University of Konstanz
Department of Economics

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Finn Martensen

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Finn Martensen*
University of Konstanz

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Abstract

In a North-South product-cycle model, I study the short- and long-run effects on Northern unemployment of (i) trade liberalization, (ii) tighter international patent protection, and (iii) Southern market expansion. Besides production workers, I also consider R&D workers, which is new to the literature on short-run effects. In the short run, R&D workers are affected before production workers in case of trade liberalization and tighter international patent protection. Unilateral Northern trade liberalization increases unemployment in the short and long run, while Southern trade liberalization has stronger opposite effects. Surprisingly, tighter international patent protection yields a short-run unemployment increase, although it decreases unemployment in the long run. An expansion of the Southern market yields a short- and long-run decrease in unemployment.

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1 Introduction

1.1 Motivation and Contribution

The majority of people in industrialized countries views free trade as a threat for job security. About 80% of the French population view globalization as hurting employment, according to an opinion poll in 2012 (Vinocur 2012). In the United States, more than 60% say that international trade is bad for job security and that imports destroy jobs (Teixeira 2007).

In fact, there is evidence that trade liberalization increases unemployment in the short run, but in the long run, unemployment decreases or is not affected (Trefler 2004; Dutt et al. 2009; Felbermayr et al. 2011b). The theoretical literature mostly considers only long-run effects in models of comparative advantage (Davis 1998a; Davidson et al. 1999; Dutt et al. 2009), intra-industry trade with heterogeneous firms (Egger and Kreickemeier 2009; Felbermayr et al. 2011a), or trade due to product cycles (see the Literature Review in Section 1.2).

Only Dutt et al. discuss short run effects of trade on unemployment: Trade liberalization leads to changes in product demand. This change causes firm exit and hence labor turnover. But focusing on product demand neglects a dynamic perspective, in which workers are employed for research and development (R&D). The importance of R&D activity can be seen in R&D intensity, defined as R&D expenditures as a percentage of value added. Table 1 shows R&D intensity for 2007 for some industrialized countries. For total manufacturing, R&D intensity is on average around 10%. For high tech industries, R&D intensity even varies between 18% and 37%. So, R&D is a substantial economic activity in industrialized countries.

R&D intensity (%)							
Manufacturing sector	AUT	FIN	DEU	JPN	KOR	SWE	USA
Total	6.7	9.4	7.3	11.1	8.8	12.5	10.2
High tech	19.5	29.2	18.0	28.7		35.4	36.8
Medium-high tech	11.1	7.4	9.8	14.7		14.9	9.8

Table 1: R&D expenditures as a percentage of value added for 2007. Source: OECD STAN database

R&D is captured in endogenous growth models, in which international product cycles lead to trade (Grossman and Helpman 1991c; Helpman 1993). So far, there is no research in the short-run effects on unemployment for this kind of models.[1] I explore this gap in a North-South product-cycle model with fully endogenous growth. Minimum wage unemployment only exists in the North. The model allows to analyze trade liberalization,[2] changes in international intellectual property protection,[3] and an expansion of the Southern market[4] in a unified framework. These aspects come along with trade liberalization and have inspired much research.[5] Being able to analyze all three issues in both short and long run, i.e. the instantaneous effect on the transitional dynamics and the steady-state effect, and to demonstrate steady-state stability is new in this literature.

I find that bilateral trade liberalization leads to a short- and long-run decrease in unemployment. Although lower tariffs lead to lower price-markup and hence lower revenue in the North, revenue from sales in the South increases. Since the latter effect is stronger, the increase in profits leads to higher R&D incentives and hence higher R&D employment, even in the short run. This suggests that trade liberalization has less drastic short run effects on unemployment in countries with high R&D intensities. Besides trade liberalization, a market expansion in Southern countries lowers unemployment in both the short and the long run, as goods produced in the North can be sold to more consumers in the South.

Surprisingly, a tightening of international patent protection increases unemployment in the short run, but decreases unemployment in the long run. Although there is no immediate effect on profits, tighter protection extends the expected incumbency period of a monopolist. Although this encourages inno-

[1]See Feenstra and Rose (2000) for evidence of trade due to product cycles.

[2]To give examples of trade liberalization, India reduced import-weighted average tariffs from 54% in 1990 to 8.18% in 2009, China reduced its average tariff rate from 32.2% in 1992 to 4.1% in 2011, and the European Union reduced its average tariff rate from 5.05% in 1990 to 1.09% in 2011 (World Bank 2013).

[3]The TRIPS agreement in 1994 provided a tightening of international intellectual property protection. In 2001, it was amended to ease access of developing countries to medicines. For instance, India subsequently declined patent protection for several drugs to allow production of cheaper generics (Wall Street Journal 2013): In April 2013, Novartis was finally declined patent protection for a cancer drug. In November 2012, India's Intellectual Property Appellate Board decided that Roche loses its patent protection for a hepatitis C drug. In March 2012, the Indian patent appeals office confirmed a decision of the Indian government to award a domestic drug producer a compulsory licence to produce and sell a generic of a patented cancer drug of Bayer.

[4]The population weight has turned in favor of developing countries. When entering the world trading system, China added a workforce of 760 million, India added 440 million, and the former Soviet countries added 260 million workers (Venables 2006).

[5]For research on international patent protection, see e.g. Helpman (1993), Glass and Saggi (2002), Glass and Wu (2007), Dinopoulos and Segerstrom (2010), Gustafsson and Segerstrom (2011), and Jakobsson and Segerstrom (2012). Southern market expansion has been considered by Gustafsson and Segerstrom (2010, 2011), among others.

vation in the long run, it decreases innovation in the short run: As the threat of being copied by the South is lower than before, a Northern industry has to file patents less frequently than before to keep industry leadership in the North. But as the return to an innovation now pays off more, innovation increases in the long run. The results on innovation challenge results by Helpman (1993), who finds short-run increases, but long-run decreases in innovation due to tighter intellectual property protection.

Another contribution to the literature on trade liberalization and endogenous growth is that I establish a simple way to remove tariff-neutrality (Dinopoulos and Segerstrom 2007; Grieben and Şener 2009a), which means that import tariffs have no effect on innovation if wages are set competitively. Grieben and Şener (2009b, 2012) propose that tariff neutrality can be removed by union wage bargaining, but only if there is a fixed component, such as a minimum wage. Unfortunately, wage bargaining complicates the model. I obtain tariff non-neutrality simply by a minimum wage, which makes the analysis considerably easier.

Lastly, I show that the rent-protection approach to achieve fully endogenous growth without scale effects is not a perfect substitute for the simpler approach used by Dinopoulos and Segerstrom (1999), since the simpler approach produces an unstable steady state in this framework. See Appendix E for details.

1.2 Literature Review

I mainly contribute to a growing young literature that analyzes the effects of various forms of globalization on unemployment and R&D based endogenous growth (Şener 2001; Arnold 2002; Şener 2006; Grieben and Şener 2009b, 2012; Stepanok 2013). This literature focuses on steady state analysis and commonly neglects two aspects: First, we do not know anything about the short-run effects of globalization. As convergence periods to steady states are rather long (Perez-Sebastian 2000; Steger 2003), we also need to know a model's predictions on instantaneous effects, e.g. to give policy advice or to test a model empirically. Second, we know little about steady-state stability. Stability is mostly not analyzed[6] – Arnold (2002) is an exception, but he focuses only on intellec-

[6]It is, however, usual to neglect these issues in a first step. For several seminal papers in the R&D based endogenous growth literature, stability checks have been subsequently done by others. See Benhabib et al. (1994) and Arnold (2000) for an analysis of Romer's (1990) path-breaking paper. Mondal (2008) demonstrates the stability of the steady state by Grossman and Helpman (1991a). Arnold (2006) analyzes the transitional dynamics of the seminal paper by Jones (1995). Steger (2003) shows the stability for the Segerstrom (1998) model. Also,

tual property protection. But stability is necessary for validity. And validity is even more of concern as the predictions, for instance for trade liberalization, are ambiguous: Trade liberalization reduces unemployment under some conditions, while it increases unemployment under other conditions. The results also depend on whether trade liberalization occurs bilaterally or unilaterally. This calls for a framework that ensures validity by stability and that can distinguish between unilateral and bilateral trade liberalization.

This strand of the literature starts with a paper by Şener (2001) who adds a search and matching process to the quality-ladder model by Dinopoulos and Segerstrom (1999). Workers can work either in the R&D sector or in the production sector, but only the production sector is subject to search frictions. A lower global import tariff enhances innovation and growth, but it has an ambiguous effect on overall unemployment:[7] For a low innovation rate, unemployment increases, while it decreases for a high innovation rate. Şener only considers bilateral trade liberalization. Also, he does not prove the steady state's stability.

Building on the paper by Şener (2001), Stepanok (2013) assumes that also R&D firms undergo a time-consuming labor market search process. If common iceberg transport costs are reduced, unemployment may increase or decrease.[8] The sign depends on the wage bargaining power of the firm and the resulting wage: A high bargaining power leads to a reduction in unemployment, while a low bargaining power of the firm leads to an increase in unemployment.

Arnold (2002) adds simple labor market frictions to the horizontal innovations model by Helpman (1993). Higher Southern imitation rates and a larger population size of the South either increase, decrease, or produce hump-shaped reactions of Northern innovation, depending on the degree of Northern labor market flexibility. He establishes the stability of his model's steady state, but he does not analyze trade liberalization.

Besides frictional unemployment, several papers have explored structural unemployment.[9] Şener (2006) considers a rigid wage in one of two otherwise

the whole literature about North-South trade in the Schumpeterian growth framework (e.g. Grossman and Helpman (1991c), Glass and Saggi (2002), Glass and Wu (2007), Dinopoulos and Segerstrom (2007), Grieben and Şener (2009a), Gustafsson and Segerstrom (2010), and Dinopoulos and Segerstrom (2010)) analyzes steady states and assumes the stability of these, but does not proof it. An exception is a paper by Glass and Wu (2007), who react to the discussions by Davidson and Segerstrom (1998) and Cheng and Tao (1999).

[7] These findings hold for the fully endogenous growth version of his model, in which changes in policy parameters have permanent, not only transitional effects on growth.

[8] Again, I restrict the discussion to the fully endogenous growth version of this model.

[9] Grieben (2004) also focuses on wage rigidity as a source of unemployment, but he analyzes changes in labor market institutions in a model with trade. Also, the model's transitional

symmetric countries. However, the focus of his analysis is completely different, as he considers changes in labor market institutions and demographic and technological shocks. Concerning trade liberalization, he restricts his discussion to how the shocks under consideration work under free trade and autarky: A switch to free trade increases unemployment, and it also increases aggregate R&D. Concerning such a comparison, Baldwin and Forslid (1999) argue that incremental trade liberalizations are what we observe in reality, instead of switches from autarky to free trade.[10] In addition, Rivera-Batiz and Romer (1991) find nonlinear relationships between incremental trade liberalization and growth. This emphasises that comparisons of autarky versus free trade are not the appropriate way to analyze trade liberalization.

The analysis of incremental trade liberalization is further developed by Grieben and Şener (2009b, 2012). They introduce union wage bargaining to generate unemployment and consider both unilateral and bilateral trade liberalization. None of their papers shows steady state stability. Grieben and Şener (2009b) consider unemployment in the North within a North-South quality-ladder product-cycle model. They obtain the same results as I do, but the results can only be determined analytically for zero ad-valorem tariff rates and might be invalid for sufficiently high tariff rates, although the threshold can not be determined. A numerical investigation captures import tariffs of only 1%. Grieben and Şener (2012) extend this model to endogenous Southern imitation and Southern union wage bargaining, but obtain the same results concerning Northern unemployment as in the previous paper. Their numerical analysis can account for import tariffs of 20%.

There is only little theoretical work on the short-run effects of globalization. Dutt et al. (2009) briefly discuss the short-run effect of trade liberalization in a model with Ricardian and Heckscher-Ohlin trade. Unemployment is a result of time-consuming matching processes, and the short-run increase in unemployment results from slower job creation than job destruction.

The key distinctions to the existing papers are that I analyze all issues in one model, while most papers have only focused on either common trade liberalization or changes in international patent protection. Grieben and Şener (2009b, 2012) have analyzed all issues, but my model is more tractable and yields the same results on Northern unemployment. In addition to the conventional

dynamics are intractable.

[10] Complete switches from autarky to free trade have however happened to some extent, e.g. in Eastern Germany at the German reunification.

steady-state analysis, I analyze short-run effects, as I have tractable transitional dynamics. I also show steady-state stability. The short-run effects in my model do not stem from frictions on the labor market, but from jumps to the new transition paths to steady-state innovation. This has not been analyzed before.

1.3 How Do I Approach This?

The model is a quality-ladder product-cycle model à la Grossman and Helpman (1991c) and is very similar to the model by Grieben and Şener (2009b). I eliminate the scale effect by costly rent-protection activities (Dinopoulos and Syropoulos 2007).[11] This yields a fully endogenous growth model. Unemployment results from a minimum wage.

I build a model without scale effects as this has turned out to be standard in this literature since the seminal paper by Jones (1995).[12] However, in the realm of non-scale growth models, two options appear: Semi-endogenous growth frameworks and fully-endogenous growth frameworks. In the semi-endogenous growth framework, the steady-state growth rate is just proportional to the population growth rate and can not be affected by policy variables, such as import tariffs or R&D subsidies. Policies can, however, affect the transitional dynamics. By contrast, fully endogenous growth frameworks are characterized by steady state growth rates that *can* be affected by policy variables. This is supported by empirical evidence (Zachariadis 2003; Ha and Howitt 2007; Madsen 2008; Madsen et al. 2010; Madsen and Ang 2011; Venturini 2012a,b), so I opt for fully-endogenous growth theory.[13]

[11] This approach complicates the model without being necessary for the research question at hand. But it turns out to be crucial for the steady state's stability. I show in Appendix E that a simpler mechanism to remove the scale effect yields an unstable steady state.

[12] To keep models simple, it is possible to maintain scale effects (i) unless the research question is not about the effect of population sizes on growth and (ii) if maintaining the scale effect does not alter the paper's main results. As I focus on relative population sizes, I remove the scale effect to make sure that the model's predictions are *not* scale effect predictions.

[13] Despite this evidence, Gustafsson and Segerstrom (2010) justify their semi-endogenous growth model by arguing that Ha and Howitt (2007) (and the other studies which they do not mention) analyze steady-state relationships with data for 50 years. Gustafsson and Segerstrom refer to Steger (2003) who finds that, using Segerstrom's (1998) semi-endogenous growth model, it takes about 38 years to go half the distance to the steady state. This even seems to be a lower bound, as Perez-Sebastian (2000) calibrates the transitional dynamics of an endogenous growth model with imitation to Japanese data and finds, depending on the parameters, half-lifes between 39 and 149 years. This suggests that a sample of 50 years should not be considered as a sample of 50 steady states. Hence, it is important to consider transitional dynamics instead of steady-state relationships when testing the predictions of endogenous growth models. However, Sedgley and Elmslie (2010) do exactly this and find no support for semi-endogenous growth theory. Admittedly, they find no means to discriminate between first-generation endogenous growth models and second-generation fully endogenous

A minimum wage generates unemployment, as in papers by Davis (1998a,b) and Şener (2006).[14] This institution can also be interpreted as a rigid wage or as a bargained wage (ibid.), but I omit this micro-foundation here. A minimum wage is analytically the simplest way to create unemployment, while time-consuming matching processes would make the analytics more difficult.

Here, the objective is first to identify the activities – R&D or production – in which jobs are destroyed and created. The source of the transition to the new steady state is therefore time-consuming R&D, but not frictions on the labor market with different rates of job creation and job destruction.

I proceed as follows: First, I only consider a Northern import tariff. In Section 2, I set up the model and present all equilibrium conditions. I then solve for equilibrium transitional dynamics and analyze the short-run effects of globalization issues. Afterwards, I derive necessary and sufficient conditions for the steady state's existence and stability and analyze the effects of globalization on steady state unemployment.

Second, I add a Southern import tariff in Section 3. Again, I derive the model's transitional dynamics and discuss the short run effects of Southern trade liberalization. I calibrate the model and analyze the steady state's stability and the effects of unilateral and bilateral trade liberalization numerically. Proofs and lengthy derivations are in the Appendix. To justify the rent-protection approach to remove the scale effect, I show the instability of the steady state if I used a simpler approach.

2 The Model

2.1 Non-Technical Overview

There are two countries, North (N) and South (S). There is a continuum of industries that produce final consumption goods. All consumption goods can be produced in both the North and the South. The goods can be internationally traded, but the North charges an ad-valorem import tariff. In the North, firms in all industries seek to improve the existing products' quality level in their respective industry. In the South, firms can imitate the Northern production technology, but they do not improve the existing products. For simplicity, imi-

growth models. But, as the elimination of scale effects has been generally acknowledged, I opt for non-scale fully endogenous growth theory.

[14] Grieben (2004) uses a fixed relative wage of heterogeneous workers.

tation activity in the South is costless and occurs at an exogenous rate (Arnold 2002), while innovation activity in the North is costly and endogenous.

A new quality level improves the consumer's satisfaction by a fixed proportion relative to the previous quality level. Once a firm develops a new quality level, it owns a patent for the corresponding technology and hence has a monopoly position as *quality leader*. The technology of the previous quality level immediately becomes common knowledge and is hence produced and sold competitively by *quality followers*. I also refer to quality leaders as *incumbents*, while firms that develop new quality levels are *challengers*. Perfect competition is also implied when the South acquires the technology for producing a certain quality level, as this also entails the technology becoming common knowledge.

The Northern quality leader engages in costly *rent-protection activities* that make it more difficult for challengers to understand the incumbent's state-of-the-art technology and subsequently invent the next quality level. Workers for rent-protection activities form a separate labor market. All other workers, called general purpose workers, are homogeneous and can work in either R&D or the production of final goods. These workers earn a fixed wage. Let us now move on to a detailed presentation of the model's assumptions.

2.2 The Model's Assumptions

Households in the North have at time 0 an initial size of $L_{N,0}$ and grow exponentially at rate g_L in continuous time t. They maximize the standard lifetime utility function

$$U_N = \int_0^\infty L_{N,t} e^{-\rho t} \ln \nu_{N,t} \mathrm{d}t, \tag{1}$$

where ρ is the usual intertemporal discount factor and $\ln \nu_{N,t}$ is instantaneous utility, defined below. I assume $\rho > g_L$ to keep utility bounded. The household's intertemporal budget constraint,

$$\dot{A}_{N,t} = r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}, \tag{2}$$

is also standard: $A_{N,t}$ are the Northern household's assets, $r_{N,t}$ is the Northern interest rate at time t, $W_{N,t}$ is the Northern household's labor income (which takes into account both types of workers and unemployed workers), $c_{N,t}$ is Northern per capita consumption expenditure, and $T_{N,t}$ are lump-sum transfers to Northern households from the Northern government, financed by its tariff revenue. Households own firms that make profits, so assets are shares. There is no physical capital. As indicated by the definition of $r_{N,t}$, there is no global financial market. The Southern financial market does not exist, so Southern households receive only labor income and do not make any intertemporal consumption choices.[15]

There is a continuum of product lines of final consumption goods, each produced by one industry. The product line and its respective industry are indexed by $\omega \in [0,1]$. At time t, each product is of a certain quality level, $q_t(\omega)$. Quality improves stepwise, and each improvement yields an increase by a given factor $\lambda > 1$. So, at time t, the quality level $q_t(\omega)$ is $\lambda^{J_t(\omega)}$, where $J_t(\omega) \in \mathbb{N}_0$ is the number of quality steps that have been taken in industry ω at time t. This is known as the quality-ladder model (Grossman and Helpman 1991d). Both Southern and Northern households value product quality; household utility at time t is given by

$$\ln \nu_{i,t} = \int_0^1 \ln \sum_{j=0}^{\infty} \lambda^j x_{i,t}(j,\omega) \mathrm{d}\omega, \qquad i \in \{N, S\} \tag{3}$$

where $x_{i,t}(.)$ is the quantity of the good with quality level j that is bought by a household in country $i \in \{N, S\}$ from industry ω at time t. Households maximize instantaneous utility subject to

$$c_{i,t} = \int_0^1 \sum_{j=0}^{\infty} p_{i,t}(j,\omega) x_{i,t}(j,\omega) \mathrm{d}\omega. \tag{4}$$

where $c_{i,t}$ is the total amount spent by a household in country $i \in \{N, S\}$ at time t and $p_{i,t}(.)$ is the price of industry ω's product of quality level j in country i at time t.

New quality levels are discovered by firms that invest in R&D. There is free entry in R&D, and there are no fixed costs to start R&D. The arrival rate of innovation follows a Poisson process. The innovation process is linear, such that the arrival rate of innovation in firm m in industry ω at time t, $\iota_{m,t}(\omega)$, increases

[15] Similar assumptions are made by Helpman (1993) and Arnold (2002). As soon as Southern imitation is endogenous, there has to be a financial market in the South to finance imitation activities. Hence, consumers can invest their savings and make intertemporal consumption decisions. See Grossman and Helpman (1991c) or Grieben and Şener (2009a, 2012) for such a case.

proportionally with research activity[16] by this firm, $R_{m,t}(\omega)$, such that

$$\iota_{m,t}(\omega) = \frac{R_{m,t}(\omega)}{D_t(\omega)}, \tag{5}$$

where $D_t(\omega)$ is industry-specific R&D difficulty at time t. The arrival rates are independent across firms and industries. Therefore, and using the property of a Poisson process, the arrival rate in industry ω is the sum of all firms' arrival rates:

$$\iota_t(\omega) = \sum_{m=0}^{\infty} \iota_{m,t}(\omega) = \sum_{m=0}^{\infty} \frac{R_{m,t}(\omega)}{D_t(\omega)} = \frac{R_t(\omega)}{D_t(\omega)}. \tag{6}$$

The unit labor requirement for R&D is $a_R > 0$, hence total research employment is $L_t^R = a_R R_t$.

Once a firm has developed a new quality level, it owns a patent on the corresponding technology. By consequence, it has a monopoly for this quality level. In all industries, firms face Bertrand price competition on the product market. For the production of one unit of the consumption good, firms need one unit of labor.

When the quality leader's technology standard is overcome by another Northern firm with a better technology, the quality leader loses patent protection and its technology becomes common knowledge.[17] Quality leaders also lose their patent protection if the South starts to imitate the technology of the Northern quality leader.[18] The Southern imitation rate $\mu > 0$ is the same for all industries and it is exogenous.

R&D difficulty $D_t(\omega)$ is introduced to remove the scale effect (Jones 1995; Segerstrom 1998). $D_t(\omega)$ represents institutions that protect the quality leader's knowledge about its production technology, in the sense that it makes the acquisition or the use of this knowledge costly for other firms. As these institutions protect knowledge, they protect rents that can be drawn from this information and are hence called *rent-protecting institutions* (Dinopoulos and Syropoulos 2007). Quality leaders can invest in these institutions, which are an industry-specific stock variable with an initial value of $D_0 > 0$.[19] These investments are

[16] Research activity represents, e.g., conducting lab experiments or developing prototypes.

[17] Incumbent firms do not undertake R&D themselves, see Grossman and Helpman (1991d, p. 47).

[18] Obviously, the idea of patent protection is a bit vague in this strand of literature. An imitated product that obviously violates patent rights is hard to sell in a country where patent enforcement works due to functioning institutions.

[19] If R&D difficulty was a flow variable, then R&D difficulty would be zero if the product is currently produced by a Southern firm, i. e. $D_t(\omega) = 0$ if $\omega \in (n_{N,t}, 1]$.

only undertaken by quality leaders, which may or may not be currently in the North. The increase is hence

$$\dot{D}_t(\omega) = \begin{cases} X_t(\omega) & \text{if } \omega \in [0, n_{N,t}] \\ 0 & \text{if } \omega \in (n_{N,t}, 1] \end{cases}, \tag{7}$$

where $X_t(\omega)$ is the amount of rent-protection activities in industry ω, and $n_{N,t}$ is the share of Northern quality leaders at time t. I omit from now on the industry index ω, since all industries are structurally identical. The increase in R&D difficulty $\dot{D}_t$ is hence on average $\dot{D}_t = n_{N,t}X_t$ for each industry. The unit labor requirement for rent-protection activities, X_t, is $a_X > 0$. Labor for rent protection is supplied by a fixed fraction of the labor force (see below).

The Northern labor market is exogenously divided into two types of labor, following Dinopoulos and Syropoulos (2007). One type can work either in the production of goods or in R&D, and the other type of labor works only for rent-protection activities. The former type is called *general purpose* workers, and the latter is called *specialized* workers. General purpose workers make up for a share of $1 - s$ of the Northern labor force[20] and earn an exogenously fixed wage $\bar{w}$. It is fixed in terms of the Southern wage and higher than the latter:

$$w_N^{GP} = \bar{w} > w_S. \tag{8}$$

This can be interpreted as a minimum wage or as a bargained wage that is binding for all firms in all industries. It is sufficiently high that the labor market does not clear. I assume that the minimum wage does not bind for rent-protection workers and their labor market hence clears. This can be justified by arguing that these workers are highly specialized and earn higher wages than non-specialized workers.[21]

On the Southern labor market, workers work only in production activities, and their labor market is perfectly competitive. I take the Southern wage as the numeraire, $w_S \equiv 1$.

The North charges an ad-valorem import tariff $\tau_N > 0$. I assume $\bar{w} > 1 + \tau_N$. The government redistributes tariff revenue via lump-sum transfers to

[20] The exogenous fractionalization is not convincingly explained by Dinopoulos and Syropoulos. A possible justification might be high barriers for a worker's market entry, in the sense that being a lobbyist might require a long working experience and a high education standard.

[21] An alternative assumption could be that there is a sectoral minimum wage for general purpose workers which simply does not apply to rent-protection workers, so that their wage could also be below the minimum wage. This assumption seems arbitrary and difficult to justify.

households. Trade is balanced at each point of time.

2.3 Equilibrium Conditions

2.3.1 Households

Households maximize consumption in two steps: First, they maximize instantaneous utility at every point of time. This results in households buying – for each consumption good – the quality level with the lowest quality adjusted price, which is $\frac{p_{i,t}(j,\omega)}{\lambda^j}$ for country $i \in \{N, S\}$ and quality level j.

In a second step, Northern households maximize lifetime utility. The result is standard: Consumption follows the Euler equation,

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = r_{N,t} - \rho. \tag{9}$$

These results are standard. Details of the derivation are presented in Appendix D.

2.3.2 Labor Markets

Let us first consider the market for general purpose workers, which can be split into three parts. The first part consists of production workers, whose number is given by the demand for first rank consumption goods in North and South, $n_{N,t}\left(x_{N,t}(\omega_N)L_{N,t} + x_{S,t}(\omega_N)L_{S,t}\right)$, where $n_{N,t}$ is the share of industries with a Northern quality leader, and where industry $\omega_N \in [0, n_{N,t}]$. The second part is the number of R&D workers, given by the unit labor requirement for R&D, a_R, and the R&D activity level, R_t. The fixed wage for general purpose workers prevents market clearing, so the third part of general purpose workers is the share $u_{N,t}$ of unemployed general purpose workers. Putting all parts together, the labor market equation in the North is hence for general purpose workers

$$n_{N,t}\left(x_{N,t}(\omega_N)L_{N,t} + x_{S,t}(\omega_N)L_{S,t}\right) + a_R R_t + u_{N,t}L_{N,t} = (1-s)L_{N,t}, \tag{10}$$

where the right hand side is the supply of general purpose workers.

As already mentioned, I assume that the minimum wage does not bind for rent-protection workers. (I will take this assumption more explicitly into account in the calibration in Section 3.3.) Hence, the market for rent-protection workers is perfectly competitive and clears. It is characterized by the equation

$$n_{N,t} a_X X_t = s L_{N,t}, \tag{11}$$

where the left hand side determines the demand for rent-protection workers by the share of industries whose quality leader is located in the North, $n_{N,t}$, and the amount of rent-protection activities, X_t, and the according unit labor requirement, a_X.

All Southern workers work in the production of imitated products and the labor market clears, so the Southern labor market equation is

$$(1 - n_{N,t}) \left(x_{N,t}(\omega_S) L_{N,t} + x_{S,t}(\omega_S) L_{S,t} \right) = L_{S,t}, \tag{12}$$

where $1 - n_{N,t}$ is the share of industries currently imitated by Southern firms, and where industry $\omega_S \in (n_{N,t}, 1]$.

2.3.3 Firms

Let us now turn to optimal firm behavior. Let $V^I_{N,t}$ denote the present firm value of an incumbent monopolist, and let $V^C_{N,t}$ denote the present firm value of a challenger. I start with R&D firms to determine optimal R&D activity. I set up the present-value Hamilton-Jacobi-Bellman equation[22], following Dinopoulos and Syropoulos (2007). For the challengers, it is

$$-\dot{V}^C_{N,t} = \max_{R_{m,t}} \left\{ -e^{-r^c_{N,t}} \bar{w} a_R R_{m,t} + \frac{R_{m,t}}{D_t} \left[V^I_{N,t} - V^C_{N,t} \right] \right\}, \tag{13}$$

where $r^c_{N,t} \equiv \int_0^t r_{N,s} \mathrm{d}s$ is the cumulative interest rate for time t. The first part on the right hand side is the cost of R&D, and the second part is the expected gain.[23] The first-order condition for the maximization problem in equation (13) yields

$$-e^{-r^c_{N,t}} \bar{w} a_R + \frac{1}{D_t} \left[V^I_{N,t} - V^C_{N,t} \right] \stackrel{!}{=} 0. \tag{14}$$

[22]See Kamien and Schwartz (1991) for a derivation of the present-value form, and Malliaris and Brock (1982) for details about stochastic optimal control.

[23]The interpretation of the current-value Bellman equation is a no-arbitrage equation, and the decision is whether to keep assets or not. By contrast, the interpretation of the present-value form is whether to hold assets or not. This is better to see if $-\dot{V}^C_{N,t}$ is on the right hand side. Then, the present value of assets is zero. That means, discounting the return from the assets at its opportunity cost gives a present value of zero. This is a different view of the no-arbitrage condition. If the present value of assets were negative, nobody would invest. If it were positive, free entry opportunities into R&D would not be completely used.

In other words, a finite equilibrium value of $R_{m,t}$ is only obtained if costs equal benefits. Hence, we have $-\dot{V}^C_{N,t} = 0$. As there is free entry in innovation, the value of a challenging firm, $V^C_{N,t}$, must be zero in equilibrium. Hence, equation (14) can be rearranged to

$$\frac{e^{r^c_{N,t}} V^I_{N,t}}{D_t} = \bar{w} a_R, \tag{15}$$

where $e^{r^c_{N,t}} V^I_{N,t}$ is the current value of a challenging firm, which I denote by $v^I_{N,t}$. Using this, the free-entry-in-innovation condition is

$$\frac{v^I_{N,t}}{D_t} = \bar{w} a_R. \tag{16}$$

This is the usual result that equates the expected marginal benefit with the marginal cost of R&D activity.

The incumbent's optimization problem is about rent-protection activities, X_t, and prices in North and South, $p_{N,t}$ and $p_{S,t}$. He maximizes profits from sales in both countries, $\pi_{N,t}(p_{N,t}, p_{S,t})$, less cost for rent-protection activities, $w^{RP}_{N,t} a_X X_t$ and plus the expected loss from being pushed from his monopoly position, $(\mu + \iota_t)\left[V^C_{N,t} - V^I_{N,t}\right]$.

Using the labor market equation for specialized workers, (11), I determine D_t as

$$\begin{aligned} D_t =& D_0 + \int_0^t \dot{D}_\tau \mathrm{d}\tau = D_0 + \frac{s}{a_X} L_{N0} \int_0^t e^{g_L \tau} \mathrm{d}\tau \\ =& D_0 + \frac{s}{a_X}\left[\frac{1}{g_L} L_{N,0} e^{g_L t} - \frac{1}{g_L} L_{N,0}\right] \\ =& D_0 + \frac{s}{a_X g_L}\left[L_{N,t} - L_{N,0}\right] \end{aligned} \tag{17}$$

which can again be rewritten using equation (11) as

$$D_t = D_0 + \frac{1}{g_L}\left[n_{N,t} X_t - n_{N,0} X_0\right]. \tag{18}$$

Using equations (6) and (17) for ι_t and D_t, the optimization problem is

$$\begin{aligned} -\dot{V}^I_{N,t} = \max_{p_{N,t}, p_{S,t}, X_t} \Bigg\{ & e^{-r^c_{N,t}}\left(\pi_{N,t}(p_{N,t}, p_{S,t}) - w^{RP}_{N,t} a_X X_t\right) + \\ & \left(\mu + \frac{R_t}{D_0 + \frac{1}{g_L}\left[n_{N,t} X_t - n_{N,0} X_0\right]}\right)\left[V^C_{N,t} - V^I_{N,t}\right]\Bigg\}. \end{aligned} \tag{19}$$

The maximization problem in equation (19) yields as first-order condition for optimal rent-protection activities X_t

$$- e^{-r^c_{N,t}} w^{RP}_{N,t} a_X - \frac{R_t \frac{1}{g_L} n_{N,t}}{\left[D_0 + \frac{1}{g_L}[n_{N,t}X_t - n_{N,0}X_0]\right]^2} \left[V^C_{N,t} - V^I_{N,t}\right] \stackrel{!}{=} 0. \quad (20)$$

Setting $V^C_{N,t} = 0$, using the definition of ι_t from equation (6), and using $e^{-r^c_{N,t}} v^I_{N,t} = V^I_{N,t}$ in the first-order condition yields

$$\frac{v^I_{N,t}}{D_t} = w^{RP}_{N,t} \frac{a_X g_L}{\iota_t n_{N,t}}. \quad (21)$$

Using $\dot{V}^I_{N,t} = -r_{N,t} e^{-r^c_{N,t}} v^I_{N,t} + e^{-r^c_{N,t}} \dot{v}^I_{N,t}$ and $V^C_{N,t} = 0$ in equation (19) yields, after multiplying by $e^{r^c_{N,t}}$,

$$r_{N,t} v^I_{N,t} - \dot{v}^I_{N,t} = \pi_{N,t}(p_{N,t}, p_{S,t}, X_t) - (\mu + \iota_t)\, v^I_{N,t}. \quad (22)$$

This can be rearranged to

$$v^I_{N,t} = \frac{\pi_{N,t} - w^{RP}_{N,t} a_X X_t}{r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}, \quad (23)$$

and using this to replace $v^I_{N,t}$ as well as equation (18) to replace D_t in equation (21), we have

$$\begin{aligned} &\pi_{N,t} - w^{RP}_{N,t} a_X X_t \\ &\quad = w^{RP}_{N,t} \frac{a_X g_L}{\iota_t n_{N,t}} \left(r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} \right) \left[D_0 + \frac{1}{g_L} \left[n_{N,t} X_t - n_{N,0} X_0 \right] \right]. \end{aligned} \quad (24)$$

Solving for X_t, the optimal level of rent protection is hence

$$X^o_t = \frac{\pi_{N,t}}{r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}} \frac{\iota_t}{w^{RP}_{N,t} a_X} - \frac{\Delta \left(r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} \right)}{n_{N,t} \left(r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} \right)}. \quad (25)$$

where

$$\Delta \equiv D_0 g_L - \frac{s L_{N,0}}{a_X} \quad (26)$$

is constant over time. I plug X^o_t from above into $v^I_{N,t}$ in equation (23) and obtain the firm value as

$$v_{N,t}^{I}=\frac{\pi_{N,t}+w_{N,t}^{RP}\frac{a_X\Delta}{n_{N,t}}}{r_{N,t}+2\iota_t+\mu-\frac{\dot{v}_{N,t}^{I}}{v_{N,t}^{I}}}. \tag{27}$$

To get the wage of rent-protection workers, I combine equation (21) and the free-entry-in-innovation condition, (16), which yields

$$w_{N,t}^{RP}=\bar{w}\frac{a_R}{a_X g_L}\iota_t n_{N,t}. \tag{28}$$

Let us turn to optimal pricing. Consider the highest existing quality level, J_t, the *first rank*, at time t in an industry. Let me explain first why we only need to have a closer look on the pricing policy for first rank, J_t, and second rank, $J_t - 1$, quality levels. All quality levels but the top quality level are produced competitively, as their production technology is common knowledge, and therefore sold at marginal costs. What does that imply for the household's decision? As households always buy the good with the lowest quality-adjusted price, no household will buy goods with a quality level lower than the second rank: A firm producing the quality level of third rank faces the same production costs as a producer of second-rank quality and hence demands the same nominal price, but the household gets a higher quality level for the same price if it buys the second quality rank. In other words, the quality-adjusted price of the second rank is strictly lower than the quality-adjusted price of the third rank quality level. Hence, we can focus on first and second rank quality levels.

Let us first look at the pricing policy of producers of the second quality rank and show that only Southern firms are on the market for products of this quality level. Remember that firms face Bertrand price competition. The price charged by Southern imitators of the second quality rank in the North is the competitive price $p_{N,t}^{S}(j=J_t-1)=1$. Northern consumers have to pay the ad-valorem import tariff in addition, hence they pay $1+\tau_N$. This is lower than the competitive price which the Northern producers would charge, $p_{N,t}^{N}(j=J_t-1)=\bar{w}$. So, quality leaders compete against Southern followers in the North. In the South, the price charged by Southern followers is $p_{S,t}^{S}(j=J_t-1)=1$, and here Southern followers price out Northern followers as well.

Second, we analyze the pricing policy of quality leaders. Top quality producers can charge a quality markup of λ against producers of the second quality rank, as this leads to equal quality-adjusted prices. Producers of second quality rank are only from the South. To price out quality followers and to catch the whole market, top quality producers charge $p^N_{N,t}(j = J_t) = \lambda(1+\tau_N) - \varepsilon$ in the North and $p^N_{S,t}(j = J_t) = \lambda - \varepsilon$ in the South, where $\varepsilon \to 0$.[24]

So, consumers only buy the top quality product within one product line. The producer's per unit revenue is $\lambda(1+\tau_N)$ for sales in the North and λ for sales in the South. The per unit cost is $\bar{w}$. So, the profit of a Northern quality leader writes as

$$\pi_{N,t} = \frac{c_{N,t}L_{N,t}}{\lambda(1+\tau_N)}\left(\lambda(1+\tau_N) - \bar{w}\right) + \frac{c_{S,t}L_{S,t}}{\lambda}\left(\lambda - \bar{w}\right). \tag{29}$$

2.3.4 International Flows

To close the model, we need to consider two other aspects: First, the dynamics of the share $n_{N,t}$ of industries whose quality leader is located in the North.[25] The share is subject to changes, depending on the relative size of the arrival rate of Northern innovation ι_t and the arrival rate of Southern imitation μ. During the time interval $\mathrm{d}t$, the outflow of industries from the North to the South is $n_{N,t}\mu\mathrm{d}t$, and the inflow is $(1-n_{N,t})\iota_t\mathrm{d}t$, so that the change in the share of the Northern industries is

$$\dot{n}_{N,t}\mathrm{d}t = (1-n_{N,t})\iota_t\mathrm{d}t - n_{N,t}\mu\mathrm{d}t, \tag{30}$$

and dividing by $\mathrm{d}t$ gives

$$\dot{n}_{N,t} = (1-n_{N,t})\iota_t - n_{N,t}\mu. \tag{31}$$

Trade between North and South is balanced at each point of time, so there is no international debt.[26] In the North, the firm's profits are given to households via dividends, and the government's tariff revenue is distributed via lump-sum transfers to households. So, household expenditure equals firm revenue plus government revenue,

$$c_{N,t}L_{N,t} = n_{N,t}\left(c_{N,t}L_{N,t} + c_{S,t}L_{S,t}\right) + (1-n_{N,t})\frac{c_{N,t}L_{N,t}}{1+\tau_N}\tau_N. \tag{32}$$

[24] This is known as *limit pricing*.

[25] It can also be interpreted as the average share of time in which the quality leader is located in the North.

[26] This is standard in this literature, see e. g. Grossman and Helpman (1991b, p. 149), Arnold (2002) or Grieben and Şener (2009a).

Equation (32) can be rearranged to

$$c_{N,t}L_{N,t} = (1+\tau_N)c_{S,t}L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}, \tag{33}$$

and I refer to this as the balanced-trade condition.

2.4 Equilibrium: Transitional Dynamics

We are now in a position to solve the model. The Southern labor market condition, (12), reduces, after replacing $c_{N,t}$ using the balanced trade condition, (33), to

$$\frac{c_{S,t}L_{S,t}}{w_S} = L_{S,t}, \tag{34}$$

so

$$c_{S,t} = c_S = w_S = 1, \tag{35}$$

which means that Southern per-capita consumption equals the Southern wage, w_S, which is the numeraire.

I use the firm value, (27), in the free-entry-in-innovation condition, (16), to replace $v^I_{N,t}$, which yields:

$$\bar{w}a_R D_t = \frac{\pi_{N,t} + w^{RP}_{N,t}\frac{a_X\Delta}{n_{N,t}}}{r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{36}$$

Solving for $r_{N,t}$, I obtain

$$r_{N,t} = \frac{\pi_{N,t} + w^{RP}_{N,t}\frac{a_X\Delta}{n_{N,t}}}{\bar{w}a_R D_t} - 2\iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}, \tag{37}$$

which I use in the Keynes-Ramsey rule (9) for Northern per-capita consumption:

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \underbrace{\frac{\pi_{N,t} + w^{RP}_{N,t}\frac{a_X\Delta}{n_{N,t}}}{\bar{w}a_R D_t} - 2\iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}_{=r_{N,t}} - \rho. \tag{38}$$

To replace $\pi_{N,t}$, I use the balanced-trade condition, (33), in the profit equation, (29), and with $c_S = 1$, I get

$$\pi_{N,t} = L_{S,t} \frac{1}{1-n_{N,t}} \underbrace{\frac{\lambda - \bar{w}}{\lambda}}_{\equiv \Lambda} + L_{S,t} \frac{n_{N,t}}{1-n_{N,t}} \tau_N, \tag{39}$$

where Λ is the ratio of profit to revenue. Replacing the wage of rent-protection workers $w_{N,t}^{RP}$ by equation (28) and using the definition of Δ in (26), we can rearrange the above equation (38) to

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{\Lambda L_{S,t} \frac{1}{1-n_{N,t}} + \frac{n_{N,t}}{1-n_{N,t}} \tau_N L_{S,t}}{\bar{w} a_R D_t} - \frac{\frac{s}{a_X g_L} L_{N,t}}{D_t} \iota_t - \iota_t - \mu + \frac{\dot{v}_{N,t}^I}{v_{N,t}^I} - \rho. \tag{40}$$

Using the labor market equation for specialized workers (11), we can derive that

$$\frac{\dot{D}_t}{D_t} = \frac{n_{N,t} X_t}{D_t} = \frac{\frac{s}{a_X} L_{N,t}}{D_t}, \tag{41}$$

and using the free-entry-in-innovation condition, (16), we can show that

$$\frac{\dot{v}_{N,t}^I}{v_{N,t}^I} = \frac{\dot{D}_t}{D_t}, \tag{42}$$

since a_R and $\bar{w}$ are constant over time. Hence, we can rewrite equation (40) as

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{L_{S,t} \frac{1}{1-n_{N,t}} \Lambda + L_{S,t} \frac{n_{N,t}}{1-n_{N,t}} \tau_N}{\bar{w} a_R D_t} - \frac{1}{g_L} \frac{\dot{v}_{N,t}^I}{v_{N,t}^I} \iota_t - \iota_t - \mu + \frac{\dot{v}_{N,t}^I}{v_{N,t}^I} - \rho. \tag{43}$$

To replace $\frac{\dot{c}_{N,t}}{c_{N,t}}$, I take logs in the balanced-trade condition (33) and differentiate it with respect to time. That yields

$$\frac{\dot{c}_{N,t}}{c_{N,t}} + \frac{\dot{L}_{N,t}}{L_{N,t}} = \frac{\dot{L}_{S,t}}{L_{S,t}} + \frac{\dot{n}_{N,t}}{n_{N,t}} \frac{1}{1-n_{N,t}}, \tag{44}$$

as c_S is constant and always equals 1. Since $L_{N,t}$ and $L_{S,t}$ both grow at rate g_L, the equation reduces to

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{\dot{n}_{N,t}}{n_{N,t}} \frac{1}{1-n_{N,t}}. \tag{45}$$

We then have

$$\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}} = \frac{L_{S,t}\frac{1}{1-n_{N,t}}\Lambda + L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\tau_N}{\bar{w}a_R D_t} - \frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}\iota_t - \iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \rho. \tag{46}$$

Using equation (17) and the equilibrium equation (11) for specialized workers to replace D_t, and using the equation for balanced industry flows, (31), in equation (46) to replace ι_t, we obtain after solving for $\dot{n}_{N,t}$

$$\dot{n}_{N,t} = \left(\overbrace{\left(\frac{\Lambda}{\bar{w}a_R}\frac{L_{S,t}}{D_t} + \left(\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \mu - \rho\right)\right)}^{\equiv\beta_{1,t}} n_{N,t} - \underbrace{\left(\frac{\mu}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \rho - \frac{\tau_N}{\bar{w}a_R}\frac{L_{S,t}}{D_t}\right)}_{\equiv\beta_{2,t}} n^2_{N,t}\right)\frac{1}{1+\underbrace{\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)}_{\equiv\beta_{3,t}} n_{N,t}}, \tag{47}$$

where $\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}$ is deterministically given by the dynamic version of the free entry in innovation condition, (42), and the growth rate of R&D difficulty, (41). We now have a nonlinear, non-autonomous differential equation of first order and first degree for $n_{N,t}$.

Using again (31) to replace ι_t in equation (28) yields the wage of rent-protection workers in terms of $n_{N,t}$,

$$w^{RP}_{N,t} = \bar{w}\frac{a_R}{a_X g_L} n_{N,t}\left(\frac{\dot{n}_{N,t}}{1-n_{N,t}} + \mu\frac{n_{N,t}}{1-n_{N,t}}\right). \tag{48}$$

To finish the model's solution, we need to state the Northern unemployment rate, $u_{N,t}$, in terms of $n_{N,t}$ and the model's parameters. Therefore, we use the balanced trade condition, equation (33), in the Northern labor market equation (10). To replace R_t, we use first the definition of ι_t in equation (5) and then the equation for balanced industry flows (31). This yields

$$u_{N,t} = 1 - s - \frac{L_{S,t}}{L_{N,t}}\frac{n_{N,t}}{1-n_{N,t}}\frac{1}{\lambda} - a_R\frac{D_t}{L_{N,t}}\left(\frac{\dot{n}_{N,t}}{1-n_{N,t}} + \mu\frac{n_{N,t}}{1-n_{N,t}}\right). \tag{49}$$

The first component, $1 - s$, is the share of general purpose workers. The second component is the share of production workers, and the third component is the share of R&D workers.

We now consider an equilibrium of the model in which the wage of rent-protection workers is above the minimum wage, $w_{N,t}^{RP} > \bar{w}$, and in which there is positive unemployment. The way unemployment is generated in this model may not be obvious at first sight, as the optimization problem of challenging firms is linear in R&D activity $R_{m,t}$. If the free-entry-in-innovation condition holds, a single firm could employ more and more R&D staff without violating this condition. First, in equilibrium, there is no incentive to deviate in any direction. Second, this would prop up the innovation rate, and a higher innovation rate would result in a lower interest rate. The decline in the interest rate and the resulting decline in $\frac{\dot{c}_{N,t}}{c_{N,t}}$ would not match the increase in $\frac{\dot{n}_{N,t}}{n_{N,t}} \frac{1}{1-n_{N,t}}$. But that means that the expected marginal benefit from R&D would be lower than the marginal cost. If this were the case, people would stop doing R&D, which would generate unemployment.

Let us now determine the short-run effects of globalization on unemployment and, in particular, which employment share reacts immediately to changes in globalization parameters. The short-run effect is what happens immediately, that is if we keep time constant. Keeping time constant also means to have a constant share of Northern quality leaders, $n_{N,t}$, which is the state variable. It does not change in the short run because it only depends on the history of the model's parameters.

Starting from any state of $n_{N,t}$, a decrease in the Northern import tariff, τ_N, translates only into an immediate fall of $\dot{n}_{N,t}$ and hence lowers the share of R&D workers, but there is no immediate change in the share of production workers. A decrease in τ_N decreases the price markup in the North, and hence the incumbents' profit and the incentives to innovate. It has no immediate effects on production because the lower tariff revenue from higher import tariffs is returned to Northern households, such that the price decrease for Northern consumers is neutralized. For Southern demand, there is also no change. Hence, production is still the same.

A decrease in the imitation rate, μ, yields also no immediate change in the share of production workers. But what is surprising is that the share of R&D workers decreases, caused by a decrease in the innovation rate ι_t. The intuition for this effect is easy to see: Suppose that the share of quality leaders is lower than in steady state when μ decreases. As the danger of being imitated is now lower, the North has to put less effort into R&D to gain additional market shares. More formally, the decrease in μ leads to both an increase in $r_{N,t}$ and hence $\frac{\dot{c}_{N,t}}{c_{N,t}}$ (see equation (38)). The decrease in μ also leads to an increase in $\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}$ (see equation (31)), but this increase is stronger for a constant innovation rate.[27] Hence, to reestablish equality in equation (45), innovation is reduced: It raises the interest rate and hence $\frac{\dot{c}_{N,t}}{c_{N,t}}$, but it lowers $\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}$.

By contrast, a change in the Southern market size, $L_{S,t}$, affects both production and R&D worker shares. Demand from the South increases relative to demand in the North and production capacities are immediately increased. But this also increases profits and hence innovation activities increase. Let us summarize these findings in the first main result:

Proposition 1 (Short run effects)

Starting at any state, a decrease in the Northern import tariff, τ_N, and the Southern imitation rate, μ, increase unemployment $u_{N,t}$. An increase in Southern market size, $L_{S,t}$, yields a decrease in unemployment.

The proofs are provided in Appendix A.1. To distinguish these results from the paper by Dutt et al. (2009), we need to take into account that they consider frictional instead of structural unemployment. In their model, the short-run increase in unemployment comes from job destruction in import-competing sectors, which is faster than job creation in exporting sectors. So, the short-run effect and the transition towards the new steady state is a result from time-consuming frictions in the labor market.

In this model, the short-run effects and the transition to the new steady state result from time-consuming R&D processes and slow adjustments of the share of Northern quality leaders. As I want to single out this effect, I consider structural unemployment. Trade liberalization does not lead to firm exit and job destruction, as it has no effects on product demand. Consumers spend their income equally across all industries, and whether they buy a good from an industrialized country or from a developing country does not result from relative prices, but from quality leadership. This is not affected in the short run by import tariffs, but by innovative activities. However, if I had a matching

[27]Differentiating equation (38) gives $\frac{\partial \frac{\dot{c}_{N,t}}{c_{N,t}}}{\partial \mu} = -1$, while using equation (31) yields $\frac{\partial \frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}}{\partial \mu} = -\frac{1}{1-n_{N,t}}$.

framework, there would not be much difference. It would only take longer to employ additional research workers. Nevertheless, job creation in research would start earlier than job creation in production.

Compared to models with full employment, this result also reveals that a model with unemployment yields different predictions on changes in employment shares. If the labor market were perfectly competitive, any immediate change in the share of R&D workers would require the opposite change in the share of production workers. In our case, the share of unemployed gives us an additional degree of freedom, as one of the three shares of workers can be kept constant.

2.5 Equilibrium: Steady State

Equations (47) and (49) determine the equilibrium of this model for any point of time and any initial value of n_N. The model is in steady state equilibrium if the differential equation (47) is at a point of rest, that is if $n_{N,t}$ is constant. From equation (31), this can only hold if the innovation rate ι_t is constant. For that, R_t and D_t have to grow at the same rate. For a constant share of R&D workers, both grow at the population growth rate, g_L. Since (7) still holds, we have

$$\frac{\dot{D}_t}{D_t} = \frac{n_{N,t} X_t}{D_t} = g_L, \tag{50}$$

so that the steady-state value of D_t is

$$D_t = \frac{n_{N,t} X_t}{g_L}. \tag{51}$$

Using the labor market equation (11) for rent-protection workers, this can be rewritten as

$$D_t = \frac{s L_{N,t}}{a_X g_L}. \tag{52}$$

By equation (42), the firm value $v_{N,t}$ also grows at rate g_L in the steady state. In this case, the differential equation (47) writes as

$$\dot{n}_{N,t} = \left(\overbrace{\left(\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + (g_L - \mu - \rho) \right)}^{\equiv \tilde{\beta}_1} n_{N,t} - \underbrace{\left(\mu + g_L - \rho - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} \right)}_{\equiv \tilde{\beta}_2} n_{N,t}^2 \right) \frac{1}{1 + 2 n_{N,t}}, \tag{53}$$

where the parameter $a_{RX} \equiv \frac{a_R}{a_X}$ gives the ratio of the unit labor requirement for R&D, a_R and for rent protection, a_X. The only possible steady state with $n_N^* > 0$ is at

$$n_N^* = \frac{\tilde{\beta}_1}{\tilde{\beta}_2} = \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{g_L + \mu - \rho - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}}, \tag{54}$$

where the parameter $a_{RX} \equiv \frac{a_R}{a_X}$ gives the ratio of the unit labor requirements for R&D, a_R, and for rent protection, a_X. From the equilibrium equation for industry flows, (31), we have for $\dot{n}_N = 0$ that

$$n_N^* = \frac{\iota^*}{\iota^* + \mu}, \tag{55}$$

which allows to solve by use of the steady state expression for n_N^*, equation (54), for the steady state innovation rate,

$$\iota^* = \mu \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{2\mu - (\Lambda + \tau_N) \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}}. \tag{56}$$

Constant n_N^* and ι^* imply from equation (28) that the wage of rent-protection workers $w_N^{RP^*}$ is also constant in steady state. By the dynamic version of the balanced trade condition, equation (45), we also have $\dot{c}_{N,t} = 0$ in steady state. First, this implies from equation (9) that $r_N^* = \rho$. Second, we can recursively define c_N^* from the balanced trade condition, equation (33), using $c_S = 1$, and get

$$c_N^* = (1 + \tau_N) \frac{L_{S,t}}{L_{N,t}} \frac{n_N^*}{1 - n_N^*}. \tag{57}$$

Northern steady state per capita consumption increases with the steady state share of Northern industries, n_N^*. These firms make profits that consumers obtain by their wage and capital income, which increases household income.

The steady-state growth rate is the growth rate of instantaneous utility (Grossman and Helpman 1991c), which grows as quality improves over time.[28] The steady state growth rate of instantaneous utility is[29]

$$g_\nu^* = \iota^* \ln \lambda. \tag{58}$$

As a higher innovation rate leads to a faster increase in product quality, consumer satisfaction increases faster with a higher innovation rate.

Note that this allows to distinguish between level and growth effects on utility: The level effect is the effect on c_N^*, which increases instantaneous utility, ν_t, and the growth effect is the effect on the growth rate of instantaneous utility, g_ν^*.

The wage of rent-protection workers in equation (48) now turns into

$$w_N^{RP^*} = \bar{w} \frac{a_R}{a_X g_L} n_N^* \left(\mu \frac{n_N^*}{1 - n_N^*} \right) \tag{59}$$

for the steady state.

The unemployment rate, (49), is also constant for $\dot{n}_{N,t} = 0$. That yields the steady state unemployment rate,

$$u_N^* = (1 - s) - \frac{n_N^*}{1 - n_N^*} \frac{L_{S,t}}{L_{N,t}} \frac{1}{\lambda} - \frac{n_N^*}{1 - n_N^*} a_{RX} \frac{s}{g_L} \mu. \tag{60}$$

A higher steady state share of quality leaders decreases Northern unemployment for two reasons: First, a higher innovation rate results in a higher share of Northern quality leaders, which increases production in the North. This is the first term in parentheses. Second, as higher R&D activity requires more resources, more people are employed in R&D. This is the second term in parentheses.

We have now determined the endogenous variables in steady state. Before we analyze the effects of globalization on these variables, we should take a closer look at the conditions for stability and feasibility of the steady state.

[28] Instantaneous utility can be interpreted as an aggregate production function and the consumption goods as intermediate goods. An increase in quality hence increases aggregate production.

[29] See Appendix D.3 for a derivation.

Proposition 2 (Steady state)

A unique globally stable steady state exists where

- $0 < n_N^* < 1$, ι^*, c_N^*, u_N^*, $w_N^{RP^*}$, r_N^* *are constant,*
- $v_{N,t}^I$, R_t, X_t, D_t *grow at rate* g_L,

if and only if $2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{S,t}} > \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \mu + \rho - g_L$.
The steady state is feasible, i.e. it yields a positive unemployment rate $u_N^* > 0$, *if and only if* $1 - s \geq \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{2\mu - (\Lambda + \tau_N) \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}} \left(\frac{L_{S,t}}{L_{N,t}} \frac{1}{\lambda} + a_{RX} \frac{s}{g_L} \mu \right)$.

The proof for the constant variables has been provided in the text. All other proofs are provided in Appendix A.2.

Once we have determined the steady state's stability criteria, we can analyze the effects of globalization on the steady state variables. Assume a decrease in the Northern ad-valorem import tariff, τ_N. This implies that Northern quality leaders charge lower prices, which decreases profits from sales in the North, ceteris paribus. Lower profits decrease the Northern firm values and hence the incentives to innovate. To maintain equality with R&D cost, R&D activity is reduced.

Now consider an increase in the Southern imitation rate, μ. This means that the expected incumbency period declines, ceteris paribus, and consequently the firm value. Hence, innovation incentives decline and R&D activities are reduced to match the reduced R&D incentives. This reduces the share of Northern industries.

Finally, what happens if the Southern market size, $L_{S,t}$, increases? This has a market size effect as sales in the South increase relative to sales in the North. For any given innovation, this increases profits per product line and hence the incentives to undertake R&D.

Proposition 3 (Long run effects)

A decrease in the Northern ad-valorem import tariff τ_N *increases the steady state unemployment rate* u_N^*. *A decrease in the Southern imitation rate* μ *and an increase in the Southern market size* $L_{S,t}$ *decrease* u_N^*.

For proofs, see Appendix A.3. These results are similar to the results by Grieben and Şener (2009b), but as my model is simpler, this can be shown for a strictly positive tariff rate. That is, the results hold for a larger range of parameter values, defined in Proposition 2. Grieben and Şener (2012) also find similar results, but they consider unemployment in both North and South due to union wage bargaining. Compared to Arnold (2002), who only focuses on changes in the imitation rate in a model with frictional unemployment, my model's results coincide with his results for a high outflow rate from unemployment. But he analyses neither trade liberalization nor short run effects. Şener (2001) analyses bilateral trade liberalization between symmetric countries and finds that the effect on aggregate unemployment depends on the size of the innovation rate: For a low innovation rate, unemployment increases, as an increase in innovation leads to more labor turnover among unskilled production workers. Although more unskilled workers decide to become skilled, this effect only becomes stronger as the innovation rate becomes sufficiently large.

3 The Model with a Southern Import Tariff

For analytical reasons, we have so far only considered a Northern ad-valorem import tariff. The more realistic case is one where there are also trade barriers raised by the South. So, in addition to the model presented in Section 2, there is also a Southern ad-valorem import tariff, $\tau_S > 0$. The Southern government also redistributes tariff revenue by lump-sum transfers to Southern households.

Price-setting in the North is not affected by this change. In the South, Northern quality leaders still compete against Southern imitators who charge a price of 1. Hence, Southern consumers are willing to pay a markup of λ for the top quality product, but that means that the producer's price is $\frac{\lambda}{1+\tau_S}$. Profits from sales for Northern quality leaders are now

$$\pi_{N,t} = \frac{c_{N,t} L_{N,t}}{\lambda(1+\tau_N)} \left(\lambda(1+\tau_N) - \bar{w}\right) + \frac{c_{S,t} L_{S,t}}{\lambda} \left(\frac{\lambda}{1+\tau_S} - \bar{w}\right). \qquad (61)$$

For positive profits from Southern sales, we need of course $\frac{\lambda}{1+\tau_S} > \bar{w}$ as a parameter restriction.

The Northern and Southern labor market equations (10), (11), and (12) do not change, but the balanced-trade condition does, as firm revenue changes. Trade is still balanced at every point of time, and per capita expenditure equals firm revenue plus government revenue:

$$c_{N,t} L_{N,t} = n_{N,t} \left(c_{N,t} L_{N,t} + \frac{c_{S,t} L_{S,t}}{1+\tau_S}\right) + (1-n_{N,t}) \frac{c_{N,t} L_{N,t}}{1+\tau_N} \tau_N, \qquad (62)$$

and simplifying this yields the new balanced-trade condition,

$$c_{N,t}L_{N,t} = c_{S,t}L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\frac{1+\tau_N}{1+\tau_S}. \tag{63}$$

3.1 Equilibrium Solution

I determine the transitional dynamics of the extended model. Using the balanced-trade condition (63) in the Southern labor market condition (12), we have

$$c_{S,t}\left(1 - n_{N,t}\frac{\tau_S}{1+\tau_S}\right) = 1, \tag{64}$$

which is different to the previous model, but colludes to $c_S = 1$ if $\tau_S = 0$. Southern per-capita consumption is now larger than the Southern wage, w_S, which is the numeraire. It increases with an increasing share of Northern quality leaders, and with an increasing Southern ad-valorem import tariff. This reflects the effect of Southern tariff revenue. The higher the share of Northern industries, the more tariff revenue for the Southern government. This is redistributed to Southern consumers, whose spending is higher than without tariffs.

Differentiating the balanced trade condition (63) with respect to time yields now

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{\dot{c}_{S,t}}{c_{S,t}} + \frac{\dot{n}_{N,t}}{n_{N,t}(1-n_{N,t})}. \tag{65}$$

We can replace $c_{S,t}$ by differentiating equation (64) with respect to time, which yields

$$\frac{\dot{c}_{S,t}}{c_{S,t}} = \frac{\dot{n}_{N,t}\tau_S}{1+\tau_S-n_{N,t}\tau_S}. \tag{66}$$

Using equations (61), (63), (64), (66), and (65) in equation (38) yields, after using again equation (31) to replace ι_t,

$$\dot{n}_{N,t}\left(\frac{\tau_S}{1+\tau_S-n_{N,t}\tau_S} + \frac{1}{n_{N,t}(1-n_{N,t})} + \left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\frac{1}{1-n_{N,t}}\right) = \frac{\frac{1+\tau_S}{1+\tau_S-n_{N,t}\tau_S}L_{S,t}\left[\frac{n_{N,t}}{1-n_{N,t}}\frac{1+\tau_N}{1+\tau_S}\left(1-\frac{\bar{w}}{\lambda(1+\tau_N)}\right)+\left(\frac{1}{1+\tau_S}-\frac{\bar{w}}{\lambda}\right)\right]}{\bar{w}a_R D_t} - \left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\left(\mu\frac{n_{N,t}}{1-n_{N,t}}\right) - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \rho. \tag{67}$$

This can be rearranged to

$$\dot{n}_{N,t} = \Gamma_{1,t}\Gamma_{2,t}n_{N,t}, \tag{68}$$

where

$$\begin{aligned}\Gamma_{1,t} =& n_{N,t}\left(\frac{1+\tau_N}{1+\tau_S-n_{N,t}\tau_S}\Lambda_N\frac{L_{S,t}}{\bar{w}a_R D_t}-\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\mu\right)\\ &+\left(\frac{1+\tau_S}{1+\tau_S-n_{N,t}\tau_S}\Lambda_S\frac{L_{S,t}}{\bar{w}a_R D_t}-\left(\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+\rho\right)\right)(1-n_{N,t}), \quad (69)\\ \Lambda_N =& 1-\frac{\bar{w}}{\lambda(1+\tau_N)}, \quad (70)\\ \Lambda_S =& \frac{1}{1+\tau_S}-\frac{\bar{w}}{\lambda}, \quad (71)\end{aligned}$$

and

$$\Gamma_{2,t} = \frac{1+\tau_S(1-n_{N,t})}{1+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n^2_{N,t})\tau_S}. \tag{72}$$

Finally, the unemployment rate is the same as in equation (49): The change in the balanced-trade condition and in Southern per-capita consumption exactly cancel, such that the expression for Northern production is the same.

3.2 Short-Run Effects

We can now examine the short-run effects of Southern trade liberalization. A lower Southern import tariff increases the revenue from sales for Northern firms, but is has no effects on product demand. Hence, the share of production workers does not change in the short run, as the share of Northern industry leaders is constant in the short run. However, the higher revenue from sales in the South increases the innovation incentives. More workers are employed for R&D, which decreases unemployment.

Proposition 4 (Southern trade liberalization)

A decrease in the Southern tariff τ_S leads to an instantaneous decrease in unemployment $u_{N,t}$ if $n_{N,t} \leq n^*_N$.

The proof is in Appendix A.4. For $\dot{n}_{N,t} < 0$, an analytical proof is not possible. For plausible parameter values, the calibration shows that the result holds as well for $\dot{n}_{N,t} < 0$ (Section 3.3.1). The short-run effects of changes in τ_N, L_S, and μ on unemployment $u_{N,t}$ are still valid (see Appendix A.5 for proofs).

3.3 Calibration

An analytical steady state solution or stability analysis is not possible here (see Appendix B). I therefore calibrate the model to analyze Southern trade liberalization and to demonstrate steady-state stability.

I use reasonable values for the imitation rate μ, the population growth rate g_L, the discount rate ρ, the Northern and Southern ad-valorem import tariff rates, τ_N and τ_S, and the Northern real wage, $\bar{w}$. I set λ to get a reasonable value for the price markup in the North. For s and L_S/L_N, I take values from the related literature (Grieben and Şener 2009b, 2012). For the remaining parameters, a_R and a_X, I choose values to get reasonable unemployment rates of less than 20%. Without loss of generality, I assume that D_t grows at rate g_L.[30] I can hence omit to calibrate the parameters D_0 and $L_{N,0}$. The parameter values satisfy the stability conditions in Proposition 2.[31]

Parameter	Target	Value	Source
ρ	Annual stock market return	0.03	Caballero et al. (2008)
g_L	Population growth rate	0.012	Gustafsson and Segerstrom (2010)
μ	Annual imitation rate	0.23	Eaton and Kortum (1999)
τ_N, τ_S	Average import tariff	0.04	World Bank (2013)
$\bar{w}$	Relative marginal costs	1.4	Gustafsson and Segerstrom (2010)
λ	Price markup	1.7	Norrbin (1993), Basu (1996)
L_S/L_N	Relative population size	3.93	Grieben and Şener (2012)
s		0.001	Grieben and Şener (2012)
a_R/a_X	get $u_N^* < 20\%$	17.6	

Table 2: Calibration of the extended model

In this model, $w_S = 1$ is the Southern wage, while $\bar{w}$ is the wage of Northern workers, which also reflects the real wage differential between North and South. The interpretation should however be one of different marginal costs, as workers in the North and the South may not have the same productivity, as Gustafsson and Segerstrom (2010) emphasize. I have not explicitly modelled productivity differences to save parameters and since the paper's focus is not on explaining

[30] A constant growth rate of D_t that is equal to the population growth rate g_L is only a necessary condition for a steady state, but not sufficient. That means that this growth rate can also hold outside of the steady state.

[31] The numbers are chosen to have reasonable size. Of course, the exact numbers should not be taken too seriously, they rather serve to illustrate the qualitative effects.

wage differentials between the North and the South. However, for the calibration, it makes sense to interpret $\bar{w}$ as a ratio of marginal costs. I set $\bar{w} = 1.4$ which is close to the value of Gustafsson and Segerstrom (2010).[32]

I assume a common import tariff of $\tau_N = \tau_S = 4\%$. This covers a broad range of EU tariffs according to tariff data from the World Trade Organization (2013)[33], and is approximately equal to the Chinese average import tariff in 2011 (World Bank 2013).

For Northern industry leaders, the price markup over marginal costs is $\frac{\lambda(1+\tau_N)}{\bar{w}}$ in the North. The literature generally refers to Norrbin (1993) and Basu (1996) to justify a markup between 5% and 40%. For specific industries, Bresnahan (1981) found a markup of 10% in the automobile industry, and Ellison and Ellison (2009) estimated mean markups of high quality computer modules around 25%.[34] I set $\lambda = 1.7$, which yields a markup of approximately 26%.

For the imitation rate, Eaton and Kortum (1999) provide estimates. They refer to Mansfield et al. (1981), who state that within 4 years, 60 percent of all patented innovations were imitated. Assuming an exponential distribution for successful imitations, the annual imitation rate is 0.23.[35]

For the utility discount rate, which equals the real interest rate in steady state, I set $\rho = 0.03$.[36] I set the population growth rate to $g_L = 0.012$.[37] For the South-North population ratio, I take $L_S/L_N = 3.93$ from Grieben and Şener (2012). From the same source, I set the share of rent-protection workers to $s = 0.001$. The last parameter, the unit labor requirement ratio a_{RX} for R&D and rent protection, is set to 17.6 to yield an unemployment rate lower than 20%.[38]

[32] Gustafsson and Segerstrom (2010) refer to Jones (2002) who gives a wage ratio of 2.17 between the U.S. and Mexico. As Gustafsson and Segerstrom assume that Northern and Southern workers are not equally productive, they assume a ratio of marginal costs of 1.6.

[33] The EU average tariff in 2011 is 1.09%

[34] In case of patent protected pharmaceuticals, Berndt et al. (1995) rely on informal information to use a cost/price ratio of 10-25%, which yields a markup of 400-1000%.

[35] Solving $0.6 = 1 - exp(-4\mu)$ yields $\mu \approx 0.23$.

[36] Dinopoulos and Segerstrom (1999) use 3%. Lundborg and Segerstrom (2002) use 5%, while Steger (2003) uses 4%, as well as Stepanok (2013). The latter refers to McGrattan and Prescott (2005), who estimate this value for the real interest rate on intangible capital for the 1990s in the U.S. For ρ, Gustafsson and Segerstrom (2010) use 7% as the average return on the U.S. stock market from 1889-1978, based on Mehra and Prescott (1985, p. 145). The last number seems quite high, as U.S.-long real interest rates varied between 2% and 4% between 1991 and 2002 (Caballero et al. 2008).

[37] This is in line with the literature; e.g. Grieben and Şener (2012) set $g_L = 0.01$, while Gustafsson and Segerstrom (2010) set $g_L = 0.014$.

[38] Given these parameters, the upper bound for equal import tariffs that yields a feasible steady state is $\tau_S = \tau_N = 4.92\%$.

As the wage of rent-protection workers is an increasing function of the share of Northern quality leaders, the assumption that the wage of rent-protection workers is above the minimum wage holds if $n_{N,t} \geq 0.0517 \equiv n_N^{\min}$. The unemployment rate decreases with $n_{N,t}$ and is positive if $n_{N,t} \leq 0.274 \equiv n_N^{\max}$. (In Appendix A.6, Figures 2 and 3 display the value of the wage of rent-protection workers and the unemployment rate for this calibration and for the relevant range of $n_{N,t}$.) For the transitional dynamics, we only consider values of $n_{N,t}$ between $n_N^{\min}$ and $n_N^{\max}$.

3.3.1 Short-Run Effects

In the case of Southern trade liberalization, i.e. a decrease in τ_S, we could not determine the short-run effect on unemployment analytically if $n_{N,t}$ is above its steady-state value. Using the parameters above, we can examine this effect numerically. Again, the unemployment equation (49) reveals that only the share of R&D workers is affected. As the state variable $n_{N,t}$ is constant in the short run, all that matters for unemployment in the short run is the effect on the differential equation (68). Figure 1 depicts the value of $-\frac{\partial \dot{n}_{N,t}}{\partial \tau_S}$, evaluated at $\tau_N = \tau_S = 0.04$, for all values of $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$. The negative value of the derivative is always positive. Hence, a decrease in τ_S leads to an increase in the share of R&D workers in equation (49).

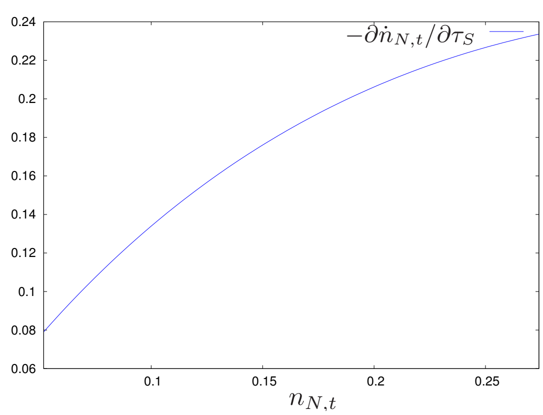

Figure 1: Negative of the derivative of equation (68) with respect to τ_S, evaluated at $\tau_N = \tau_S = 0.04$ for $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$.

3.3.2 Long-Run Effects

I analyze the effects of changes in tariff rates on the steady-state unemployment rate, and I consider three different scenarios: First, I analyze Northern unilateral trade liberalization. Second, I compare this to Southern trade liberalization, and third, to bilateral trade liberalization. I consider incremental changes in import tariffs by 0.01 percentage points. The numerical results are shown in Table 3. I only focus on few endogenous variables: The share of Northern industries, n_N^*, the innovation rate, ι^*, and the unemployment rate, u_N^*. I also state the elasticity of the innovation rate with respect to import tariffs. The last line gives the slope of the differential equation to indicate the stability of each steady state.

Unilateral Northern trade liberalization yields an increase in the unemployment rate, while Southern trade liberalization yields a decrease. The effect of Southern trade liberalization is stronger, as can be seen from the absolute value of the elasticity. Unsurprisingly, bilateral trade liberalization yields a decrease in the Northern unemployment rate, but this effect is reduced by the decrease in the Northern import tariff. But still, the decrease in the unemployment rate is larger than in the first scenario, in which the North unilaterally decreases its import tariff.

	Baseline	$\tau_N \downarrow$	$\tau_S \downarrow$	$\tau_N \downarrow$, $\tau_S \downarrow$
Share of Northern industries n_N^*	0.2437	0.2430	0.2458	0.2451
Innovation rate ι^*	0.0741	0.0738	0.075	0.0747
Unemployment rate u_N^*	0.1453	0.1485	0.1354	0.1387
Elasticity $\frac{\mathrm{d}\iota^*}{\mathrm{d}\tau_i}\frac{\tau_i}{\iota^*}$, $i \in \{N, S\}$	-	1.5091	-4.6097	-3.082
Slope $\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N}$	-0.0106	-0.0106	-0.0107	-0.0107

Table 3: Numerical results for unilateral and bilateral trade liberalization by 0.01 percentage points.

4 Conclusion

I have set up a simple model of North-South product cycles with Northern unemployment. The model allows insights in the short- and long-run effects on unemployment of several issues related to globalization. This paper considers not only changes in production, but also changes in innovation incentives and hence on employment in R&D. I show that R&D workers are affected before production workers by changes in trade policies and in international patent protection. Thus, focusing only on production workers neglects important short-run effects of globalization on unemployment.

Bilateral trade liberalization leads to both short- and long-run decreases in unemployment. However, unilateral Northern trade liberalization increases unemployment in both short and long run, while Southern trade liberalization has opposite effects. Surprisingly, tighter international intellectual property protection yields a short-run unemployment increase, though it decreases unemployment in the long run. An increase in the Southern market size yields a short- and long-run decrease in unemployment. I have also derived conditions for steady-state stability.

These findings suggest that countries with a higher share of research intensive industries might react differently to trade liberalization: A higher research intensity might lead to a less drastic short-run increase in unemployment. So, to explain (presumably existing) cross country variation in the short-run effects of trade liberalization on unemployment, R&D intensity might play an important role. Empirical research might want to consider this.

The seminal paper by Helpman (1993) has already found diametric short- and long-run effects of tighter intellectual property protection on innovation, but my results are exactly opposite. The short-run effects of tighter protection are mostly neglected in the recent literature (Glass and Saggi 2002; Glass and Wu 2007; Jakobsson and Segerstrom 2012), but the results here emphasize that the short run effects should be an important part of the research into this topic.

For future research, several areas offer scope for extensions and alternative assumptions: First, different trade policies can have different effects on growth (Baldwin and Forslid 1999). It therefore remains to investigate the effects of, e.g., import quotas, specific tariffs, and iceberg trade costs.

Second, Southern activity can be endogenized besides production of imitated technologies. An extension to endogenous imitation is also straightforward to do. A shift of production is another issue: Apple produces in China, and car manufacturers, such as Volkswagen, have production facilities in both North (Germany, U.S.) and South (e.g. China, Mexico, Brazil).

A Proofs

A.1 Proof of Proposition 1

Deriving the unemployment rate (49) with respect to the Northern import tariff, τ_N, reduces to deriving the share of R&D workers, as the share of Northern quality leaders, $n_{N,t}$, is constant in the short run. This includes deriving the differential equation (47) for $n_{N,t}$ with respect to τ_N:

$$\frac{\partial u_{N,t}}{\partial \tau_N} = -a_R \frac{D_t}{L_{N,t}} \frac{1}{1-n_{N,t}} \underbrace{\frac{L_{S,t}}{\bar{w} a_R D_t} \frac{n_{N,t}^2}{1+\left(\frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I}+1\right) n_{N,t}}}_{=\frac{\partial \dot{n}_{N,t}}{\partial \tau_N}} < 0. \tag{73}$$

The derivative is negative. Hence, a lower Northern import tariff τ_N increases unemployment.

If the relative market size of Southern countries, η_S, increases, the derivative of (49) affects both production and R&D workers:

$$\frac{\partial u_{N,t}}{\partial L_{S,t}} = -\frac{1}{L_{N,t}} \frac{n_{N,t}}{1-n_{N,t}} \frac{1}{\lambda} - a_R \frac{D_t}{L_{N,t}} \frac{1}{1-n_{N,t}} \frac{\left(\frac{\Lambda}{\bar{w} a_R D_t} n_{N,t} + \frac{\tau_N}{\bar{w} a_R D_t} n_{N,t}^2\right)}{1+\left(\frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I}+1\right) n_{N,t}} < 0. \tag{74}$$

The first part is the marginal effect on production workers, and the second part is the marginal effect on research workers. Both effects are negative. Hence an increase of the Southern market reduces unemployment, as the shares of both production and R&D workers increase.

If the imitation rate μ increases, we have to consider the sign of a larger term. The relevant derivative is negative:

$$\begin{aligned}\frac{\partial u_{N,t}}{\partial \mu} &= -a_R \frac{D_t}{L_{N,t}} \left(\frac{\left(-n_{N,t} - \frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I} n_{N,t}^2\right)}{1+\left(\frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I}+1\right) n_{N,t}} \frac{1}{1-n_{N,t}} + \frac{n_{N,t}}{1-n_{N,t}} \right) \\ &= -a_R \frac{D_t}{L_{N,t}} \frac{n_{N,t}^2}{(1-n_{N,t})\left(1+\left(\frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I}+1\right) n_{N,t}\right)} < 0. \end{aligned} \tag{75}$$

Hence, a tightening of international patent protection, represented by a decrease in μ, increases unemployment in the short run, as the share of research workers decreases and the share of production workers increases.

A.2 Proof of Proposition 2

To show that $v^I_{N,t}$, R_t, X_t, D_t grow at rate g_L, note first that X_t always grows at rate g_L. This follows from a constant n^*_N and the labor market equation (11) for rent-protection workers. From equation (17), it follows that D_t grows at the same rate. Then, from the free-entry-in-innovation condition (16), it follows that $v^I_{N,t}$ must also grow at rate g_L. Finally, for a constant ι^*, it follows from equation (6) that R_t also grows at rate g_L.

The steady state n^*_N in equation (54) satisfies $0 < n^*_N < 1$ under two conditions:

1. Either $0 < \tilde{\beta}_1 < \tilde{\beta}_2$, that is

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX}} > \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \mu + \rho - g_L, \tag{76}$$

2. or $0 > \tilde{\beta}_1 > \tilde{\beta}_2$, that is

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} < \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} < \mu + \rho - g_L. \tag{77}$$

Uniqueness is guaranteed in either case. We can rule out the latter case by considering local stability.

To analyze the local stability of the differential equation (47), its derivative with respect to n_N, evaluated at the interior steady state $n^*_N = \frac{\tilde{\beta}_1}{\tilde{\beta}_2}$, is

$$\left.\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N}\right|_{n_N=\frac{\tilde{\beta}_1}{\tilde{\beta}_2}} = \left.\frac{\tilde{\beta}_1 - 2\tilde{\beta}_2 n_N - 2\tilde{\beta}_2 n_N^2}{(1+2n_N)^2}\right|_{n_N=\frac{\tilde{\beta}_1}{\tilde{\beta}_2}} \tag{78}$$

$$= \frac{-\tilde{\beta}_1 - 2\frac{\tilde{\beta}_1^{\,2}}{\tilde{\beta}_2}}{\left(1+2\frac{\tilde{\beta}_1}{\tilde{\beta}_2}\right)^2}. \tag{79}$$

As a locally stable steady state requires $\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N} < 0$, we need $-\tilde{\beta}_1 - 2\frac{\tilde{\beta}_1^{\,2}}{\tilde{\beta}_2} < 0$. This is only satisfied if $0 < \tilde{\beta}_1 < \tilde{\beta}_2$ if we require $0 < n^*_N = \frac{\tilde{\beta}_1}{\tilde{\beta}_2} < 1$. It follows that the necessary and sufficient conditions for the local stability of an interior steady state are hence

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \mu + \rho - g_L, \tag{80}$$

where the first inequality results from $\tilde{\beta}_1 < \tilde{\beta}_2$ as we require $n_N^* < 1$ for an interior steady state, and the second inequality from $\tilde{\beta}_1 > 0$. If these two inequalities are satisfied, it follows that $\tilde{\beta}_2 > 0$.

To demonstrate the global stability of the interior steady state, we take a look at the stability of the steady state at $n_N^* = 0$. Differentiating the differential equation for n_N with respect to n_N and evaluating it at $n_N = 0$, we have, if $\tilde{\beta}_1 > 0$,

$$\left.\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N}\right|_{n_N=0} = \frac{\tilde{\beta}_1}{(1+2n_N)^2} > 0, \tag{81}$$

hence the steady state at $n_N = 0$ is unstable. As the differential equation is a continuous function, we have $\dot{n}_N > 0 \; \forall \; n_N \in \left(0, \frac{\tilde{\beta}_1}{\tilde{\beta}_2}\right)$ and $\dot{n}_N < 0 \; \forall \; n_N > \frac{\tilde{\beta}_1}{\tilde{\beta}_2}$. This establishes global stability of the steady state under the above stated necessary and sufficient conditions.

For a feasible steady state, we need an unemployment rate that is within the range $1 - s > u_N^* > 0$. This generates only one additional assumption, as $1-s \geq u_N^*$ is trivially satisfied if the condition for a globally stable interior steady state is satisfied: This reduces to $0 \leq \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{2\mu - (\Lambda+\tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}} \left(\frac{L_{S,t}}{L_{N,t}}\frac{1}{\lambda} + a_{RX}\frac{s}{g_L}\mu\right)$. The first term is equal to $\frac{\iota^*}{\mu}$, and the second term is positive. It hence follows that for any $\iota^* > 0$, we have $1 - s > u_N^*$. But the requirement $u_N^* \geq 0$ yields the assumption

$$1 - s \geq \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{S,t}} + g_L - \mu - \rho}{2\mu - (\Lambda + \tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}} \left(\frac{L_{S,t}}{L_{N,t}}\frac{1}{\lambda} + a_{RX}\frac{s}{g_L}\mu\right). \tag{82}$$

A.3 Proof of Proposition 3

In equation (54), only the denominator depends on τ_N. If τ_N decreases, the denominator increases and n_N^* decreases. As u_N^* decreases with n_N^*, and as τ_N affects u_N^* only through n_N^*, u_N^* increases with τ_N.

An increase in $L_{S,t}$ increases the numerator and decreases the denominator in equation (54). Hence, n_N^* increases with $L_{S,t}$. So, u_N^* decreases with $L_{S,t}$ indirectly through n_N^* and also directly, which is obvious.

The effect of a change in μ on u_N^* is less obvious. First, n_N^* decreases with μ, which is obvious from (54). This increases the share of production workers. The share of R&D workers contains the term $\frac{n_N^*}{1-n_N^*}\mu$, which is just equal to ι^*. The derivative of ι^* with respect to μ is

$$\frac{\partial \iota^*}{\partial \mu} = \frac{-\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}(\Lambda+\tau_N)(\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho) - \mu(2\mu - (\Lambda+\tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}})}{\left(2\mu - (\Lambda+\tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}\right)^2}. \tag{83}$$

Since $\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho > 0$ and $2\mu - (\Lambda+\tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > 0$, and $\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > 0$, $\mu > 0$, $\Lambda > 0$, and $\tau_N > 0$, the derivative is negative. Hence, u_N^* decreases if μ decreases.

A.4 Proof of Proposition 4

Deriving the unemployment rate $u_{N,t}$ with respect to the Southern import tariff τ_S reduces to deriving the share of R&D workers,

$$\frac{\partial u_{N,t}}{\partial \tau_S} = -a_R \frac{D_t}{L_{N,t}} \frac{1}{1-n_{N,t}} \frac{\partial \dot{n}_{N,t}}{\partial \tau_S}. \tag{84}$$

The sign of the derivative depends on the sign of the term

$$\frac{\partial \dot{n}_{N,t}}{\partial \tau_S} = \frac{\partial \Gamma_{1,t}}{\partial \tau_S}\Gamma_{2,t} n_{N,t} + \Gamma_{1,t}\frac{\partial \Gamma_{2,t}}{\partial \tau_S} n_{N,t}. \tag{85}$$

For the first term, we have

$$\begin{aligned}\frac{\partial \Gamma_{1,t}}{\partial \tau_S} =& n_{N,t}\left(\frac{-(1+\tau_N)(1-n_{N,t})}{(1+\tau_S - n_{N,t}\tau_S)^2}\Lambda_N \frac{L_{S,t}}{\bar{w} a_R D_t}\right) \\ &+ (1-n_{N,t})\frac{n_{N,t}}{(1+\tau_S-n_{N,t}\tau_S)^2}\Lambda_S\frac{L_{S,t}}{\bar{w} a_R D_t} \\ &+ (1-n_{N,t})\frac{1}{1+\tau_S - n_{N,t}\tau_S}\frac{-1}{1+\tau_S}\frac{L_{S,t}}{\bar{w} a_R D_t}.\end{aligned} \tag{86}$$

The first line is obviously negative. The sum of the second and the third line is also negative, since the sum depends on the sign of

$$\frac{n_{N,t}}{1+\tau_S - n_{N,t}\tau_S}\left(\frac{1}{1+\tau_S} - \frac{\bar{w}}{\lambda}\right) - \frac{1}{1+\tau_S}, \tag{87}$$

which is negative since

$$\frac{n_{N,t}}{1+\tau_S-n_{N,t}\tau_S}<1. \tag{88}$$

Next, $\Gamma_{2,t}$ is obviously positive.

For the second term of equation (85), we have

$$\frac{\partial \Gamma_{2,t}}{\partial \tau_S}=\frac{-n_{N,t}(1-n_{N,t})}{\left(1+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n^2_{N,t})\tau_S\right)^2}, \tag{89}$$

and the numerator is negative for any $0<n_{N,t}<1$, while the denominator is positive. The sign of $\Gamma_{1,t}$ is positive or negative if $n_{N,t}$ is below or above the steady-state value, and the sign of $\Gamma_{1,t}$ determines the sign of $\dot{n}_{N,t}$. So, if $n_{N,t}<n^*_N$, the second term is also negative. At the steady state, the second term is zero, since $\Gamma_{1,t}=0$.

So, if the first term is always negative and the second term is non-positive if $n_{N,t}\leq n^*_N$, we have $\frac{\partial \dot{n}_{N,t}}{\partial \tau_S}<0$ if $n_{N,t}\leq n^*_N$. So, if the Southern import tariff τ_S decreases, $\dot{n}_{N,t}$ increases and the unemployment rate $u_{N,t}$ decreases if $n_{N,t}\leq n^*_N$.

A.5 Proof of Other Short-Run Effects in the Extended Model

Relating to Appendix A.1, we only need to reconsider the derivatives of $\dot{n}_{N,t}$ with respect to τ_N, $L_{S,t}$, and μ. First, the derivative of (68) with respect to τ_N is

$$\frac{\partial \dot{n}_{N,t}}{\partial \tau_N}=\frac{\partial \Gamma_{1,t}}{\partial \tau_N}\Gamma_{2,t}n_{N,t}, \tag{90}$$

and for the derivative of $\Gamma_{1,t}$ with respect to τ_N, we have

$$\frac{\partial \Gamma_{1,t}}{\partial \tau_N}=n_{N,t}\frac{1}{1+\tau_S-n_{N,t}\tau_S}\Lambda_N\frac{L_{S,t}}{\bar{w}a_RD_t}+n_{N,t}\frac{1}{1+\tau_S-n_{N,t}\tau_S}\frac{\bar{w}}{\lambda(1+\tau_N)}\frac{L_{S,t}}{\bar{w}a_RD_t}, \tag{91}$$

which is obviously positive. Hence, if τ_N decreases, $\dot{n}_{N,t}$ decreases, and the unemployment rate $u_{N,t}$ increases.

Second, the derivative of (68) with respect to $L_{S,t}$ is

$$\frac{\partial \dot{n}_{N,t}}{\partial L_{S,t}}=\frac{\partial \Gamma_{1,t}}{\partial L_{S,t}}\Gamma_{2,t}n_{N,t}, \tag{92}$$

as only $\Gamma_{1,t}$ depends on $L_{S,t}$. Since $\Gamma_{2,t} > 0$ and $n_{N,t} > 0$, and since

$$\frac{\partial \Gamma_{1,t}}{\partial L_{S,t}} = n_{N,t} \frac{1+\tau_N}{1+\tau_S - n_{N,t}\tau_S} \Lambda_N \frac{1}{\bar{w} a_R D_t} + (1-n_{N,t}) \frac{1+\tau_S}{1+\tau_S - n_{N,t}\tau_S} \Lambda_S \frac{1}{\bar{w} a_R D_t}, \tag{93}$$

which is obviously positive if $\Lambda_N > 0$ and $\Lambda_S > 0$, the derivative is positive. Hence, if the Southern market size $L_{S,t}$ increases, $\dot{n}_{N,t}$ increases, and the unemployment rate $u_{N,t}$ decreases.

Third, for an increase in the imitation rate, we need to consider two terms to determine the effect on ι_t:

$$\begin{aligned} \frac{\partial \iota_t}{\partial \mu} &= \frac{\partial \dot{n}_{N,t}}{\partial \mu} \frac{1}{1-n_{N,t}} + \frac{n_{N,t}}{1-n_{N,t}} \\ &= \frac{\partial \Gamma_{1,t}}{\partial \mu} \Gamma_{2,t} \frac{n_{N,t}}{1-n_{N,t}} + \frac{n_{N,t}}{1-n_{N,t}} \\ &= \left((-n_{N,t}-1)\Gamma_{2,t}+1\right) \frac{n_{N,t}}{1-n_{N,t}} \end{aligned} \tag{94}$$

For the term in parentheses, we have

$$\begin{aligned} -(1+n_{N,t})\Gamma_{2,t}+1 &= \frac{-(1+n_{N,t})(1+\tau_S(1-n_{N,t}))}{1+2n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n_{N,t}^2)\tau_S} + 1 \\ &= n_{N,t} \frac{1+2\tau_S(1-n_{N,t})}{1+2n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n_{N,t}^2)\tau_S}, \end{aligned} \tag{95}$$

which is obviously positive. Hence, $\frac{\partial \iota_t}{\partial \mu} > 0$, so R&D employment increases with an increasing imitation rate μ. As the share of production workers does not change, the unemployment rate $u_{N,t}$ decreases.

A.6 Feasible Range of Industry Shares

Figure 2 displays the wage of rent-protection workers for the range of $n_{N,t}$ in which $\bar{w} \leq w^{RP}$ and $0 \leq u_{N,t}$, using the calibration in Section 3.3. The wage is obviously increasing with $n_{N,t}$.

Figure 3 displays the Northern unemployment rate of general-purpose workers for the same range of $n_{N,t}$. The unemployment rate is obviously decreasing with $n_{N,t}$.

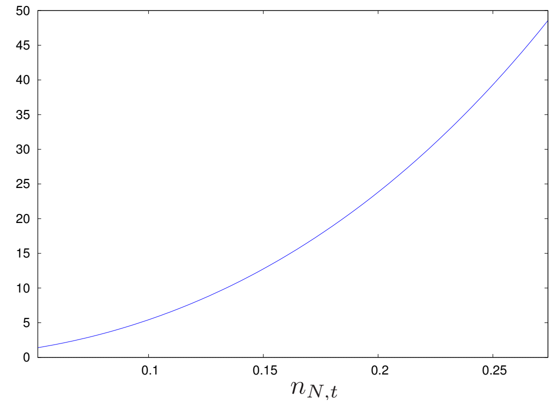

Figure 2: Wage of rent-protection workers for $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$.

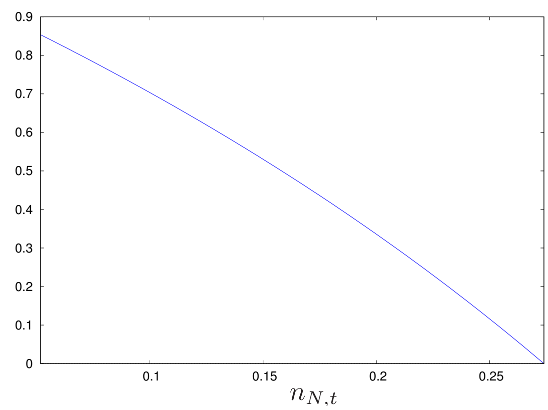

Figure 3: Northern unemployment rate $u_{N,t}$ for $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$.

B Steady State of Extended Model

Equation (68) has three sources for a steady state: Either $\Gamma_1^* = 0$, or $\Gamma_2^* = 0$, or $n_{N,t} = 0$. The last one is out of interest, and $\Gamma_2^* = 0$ only if $n_N^* = \frac{1+\tau_N}{\tau_N} > 1$, which is also out of interest. So, only $\Gamma_1^* = 0$ is relevant and yields a quadratic equation:

$$n_N^{*2} + n_N^* \underbrace{\left[\frac{(1+\tau_N)\Lambda_1 \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} - (1+\tau_S)\Lambda_2 \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} - (\mu + g_L - \rho) + 2\tau_S(\rho - g_L)}{\tau_S(\mu + g_L - \rho)} \right]}_{\equiv p}$$

$$+ \underbrace{\frac{1+\tau_S}{\tau_S} \frac{(\Lambda_2 \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} - \mu + g_L - \rho)}{\mu + g_L - \rho}}_{\equiv q} = 0, \tag{96}$$

which could be solved by the well-known formula

$$n_{N_{1,2}}^* = -\frac{p}{2} \pm \sqrt{\frac{p^2}{4} - q}. \tag{97}$$

However, this yields no analytically tractable solution.

C Level of R&D Difficulty

An equivalent way of assuming that D_t always grows at rate g_L is to determine the level of D_t more rigorously using the labor market equation for specialized workers (11). With an initial level $D_0 > 0$, D_t is

$$\begin{aligned} D_t =& D_0 + \int_0^t \dot{D}_\tau \mathrm{d}\tau = D_0 + \int_0^t n_{N,\tau} X_\tau \mathrm{d}\tau = D_0 + \frac{s}{a_X} L_{N0} \int_0^t e^{g_L \tau} \mathrm{d}\tau \\ =& D_0 + \frac{s}{a_X} \left[\frac{1}{g_L} L_{N,0} e^{g_L t} - \frac{1}{g_L} L_{N,0} \right] \\ =& D_0 + \frac{s}{a_X g_L} \left[L_{N,t} - L_{N,0} \right], \end{aligned}$$

which can again be rewritten using equation (11) as

$$D_t = D_0 + \frac{1}{g_L} \left[n_{N,t} X_t - n_{N,0} X_0 \right]. \tag{98}$$

Choosing an arbitrary level for D_0 complicates the analysis, as the growth rate of D_t is g_L only if $t \to \infty$, when $D_0 - \frac{n_{N,0}X_0}{g_L}$ becomes negligible. Assuming that $\frac{\dot{D}_t}{D_t} = g_L$ always holds is equivalent to setting $D_0 = \frac{n_{N,0}X_0}{g_L}$, which is without loss of generality for the main results and can be justified formally by deriving

$$\begin{aligned} D_0 &= \int_{-\infty}^{0} \dot{D}_\tau \mathrm{d}\tau = \int_{-\infty}^{0} n_{N,\tau} X_\tau \mathrm{d}\tau = \int_{-\infty}^{0} \frac{sL_{N,\tau}}{a_X} \mathrm{d}\tau \\ &= \frac{sL_{N,0}}{a_X} \int_{-\infty}^{0} e^{g_L \tau} \mathrm{d}\tau = \frac{sL_{N,0}}{a_X g_L} \left[e^{g_L 0} - e^{g_L(-\infty)} \right] = \frac{sL_{N,0}}{a_X g_L}. \end{aligned}$$

D Household Optimization

D.1 Maximization of Instantaneous Utility

Let us first consider the household's decision between goods of different quality within one industry ω. The marginal rate of substitution of a Northern household between two arbitrary quality levels, $j = b$ and $j = b + 1$, is equal to the relative prices

$$\frac{\partial \nu_{N,t} / \partial x_{N,t}(j = b + 1, \omega)}{\partial \nu_{N,t} / \partial x_{N,t}(j = b, \omega)} = \frac{\lambda^{b+1}}{\lambda^b} = \frac{p_{N,t}(b + 1, \omega)}{p_{N,t}(b, \omega)}. \tag{99}$$

Interpreted differently, the household is indifferent between two quality levels if their quality adjusted prices are equal, that is if

$$\frac{p_{N,t}(b, \omega)}{\lambda^b} = \frac{p_{N,t}(b + 1, \omega)}{\lambda^{b+1}}. \tag{100}$$

This implies that the household will always buy the quality level with the lowest quality adjusted price in industry ω at time t, and I denote this quality level by the quality index $k_t(\omega)$. So in the following, I can simplify the decision about quality levels and instead focus on the quality level with the lowest quality adjusted price.[39]

Given this result, households maximize the instantaneous utility function (3) subject to the instantaneous budget constraint (4). The maximization problem

[39] In conjunction with the pricing decision of firms, this is always the state-of-the-art product. Firm price setting is excluded in this appendix, so we ignore the knowledge about which quality level has the lowest quality adjusted price.

is hence

$$\max_{\int_0^1 x_{N,t}(k_t(\omega),\omega)\mathrm{d}\omega} \int_0^1 \ln\left(\lambda^{k_t(\omega)} x_{N,t}(k_t(\omega),\omega)\right)\mathrm{d}\omega + \mu\left(c_{N,t} - \int_0^1 p_{N,t}(k_t(\omega),\omega) x_{N,t}(k_t(\omega),\omega)\mathrm{d}\omega\right), \tag{101}$$

and the first-order condition for any industry ω is

$$\frac{\lambda^{k_t(\omega)}}{\lambda^{k_t(\omega)} x_{N,t}(k_t(\omega),\omega)} - \mu p_{N,t}(k_t(\omega),\omega) \overset{!}{=} 0, \tag{102}$$

such that demand is

$$x_{N,t}(k_t(\omega),\omega) = \frac{1}{\mu p_{N,t}(k_t(\omega),\omega)}. \tag{103}$$

Plugging this into the budget constraint gives

$$c_{N,t} = \int_0^1 \frac{1}{\mu}\mathrm{d}\omega = \frac{1}{\mu}, \tag{104}$$

and hence for demand, we have

$$x_{N,t}(k_t(\omega),\omega) = \frac{c_{N,t}}{p_{N,t}(k_t(\omega),\omega)}, \tag{105}$$

such that instantaneous utility can be rewritten as

$$\begin{aligned} \ln \nu_{N,t} &= \int_0^1 \ln\left(\lambda^{k_t(\omega)} x_{N,t}(k_t(\omega),\omega)\right)\mathrm{d}\omega \\ &= \int_0^1 \ln\left(\lambda^{k_t(\omega)} \frac{c_{N,t}}{p_{N,t}(k_t(\omega),\omega)}\right)\mathrm{d}\omega \\ &= \ln c_{N,t} + \underbrace{\int_0^1 \ln\left(\frac{\lambda^{k_t(\omega)}}{p_{N,t}(k_t(\omega),\omega)}\right)\mathrm{d}\omega}_{\equiv\Theta_t}. \end{aligned} \tag{106}$$

Inserting this into the household's lifetime optimization problem yields

$$\begin{aligned} \max_{[c_{N,t}]_{t=0}^{\infty}} U_N &= \int_0^{\infty} e^{-\rho t} L_{N,t} \ln c_{N,t}\mathrm{d}t + \int_0^{\infty} e^{-\rho t} L_{N,t}\Theta_t \mathrm{d}t \\ \text{s.t.} \quad \dot{A}_{N,t} &= r_{N,t}A_{N,t} + W_{N,t} - c_{N,t}L_{N,t} + T_{N,t}, \end{aligned} \tag{107}$$

where $[c_{N,t}]_{t=0}^{\infty}$ is the path of consumption expenditures. Since the term Θ_t is independent of $c_{N,t}$, the maximization problem reduces to

$$\max_{[c_{N,t}]_{t=0}^{\infty}} U_N = \int_0^{\infty} e^{-\rho t} L_{N,t} \ln c_{N,t} \mathrm{d}t$$
$$\text{s.t.} \quad \dot{A}_{N,t} = r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}. \tag{108}$$

D.2 Maximization of Lifetime Utility

The present value Hamiltonian to this problem is

$$H = e^{-\rho t} L_{N,t} \ln c_{N,t} + \mu_{N,t}(r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}). \tag{109}$$

The optimality conditions are the maximum condition

$$\frac{\partial H}{\partial c_{N,t}} = e^{-\rho t} \frac{L_{N,t}}{c_{N,t}} - \mu_{N,t} L_{N,t} \overset{!}{=} 0, \tag{110}$$

the multiplier equation

$$\frac{\partial H}{\partial A_{N,t}} = \mu_{N,t} r_{N,t} \overset{!}{=} -\dot{\mu}_{N,t}, \tag{111}$$

the equation of motion

$$\frac{\partial H}{\partial \mu_{N,t}} \overset{!}{=} r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}, \tag{112}$$

the transversality condition

$$\lim_{t \to \infty} \mu_{N,t} A_{N,t} \overset{!}{=} 0, \tag{113}$$

and the initial condition

$$A_0 > 0. \tag{114}$$

To solve the optimum conditions, let us start with the multiplier equation. It can be rearranged to

$$\frac{\dot{\mu}_{N,t}}{\mu_{N,t}} = -r_{N,t} \tag{115}$$

and, integrating over time, results in

$$\ln \mu_{N,t} = -r_{N,t}^c + C_1, \tag{116}$$

where C_1 is an arbitrary constant and $r^c_{N,t} \equiv \int_0^t r_{N,s} \mathrm{d}s$. Exponentiating both sides gives

$$\mu_{N,t} = e^{-r^c_{N,t}+C_1} = C_2 e^{-r^c_{N,t}}. \tag{117}$$

This can be used in (111):

$$e^{-\rho t} \frac{1}{c_{N,t}} = \mu_{N,t} = C_2 e^{-r^c_{N,t}} \Leftrightarrow \frac{e^{r^c_{N,t}-\rho t}}{C_2} = c_{N,t}, \tag{118}$$

taking (natural) logs results in

$$\ln c_{N,t} = r^c_{N,t} - \rho t - \ln C_2, \tag{119}$$

and differentiating both sides with respect to t yields the Keynes-Ramsey rule,

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = r_{N,t} - \rho. \tag{120}$$

D.3 Steady-State Utility Growth Rate

Here I derive the growth rate of instantaneous utility, given in (58). Instantaneous utility comes from consumption of imitated and non-imitated products. In steady state, where the innovation rate ι^* and the share of northern industries n^*_N are constant, the function writes as

$$\ln \nu_t = \int_0^{n^*_N} \ln \sum_{j=0}^{\infty} \lambda^j x_{N,t}(j,\omega) \mathrm{d}\omega + \int_{n^*_N}^1 \ln \sum_{j=0}^{\infty} \lambda^j x_{N,t}(j,\omega) \mathrm{d}\omega. \tag{121}$$

The consumer chooses in each industry only the highest quality product. At time t, the expected number of innovations in any industry is $\iota^* t$. We can hence write

$$\ln \nu_{N,t} = \int_0^{n^*_N} \ln \lambda^{\iota^* t} x_{N,t}(\iota^* t,\omega) \mathrm{d}\omega + \int_{n^*_N}^1 \ln \lambda^{\iota^* t} x_{N,t}(\iota^* t,\omega) \mathrm{d}\omega. \tag{122}$$

Using the demand functions, we have

$$\ln \nu_t = \int_0^{n^*_N} \ln \lambda^{\iota^* t} \frac{c^*_N}{\lambda(1+\tau_N)} \mathrm{d}\omega + \int_{n^*_N}^1 \ln \lambda^{\iota^* t} \frac{c^*_N}{1+\tau_N} \mathrm{d}\omega. \tag{123}$$

As none of the terms depends on ω, we can write this as

$$\ln \nu_t = \iota^* t \ln \lambda + \ln c_N^* - n_N^* \ln \lambda - \ln(1 + \tau_N), \tag{124}$$

and differentiating with respect to time yields finally the steady state growth rate g_ν^* of instantaneous utility ν_t,

$$g_\nu^* = \frac{\dot{\nu}_t}{\nu_t} = \iota^* \ln \lambda. \tag{125}$$

E Why Not a Simpler R&D Difficulty?

The focus of this paper is on the analysis of trade liberalization on unemployment and growth. Therefore, it seems unnatural to complicate the model with a micro-founded approach to eliminate the scale effect. The use of rent-protection activities is in no way essential for the paper's objective, as the only objective of this approach is to remove the scale effect. This could be done more easily, as in Dinopoulos and Segerstrom (1999), by defining

$$D_t = k L_{N,t}, \tag{126}$$

where $k > 0$ is an R&D difficulty parameter. R&D difficulty is proportional to the Northern population. This approach can be justified as a simple representation of a model with also horizontal innovation, which means that new product lines are developed as well as new quality levels. As a result, the number of researchers per product line remains constant. We omit the microfoundation here, and only implement the result in this simple manner.

I show that this simpler approach leads to an unambiguously unstable steady state in case of just a Northern ad-valorem import tariff, and if all other assumptions are kept. This justifies why the rent-protection approach is used instead as a micro-founded scale removal tool.

E.1 Equilibrium Conditions

As there are no rent-protection activities, there are also no workers for this activity, and quality leaders do not face any costs besides production costs. So, in the North, there is only one labor market for workers who work either in production or in R&D, and the labor market equation writes as

$$n_{N,t}\left(\frac{c_{N,t}L_{N,t}}{\lambda(1+\tau_N)}+\frac{c_{S,t}L_{S,t}}{\lambda}\right)+a_R R_t+u_t L_{N,t}=L_{N,t}. \tag{127}$$

As quality leaders do not engage in costly rent-protection activities, the firm value can be written as

$$v^I_{N,t}=\frac{\pi_{N,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}, \tag{128}$$

where profits from sales, $\pi_{N,t}$, are given as before.

The optimization problem of R&D firms is easier to solve than before as there is now no R&D *contest* between incumbent and challengers, but a R&D *race* between challengers. R&D firms maximize their expected gain minus R&D costs, that is

$$\max_{R_{m,t}} v^I_{N,t}\iota_{m,t}-\bar{w}a_R R_{m,t}, \tag{129}$$

subject to (5), which yields

$$v^I_{N,t}\overset{!}{=}\bar{w}a_R D_t. \tag{130}$$

All other equilibrium conditions remain valid and I refrain from stating them here again explicitly.

E.2 The Model's Solution

Again, the Southern labor market equation (12) reduces, using the balanced-trade condition (33), to $c_S=1$. The firm value is

$$v^I_{N,t}=\frac{c_{N,t}L_{N,t}\left(1-\frac{\bar{w}}{\lambda(1+\tau_N)}\right)+c_{S,t}L_{S,t}\left(1-\frac{\bar{w}}{\lambda}\right)}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}.$$

Defining again $\Lambda\equiv\frac{\lambda-\bar{w}}{\lambda}$ as in (39), using the balanced trade condition (33) and $c_S=1$ yields

$$v^I_{N,t}=\frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{131}$$

Using the FEIN condition (130), we can write

$$\bar{w}a_R D_t = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{132}$$

Solving for $r_{N,t}$ gives

$$r_{N,t} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}. \tag{133}$$

Differentiating the FEIN condition with respect to time after taking logs and using the definition of D_t in equation (126) yields

$$\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} = \frac{\dot{D}_t}{D_t} = g_L. \tag{134}$$

Using this result in equation (133), which we plug into the Keynes-Ramsey rule, equation (9), we have

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + g_L - \rho. \tag{135}$$

Again, we use the dynamic version of the balanced-trade condition, (45), to replace the left hand side of equation (135), yielding

$$\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + g_L - \rho, \tag{136}$$

and the equation for industry flows, (31), serves to replace ι_t. We finally obtain

$$\dot{n}_{N,t} = \frac{n_{N,t}}{1+n_{N,t}}\left[\underbrace{\left[\frac{\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} + \left(g_L-\rho-\mu\right)\right]}_{\equiv\gamma_1} - \underbrace{\left(g_L-\rho-\frac{\tau_N L_{S,t}}{\bar{w}a_R k L_{N,t}}\right)}_{\equiv\gamma_2} n_{N,t}\right] \tag{137}$$

$$= \frac{n_{N,t}}{1+n_{N,t}}\left(\gamma_1-\gamma_2 n_{N,t}\right). \tag{138}$$

This is an autonomous nonlinear differential equation. There are only two possible steady states, either $n^*_N = 0$ or $n^*_N = \frac{\gamma_1}{\gamma_2}$. We are only interested in the latter, as we only look at interior solutions. As γ_2 is negative by assumption (since $\rho > g_L$ and $\tau_N \frac{\eta_S}{\bar{w} a_R k} > 0$), we need $\gamma_1 < 0$ for $n_N^* > 0$. Taking the derivative of the differential equation and evaluating it at the steady state, we have

$$\left.\frac{d\dot{n}_N}{dn_N}\right|_{n_N=\frac{\gamma_1}{\gamma_2}} = \underbrace{\left.\frac{1}{(1+n_N)^2}\left(\gamma_1 - \gamma_2 n_N\right)\right|_{n_N=\frac{\gamma_1}{\gamma_2}}}_{=0} - \gamma_2 \left.\frac{n_N}{1+n_N}\right|_{n_N=\frac{\gamma_1}{\gamma_2}} > 0, \quad (139)$$

which implies an unstable steady state. Put differently, the condition for a stable steady state, $\gamma_2 > 0$, is not in accordance with the model's assumptions.

So, we can not replace the rent-protection approach by this simple approach. Instead, the rent-protection approach helps the model to have a stable interior steady state.

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