North-South Trade, Unemployment and Growth: What’s the Role of Labor Unions?

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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 find that unilateral Northern trade liberalization reduces growth and increases unemployment in both countries, while unilateral Southern trade liberalization has the opposite effects. We show that the existence of labor unions matters for trade liberalization to have any effect on Northern innovation and worldwide growth. 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: trade liberalization, product cycle, endogenous growth, labor unions, unemployment
JEL classification: F16, F43, J51, O31

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1 Introduction

The impact of trade liberalization on economic growth still remains controversial and hence a matter of ongoing interest for both theoretical and empirical research (Estevadeordal and Taylor 2008, Segerstrom 2011). While being convenient for modeling purposes, the early literature’s focus on the effects of a regime switch from autarky to free trade can be analytically misleading and empirically misspecified, as forcefully argued by Baldwin and Forslid (1999, pp. 798-799). One standard approach of the R&D-based endogenous growth literature is to analyze bilateral incremental trade liberalization in a symmetric two-country framework. For example, the argument in the North-North growth model of Dinopoulos and Segerstrom (1999) goes as follows. A bilateral reduction in tariffs raises export profits and thus total profits of monopolistic firms. This increases the expected rewards from successful innovation and raises the incentives to engage in R&D. Thus, a larger portion of the economy’s resources is invested in R&D, spurring technological progress and thus economic growth.

More recent research has extended this R&D-based growth-trade approach by incorporating heterogeneous firms1 and also by considering unilateral incremental trade liberalization.2 As rapidly growing countries such as China and India are becoming increasingly more prevalent in the global economy, it becomes crucial to investigate the effects of incremental trade liberalization in asymmetric North-South models. Grieben and Şener (2009) take a step in this direction by considering tariff cuts in a fully-endogenous non-scale growth model with Northern innovation and Southern imitation. Their baseline model implies that neither unilateral nor bilateral incremental trade liberalization has any effect on long-run economic growth (“tariff neutrality”).

The current paper further extends the model of Grieben and Şener (2009) by incorporating wage bargaining and thereby generating unemployment, a feature that is completely ignored by the literature re-

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1 Dinopoulos and Unel (2011) study a variety-expansion growth framework with two structurally-identical countries, but allowing for heterogeneous firms that differ in their product quality levels. They show that lower trade costs or lower import tariffs in general have an ambiguous net effect on economic growth. Other recent endogenous growth models with heterogeneous firms include Haruyama and Zhao (2010), as well as Segerstrom and Stepanok (2011).

2 Dinopoulos and Syropoulos (1997), Baldwin and Forslid (1999), Ben-David and Loewy (2000), as well as Naito (2011) study the effects of unilateral, as opposed to bilateral trade liberalization. However, they remain within a framework of structurally identical (Northern) countries and hence are unable to analyze the possible issue of whether the growth effect depends on which country reduces tariff rates. Dinopoulos and Segerstrom (2007) do analyze an asymmetric North-South model, but their trade costs take the specific form of symmetric iceberg transportation costs that cannot be given a policy interpretation, and that cannot be reduced unilaterally. Grieben (2005) does analyze unilateral trade liberalization in an asymmetric North-South model. In contrast to the present paper, he considers a full-employment setting where the South produces only a traditional good but does not engage in any imitation activity. Grieben focuses on wage inequality effects of trade liberalization.
viewed above. More specifically, we assume that both the Northern and the Southern labor markets for production workers are unionized. The wage setting by unions coupled with a rigid outside option for workers results in involuntary Northern and Southern unemployment. This 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.\(^3\) We show that adding wage bargaining removes the tariff-neutrality result from Grieben and Şener (2009). Instead, the growth effects of incremental trade liberalization crucially depend on which country reduces its import tariffs. Unilateral Northern (Southern) trade liberalization reduces (increases) worldwide economic growth and Northern welfare, while bilateral trade liberalization promotes growth and both countries’ welfare for a wide range of plausible parameters when we implement the model numerically. With regards to the unemployment effects of trade liberalization, we have the following results. When (unilateral or bilateral) trade liberalization raises the Northern innovation rate, both Northern and Southern unemployment rates decrease. Whereas when trade liberalization reduces Northern innovation, both countries’ unemployment rates increase.

Our results are 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.\(^4\) A second strand explores the role of unions in static trade models without unemployment.\(^5\) A third strand uses dynamic endogenous growth settings with unemployment, but labor unions are not incorporated.\(^6\) Hence, the question of how trade liberalization affects growth and unemployment in a setting with unionized labor markets remains open to investigation. In the current paper, we intend to fill precisely this gap by modeling labor unions in a dynamic two-country setting with sustained TFP growth driven by endogenous R&D.

\(^3\) Nickell et al. (2005, Table 3, p. 7) report inter alia the following collective bargaining coverage rates for major OECD countries in 1994: 17% in the US, 21% in Japan, 40% in the UK, 78% in Spain, 82% in Italy, 92% in Germany, and 95% in France. 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. Note that the collective bargaining coverage rates are typically much higher than union membership rates. Yao and Zhong (2011) 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.

\(^4\) See e.g. Matusz, (1996), Davidson et al. (1999), Andersen (2005), Dutt et al. (2009), and Eckel and Egger (2009), Egger and Kreickemeier (2009), Helpman and Itsikhoki (2010), Boulhol (2011), Davis and Harrigan (2011), and Felbermayr et al. (2011a). This literature assumes structurally identical countries and symmetric cuts in trade costs.

\(^5\) See e.g. Naylor (1999), Zhao (2001), Bastos and Kreickemeier (2009), and Lommerud et al. (2009, 2012).

\(^6\) 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 shocks instead of tariff cuts.
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 effects of labor unions, which so far has been confined to closed-economy settings.\(^7\) 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 worldwide economic growth. Stronger Southern labor unions also reduce Southern imitation, but increase Northern innovation and worldwide economic growth.

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 imitated products (“product-cycle trade”).\(^8\) The governments in both regions impose ad-valorem tariffs on

\(^7\) 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.

\(^8\) 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.
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. ⁹ 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 \( N_0 \) 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 \( N_i = N_0 e^{nt} \). The representative household maximizes the per-capita utility function

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

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

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

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 \( \omega \) at time \( t \). Hence, product quality starts at \( \lambda^0 = 1 \) in any industry \( \omega \) 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 expenditure across products to maximize \( f_i(t) \) for given product prices. Since products in a typical industry \( \omega \) differ only in their quality, and \( \lambda \) 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

⁹ 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.
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 \( \int_0^\infty N_0 e^{-\rho t} \log c_i(t) \, dt \) 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”

\[
\frac{\dot{c}_i(t)}{c_i(t)} = r(t) - \rho \quad \text{for } i = N, S. \tag{3}
\]

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 \( \omega \).

### 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.\(^{10}\) In the South, there is only one type of labor that 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.

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\(^{10}\) 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.
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. 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.\(^{11}\)

Consider first the profits of firms in a Northern industry. In the Northern market, the Southern followers face an ad-valorem tariff rate $\tau_N$. 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 Northern quality leader charges the limit price $p^N_N = \lambda w_S(1+\tau_N) - \varepsilon$ with $\varepsilon \to 0$ and drives the Southern followers out of the market. The profits of the Northern quality leader from sales in the Northern market are:

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

\(^{11}\) 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.
In the Southern market, the Northern quality leader faces an ad-valorem tariff rate $\tau_S$. 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 $\lambda w_S$. This implies that the Northern leader charges the limit price $p^S_N = \lambda w_S - \varepsilon$ with $\varepsilon \to 0$, of which the Northern firm receives only $\lambda w_S/(1+\tau_S)$. The profits of the Northern quality leader from exports are:

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

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

$$\pi^P_N = \pi^S_N + \pi^S_N = c_N N_N \left[ 1 - \frac{w_L}{\lambda w_S (1+\tau_N)} \right] + c_S N_S \left( \frac{1}{1+\tau_S} - \frac{w_L}{\lambda w_S} \right).$$ (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 $\tau_S$. 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 $\varepsilon \to 0$ 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 $\tau_N$. 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 $w_L$. This implies that the Southern leader charges the limit price $p^S_S = w_L - \varepsilon$ with $\varepsilon \to 0$, of which the Southern firm receives only $w_L/(1+\tau_N)$. The profits of the Southern quality leader from exports are:

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

$\pi^S_S > 0$ is ensured by our above assumption $(1 + \tau_N)w_S < w_L$. Hence total profits from sales of Southern monopolists are:
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 \( \gamma \) is the unit labor requirement of such activities. Hence, a Northern incumbent’s profit flow net of rent protection costs then equals:

\[
\pi_N = \pi_N^R - w_H \gamma X.
\]  

### 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 \( j \) is given as

\[
t_j = R_j / \left( \delta D \right)^{\varepsilon} \quad \text{with} \quad \dot{D} = n_N \delta X \quad \text{and} \quad \varepsilon \in (0,1),
\]

where \( R_j \) represents the innovation intensity of a typical Northern entrepreneur \( j \) targeting industry \( \omega \), and \( D \) measures the difficulty of conducting R&D in industry \( \omega \) at time \( t \). The R&D technology in (7) implies that there are constant returns to scale in \( R_j \) for the individual Northern entrepreneur. According to (7), R&D difficulty \( D \) is modeled as a stock variable, where \( n_N \) is the proportion of industries located in the North, \( X \) is the flow of RPAs undertaken by the Northern incumbent in industry \( \omega \) at time \( t \), and \( \delta \) measures the effectiveness of these RPAs. The equation of motion for \( D \) in (7) implies that whenever an industry is registered as a Northern industry – the probability of which is equal to \( n_N \) in equilibrium – Northern incumbents undertake RPAs which increase the stock of R&D difficulty in that industry by \( \delta X \).

For a constant steady-state innovation rate, R&D difficulty must grow at the same rate as the labor force, hence \( \dot{D} = n \dot{D} \) is required. From this and (7), we obtain the steady-state stock of R&D difficulty:

\[
D = n_N \delta X / n.
\]

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

\[
t = \sum_j t_j = R / \left( \delta D \right)^{\varepsilon} = \left( R / D \right)^{\varepsilon} \quad \text{with} \quad R = \sum_j R_j,
\]

where \( \varepsilon < 1 \) captures the degree of diminishing returns to R&D at the industry level. A higher level of \( \varepsilon \)
implies a weaker diminishing-returns effect.\textsuperscript{12} Entrepreneurs participating in R&D races hire general-purpose labor to perform R&D. The cost of conducting $R_j$ units of R&D activity is $w_L(1-\sigma_i)a_i R_j$, where $\sigma_i$ is a public innovative R&D subsidy rate (financed by lump-sum taxation for simplicity), and $a_i$ 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

$$
\max_{R_j} \frac{v_{N}R_j}{R^{1-\varepsilon}} - w_L(1-\sigma_i)a_i R_j dt \Rightarrow v_N = w_L(1-\sigma_i)a_i D^{\varepsilon} R^{1-\varepsilon},
$$

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) $\mu_j$ by any Southern firm $j$ is given as

$$
\mu_j = \frac{M_j}{(M^{1-\varepsilon} D^{\varepsilon})},
$$

where $M_j$ represents the imitation intensity of a typical Southern entrepreneur $j$ targeting industry $\omega$. 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

$$
\mu = \sum_j \mu_j = \frac{M}{(M^{1-\varepsilon} D^{\varepsilon})} = \left(\frac{M}{D}\right)^{\varepsilon} \text{ with } M = \sum_j M_j.
$$

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 $m = \mu v_N$.

The cost of conducting $M_j$ units of imitative activity in the South is $w_S a_\mu M_j$, where $a_\mu$ 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

\textsuperscript{12} 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.
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. 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 $(t + \mu) dt$, 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 $1 - (t + \mu) dt$, 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:

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

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

$$v_N = \frac{\pi_N}{r + t + \mu - (\dot{v}_N / v_N)} .$$  \hspace{1cm} (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 $udt$, 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 $1 - u dt$, 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:

$$\pi_S dt - v_S u dt + \dot{v}_S (1 - u dt) dt = r v_S dt .$$  \hspace{1cm} (16)

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

$$v_S = \frac{\pi_S}{r + t - (\dot{v}_S / v_S)} .$$  \hspace{1cm} (17)
2.6 Optimal Rent Protection Decision by Northern Incumbents

Substituting $D$ from (8) into (9) and (12), we derive $t(X) = \left(\frac{R_H}{\pi_e dX}\right)^\epsilon$ and $\mu(X) = \left(\frac{M_H}{\pi_e dX}\right)^\epsilon$, which shows that an increase in RPAs $X$ reduces both $t$ and $\mu$ and thus diminishes the threat of replacement faced by the incumbent Northern leader firm. 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 $t$ and $\mu$ 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

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

where (6) is used for $\pi_N$ and the expressions for $t(X)$ and $\mu(X)$ are from above. Setting the derivative of the expected return with respect to $X$ to zero, using $\frac{d}{dX} (t(X)/dt = -\epsilon \tau \frac{1}{X} < 0$ and $\frac{d}{dX} \mu(X)/dt = -\epsilon \mu \frac{1}{X} < 0$, and taking limits as $dt \to 0$, we derive the first order condition for the optimal $X$ as:

$$
X = \epsilon v_N (t + \mu) / (w_H\gamma).
$$

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 $t$ and imitation $\mu$ (the instantaneous probability of full capital loss at each point in time). The optimal level of $X$ increases with $\epsilon$, the effectiveness by which RPAs reduce $t$ and $\mu$, 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

$$
v_N = c_N N_s \left[1 - \frac{w_N}{w_S} \right] + c_S N_S \left[\frac{1}{1 + \tau_S} - \frac{w_S}{w_N}\right].
$$

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:

$$
n_N \frac{c_N N_s}{w_S \delta} \frac{w_S \lambda}{1 + \tau_S} = (1 - n_N) \frac{c_N N_s}{w_N} \frac{w_N}{1 + \tau_N}.
$$

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 \( \mu n_N \). Constancy of industry shares in the steady state requires \( \iota (1 - n_N) = \mu n_N \), which implies
\[
n_N = \frac{\iota}{(1 + \mu)}.
\] (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
\[
\frac{c_N}{c_S} = \frac{\eta_S (1 + \tau_N)}{\mu (1 + \tau_N)}.
\] (21)

The relative North-South consumption expenditure \( c_N/c_S \) is increasing in \( \iota/\mu = n_N/n_S \), since an increase in the relative proportion of Northern industries \( n_N/n_S \) raises the relative size of Northern exports, thereby increasing the relative Northern income available for consumption. \( c_N/c_S \) is increasing in \( \tau_N \), 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 \( \tau_S \), 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), \( a_R = a_D l_t^{1/2} \); hence the Northern general-purpose labor market equilibrium (LABN) condition is
\[
L_N = \frac{n_N}{\lambda w_S} \left( \frac{c_N N_N}{1 + \tau_N} + c_S N_S \right) + a_D l_t^{1/2} = (1 - s_N - u_N)N_N \quad \text{LABN}.
\] (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 \( \iota \) and \( \mu \), 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

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

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

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

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 $\mu$ and $\iota$, 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. Third, after the wage bargaining is settled, the firm decides about the level of manufacturing employment and starts production. The bargained

\[\text{---}\]

13 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.

14 Since the Northern firms’ production labor demand (22) does not (directly) depend on $w_L$, there is no pass-through
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

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

\( \alpha \in [0,1[ \) is the relative bargaining power of the Northern labor union, and \( W_N \equiv (w_L - w_N)^\theta (1 - s_N - u_N)N_N \) is the expected excess-wage income received by the Northern union members. \( w_N \) 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.\(^{15}\) \( w_N \) can be given various 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, \( w_N \) serves as the natural reference point for the labor union.\(^{16}\) \( \bar{W}_N \) 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’\(^{17}\), 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 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.

\(^{15}\) The underlying labor union’s objective is a Stone-Geary type utility function \( U(w_L, L_N) = (w_L - w_N)^\theta (L_N)^\chi \), where \( \theta \geq 0 \) and \( \chi \geq 0 \) represent, respectively, the union’s preference for excess wages and employment, cf. Mezzetti and Dinopoulos (1991, p. 82).

\(^{16}\) 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 \( w_N \) 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.

\(^{17}\) Palokangas (2004, p. 205, fn. 6), with reference to Binmore at 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). See also Cahuc and Zylberberg (2004, p. 389), or Hall and Milgrom (2008) on this argument.
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

$$\Omega_N = \left\{ \left( w_L - \frac{w_N}{r} \right)^{\beta} \left[ \left( 1 - s_N - u_N \right) N_N \right]^\alpha \right\} \left\{ c_N N_N \left[ \frac{1 - \frac{w_N}{\bar{w}_N} + \frac{\alpha}{r} \frac{1}{\bar{v}_N}}{+ \frac{\alpha}{r} (1 + \varepsilon) (t + \mu) - \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] + c_s N_s \left[ \frac{1 - \frac{w_N}{\bar{w}_N} - \frac{\alpha}{r} \frac{1}{\bar{v}_N}}{+ \frac{\alpha}{r} (1 + \varepsilon) (t + \mu) - \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] \right\}^{1-\alpha} \rightarrow \max! \quad (26)$$

The first order condition is

$$\frac{\alpha \theta}{w_L - \frac{w_N}{r}} \left[ c_N N_N \left[ \frac{1 - \frac{w_L}{\lambda w_s (1 + \tau_N)}}{+ \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] + c_s N_s \left[ \frac{1 - \frac{w_L}{\lambda w_s (1 + \tau_N)}}{+ \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] \right] = \left( 1 - \alpha \right) \left[ c_N N_N \left[ \frac{1 - \frac{w_L}{\lambda w_s (1 + \tau_N)}}{+ \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] + c_s N_s \left[ \frac{1 - \frac{w_L}{\lambda w_s (1 + \tau_N)}}{+ \frac{\alpha}{r} \frac{1}{\bar{v}_N}} \right] \right] \right\}^{1-\alpha} = \max! \quad (27)$$

which implies that the increase in the firm’s profits extraction by the labor union through a marginal increase in $w_L - \frac{w_N}{r}$, evaluated by the union’s share $\alpha$ in $\Omega_N$ and the union’s excess wage preference $\theta$ (LHS), must equal the increase in the firms’ production costs by this marginal increase in $w_L - \frac{w_N}{r}$, evaluated by the firm’s share $1 - \alpha$ in $\Omega_N$ (RHS). For the remainder of the paper, we normalize $\theta = 1$ 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 $\alpha$:

$$w_L = \frac{\alpha \lambda w_s \left[ t (1 + \tau_N) + \mu \right]}{t + \mu (1 + \tau_S)} + (1 - \alpha) w_N \quad \forall \alpha \in [0,1[, \quad \text{given} \quad \frac{\lambda w_s [t (1 + \tau_N) + \mu]}{t + \mu (1 + \tau_S)} \equiv w_L^{\max} > w_N \quad (28)$$

$w_L^{\max}$ 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 $w_L^{\max} > w_L > w_N$.

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

$$\Omega_S = \left\{ \left( w_S - \frac{w_S}{r} \right)^{\beta} \left[ (1 - u_S) N_N \right]^\alpha \right\} \left\{ c_N N_N \left[ \frac{1 - \frac{w_S}{\bar{w}_N} - \frac{\beta}{r} \frac{1}{\bar{v}_S}}{+ \frac{\beta}{r} (1 + \varepsilon) (t + \mu) - \frac{\beta}{r} \frac{1}{\bar{v}_S}} \right] + c_s N_s \left[ \frac{1 - \frac{w_S}{\bar{w}_N} + \frac{\beta}{r} \frac{1}{\bar{v}_S}}{+ \frac{\beta}{r} (1 + \varepsilon) (t + \mu) - \frac{\beta}{r} \frac{1}{\bar{v}_S}} \right] \right\}^{1-\beta} \rightarrow \max! \quad (29)$$

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 $w_S$ is the Southern reservation wage level. Using again $\theta = 1$ and the BOT con-

---

18 The second derivative of (26) with respect to $w_L$ is negative, hence the f.o.c. is also sufficient for a maximum.
dition (21), the solution of (29) is the following Southern wage rate as an increasing function of $\beta$:

$$w_s = \frac{\beta w_L \left[ t + \mu (1 + \tau_s) \right]}{t (1 + \tau_s) + \mu} + (1 - \beta) w_s \quad \forall \beta \in [0,1[,$$

\[\text{given } \frac{w_L \left[ t + \mu (1 + \tau_s) \right]}{t (1 + \tau_s) + \mu} = w_s^{\text{max}} > w_s. \quad (30)\]

$w_s^{\text{max}}$ is the maximum wage rate that would apply for $\beta \to 1$, and we maintain $w_s^{\text{max}} > w_s > w_s$. 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 $w_S = 0$, 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 $w_S = 0$, (28) and (30) can be solved for the wage rates

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

$$w_S = \frac{\beta \left[ t + \mu (1 + \tau_s) \right] (1 - \alpha) w_N}{t (1 + \tau_N) + \mu (1 - \alpha \beta \lambda)}. \quad (32)$$

To ensure $w_L > 0$, we require $\alpha \beta \lambda < 1$, while $\beta \lambda > 1$ is necessary to ensure $w_L > w_N$. 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 $w_N$, such that the presence of a Northern labor union is justified from a union’s perspective.\footnote{We later verify numerically that the bargained wage rates in both countries exceed the hypothetical competitive wage rates $w_N^{\text{comp}}$ and $w_S^{\text{comp}}$, respectively, further justifying the existence of labor unions ex post. For the general case $w_S > 0$, 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 $w_N > w_N$ and $w_S > w_S$, respectively.}

Under this restriction, the wage rates have the following intuitive properties: ceteris paribus, both $w_L$ and $w_S$ are increasing in $\alpha$, $\beta$, and $w_N$. 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 $w_S = 0$, while $w_S$ is increasing in $\tau_S$ and decreasing in $\tau_N$. Ceteris paribus (i.e., for given $t$ and $\mu$), there are two main channels by which tariff changes affect $w_S$. First, an increase in $\tau_N$ 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 $\tau_S$ 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:

\[
\beta_{\min} = \frac{t(1 + \tau_N) + \mu}{\lambda(1 + \tau_S)} < \beta < \frac{t(1 + \tau_N) + \mu}{(1 + \tau_N)[1 + \mu(1 + \tau_S)]} = \beta_{\max}.
\]

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

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

By how much can \( \lambda \) be increased to yield realistic North-South wage differences, as suggested by Gustafsson and Segerstrom (2010)? As can be seen in (33), the upper bound of this wage gap is essentially determined by \( \lambda \), 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. This justifies to consider at least the upper bound 1.4 of the standard range, which would imply \( \lambda = 1.94 \). 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, \( c_S = 1 \), and solve the model for an interior steady-state equilibrium where the endogenous variables \( c_N, u_N \in (0, 1 - s_N), u_S \in (0, 1) \), \( t, \mu, n_N, w_S, w_L, \ldots \)

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20 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 \( w_S > w_N/\lambda \).

21 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. This gives \( \lambda w_S(1 + \tau_N)/w_L = 549/228 = 2.40 \), implying \( \lambda = 3.33 \).
$w_L$, and $w_H$ are non-negative and remain constant. $\pi^P_N$, $\pi_S$, $X$, $D$, $R$, $M$, $v_N$, and $v_S$ are also non-negative and grow at a common rate of $n > 0$, and $r = \rho$.

First note that with $c_S = 1$, (21) gives $c_N$ as a function of $t$ and $\mu$ only, and (20) determines $n_N$ as a function of $t$ and $\mu$ only. We use $c_S = 1$, (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

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

where $A_s = a_s \delta S / (n \gamma)$ 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 $c_S = 1$ to substitute for $c_N$ allows to rewrite the Northern unemployment rate as a function of $t$ and $\mu$ only:

$$u_N = 1 - s_N - \frac{t \eta_S (t(1 + \tau_N) + \mu)(1 - \alpha \beta) - t^\lambda A_s}{(t + \mu) \beta \gamma w_N \mu (1 + \tau_s)} \quad \text{LABN}(u_N, t, \mu). \quad (34)$$

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

$$\frac{1 - n_N}{w_L} \left( \frac{c_N}{1 + \tau_N} + \eta_S \right) + n_S \mu^\lambda A_s = (1 - u_S) \eta_S,$$

where $A_s = a_s \delta S / (n \gamma)$ 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 $c_S = 1$ to substitute for $c_N$ allows to rewrite $u_S$ as a function of $t$ and $\mu$ only:

$$u_S = 1 - \frac{(1 - \alpha \beta)(t(1 + \tau_N) + \mu)}{(t + \mu)(1 - \alpha) w_N (1 + \tau_s)} - \frac{t \mu^\lambda A_s}{(t + \mu) \eta_s} \quad \text{LABS}(u_S, t, \mu). \quad (35)$$

---

22 The competitive wage rate $w^\text{comp}_L$ is the wage rate that clears the Northern general-purpose labor market under no bargaining. Any higher bargained wage rate $w_L > w^\text{comp}_L$, 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 $r$ 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.
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 \( A_t = a_t \delta s_N/(n \gamma) \). This gives the Northern specialized-labor wage rate as an increasing function of \( t \) only:

\[
w_N = \varepsilon (1-\alpha) w_N (1-\sigma_i) A_t \frac{t^2}{(1-\alpha \beta \lambda) s_N}.
\]

(36)

It remains to determine the steady-state values of \( t \) and \( \mu \). Setting (19) equal to (10), using (9) to substitute for \( R \), using (8) and (23) to substitute for \( D \) and \( X \), respectively, using \( r = \rho \), \( \dot{v}_N/v_N = n \), \( A_t = a_t \delta s_N/(n \gamma) \), (21) to substitute for \( c_N, c_S = 1 \), (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) condition

\[
\eta_s \frac{t(1+\tau_N)+\mu}{\mu(1+\tau_s)}(1-\frac{1}{\beta \lambda}) \left( \frac{(1-\alpha)w_N(1-\sigma_i)A_t}{1-\alpha \beta \lambda} \right) \frac{\tau_N}{\mu + (1+\varepsilon)(t+\mu) - n} = \text{FEIN}(t, \mu).
\]

(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 \( \mu \) and \( t \) terms on the LHS of (37) and totally differentiate. We find that the LHS of the resulting expression is unambiguously decreasing in \( \mu \). It is also decreasing in \( t \) provided that the following holds:

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

(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(\( t, \mu \)) curve is unambiguously downward sloping in \((t, \mu)\) 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, \( A_\mu = a_\mu \delta s_N/(n \gamma) \), (21) to substitute for \( c_N, c_S = 1 \), (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

\[\text{FEIM}(t, \mu).\]

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\(^{23}\) 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.
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 $\mu$ and $\iota$ terms on the LHS of (39) and totally differentiate. We find that the LHS of the resulting expression is unambiguously decreasing in $\mu$. Numerical simulations show that it is also decreasing in $\iota$ for a wide range of plausible parameter values. Thus, the FEIM curve is also downward sloping in the $(\iota, \mu)$ space. Dividing (37) by (39) gives the relative profitability (RP) condition

$$\left(\frac{\rho + \iota - n}{\rho + (1 + \varepsilon)(\iota + n)(1 - \frac{1}{\beta})}\right) = \frac{1 - \sigma_i}{\sigma_{\mu}} \frac{(1 - \frac{1}{\rho})}{(\iota + 1 - \frac{1}{\mu})} \text{RP}(t, \mu),$$

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

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

which again is fulfilled for any $\varepsilon \leq 0.5$. Our numerical simulations in the Mathematica Appendix show that the LHS of the resulting expression is declining in $\iota$ for a wide range of plausible parameter values, such that the RP curve is upward sloping in $(\iota, \mu)$ space. The Mathematica Appendix also shows 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 FEIM curves that jointly pin down the steady-state values of $\iota^*$ and $\mu^*$ for the special case $w_3 = 0$, 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 \( \iota^* \) and \( \mu^* \) 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 \( c_S = 1 \), \( v^*_N \) follows from (19) for given \( r = \rho \) from (3) and \( \dot{v}_N/v_N = n \), \( \pi^*_N \) follows from (4), \( \pi^*_S \) 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).

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

\[
F_N = \frac{1}{\rho} \left[ \frac{\iota \log(\lambda)}{\rho} + (1-n_N) \log \left( \frac{c_N}{p^N_S} \right) + n_N \log \left( \frac{c_N}{p^N_S} \right) \right], \tag{42}
\]

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 \( \iota \), 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 \( p^N_S = w_L \) and purchases \( c_N/p^N_S \) units. In the remaining fraction \( n_N \) of industries, she faces a price of \( p^N_S = \lambda w_S(1+\tau_S) > p^N_S \) and buys \( c_N/p^N_S \) units.\(^24\),\(^25\) Similarly, Southern per-capita steady-state welfare can be expressed as

\[
F_S = \frac{1}{\rho} \left[ \frac{\iota \log(\lambda)}{\rho} + (1-n_N) \log \left( \frac{c_S}{p^S_S} \right) + n_N \log \left( \frac{c_S}{p^S_S} \right) \right], \tag{43}
\]

where \( c_S = 1 \) 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 reduces the

\(^24\) \( p^N_N > p^N_S \) follows from (33) for the entire feasible range of \( \beta \).

\(^25\) Combining (21) for \( c_S = 1 \), (31), and (34) reveals that for given \( \iota \) and \( \mu \), Northern per-capita consumption expenditure is declining in \( u_N \) (and rising in \( w_L \)): \[ c_N = \frac{(1-s_N-u_N-i^*A)(1+\mu)(1+\tau_S)\lambda\beta w_L}{\iota(1+\tau_S) + \mu} \]. This explains how unemployment ceteris paribus reduces \( F_N \), although it does not show up directly in (42).
LHS of FEIM (39).\footnote{The Mathematica Appendix shows that in the general case \( w_S > 0 \), a reduction in \( \tau_N \) turns the more general version of the RP curve slightly counterclockwise, while all effects discussed below remain qualitatively unchanged.} For any given \( \mu \), a reduction in \( \iota \) is required to restore FEIM. Hence this curve shifts downward as illustrated in Figure 1 above, and the steady-state values of both \( \iota \) and \( \mu \) 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.

A lower \( \tau_N \) exerts multiple effects on imitative R&D profitability. First, it directly increases the net price received by the Southern imitator from exports to the North \( w_L / (1 + \tau_N) \). This increases \( \pi_S \) and thus imitative R&D profitability. Second, a lower \( \tau_N \) increases the Southern wage rate \( w_S \) and directly raises the cost of imitative R&D (i.e., with profit sharing in place, Southern firms tend to pass on the higher export profits for given Northern per capita expenditure \( c_N \) in the form of a higher bargained wage rate). This decreases imitative R&D profitability. Third, it reduces \( c_N \) and thus the total sales of the Southern imitator in the Northern market. This decreases \( \pi_S \) and thus imitative R&D profitability. Finally, a lower \( \tau_N \) reduces the North-South relative wage \( w_L / w_S \) and thus the price marginal-cost ratio of the Southern firm in both markets, ignoring the direct impact of \( \tau_N \).\footnote{In the Southern market, the imitator’s price marginal-cost ratio is \( w_L (1 + \tau_S) / w_S \). In the Northern market, the imitator’s price marginal-cost ratio is \( w_L / [w_S (1 + \tau_N)] \).} This decreases \( \pi_S \) and decreases imitative R&D profitability. The net effect follows from (39), which is a fall in imitative R&D profitability.

Restoring FEIM requires a fall in \( \mu \), which works its effect via multiple channels. First, a lower \( \mu \) implies lower imitative R&D costs due to the decreasing-returns-to-scale technology. Second, it increases the total export sales of Southern firms by increasing \( c_N \). Third, a lower \( \mu \) raises the price marginal-cost ratio for Southern imitators in both markets by increasing \( w_L / w_S \). All of these raise imitative R&D profitability and reestablish equilibrium.

The downward shift in FEIM implies a movement down the RP curve. More specifically, when \( \mu \) declines, the profitability of innovative R&D increases by less than the profitability of imitative R&D, given that condition (41) is fulfilled. In short, the relative profitability of innovation declines; hence, a decrease in \( \iota \) is required to restore RP.

From (34) it follows that a decrease in \( \tau_N \) affects \( u_N \) in three ways. First, one direct impact of a lower \( \tau_N \) is to increase the Southern firms’ export profits \( \pi_S^N \), and hence the Southern bargained wage rate \( w_S \) for given \( \iota \) and \( \mu \). 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). A second impact of a lower $\tau_N$ is to reduce the Northern innovation rate $\iota$, 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 $\tau_N$ is to reduce the Southern imitation rate $\mu$, which implies an increase in Northern production labor demand by raising $n_N$. Further second-order effects work through the impact of changes in $\iota$ and $\mu$ on $w_S$ and $c_N$. Our numerical simulations in section 3.3 reveal that for plausible parameter values, the negative employment effects dominate, such that a decline in $\tau_N$ 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 $\iota$. 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 $\tau_S$ is to reduce the Southern imitation rate $\mu$, 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 $\iota$ and $\mu$ 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 $\tau_N$ 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 FEIM (39). An increase in $\iota$ for any given $\mu$ is required to restore FEIM. Hence this curve shifts upward (opposite to Figure 1 above), and the steady-state values of both $\iota$ and $\mu$ increase. Thus, unilateral Southern trade liberalization raises Northern innovation and worldwide economic growth.

A lower $\tau_S$ exerts multiple effects on imitative R&D profitability. First, it directly reduces the net price received by the Southern imitator from home sales $w_S(1+\tau_S)$. This reduces $\pi_S$ and thus imitative R&D profitability. Second, a lower $\tau_S$ reduces $w_S$ which reduces the cost of R&D (i.e., with profit sharing

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28 There are two additional effects on Northern production employment that cancel out: a decrease in $\tau_N$ 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 $c_S \equiv 1$.

29 For example, if $\iota/\mu$ decreases, this would reduce $Q_N$ by decreasing $c_N$, see (21), and by increasing $w_S$, see (32), which would reduce Northern production labor demand further.

30 The Mathematica Appendix shows that in the general case $\mu > 0$, a reduction in $\tau_S$ turns the more general version of the RP curve slightly clockwise, while all effects discussed below remain qualitatively unchanged.
in place, Southern firms tend to pass on the lower domestic profits for given $c_N$ in the form of a lower bargained wage rate. This increases imitative R&D profitability. Third, it increases $c_N$ and thus the total sales of the Southern imitator in the Northern market. This increases $\pi_S$ and thus imitative R&D profitability. Finally, a lower $\tau_S$ raises $w_L/w_S$ and thus increases the price marginal-cost ratio of the Southern firm in both markets, ignoring the direct impact of a lower $\tau_S$. This increases $\pi_S$ and increases imitative R&D profitability. The net effect follows from (39), which is an increase in imitative R&D profitability.

Restoring FEIM requires an increase in $\mu$, which works its effects through the same channels identified in the case of a decline in $\tau_N$, but in the opposite direction. In short, a higher $\mu$ reestablishes equilibrium by decreasing imitative R&D profitability. The upward shift in FEIM implies a movement up the RP curve. The relative profitability of innovation increases; hence an increase in $i$ is required to restore RP.

From (34) it follows that unilateral Southern trade liberalization affects $u_N$ in four ways. First, for given levels of $i$ and $\mu$, a decrease in $\tau_S$ increases $c_N$, as required by the BOT condition (21). Second, a decrease in $\tau_S$ reduces $w_S$, as given in (32). Both effects raise $Q_N$ and hence the demand for Northern production labor. Third, a lower $\tau_S$ raises $i$, 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 $\tau_S$ raises $\mu$, 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 $i$ and $\mu$ 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 $\tau_S$ reduces $u^*_N$.

From (35) it follows that unilateral Southern trade liberalization affects $u_S$ in four ways. First, for given $i$ and $\mu$, a lower $\tau_S$ reduces $p_S$ 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 $i$. 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 $\tau_S$ leads to an increase in $\mu$, 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 $i$ and $\mu$ 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 $\tau_S$ is to reduce $u^*_S$. 

24
Finally, we analyze **bilateral trade liberalization** that takes the form of a simultaneous decline in both $\tau_N$ and $\tau_S$ by the same amount (i.e., $d\tau_N = d\tau_S = d\tau < 0$), while we allow for different tariff levels across countries. Provided that $\tau_S - \tau_N < \mu'\iota$ holds ex ante,\(^{31}\) which comprises equal tariff levels $\tau_S = \tau_N$ as a special case, $d\tau < 0$ raises the LHS of the FEIM condition (39), such that the FEIM curve shifts upward, while the RP curve for $w_S = 0$ is again not (and for $w_S > 0$ not significantly) affected. Hence, both $\iota^*$ and $\mu^*$ 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

**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.*

Appendix A derives the steady-state equilibrium under the alternative assumption of competitive wage determination in both countries. We demonstrate, and explain intuitively, that with competitive wage determination, the “tariff-neutrality” result of Grieben and Şener (2009, Proposition 2, p. 1055) is reestablished, i.e. changes in $\tau_N$ or $\tau_S$ have no impact on $\iota$ and $\mu$.

Our analysis so far allows to conclude two main things. First, the labor market imperfections captured by wage bargaining in North and South are crucial for tariffs to have any effect on Northern innovation and Southern imitation in a one-sector model with symmetric production and trade structure.\(^{32}\) Second,

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\(^{31}\) The only term in (39) that contains tariff rates is $\left[ (1 + \tau_N) + \mu(1 + \tau_S) \right]$. 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 FEIM condition unaffected. However, our numerical simulations show that the condition $\tau_S - \tau_N < \mu'\iota$ is clearly fulfilled for all feasible parameter values.

\(^{32}\) Grieben and Şener (2009, section 4.2) show within a framework of perfectly competitive labor markets that adding a competitive, non-protected Southern (low-tech) sector that does not feature any technical progress is an alternative way to break the tariff-neutrality result. In that case, however, the results of our Proposition 1 here are reversed: Northern unilateral trade liberalization raises innovation, imitation, and worldwide economic growth, while
bilateral (i.e., simultaneous Northern and Southern) trade liberalization, as it took place e.g. in the Uruguay round 1986-1993 under the GATT, is more likely to yield positive growth (and employment) effects if the developing South reduces tariffs by more than the developed North. Estevadeordal and Taylor (2008, pp. 14-15) report that this is exactly what has happened in 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. 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.

3.2 Labor Unions’ Power

An increase in the Northern union’s bargaining power $\alpha$ raises the RHS of FEIM (39), given $\beta \lambda > 1$, such that a decrease in $\mu$ is required for any given $\iota$ to restore the FEIM condition. Hence, the FEIM curve in Figure 1 is shifting down, while the RP curve for the special case $w_S = 0$ (for the general case $w_S > 0$) is not (significantly) affected, and both $\iota$ and $\mu$ decrease unambiguously. An increase in the Northern reservation wage level $w_N$ has qualitatively the same effects.

As we explained earlier, an increase in $\alpha$ or $w_N$ 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 propor-

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33 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.

34 A general problem of the empirical literature is to identify the growth effects of trade policy liberalization, see e.g. the comments of Rodriguez (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 like e.g. DeJong and Ripoll (2006), who find that growth is decreasing in tariffs for countries with high income, use data consisting of a 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).
tion; thus, the relative wage \( w_L/w_S \) remains the same for given \( \iota \) and \( \mu \), as seen in (33). It follows that the price marginal-cost ratio of Southern firms in both markets and hence \( \pi_S \) remain unchanged. However, due to the rise in \( w_S \), imitative R&D costs increase. The FEIM curve shifts downward and the equilibrium level of \( \mu \) declines. As before, the decrease in \( \mu \) implies a fall in the relative profitability of innovative R&D, which triggers the reduction in \( \iota \) via a downward movement along the RP curve.

As can be seen in (34) and (35), for given \( \iota \) and \( \mu \), both \( u_N \) and \( u_S \) are increasing in \( \alpha \) and \( w_N \). 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 \( \mu \) and \( \iota \) 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 \( \alpha \) and \( w_N \).

An increase in the Southern union’s bargaining power \( \beta \) reduces the LHS of (39) and increases the RHS of (39). Hence, a decline in \( \mu \) for any given \( \iota \) is required to restore the FEIM condition, and the FEIM curve in Figure 1 shifts down again. However, the LHS of (40) rises, which also requires a decrease in \( \mu \) for any given positive \( \iota \) to restore the RP condition, and the RP curve turns counterclockwise in Figure 1. While \( \mu \) decreases unambiguously, the net effect on \( \iota \) is in general ambiguous. However, our numerical analysis below shows that for plausible parameter values, Northern innovation (and hence worldwide growth) rises.

The intuition for the curve shifts is as follows. A higher \( \beta \) 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).\(^\text{35}\) These wage changes work to reduce imitative R&D profitability. First, the higher \( w_S \) raises imitative R&D costs. Second, the fall in \( w_L/w_S \) reduce the price marginal-cost ratio of Southern firms in both markets and hence \( \pi_S \) declines. As a result, the FEIM condition shifts down. With regards to innovation profitability, we observe competing effects. First, the higher \( w_N \) 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 and hence \( \pi_N \) increases. Equation (40) implies that the relative innovation-imitation profitability increases and thus \( \iota \) increases for a given level of \( \mu \). This implies a counterclockwise shift of the RP curve.

\(^{35}\) Our numerical simulations in Table 1 below reveal that this is still true for the more general case \( w_S > 0 \).
As can be seen in (34) and (35), for given $\iota$ and $\mu$, both $u_N$ and $u_S$ are increasing in $\beta$. 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 $\mu$ and the increase in $\iota$ 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 $\mu$ and the increase in $\iota$ 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 $w_S$ has qualitatively the same effects as an increase in $\beta$. 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 $\alpha$ or the reservation wage level $w_N$ 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 $\beta$ or the reservation wage level $w_S$ raises Northern innovation and worldwide economic growth, decreases Southern imitation, reduces the Northern unemployment rate, and it increases the Southern unemployment rate.

### 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 $\rho$ 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 $w_n = 0.55$ produces a reasonable Northern replacement ratio $w_n/w_L$ 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 choice $\sigma = 0$ is a reasonable benchmark. The remaining parameters ($A_\mu$, $A_\eta$, $\alpha$, $\beta$, and $w_S$) are chosen with the objective in mind to generate reasonable values for endogenous variables, in particular to generate unemployment rates36 around 10%, and a growth rate $g = \text{log} \lambda$ 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 from Propositions 1 and 2 are confirmed for the special case $w_S = 0$ and also for the more general case $w_S > 0$. Second, bilateral trade liberalization by equal amounts raises North-South wage inequality $w_L/w_S$. 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 $\tau_N$ 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 $\tau$, $\mu$, $F_N$, 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 $\alpha$ or $w_n$) forces both Northern manufacturing and R&D workers into unemployment, which reduces $\tau$, $c_N$, and $F_N$. Sixth, qualitatively the exact opposite effects are obtained for more Southern union power (increase in $\beta$ or $w_S$, the latter not shown in Table 1 but available in the Mathematica Appendix). Seventh, while bilateral trade

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36 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%.
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 this 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 by equal amounts 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 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 prediction 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 de-
veloping 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 \(w_L^{\text{comp}}\) and \(w_S^{\text{comp}}\) as a function solely in \(\tau\) and \(\mu\), 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 \(w_L = v_N / [(1-\sigma)_{\alpha}D^rR^{1-\tau}]\). 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 \(D\), \(A_{\tau} = a_{\tau}D^\tau R^{1-\tau}\), (21) to substitute for \(c_N\), \(c_S \equiv 1\), simplifying and solving this free-entry in innovation (FEIN) condition for \(w_L^{\text{comp}}\) yields

\[
w_L^{\text{comp}} = \frac{\eta_S \left[ \tau (1+\tau_N) + \mu \right]}{\mu (1+\tau_S) \left[ \rho + (1+\epsilon)(1+\mu) - n \right] (1-\sigma_i) A_{\tau}^{\frac{\epsilon}{1-\epsilon}} + \frac{\eta_S}{w_N^{\text{comp}}} \left[ \tau + \mu (1+\tau_S) \right]}.
\]

(A.1)

From (13) we get \(w_S = v_S / (a_{\mu}D^\mu\tau\rho)\). 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 \(D\), \(A_{\tau} = a_{\mu}D^\mu\tau\rho\), (21) to substitute for \(c_N\), \(c_S \equiv 1\), simplifying and solving this free-entry in imitation (FEIM) condition for \(w_S^{\text{comp}}\) yields

\[
w_S^{\text{comp}} = \frac{\eta_S \left[ \tau + \mu (1+\tau_S) \right]}{(1+\tau_S) \left[ \rho + (1+\epsilon)(1+\mu) - n \right] A_{\mu}^{\frac{\epsilon}{1-\epsilon}} + \frac{\eta_S}{w_N^{\text{comp}}} \left[ \tau + \mu (1+\tau_S) \right]}.
\]

(A.2)

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

\[
w_L^{\text{comp}} = \frac{(\lambda - 1)\eta_S \left[ \tau (1+\tau_N) + \mu \right]}{(1+\tau_S) \left[ \lambda \mu \left[ \rho + (1+\epsilon)(1+\mu) - n \right] (1-\sigma_i) A_{\tau}^{\frac{\epsilon}{1-\epsilon}} + \mu^2 \left( \rho + (1+\epsilon)A_{\tau} \right) \right]},
\]

(A.3)
\[ w_{S_{\text{comp}}}^{\text{comp}} = \frac{(\lambda - 1)\eta_S \left[ t + \mu \left(1 + \tau_S \right) \right]}{\lambda \left(1 + \tau_S \right) \left[ \mu \left(\rho + (1 + \varepsilon) \left( t + \mu \right) - n \right)(1 - \sigma_t) \lambda^{\frac{t}{\mu^*}} + \mu^{\frac{t}{\mu^*}} \left( \rho + t - n \right) A_{\mu} \right]}. \]  
(A.4)

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

\[ \frac{n_N}{\lambda w_{S_{\text{comp}}}^{\text{comp}}} \left( \frac{c_N N_N}{1 + \tau_N} + c_S N_S \right) + a_i A^{\frac{t}{\mu^*}} D = (1 - s_N) N_N. \]

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

\[ t \left[ \rho + (1 + \varepsilon) \left( t + \mu \right) - n \right](1 - \sigma_t) A^{\frac{t}{\mu^*}} + \left( \rho + t - n \right) A_{\mu}^{\frac{t}{\mu^*}} \right] \right) \right) + A_i^{\frac{t}{\mu^*}} = 1 - s_N. \]

LABN\((t, \mu)\)  
(A.5)

Finally, we set \( u_S = 0 \) and \( w_L = w_{L_{\text{comp}}}^{\text{comp}} \) in the LABS equation from the main text:

\[ \frac{1 - n_N}{\lambda^{w_{L_{\text{comp}}}^{\text{comp}}}} \left( \frac{c_N N_N}{1 + \tau_N} + c_S N_S \right) + n_N A_{\mu}^{\frac{t}{\mu^*}} D = N_S. \]

Using (20) to substitute for \( n_N \), (A.3) to substitute for \( w_{L_{\text{comp}}}^{\text{comp}} \), (21) to substitute for \( c_N, c_S \equiv 1 \), (8) and (23) to substitute for \( D \), and the definition \( A_{\mu} = a_{\mu} \delta s_N/(n\gamma) \) yields, after simplifying, a LABS equation that is also independent of tariffs:

\[ \frac{n_N \lambda^{\mu} \left[ \rho + (1 + \varepsilon) \left( t + \mu \right) - n \right](1 - \sigma_t) A^{\frac{t}{\mu^*}} + \left( \rho + t - n \right) A_{\mu}^{\frac{t}{\mu^*}} \right] \right) + \frac{t A_{\mu}^{\frac{t}{\mu^*}}}{t + \mu} = \eta_S. \]

LABS\((t, \mu)\)  
(A.6)

For a wide range around our benchmark parameters, both LABN and LABS curves are downward sloping in \((t, \mu)\) 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, \( i_{\text{comp}}^{\text{comp}} \) and \( \mu_{\text{comp}}^{\text{comp}} \), 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 \( \tau_N \) that raises the profits from Northern domestic sales, or a decrease in \( \tau_S \) that raises the profits from Northern exports) are mitigated by a corresponding increase in \( w_{L_{\text{comp}}}^{\text{comp}} \). This effect along with the resulting general-equilibrium effects associated
with changes in $w_L^{\text{comp}}$, $w_S^{\text{comp}}$, and $c_N^{\text{comp}}$ 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 $F_N^{\text{comp}}$ and $F_S^{\text{comp}}$ 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 $w_S > 0$. 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.

**Literature**


Figure 1: Steady-state equilibrium and unilateral Northern trade liberalization for $w_s = 0$
Table 1: Numerical steady-state equilibrium with $w_s > 0$

Benchmark parameters: $\lambda = 2, \rho = 0.07, n = 0.01, \eta_S = 3.93, \alpha = 0.76, \beta = 0.51, w_N = 0.55, w_s = 0.2, s_N = 0.01, A_i = 75, \sigma_i = 0, A_\mu = 335, \varepsilon = 0.5, \tau_N = 0.1, \tau_S = 0.2$ (normalization: $c_S \equiv 1$)

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<th>$\tau_N = 0.05$</th>
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Notes: Here we provide the main results of our Mathematica Appendix, which is available from the authors’ websites. 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.
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 $\sum_j$). We then replace the per-capita Northern unit-elastic demand function $x_N(j, \omega, t)$ by $c_N/p_N^N$ and $c_S/p_S$ for the products of Northern and Southern industries, respectively. This yields

$$\log f_N(t) = \int_0^{1-n_N} \log \left( \frac{\lambda^{j_*(\omega, t)} c_N}{p_N^N} \right) d\omega + \int_{1-n_N} \log \left( \frac{\lambda^{j_*(\omega, t)} c_S}{p_N^N} \right) d\omega,$$

(A.7)

where $j_*(\omega, t)$ stands for the quality level of the state-of-the-art product in industry $\omega$ at time $t$. We then use the property $\int_0^1 \log \lambda^{j_*(\omega, t)} d\omega = u \log \lambda$ of the stochastic Poisson process (see Grossman and Helpman, 1991, p. 97), which simplifies (A.7) to

$$\log f_N(t) = u \log \lambda + (1-n_N) \log \left( \frac{c_N}{p_N^N} \right) + n_N \log \left( \frac{c_N}{p_N^N} \right).$$

(A.8)

Substituting (A.8) 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 (A.8) with respect to time $t$ gives the steady-state utility growth rate $g^* = \dot{f}_N/f_N = \dot{t} \log \lambda$. The expected discounted utility of a representative Southern citizen (43) is derived in the same way, and the same steady-state growth rate $g^* = \dot{f}_S/f_S = \dot{t} \log \lambda$ applies for the South.

Additional Reference for the Appendix R.1

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

Table 1A: Numerical steady-state equilibrium with $w_s = 0$

Benchmark parameters: $\lambda = 2$, $\rho = 0.07$, $n = 0.01$, $\eta = 3.93$, $\alpha = 0.75$, $\beta = 0.55$, $w_N = 0.85$, $w_s = 0$, $s_N = 0.01$, $A, \sigma = 50$, $A, \sigma = 400$, $\varepsilon = 0.5$, $\tau_N = 0.1$, $\tau_s = 0.2$ (normalization: $c_s \equiv 1$)

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<tr>
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<td>0.5791</td>
<td>0.4115</td>
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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.

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 \( w_s > 0 \) 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. \( \frac{\lambda w_s [t(1 + \tau_N) + \mu]}{t + \mu(1 + \tau_s)} \equiv w_L^{\text{max}} > w_N \) is required to ensure that the Northern bargained wage rate \( w_L \) is increasing in the Northern labor union’s bargaining power \( \alpha \);

4. \( \frac{w_L [t + \mu(1 + \tau_s)]}{t(1 + \tau_N) + \mu} \equiv w_S^{\text{max}} > w_S \) is required to ensure that the Southern bargained wage rate \( w_S \) is increasing in the Southern labor union’s bargaining power \( \beta \).

Solving (28) and (30) for the two bargained wage rates in the general case \( w_s > 0 \) yields

\[
\begin{align*}
  w_L &= \frac{\alpha \lambda (1 - \beta) w_s [t(1 + \tau_N) + \mu]}{(1 - \alpha \beta \lambda) [t + \mu(1 + \tau_s)]} + \frac{(1 - \alpha) w_N}{1 - \alpha \beta \lambda}, \\
  w_S &= \frac{\beta (1 - \alpha) w_N [t + \mu(1 + \tau_s)]}{(1 - \alpha \beta \lambda) [t(1 + \tau_N) + \mu]} + \frac{(1 - \beta) w_S}{1 - \alpha \beta \lambda}.
\end{align*}
\] (A.9)

(A.10)

It follows from (A.9) and (A.10) that

5. \( \alpha \beta \lambda < 1 \) is required to ensure positive bargained wage rates \( w_L \) and \( w_S \);

6. \( w_L > w_N \Leftrightarrow w_S > \frac{(1 - \beta \lambda) [t + \mu(1 + \tau_s)]}{\lambda (1 - \beta) [t(1 + \tau_N) + \mu]} \) 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. \( w_S > \overline{w}_S \iff \overline{w}_S > \frac{(1 - \alpha \lambda)\left[I(1 + \tau_y) + \mu\right]}{(1 - \alpha) I + \mu(1 + \tau_s)} \) 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. \( w_L > \overline{w}_L^{\text{comp}} \) is required for the existence of a Northern labor union to be justified ex post.

9. \( w_S > \overline{w}_S^{\text{comp}} \) is required for the existence of a Southern labor union to be justified ex post.