1717	1.2809	1.2227			
F_N^{comp}	4.9714	4.6086	5.0912	4.7284			
F_S^{comp}	0.4462	0.5791	0.4115	0.5443			

Notes: Here we provide results of our Mathematica[®] Appendix, which is available from the authors' websites. A Northern replacement rate of 0.7 is reported by Nickell et al. (2005, p. 5, Table 2) for the Netherlands in 1999, and even a somewhat larger value of 0.74 for Sweden and Switzerland. All results are qualitatively the same as for the case of a positive Southern reservation wage reported in Table 1, except for the effect of unilateral Northern trade liberalization on Southern welfare with wage bargaining, which here becomes negative.

Appendix R.3: Necessary Conditions for the Existence of a Valid Steady-State Equilibrium

We first note that our choice $\varepsilon = 0.5$ satisfies the conditions (38) and (41). In addition, the following conditions are required for an economically meaningful steady-state equilibrium in our model with a positive Southern reservation wage rate $\underline{w}_S > 0$ and wage bargaining (which are referred to as restrictions R₁ – R₉ in the Mathematica Appendix for the numerical simulations):

1. $\frac{\lambda w_S}{1 + \tau_S} > w_L$ is required to ensure positive Northern firms' export profits $\pi_N^S > 0$;
2. $w_L > (1 + \tau_N)w_S$ is required to ensure positive Southern firms' export profits $\pi_S^N > 0$;
3. $\frac{\lambda w_S [\iota(1 + \tau_N) + \mu]}{\iota + \mu(1 + \tau_S)} \equiv w_L^{\max} > \underline{w}_N$ is required to ensure that the Northern bargained wage rate w_L is increasing in the Northern labor union's bargaining power α ;
4. $\frac{w_L [\iota + \mu(1 + \tau_S)]}{\iota(1 + \tau_N) + \mu} \equiv w_S^{\max} > \underline{w}_S$ is required to ensure that the Southern bargained wage rate w_S is increasing in the Southern labor union's bargaining power β .

Solving (28) and (30) for the two bargained wage rates in the general case $\underline{w}_S > 0$ yields

$$w_L = \frac{\alpha\lambda(1 - \beta)\underline{w}_S [\iota(1 + \tau_N) + \mu]}{(1 - \alpha\beta\lambda)[\iota + \mu(1 + \tau_S)]} + \frac{(1 - \alpha)\underline{w}_N}{1 - \alpha\beta\lambda}, \quad (\text{R.3})$$

$$w_S = \frac{\beta(1 - \alpha)\underline{w}_N [\iota + \mu(1 + \tau_S)]}{(1 - \alpha\beta\lambda)[\iota(1 + \tau_N) + \mu]} + \frac{(1 - \beta)\underline{w}_S}{1 - \alpha\beta\lambda}. \quad (\text{R.4})$$

It follows from (R.3) and (R.4) that

5. $\alpha\beta\lambda < 1$ is required to ensure positive bargained wage rates w_L and w_S ;
6. $w_L > \underline{w}_N \Leftrightarrow \underline{w}_S > \frac{(1 - \beta\lambda)[\iota + \mu(1 + \tau_S)]}{\lambda(1 - \beta)[\iota(1 + \tau_N) + \mu]}$ is required for the existence of a Northern labor union to be justified ex ante ($\beta\lambda > 1$ is sufficient, but not necessary for this);

7. $w_S > \underline{w}_S \Leftrightarrow \underline{w}_N > \frac{(1-\alpha\lambda)[\iota(1+\tau_N)+\mu]}{(1-\alpha)[\iota+\mu(1+\tau_S)]}$ is required for the existence of a Southern labor union to

be justified ex ante ($\alpha\lambda > 1$ is sufficient, but not necessary for this).

8. $w_L > w_L^{comp}$ is required for the existence of a Northern labor union to be justified ex post.

9. $w_S > w_S^{comp}$ is required for the existence of a Southern labor union to be justified ex post.