Worries of Workers: Three Essays on the Effects of Globalisation, Technical Change and Competition on the Labour Market and its Institutions

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Zusammenfassung

Da jeder Mensch einen sicheren Job einem unsicheren Job vorzieht, kann jede Änderung des Status Quo dieser Welt als eine potentielle Bedrohung der Sicherheit des Arbeitsplatzes angesehen werden. Laut einer Umfrage der Financial Times betrachtet eine Mehrheit der Befragten Globalisierung als eine Gefahr für sichere Arbeitsplätze. Eine zweite mögliche Unsicherheit ist die Automatisierung von Arbeit durch Maschinen, die potentiell zu Arbeitsplatzverlust führt. Ein dritter Grund für Jobunsicherheit ist Wettbewerb, der die Firmenfluktuation verstärkt und dadurch auch die Gefahr von individueller Arbeitslosigkeit.

Ich betrachte die Auswirkungen von Globalisierung, technischem Wandel und Wettbewerb auf den Arbeitsmarkt. Dafür untersuche ich einerseits die Wirkung auf Arbeitslosigkeit, aber auch auf Mindestlöhne und auf gewerkschaftliche Lohnverhandlungen. Sowohl Mindestlöhne als auch gewerkschaftliche Lohnverhandlungen sind Anlässe oder Gründe für Arbeitnehmer, zu demonstrieren oder zu streiken, was die Bedeutung dieser Aspekte hervorhebt.

Im ersten Kapitel analysiere ich, wie Arbeitslosigkeit in Industrieländern durch Globalisierung beeinflusst wird, insbesondere durch Handelsliberalisierung, veränderten internationalen Schutz geistigen Eigentums, und einen größeren Markt in Entwicklungsländern. Dabei unterscheide ich in Industrieländern zwischen Arbeitnehmern einerseits in der Produktion, andererseits in Forschung und Entwicklung (F&E). Außerdem unterscheide ich zwischen kurz- und langfristigen Effekten, d.h. zwischen den zeitlich unmittelbaren Effekten auf die gleichgewichtige Übergangsdynamik sowie den Effekten auf das langfristige stabile Gleichgewicht.

Zu diesem Zweck verwende ich ein schumpeterianisches endogenes Wachstumsmodell mit Qualitätsleitern und Nord-Süd-Handel. Firmen im Norden entwickeln neue Qualitätsstufen für Endprodukte und haben ein Monopol für die Produkte der höchsten Qualitätsstufe, bis eine neue Qualitätsstufe im Norden entwickelt wird oder bis Qualitätsstufe von Firmen im Süden kopiert oder imitiert wird. Arbeitskräfte im Süden sind günstiger als im Norden, daher werden imitierte Produkte nur im Süden hergestellt. Daher konkurrieren Firmen aus dem Norden mit Firmen aus dem Süden, die Produkte der vormaligen höchsten Qualitätsstufe zu Wettbewerbspreisen und damit direkt zu den Lohnkosten anbieten. Die Firmen im Norden setzen ihren Preisaufschlag daher auf die Lohnkosten der Firmen im Süden.

Wenn der Norden seinen Importzoll senkt, reduzieren die monopolistischen Firmen im Norden ihre Preisaufschläge, da der Importzoll den Preis im Norden für Produkte aus dem Süden erhöht. Geringere Preisaufschläge bedeuten geringere Gewinne durch Innovation, was die F&E-

Aktivitäten und damit die F&E-Beschäftigung sowohl kurz- als auch langfristig senkt. Die Produktionsaktivitäten sinken nur im langfristigen Gleichgewicht, da sie von dem Anteil der Industrien mit Qualitätsführern im Norden abhängen. Dieser Anteil verändert sich erst im Laufe der Zeit.

Handelsliberalisierung im Süden hat entgegengesetzte Effekte. Sie führt zu mehr F&E-Aktivitäten und damit auch zu mehr Beschäftigung, da nun ein niedrigerer Anteil des Preisaufschlags im Süden in den Händen der Regierung im Süden verbleibt. Die Gewinne der Firmen im Norden steigen, was zu höherer Innovationsaktivität führt. Dies ist sowohl kurz- als auch langfristig der Fall. Die Produktionsaktivitäten steigen im Norden nur langfristig, aus dem gleichen Grund wie bei Handelsliberalisierung im Norden.

Ein besserer internationaler Schutz geistigen Eigentums führt kurzfristig zu geringerer Innovationstätigkeit und damit zu höherer Arbeitslosigkeit, während langfristig das Gegenteil der Fall ist. Kurzfristig werden weniger Ressourcen im F&E-Bereich benötigt, um den Marktanteil der Firmen im Norden beizubehalten. Im langfristigen stabilen Gleichgewicht kann ein größerer Marktanteil der Firmen im Norden beibehalten werden. Daher erhöht sich die Beschäftigung langfristig nicht nur durch die F&E-Aktivitäten, sondern auch durch die Produktionstätigkeit.

Durch die bisher genannten Aspekte wurde die Produktion nur langfristig beeinflusst. Der einzige der betrachteten Gründe, bei dem die Produktion auch kurzfristig beeinflusst wird, ist ein Anstieg der Bevölkerung in Entwicklungsländern. Die Produzenten können ihre Produkte nun an mehr Konsumenten verkaufen, was die Produktions- und F&E-Aktivitäten erhöht. Dies führt kurz- und langfristig zu mehr Beschäftigung.

Das zweite Kapitel ist motiviert durch divergierende Reallöhne in den USA und einen sinkenden realen Mindestlohn. Während der durchschnittliche Reallohn der geringst ausgebildeten Arbeitnehmern sank, stieg der Reallohn von Arbeitnehmern mit akademischer Ausbildung. Ich beleuchte die Effekte technischen Wandels und von Mindestlöhnen auf Reallöhne und höhere Bildung, sowie den Einfluss technischen Wandels auf die politsche Entscheidung über den Mindestlohn. In meinem Modell ist Technologie komplementär zu hoch ausgebildeten Arbeitnehmern, aber substitutiv zu geringer ausgebildeten Arbeitnehmern für Aufgaben, die sich leicht automatisieren lassen. Dies bezieht sich auf die „Routinisation“-Erklärung für die Polarisierung des amerikanischen Arbeitsmarktes.

Ich unterscheide zwischen Arbeitnehmern mit drei Ausbildungsstufen. Arbeitnehmer mit mittleren Fähigkeiten können sich weiter ausbilden und danach mit einer fortgeschrittenen Technologie arbeiten, die die am wenigsten ausgebildeten Arbeitnehmer in der Produktion substitutiert.

Technischer Fortschritt führt zu mehr Arbeitnehmern mit höherer Ausbildung und zu einem sinkenden Reallohn der am geringsten ausgebildeten Arbeitnehmer. Der Lohn der Arbeitnehmer mit mittlerer Ausbildung steigt, da das Verhältnis der geringst ausgebildeten Arbeitnehmer zu Arbeitnehmern mit mittlerer Ausbildung steigt. Im Falle eines Mindestlohnes steigt der Anteil von Arbeitnehmern mit höherer Ausbildung noch mehr durch technischen Fortschritt, da der

Mindestlohn das Verhältnis der geringst ausgebildeten zu mittel ausgebildeten Arbeitnehmern festlegt, und damit auch den Lohn der mittel ausgebildeten Arbeitnehmer. Daher passen sich im Falle eines Mindestlohnes die Arbeitslosenquote der geringst ausgebildeten Arbeitnehmer sowie der Anteil der Arbeitnehmer mit höherer Ausbildung an, da die Löhne der geringst und mittel ausgebildeten Arbeitnehmer sich nicht ändern können.

Um den Mindestlohn zu endogenisieren, nehme ich an, dass die Regierung einerseits Lohnungleichheit, andererseits Arbeitslosigkeit vermeiden möchte. Da technischer Fortschritt beides verstärkt, muss die Regierung zwischen beiden Aspekten abwägen. Ich kalibriere das Modell mit Daten der OECD und U.S.-amerikanischen Mikrodaten und zeige, dass technischer Fortschritt zu einem geringeren Mindestlohn führt, während ein geringerer Anteil von gering ausgebildeten Arbeitnehmern zu einem höheren Mindestlohn führt.

Im dritten Kapitel zeige ich, dass Gütermarktwettbewerb beeinflusst, ob Firmen gewerkschaftliche Lohnverhandlungen führen oder nicht, d.h. mit jedem Arbeitnehmer individuell Löhne aushandeln. Dafür untersuche ich deutsche Betriebsdaten. In der dazugehörigen Befragung geben Betriebe die Intensität des Wettbewerbs, dem sie sich gegenüber sehen, in vier Kategorien an. Die Kategorien reichen von keinem zu hohem Wettbewerb. Zusätzlich messe ich Renten pro Arbeitnehmer, was oft als Maß für Wettbewerb verwendet wird.

Ich unterscheide zwischen gewerkschaftlichen Lohnverhandlungen auf Firmenebene und Firmenverbandsebene. Bei beiden Typen zeigt sich ein u-förmiger Zusammenhang zwischen Wettbewerb und der Wahrscheinlichkeit gewerkschaftlicher Lohnverhandlungen, und ein umgedreht u-förmiger Zusammenhang zwischen Wettbewerb und der Wahrscheinlichkeit individueller Lohnverhandlungen. Im Gegensatz zu Wettbewerb erhöhen höhere Renten die Wahrscheinlichkeit von gewerkschaftlichen Lohnverhandlungen und senken die Wahrscheinlichkeit von individuellen Lohnverhandlungen. Die Effekte sind stärker für Verhandlungen auf Firmenverbandsebene als für Firmenebene. Außerdem hat der Wettbewerb keinen Einfluss auf die Renten. Wenn man nur westdeutsche Betriebe betrachtet, werden die Effekte von Renten außerdem insignifikant.

Die Ergebnisse stehen in starkem Kontrast zu der bestehenden Theorie, die einen negativen Zusammenhang zwischen Wettbewerbsintensität und gewerkschaftlichen Lohnverhandlungen beschreibt. Meine Ergebnisse lassen vermuten, dass Wettbewerb einen anderen Mechanismus bewirkt, als bisher in der Literatur betrachtet wurde. Während in einem theoretischen Papier die Renten im Falle gewerkschaftlicher Lohnverhandlungen mit den Renten bei individuellen Lohnverhandlungen verglichen werden, modelliert ein anderes theoretisches Papier geringeren Wettbewerb als höhere Kosten um eine Stelle zu schaffen.

Neben Wettbewerbsintensität und Renten kontrolliere ich für einen Indikator für wirtschaftliche Schwankungen, den Exportanteil am Umsatz und den Anteil von Arbeitnehmern mit tertiärer Ausbildung. Wirtschaftliche Schwankungen senken die Wahrscheinlichkeit gewerkschaftlicher Lohnverhandlungen auf Firmenverbandsebene. Betriebe mit höherem Exportanteil am Umsatz tendieren weniger zu gewerkschaftlichen Lohnverhandlungen, während Betriebe mit einem höheren Anteil an Arbeitnehmern mit tertiärer Ausbildung zwar weniger zu gewerkschaftlichen Lohnverhandlungen auf Firmenverbandsebene, aber mehr auf Firmenebene neigen.

Summary

As any worker favours a safe job to an unsafe job, any change in the status quo of this world can be perceived as a threat to job security. According to a poll by the Financial Times, a majority says that globalisation entails threats to workers. A second possible threat is the automation of work, which means that machines overtake the work previously done by workers. A third reason for job insecurity is competition, which fosters firm turnover and thereby possibly unemployment spells.

I consider the effects of globalisation, technical change and competition on the labour market. In particular, I focus on either unemployment, the minimum wage, or on collective wage agreements. Both the minimum wage and collective wage agreements are reasons for workers to demonstrate or to go on strike, indicating how important these issues are to workers.

In the first chapter, I analyse how unemployment in industrialized countries is affected by globalisation, namely trade liberalisation, changes in intellectual property protection, and an increase in the population of developing countries. I distinguish between production and R&D activities in industrialized countries, and I distinguish between short- and long-run effects, that is between the instantaneous effects on the transitional dynamics and the effects on the steady-state equilibrium.

To that end, I use a Schumpeterian endogenous growth model with quality ladders and North-South trade. Northern firms develop new quality levels of final goods and have a monopoly for these top-quality products, until a new quality level is developed in the North or until the product is imitated by Southern firms. Southern labour is cheaper than Northern labour, such that imitated products are only produced in the South. Thus, Northern top-quality producers compete against Southern firms who offer the previous top-quality level at competitive prices, which equal the labour costs. Northern firms therefore set their price mark-ups on the Southern labour costs.

If the North reduces its import tariff, monopolists reduce their Northern price mark-ups, as the import tariff increased the Northern price of goods produced in the South. Lower price mark-ups mean lower profits from innovation, which reduces R&D activities and therefore R&D employment in both short- and long-run. Production activities decline in the North only in the long-run equilibrium, as they depend on the share of industries with Northern quality leaders, which needs time to shift.

Southern trade liberalization has opposite effects. It increases R&D activities and hence Northern employment, as a lower part of the price mark-up charged in the South remains in the hands of the Southern government. Profits of Northern firms therefore rise, increasing innovation incentives of incumbent firms. This holds for the short and the long run. Production employment in the North increases only in the long run, for the same reason as with Northern trade liberalisation.

Stricter international intellectual property protection leads in the short run to a decline in innovation and an increase in unemployment, while the opposite holds in the long run. In the short run, less R&D resources are required to keep market shares. In the steady state, a higher market share can be maintained by Northern firms. Thus, employment increases in the long run not only by increased R&D activities, but also by increased production activities.

So far, production activities have only been increased in the long run. The only case in which production is also affected in the short run is an increase in the population of developing countries. Producers can now sell their goods to more consumers, which increases both production activities and R&D activities, leading to more employment in both short and long run.

The second chapter is motivated by diverging real wages of workers with different educational background and decreasing real minimum wages in the U.S. The average real wage of workers with the lowest skills decreased, while the average wage of college graduates increased. I focus on the effect of technical change and the minimum wage on real wages and higher education, as well as on the effect of technical change on the political decision about the minimum wage. In my model, technology complements high-skilled workers, but substitutes less skilled workers in tasks which are relatively easy to automate. This is related to the routinisation explanation for the polarization of the U.S. labour market.

I distinguish between workers with three skill levels. Workers with medium skills can opt for higher education and afterwards work with an advanced technology that substitutes the least skilled workers in the production process.

Technical change leads to an increase in higher education and to a declining real wage of the least skilled workers. The wage of medium-skilled workers increases, as the ratio of unskilled to medium-skilled workers increases. In case of a minimum wage, higher education increases even more, as the minimum wage determines the ratio of unskilled to medium-skilled workers, and therefore also the wage of medium-skilled workers. Thus, in case of a minimum wage, the unemployment rate of unskilled workers and the share of educated workers adjust, as the wages for unskilled and medium-skilled workers cannot adjust.

To endogenise the minimum wage, I assume that the government opposes both wage inequality and unemployment. As technical change increase both, the government faces a trade-off. Calibrating the model with OECD and U.S. micro data, I show that technical progress leads to a lower minimum wage, while a lower share of the lowest skilled workers increases the minimum wage.

Finally, in the third chapter, I show that product market competition affects whether firms bargain about wages with labour unions or with each worker individually. For that purpose, I use German establishment data. The according questionnaire asks establishments to indicate the degree of competition on the goods market by four categories, ranging from no competition to high competition. In addition, I measure rents per worker, which is often used as an indicator of competition.

I distinguish between firm-level and sector-level collective bargaining. For both types of collective bargaining, there is a u-shaped relation between competition and the probability of collective bargaining, and a hump-shaped relationship between competition and individual wage bargaining. By contrast, rents increase the probability of firm-level and sector-level collective bargaining and decrease the probability of individual bargaining. The effects are stronger for sector-level than for firm-level bargaining. I also show that there is no effect of competition on rents. Looking only at West German establishments, the effect of rents becomes even insignificant.

This result is in stark contrast to the existing theory, which predicts a negative relationship between competition and collective bargaining. My results indicate that competition entails a different channel than so far considered by the theoretical literature. While the main mechanism in one theoretical paper is through a comparison of the rent obtained in case of collective bargaining with the rent under individual bargaining, a different theoretical paper models less competition simply as a higher cost of vacancy posting.

Besides competition and rents, I also control for an indicator of economic turbulence, the export share and the share of workers with higher education. Economic turbulence decreases the likelihood of sectoral collective bargaining. Establishments with a higher export share are less likely to opt for collective bargaining, and establishments with a higher share of workers with higher education are less likely to opt for sector-level, but for firm-level bargaining.

Chapter 1

Globalisation, Endogenous Growth and Unemployment: Short- and Long-Run Effects

1.1 Introduction

1.1.1 Motivation and Contribution

The majority of people in industrialised countries views free trade as a threat for job security. About 80% of the French population view globalisation as hurting employment, according to an opinion poll (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 liberalisation 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 liberalisation leads to changes in product demand. This change causes firm exit and hence labour 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 1.1 shows R&D intensity for 2007 for some industrialised 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 industrialised countries.

R&D is captured in endogenous growth models, in which international product cycles lead

	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	n.a.	35.4	36.8
Medium-high tech	11.1	7.4	9.8	14.7	n.a.	14.9	9.8

Source: OECD STAN database.

Table 1.1. R&D expenditures as a percentage of value added for 2007.

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 analyse trade liberalisation,[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 liberalisation and have inspired much research.[5] Being able to analyse all three issues in both the short run and the 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.

In my model, growth is driven by research on vertical innovations, which is undertaken by Northern firms who expect patent-secured profits. As patent holders engage in price competition against Southern producers of lower quality levels, the price mark-ups of Northern patent holders in the North depend on Northern import tariffs. Also, the revenue from the South decreases with Southern import tariffs. Therefore, changes in import tariffs affect revenues.

I find that unilateral Northern trade liberalisation leads to a short- and long-run increase in unemployment. Lower Northern import tariffs lead to lower price-markups in the North and hence lower revenue in the North. This reduces R&D incentives in the North and employment in R&D decreases instantaneously, while production employment does not change instantaneously. In the long run, the reduced R&D activity leads to a lower share of industries with a Northern patent holder and hence also lower production employment. In a calibrated version of the model, I explore unilateral Southern trade liberalisation as well as bilateral Northern and Southern

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

[2]To give examples of trade liberalisation, 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 favour 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.

trade liberalisation. Southern trade liberalisation leads to a short- and long-run decrease in unemployment, as the revenue from sales in the South increases, which increases R&D incentives and hence R&D employment in the short run. Bilateral trade liberalisation leads to a short- and long-run decrease in unemployment. Although lower Northern import 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 bilateral trade liberalisation has less drastic short run effects on unemployment in countries with high R&D intensities. Besides trade liberalisation, 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 innovation 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 liberalisation 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 1.E for details.

1.1.2 Literature Review

I mainly contribute to a growing young literature that analyses the effects of various forms of globalisation 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 globalisation. 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 analysed[6] – Arnold (2002) is an exception, but he focuses only on intellectual property protection. But stability is necessary for validity. And validity is even more of concern as the predictions, for instance for trade liberalisation, are ambiguous: Trade liberalisation reduces unemployment under some conditions, while it increases unemployment under other conditions. The results also depend on whether trade liberalisation occurs bilaterally or unilaterally. This calls for a framework that ensures validity by stability and that can distinguish between unilateral and bilateral trade liberalisation.

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 liberalisation. 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 labour 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 labour 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 labour market flexibility. He establishes the stability of his model's steady state, but he does not analyse trade liberalisation.

Besides frictional unemployment, several papers have explored structural unemployment.[9] Şener (2006) considers a rigid wage in one of two otherwise symmetric countries. However, the focus of his analysis is completely different, as he considers changes in labour market institutions and demographic and technological shocks. Concerning trade liberalisation, he restricts his discussion to how the shocks under consideration work under free trade and autarky: A switch

[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 pathbreaking paper. Mondal (2008) demonstrates the stability of the steady state by Grossman and Helpman (1991a). Arnold (2006) analyses the transitional dynamics of the seminal paper by Jones (1995). Steger (2003) shows the stability for the Segerstrom (1998) model. Also, 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); Dinopoulos and Segerstrom (2010)) analyses steady states and assumes the stability of these, but does not prove 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 analyses changes in labour market institutions in a model with trade. Also, the model's transitional dynamics are intractable.

to free trade increases unemployment, and it also increases aggregate R&D. Concerning such a comparison, Baldwin and Forslid (1999) argue that incremental trade liberalisations 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 liberalisation and growth. This emphasises that comparisons of autarky versus free trade are not the appropriate way to analyse trade liberalisation.

The analysis of incremental trade liberalisation is further developed by Grieben and Şener (2009b, 2012). They introduce union wage bargaining to generate unemployment and consider both unilateral and bilateral trade liberalisation. 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 cannot 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 globalisation. Dutt et al. (2009) briefly discuss the short-run effect of trade liberalisation 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 analyse all issues in one model, while most papers have only focused on either common trade liberalisation or changes in international patent protection. Grieben and Şener (2009b, 2012) have analysed all issues, but my model is more tractable and yields the same results on Northern unemployment. In addition to the conventional steady-state analysis, I analyse 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 labour market, but from jumps to the new transition paths to steady-state innovation. This has not been analysed before.

1.1.3 How Do I Approach This?

The model is a quality-ladder product-cycle model à la Grossman and Helpman (1991c) and is 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.

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

[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 1.E that a simpler mechanism to remove the scale effect yields an unstable steady state.

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 cannot 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 characterised 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]

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 (Şener, 2006), 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 labour 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 analyse the short-run effects of globalisation issues. Afterwards, I derive necessary and sufficient conditions for the steady state's existence and stability and analyse the effects of globalisation 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 liberalisation. I calibrate the model and analyse the steady state's stability and the effects of unilateral and bilateral trade liberalisation numerically. Proofs and lengthy derivations are in the Appendix. To justify the

[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) analyse 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 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.

rent-protection approach to remove the scale effect, I show the instability of the steady state if I used a simpler approach.

1.2 The Model

1.2.1 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, imitation 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 labour 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.

1.2.2 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 maximise the standard lifetime utility function

$$U_N = \int_0^\infty L_{N,t} e^{-\rho t} \ln \nu_{N,t} \mathrm{d}t, \tag{1.1}$$

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,

$$\dot{A}_{N,t} = r_{N,t}A_{N,t} + W_{N,t} - c_{N,t}L_{N,t} + T_{N,t}, \tag{1.2}$$

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 labour 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 labour income and do not make any intertemporal consumption choices.[15]

There is a unity continuum $\Omega = [0,1]$ of product lines of final consumption goods, each produced by one industry. The product line and its respective industry are indexed by $\omega \in \Omega$. All industries are structurally identical. 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

$$\ln \nu_{i,t} = \int_0^1 \ln \sum_{j=0}^{\infty} \lambda^j x_{i,t}(j,\omega)\mathrm{d}\omega, \qquad i \in \{N,S\} \tag{1.3}$$

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 maximise instantaneous utility subject to

$$c_{i,t} = \int_0^1 \sum_{j=0}^{\infty} p_{i,t}(j,\omega)x_{i,t}(j,\omega)\mathrm{d}\omega. \tag{1.4}$$

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

$$\iota_{m,t}(\omega) = \frac{R_{m,t}(\omega)}{D_t(\omega)}, \tag{1.5}$$

where $D_t(\omega)$ is industry-specific R&D difficulty at time t. The arrival rates are independent

[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.

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

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:

$$\iota_t(\omega) = \sum_{m=0}^{\infty} \iota_{m,t}(\omega) = \sum_{m=0}^{\infty} \frac{R_{m,t}(\omega)}{D_t(\omega)} = \frac{R_t(\omega)}{D_t(\omega)}. \tag{1.6}$$

The unit labour 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 labour.

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

$$\dot{D}_t(\omega) = \begin{cases} X_t(\omega) & \text{if } \omega \in \Omega_{N,t} \\ 0 & \text{if } \omega \notin \Omega_{N,t} \end{cases}, \tag{1.7}$$

where $X_t(\omega)$ is the amount of rent-protection activities in industry ω, and $\Omega_{N,t} \subseteq \Omega$ is the sub-set of industries with a 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, where $n_{N,t} = \frac{|\Omega_{N,t}|}{|\Omega|}$ is the share of industries with a Northern quality leader at time t. The unit labour requirement for rent-protection activities, X_t, is $a_X > 0$. Labour for rent protection is supplied by a fixed fraction of the labour force (see below).

The Northern labour market is exogenously divided into two types of labour, following Dinopoulos and Syropoulos (2007). One type can work either in the production of goods or in

[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 $\omega \in (n_{N,t}, 1]$.

R&D, and the other type of labour works only for rent-protection activities. The former type is called *general purpose* workers, and the latter is called *specialised* workers. General purpose workers make up for a share of $1 - s$ of the Northern labour force[20] and earn an exogenously fixed wage $\bar{w}$. It is fixed in terms of the Southern wage and higher than the latter:

$$w_N^{GP} = \bar{w} > w_S. \tag{1.8}$$

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 labour market does not clear. I assume that the minimum wage does not bind for rent-protection workers and their labour market hence clears. This can be justified by arguing that these workers are highly specialised and earn higher wages than non-specialised workers.[21]

On the Southern labour market, workers work only in production activities, and their labour 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 households. Trade is balanced at each point of time.

1.2.3 Equilibrium Conditions

Households

Households maximise consumption in two steps: First, they maximise 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 maximise lifetime utility. The result is standard: Consumption follows the Euler equation,

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = r_{N,t} - \rho. \tag{1.9}$$

These results are standard. Details of the derivation are presented in Appendix 1.D.

[20] The exogenous fractionalisation 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.

Labour 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, $n_{N,t}\left(x_{N,t}(\omega_{N,t})L_{N,t}+x_{S,t}(\omega_{N,t})L_{S,t}\right)$, where $n_{N,t}$ is the share of industries with a Northern quality leader, and where industry $\omega_{N,t}\in\Omega_{N,t}$. As all industries $\omega\in\Omega$ are structurally identical, demand per industry $x_{N,t}(\omega_{N,t})$ is the same for each industry of $\Omega_{N,t}$. The second part is the number of R&D workers, given by the unit labour 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 labour market equation in the North is hence for general purpose workers

$$n_{N,t}\left(x_{N,t}(\omega_{N,t})L_{N,t}+x_{S,t}(\omega_{N,t})L_{S,t}\right)+a_RR_t+u_{N,t}L_{N,t}=(1-s)L_{N,t}, \tag{1.10}$$

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 1.3.3.) Hence, the market for rent-protection workers is perfectly competitive and clears. It is characterised by the equation

$$n_{N,t}a_XX_t=sL_{N,t}, \tag{1.11}$$

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 labour requirement, a_X.

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

$$(1-n_{N,t})\left(x_{N,t}(\omega_{S,t})L_{N,t}+x_{S,t}(\omega_{S,t})L_{S,t}\right)=L_{S,t}, \tag{1.12}$$

where $1-n_{N,t}$ is the share of industries currently imitated by Southern firms, and where industry $\omega_{S,t}\in\Omega_{S,t}$, where $\Omega_{S,t}$ is the complement of $\Omega_{N,t}$.

Firms

Let us now turn to optimal firm behaviour. 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

$$-\dot{V}^C_{N,t} = \max_{R_{m,t}} \left\{ -e^{-r^c_{N,t}} \bar{w} a_R R_{m,t} + \frac{R_{m,t}}{D_t} \left[V^I_{N,t} - V^C_{N,t} \right] \right\}, \tag{1.13}$$

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 maximisation problem in equation (1.13) yields

$$-e^{-r^c_{N,t}} \bar{w} a_R + \frac{1}{D_t} \left[V^I_{N,t} - V^C_{N,t} \right] \overset{!}{=} 0. \tag{1.14}$$

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 (1.14) can be rearranged to

$$\frac{e^{r^c_{N,t}} V^I_{N,t}}{D_t} = \bar{w} a_R, \tag{1.15}$$

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

$$\frac{v^I_{N,t}}{D_t} = \bar{w} a_R. \tag{1.16}$$

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

The incumbent's optimisation problem is about rent-protection activities, X_t, and prices in North and South, $p_{N,t}$ and $p_{S,t}$. He maximises 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 labour market equation for specialised workers, (1.11), I determine D_t as

$$\begin{aligned} D_t =& D_0 + \int_0^t \dot{D}_\tau \mathrm{d}\tau = D_0 + \frac{s}{a_X} L_{N0} \int_0^t e^{g_L \tau} \mathrm{d}\tau \\ =& D_0 + \frac{s}{a_X} \left[\frac{1}{g_L} L_{N,0} e^{g_L t} - \frac{1}{g_L} L_{N,0} \right] \\ =& D_0 + \frac{s}{a_X g_L} \left[L_{N,t} - L_{N,0} \right], \end{aligned} \tag{1.17}$$

[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.

which can again be rewritten using equation (1.11) as

$$D_t = D_0 + \frac{1}{g_L}\left[n_{N,t}X_t - n_{N,0}X_0\right]. \tag{1.18}$$

Using equations (1.6) and (1.17) for ι_t and D_t, the optimisation problem is

$$-\dot{V}^I_{N,t} = \max_{p_{N,t},p_{S,t},X_t}\left\{e^{-r^c_{N,t}}\left(\pi_{N,t}(p_{N,t},p_{S,t}) - w^{RP}_{N,t}a_X X_t\right) + \left(\mu + \frac{R_t}{D_0 + \frac{1}{g_L}\left[n_{N,t}X_t - n_{N,0}X_0\right]}\right)\left[V^C_{N,t} - V^I_{N,t}\right]\right\}. \tag{1.19}$$

The maximisation problem in equation (1.19) yields as first-order condition for optimal rent-protection activities X_t

$$-e^{-r^c_{N,t}}w^{RP}_{N,t}a_X - \frac{R_t\frac{1}{g_L}n_{N,t}}{\left[D_0 + \frac{1}{g_L}\left[n_{N,t}X_t - n_{N,0}X_0\right]\right]^2}\left[V^C_{N,t} - V^I_{N,t}\right] \stackrel{!}{=} 0. \tag{1.20}$$

Setting $V^C_{N,t} = 0$, using the definition of ι_t from equation (1.6), and using $e^{-r^c_{N,t}}v^I_{N,t} = V^I_{N,t}$ in the first-order condition yields

$$\frac{v^I_{N,t}}{D_t} = w^{RP}_{N,t}\frac{a_X g_L}{\iota_t n_{N,t}}. \tag{1.21}$$

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 (1.19) yields, after multiplying by $e^{r^c_{N,t}}$,

$$r_{N,t}v^I_{N,t} - \dot{v}^I_{N,t} = \pi_{N,t}(p_{N,t},p_{S,t},X_t) - (\mu + \iota_t)\,v^I_{N,t}. \tag{1.22}$$

This can be rearranged to

$$v^I_{N,t} = \frac{\pi_{N,t} - w^{RP}_{N,t}a_X X_t}{r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}, \tag{1.23}$$

and using this to replace $v^I_{N,t}$ as well as equation (1.18) to replace D_t in equation (1.21), we have

$$\begin{aligned}&\pi_{N,t} - w^{RP}_{N,t}a_X X_t\\ &\quad= w^{RP}_{N,t}\frac{a_X g_L}{\iota_t n_{N,t}}\left(r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}\right)\left[D_0 + \frac{1}{g_L}\left[n_{N,t}X_t - n_{N,0}X_0\right]\right].\end{aligned} \tag{1.24}$$

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

$$X^o_t = \frac{\pi_{N,t}}{r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}\frac{\iota_t}{w^{RP}_{N,t}a_X} - \frac{\Delta\left(r_{N,t} + \iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}\right)}{n_{N,t}\left(r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}\right)}. \tag{1.25}$$

where

$$\Delta \equiv D_0 g_L - \frac{sL_{N,0}}{a_X} \tag{1.26}$$

is constant over time. I plug X_t^o from above into $v_{N,t}^I$ in equation (1.23) and obtain the firm value as

$$v_{N,t}^I = \frac{\pi_{N,t} + w_{N,t}^{RP} \frac{a_X \Delta}{n_{N,t}}}{r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}_{N,t}^I}{v_{N,t}^I}}. \tag{1.27}$$

To get the wage of rent-protection workers, I combine equation (1.21) and the free-entry-in-innovation condition, (1.16), which yields

$$w_{N,t}^{RP} = \bar{w} \frac{a_R}{a_X g_L} \iota_t n_{N,t}. \tag{1.28}$$

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 analyse 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 $p_{N,t}^N(j = J_t) = \lambda(1+\tau_N) - \varepsilon$ in the North and $p_{S,t}^N(j = J_t) = \lambda - \varepsilon$ 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

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

cost is $\bar{w}$. So, the profit of a Northern quality leader writes as

$$\pi_{N,t} = \frac{c_{N,t}L_{N,t}}{\lambda(1+\tau_N)}\left(\lambda(1+\tau_N) - \bar{w}\right) + \frac{c_{S,t}L_{S,t}}{\lambda}\left(\lambda - \bar{w}\right). \tag{1.29}$$

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

$$\dot{n}_{N,t}\mathrm{d}t = (1-n_{N,t})\iota_t\mathrm{d}t - n_{N,t}\mu\mathrm{d}t, \tag{1.30}$$

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

$$\dot{n}_{N,t} = (1-n_{N,t})\iota_t - n_{N,t}\mu. \tag{1.31}$$

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,

$$c_{N,t}L_{N,t} = n_{N,t}\left(c_{N,t}L_{N,t} + c_{S,t}L_{S,t}\right) + (1-n_{N,t})\frac{c_{N,t}L_{N,t}}{1+\tau_N}\tau_N. \tag{1.32}$$

Equation (1.32) can be rearranged to

$$c_{N,t}L_{N,t} = (1+\tau_N)c_{S,t}L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}, \tag{1.33}$$

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

1.2.4 Equilibrium: Transitional Dynamics

We are now in a position to solve the model. The Southern labour market condition, (1.12), reduces, after replacing $c_{N,t}$ using the balanced trade condition, (1.33), to

$$\frac{c_{S,t}L_{S,t}}{w_S} = L_{S,t}, \tag{1.34}$$

so

$$c_{S,t} = c_S = w_S = 1, \tag{1.35}$$

[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).

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

I use the firm value, (1.27), in the free-entry-in-innovation condition, (1.16), to replace $v^I_{N,t}$, which yields:

$$\bar{w} a_R D_t = \frac{\pi_{N,t} + w^{RP}_{N,t} \frac{a_X \Delta}{n_{N,t}}}{r_{N,t} + 2\iota_t + \mu - \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{1.36}$$

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

$$r_{N,t} = \frac{\pi_{N,t} + w^{RP}_{N,t} \frac{a_X \Delta}{n_{N,t}}}{\bar{w} a_R D_t} - 2\iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}, \tag{1.37}$$

which I use in the Keynes-Ramsey rule (1.9) for Northern per-capita consumption:

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \underbrace{\frac{\pi_{N,t} + w^{RP}_{N,t} \frac{a_X \Delta}{n_{N,t}}}{\bar{w} a_R D_t} - 2\iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}_{= r_{N,t}} - \rho. \tag{1.38}$$

To replace $\pi_{N,t}$, I use the balanced-trade condition, (1.33), in the profit equation, (1.29), and with $c_S = 1$, I get

$$\pi_{N,t} = L_{S,t} \frac{1}{1 - n_{N,t}} \underbrace{\frac{\lambda - \bar{w}}{\lambda}}_{\equiv \Lambda} + L_{S,t} \frac{n_{N,t}}{1 - n_{N,t}} \tau_N, \tag{1.39}$$

where Λ is the ratio of profit to revenue. Replacing the wage of rent-protection workers $w^{RP}_{N,t}$ by equation (1.28) and using the definition of Δ in (1.26), we can rearrange the above equation (1.38) to

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{\Lambda L_{S,t} \frac{1}{1 - n_{N,t}} + \frac{n_{N,t}}{1 - n_{N,t}} \tau_N L_{S,t}}{\bar{w} a_R D_t} - \frac{\frac{s}{a_X g_L} L_{N,t}}{D_t} \iota_t - \iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \rho. \tag{1.40}$$

Using the labour market equation for specialised workers (1.11), we can derive that

$$\frac{\dot{D}_t}{D_t} = \frac{n_{N,t} X_t}{D_t} = \frac{\frac{s}{a_X} L_{N,t}}{D_t}, \tag{1.41}$$

and using the free-entry-in-innovation condition, (1.16), we can show that

$$\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} = \frac{\dot{D}_t}{D_t}, \tag{1.42}$$

since a_R and $\bar{w}$ are constant over time. Hence, we can rewrite equation (1.40) as

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{L_{S,t} \frac{1}{1 - n_{N,t}} \Lambda + L_{S,t} \frac{n_{N,t}}{1 - n_{N,t}} \tau_N}{\bar{w} a_R D_t} - \frac{1}{g_L} \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} \iota_t - \iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}} - \rho. \tag{1.43}$$

To replace $\frac{\dot{c}_{N,t}}{c_{N,t}}$, I take logs in the balanced-trade condition (1.33) and differentiate it with respect to time. That yields

$$\frac{\dot{c}_{N,t}}{c_{N,t}}+\frac{\dot{L}_{N,t}}{L_{N,t}}=\frac{\dot{L}_{S,t}}{L_{S,t}}+\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}, \tag{1.44}$$

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

$$\frac{\dot{c}_{N,t}}{c_{N,t}}=\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}. \tag{1.45}$$

We then have

$$\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}=\frac{L_{S,t}\frac{1}{1-n_{N,t}}\Lambda+L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\tau_N}{\bar{w}a_R D_t}-\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}\iota_t-\iota_t-\mu+\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}-\rho. \tag{1.46}$$

Using equation (1.17) and the equilibrium equation (1.11) for specialised workers to replace D_t, and using the equation for balanced industry flows, (1.31), in equation (1.46) to replace ι_t, we obtain after solving for $\dot{n}_{N,t}$

$$\dot{n}_{N,t}=\left(\overbrace{\left(\frac{\Lambda}{\bar{w}a_R}\frac{L_{S,t}}{D_t}+\left(\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}-\mu-\rho\right)\right)}^{\equiv\beta_{1,t}}n_{N,t}-\underbrace{\left(\frac{\mu}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}-\rho-\frac{\tau_N}{\bar{w}a_R}\frac{L_{S,t}}{D_t}\right)}_{\equiv\beta_{2,t}}n^2_{N,t}\right)\frac{1}{1+\underbrace{\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)}_{\equiv\beta_{3,t}}n_{N,t}}, \tag{1.47}$$

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, (1.42), and the growth rate of R&D difficulty, (1.41). We now have a nonlinear, non-autonomous differential equation of first order and first degree for $n_{N,t}$.

Using again (1.31) to replace ι_t in equation (1.28) yields the wage of rent-protection workers in terms of $n_{N,t}$,

$$w^{RP}_{N,t}=\bar{w}\frac{a_R}{a_X g_L}n_{N,t}\left(\frac{\dot{n}_{N,t}}{1-n_{N,t}}+\mu\frac{n_{N,t}}{1-n_{N,t}}\right). \tag{1.48}$$

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 (1.33), in the Northern labour market equation (1.10). To replace R_t, we use first the definition of ι_t in equation (1.5) and then the equation for balanced industry flows (1.31). This yields

$$u_{N,t}=1-s-\frac{L_{S,t}}{L_{N,t}}\frac{n_{N,t}}{1-n_{N,t}}\frac{1}{\lambda}-a_R\frac{D_t}{L_{N,t}}\left(\frac{\dot{n}_{N,t}}{1-n_{N,t}}+\mu\frac{n_{N,t}}{1-n_{N,t}}\right). \tag{1.49}$$

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 optimisation 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 globalisation on unemployment and, in particular, which employment share reacts immediately to changes in globalisation 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 neutralised. 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 (1.38)). 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 (1.31)), but this increase is stronger for a constant innovation rate.[27] Hence, to reestablish equality in equation (1.45), 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

[27] Differentiating equation (1.38) gives $\frac{\partial \frac{\dot{c}_{N,t}}{c_{N,t}}}{\partial \mu} = -1$, while using equation (1.31) yields $\frac{\partial \frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}}}{\partial \mu} = -\frac{1}{1-n_{N,t}}$.

activities increase. Let us summarise these findings in the first main result:

Proposition 1 (Short run effects)

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

The proofs are provided in Appendix 1.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 labour 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 liberalisation 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 industrialised 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 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 labour 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.

1.2.5 Equilibrium: Steady State

Equations (1.47) and (1.49) 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 (1.47) is at a point of rest, that is if $n_{N,t}$ is constant. From equation (1.31), 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 (1.7) still holds, we have

$$\frac{\dot{D}_t}{D_t} = \frac{n_{N,t} X_t}{D_t} = g_L, \tag{1.50}$$

so that the steady-state value of D_t is

$$D_t = \frac{n_{N,t} X_t}{g_L}. \tag{1.51}$$

Using the labour market equation (1.11) for rent-protection workers, this can be rewritten as

$$D_t = \frac{s L_{N,t}}{a_X g_L}. \tag{1.52}$$

By equation (1.42), the firm value $v_{N,t}$ also grows at rate g_L in the steady state. In this case, the differential equation (1.47) writes as

$$\dot{n}_{N,t} = \left(\overbrace{\left(\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + (g_L - \mu - \rho) \right)}^{\equiv \tilde{\beta}_1} n_{N,t} - \underbrace{\left(\mu + g_L - \rho - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} \right)}_{\equiv \tilde{\beta}_2} n_{N,t}^2 \right) \frac{1}{1 + 2 n_{N,t}}, \tag{1.53}$$

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

$$n_N^* = \frac{\tilde{\beta}_1}{\tilde{\beta}_2} = \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{g_L + \mu - \rho - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}}, \tag{1.54}$$

where the parameter $a_{RX} \equiv \frac{a_R}{a_X}$ gives the ratio of the unit labour requirements for R&D, a_R, and for rent protection, a_X. From the equilibrium equation for industry flows, (1.31), we have for $\dot{n}_N = 0$ that

$$n_N^* = \frac{\iota^*}{\iota^* + \mu}, \tag{1.55}$$

which allows to solve by use of the steady state expression for n_N^*, equation (1.54), for the steady state innovation rate,

$$\iota^* = \mu \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho}{2\mu - (\Lambda + \tau_N) \frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}}. \tag{1.56}$$

Constant n_N^* and ι^* imply from equation (1.28) 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 (1.45), we also have $\dot{c}_{N,t} = 0$ in steady state. First, this implies from equation (1.9) that $r_N^* = \rho$. Second, we can recursively define c_N^* from the balanced trade condition, equation (1.33), using $c_S = 1$, and get

$$c_N^* = (1 + \tau_N) \frac{L_{S,t}}{L_{N,t}} \frac{n_N^*}{1 - n_N^*}. \tag{1.57}$$

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]

$$g_\nu^* = \iota^* \ln \lambda. \tag{1.58}$$

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 (1.48) now turns into

$$w_N^{RP^*} = \bar{w} \frac{a_R}{a_X g_L} n_N^* \left(\mu \frac{n_N^*}{1 - n_N^*} \right) \tag{1.59}$$

for the steady state.

The unemployment rate, (1.49), is also constant for $\dot{n}_{N,t} = 0$. That yields the steady state unemployment rate,

$$u_N^* = (1 - s) - \frac{n_N^*}{1 - n_N^*} \frac{L_{S,t}}{L_{N,t}} \frac{1}{\lambda} - \frac{n_N^*}{1 - n_N^*} a_{RX} \frac{s}{g_L} \mu. \tag{1.60}$$

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 analyse the effects of globalisation on these variables, we should take a closer look at the conditions for stability and feasibility of the steady state.

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,

[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 1.D.3 for a derivation.

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 1.A.2.

Once we have determined the steady state's stability criteria, we can analyse the effects of globalisation 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 of the Northern ad-valorem import tariff τ_N *increases the steady state unemployment rate* u_N^*. *A decrease of the Southern imitation rate* μ *or an increase of the Southern market size* $L_{S,t}$ *decrease* u_N^*.

For proofs, see Appendix 1.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 liberalisation nor short run effects. Şener (2001) analyses bilateral trade liberalisation 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 labour 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.

1.3 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 1.2, 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

$$\pi_{N,t} = \frac{c_{N,t}L_{N,t}}{\lambda(1+\tau_N)}\left(\lambda(1+\tau_N) - \bar{w}\right) + \frac{c_{S,t}L_{S,t}}{\lambda}\left(\frac{\lambda}{1+\tau_S} - \bar{w}\right). \tag{1.61}$$

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 labour market equations (1.10), (1.11), and (1.12) 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:

$$c_{N,t}L_{N,t} = n_{N,t}\left(c_{N,t}L_{N,t} + \frac{c_{S,t}L_{S,t}}{1+\tau_S}\right) + (1-n_{N,t})\frac{c_{N,t}L_{N,t}}{1+\tau_N}\tau_N, \tag{1.62}$$

and simplifying this yields the new balanced-trade condition,

$$c_{N,t}L_{N,t} = c_{S,t}L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\frac{1+\tau_N}{1+\tau_S}. \tag{1.63}$$

1.3.1 Equilibrium Solution

I determine the transitional dynamics of the extended model. Using the balanced-trade condition (1.63) in the Southern labour market condition (1.12), we have

$$c_{S,t}\left(1 - n_{N,t}\frac{\tau_S}{1+\tau_S}\right) = 1, \tag{1.64}$$

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 (1.63) with respect to time yields now

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{\dot{c}_{S,t}}{c_{S,t}} + \frac{\dot{n}_{N,t}}{n_{N,t}(1-n_{N,t})}. \tag{1.65}$$

We can replace $c_{S,t}$ by differentiating equation (1.64) with respect to time, which yields

$$\frac{\dot{c}_{S,t}}{c_{S,t}} = \frac{\dot{n}_{N,t}\tau_S}{1+\tau_S-n_{N,t}\tau_S}. \tag{1.66}$$

Using equations (1.61), (1.63), (1.64), (1.66), and (1.65) in equation (1.38) yields, after using again equation (1.31) to replace ι_t,

$$\begin{aligned}\dot{n}_{N,t}\left(\frac{\tau_S}{1+\tau_S-n_{N,t}\tau_S}+\frac{1}{n_{N,t}(1-n_{N,t})}+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\frac{1}{1-n_{N,t}}\right)=\\ \frac{\frac{1+\tau_S}{1+\tau_S-n_{N,t}\tau_S}L_{S,t}\left[\frac{n_{N,t}}{1-n_{N,t}}\frac{1+\tau_N}{1+\tau_S}\left(1-\frac{\bar{w}}{\lambda(1+\tau_N)}\right)+\left(\frac{1}{1+\tau_S}-\frac{\bar{w}}{\lambda}\right)\right]}{\bar{w}a_R D_t}\\ -\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\left(\mu\frac{n_{N,t}}{1-n_{N,t}}\right)-\mu+\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}-\rho.\end{aligned} \tag{1.67}$$

This can be rearranged to

$$\dot{n}_{N,t} = \Gamma_{1,t}\Gamma_{2,t}n_{N,t}, \tag{1.68}$$

where

$$\begin{aligned}\Gamma_{1,t} =& n_{N,t}\left(\frac{1+\tau_N}{1+\tau_S-n_{N,t}\tau_S}\Lambda_N\frac{L_{S,t}}{\bar{w}a_R D_t}-\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)\mu\right)\\ &+\left(\frac{1+\tau_S}{1+\tau_S-n_{N,t}\tau_S}\Lambda_S\frac{L_{S,t}}{\bar{w}a_R D_t}-\left(\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+\rho\right)\right)(1-n_{N,t}),\end{aligned} \tag{1.69}$$

$$\Lambda_N = 1-\frac{\bar{w}}{\lambda(1+\tau_N)}, \tag{1.70}$$

$$\Lambda_S = \frac{1}{1+\tau_S}-\frac{\bar{w}}{\lambda}, \tag{1.71}$$

and

$$\Gamma_{2,t} = \frac{1+\tau_S(1-n_{N,t})}{1+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right)n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n^2_{N,t})\tau_S}. \tag{1.72}$$

Finally, the unemployment rate is the same as in equation (1.49): 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.

1.3.2 Short-Run Effects

We can now examine the short-run effects of Southern trade liberalisation. 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 liberalisation)

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 1.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 1.3.3). The short-run effects of changes in τ_N, L_S, and μ on unemployment $u_{N,t}$ are still valid (see Appendix 1.A.5 for proofs).

For bilateral trade liberalisation of equal amounts, that is $\mathrm{d}\tau_s = \mathrm{d}\tau_N$, an analytical proof is also not possible, and I investigate this issue in the calibration below.

1.3.3 Calibration

An analytical steady state solution or stability analysis is not possible here (see Appendix 1.B). I therefore calibrate the model to analyse unilateral Southern as well as bilateral Southern and Northern trade liberalisation 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). I assume that time t is arbitrarily large such that D_t grows at rate g_L and such that $\frac{L_{S,t}}{D_t}$ reduces to $\frac{L_{S,0}/L_{N,0}}{s/(a_X g_L)}$.[30] This is without loss of generality, as the growth rate of D_t does not depend on $n_{N,t}$.[31] I can hence omit to calibrate the parameters D_0 and $L_{N,0}$. For the remaining parameters, a_R and a_X, I choose values to get reasonable unemployment rates of less than 20%. The parameter values satisfy the stability conditions in Proposition 2.[32]

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

[30] See Appendix 1.C for a formal derivation and an alternative argument.

[31] 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 of $n_{N,t}$, but not sufficient. That means that this growth rate can also hold outside of the steady state.

[32] 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.

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 (2009b, 2012)
s		0.001	Grieben and Şener (2009b, 2012)
t	get $\frac{\dot{D}_t}{D_t} = g_L$	∞	
a_R/a_X	get $u_N^* < 20\%$	17.6	

Table 1.2. Calibration of the extended model

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) emphasise. I have not explicitly modelled productivity differences to save parameters and since the paper's focus is not on explaining 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).[33]

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)[34], 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%.[35] 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.[36]

For the utility discount rate, which equals the real interest rate in steady state, I set $\rho = 0.03$.[37] I set the population growth rate to $g_L = 0.012$.[38] For the South-North population ratio,

[33] 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.

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

[35] 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%.

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

[37] 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).

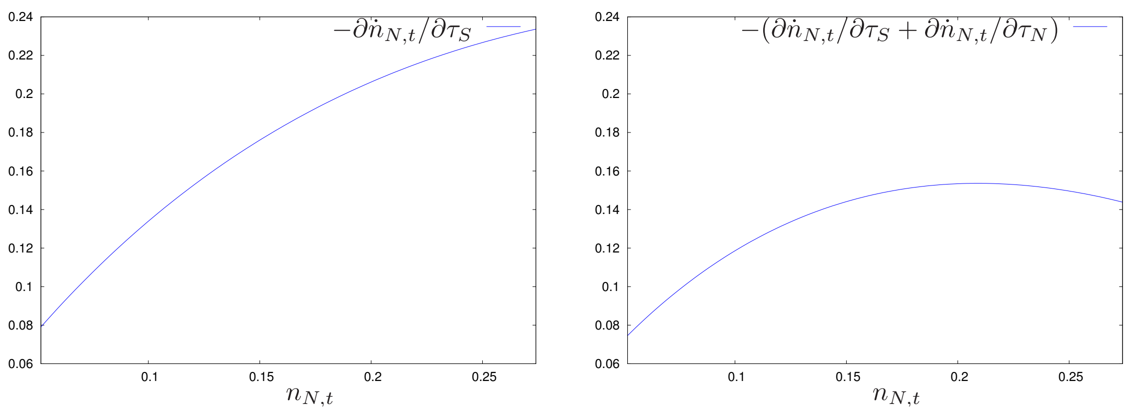
[38] This is in line with the literature; e.g. Grieben and Şener (2012) set $g_L = 0.01$, while Gustafsson and

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 labour requirement ratio a_{RX} for R&D and rent protection, is set to 17.6 to yield an unemployment rate lower than 20%.[39]

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 1.A.6, Figures 1.A.1 and 1.A.2 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 $n_N^{\max}$.

Short-Run Effects

In the case of Southern trade liberalisation, 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. Also, we could not determined the effect of bilateral trade liberalisation on unemployment analytically. Using the parameters above, we can examine these effects numerically. Again, the unemployment equation (1.49) 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 (1.68). Figure 1.1 depicts in the left panel the value of $-\frac{\partial \dot{n}_{N,t}}{\partial \tau_S}$, and in the right panel the value of $-\left(\frac{\partial \dot{n}_{N,t}}{\partial \tau_S} + \frac{\partial \dot{n}_{N,t}}{\partial \tau_N}\right)$. The derivatives are evaluated at $\tau_N = \tau_S = 0.04$ for all values of $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$. As we see, the negative values of the derivatives are in both panels always positive. Hence, a decrease in τ_S and a decrease in both τ_S and τ_N lead to an increase in the share of R&D workers in equation (1.49).



Notes: Negative of the derivative of equation (1.68) with respect to τ_S (left panel), and the negative sum of the derivatives of equation (1.68) with respect to τ_S and with respect to τ_N (right panel), evaluated at $\tau_N = \tau_S = 0.04$ for $n_N^{\min} \leq n_{N,t} \leq n_N^{\max}$.

Figure 1.1. Short-run effects of unilateral Southern and bilateral Northern and Southern trade liberalisation.

Segerstrom (2010) set $g_L = 0.014$.

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

Long-Run Effects

I analyse the effects of changes in tariff rates on the steady-state unemployment rate, and I consider three different scenarios: First, I analyse Northern unilateral trade liberalisation. Second, I compare this to Southern trade liberalisation, and third, to bilateral trade liberalisation. I consider incremental changes in import tariffs by 0.01 percentage points. The numerical results are shown in Table 1.3. 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 liberalisation yields an increase in the unemployment rate, while Southern trade liberalisation yields a decrease. The effect of Southern trade liberalisation is stronger, as can be seen from the absolute value of the elasticity. Unsurprisingly, bilateral trade liberalisation 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	0.0750	0.0747
Unemployment rate u_N^*	0.1453	0.1485	0.1354	0.1387
Elasticity $\frac{d\iota^*}{d\tau_i}\frac{\tau_i}{\iota^*}$, $i \in \{N, S\}$	-	1.5091	-4.6097	-3.0820
Slope $\frac{d\dot{n}_N}{dn_N}$	-0.0106	-0.0106	-0.0107	-0.0107

Notes: Import tariffs change by 0.01 percentage points.

Table 1.3. Numerical results for unilateral and bilateral trade liberalisation.

1.4 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 globalisation. 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 globalisation on unemployment.

Bilateral trade liberalisation leads to both short- and long-run decreases in unemployment. However, unilateral Northern trade liberalisation increases unemployment in both short and long run, while Southern trade liberalisation 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 liberalisation: 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 liberalisation 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 emphasise 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 endogenised 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).

Appendix to Chapter 1

1.A Proofs

1.A.1 Proof of Proposition 1

Deriving the unemployment rate (1.49) 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 (1.47) for $n_{N,t}$ with respect to τ_N:

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

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 (1.49) affects both production and R&D workers:

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

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:

$$\frac{\partial u_{N,t}}{\partial \mu} = -a_R \frac{D_t}{L_{N,t}} \left(\frac{\left(-n_{N,t} - \frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} n^2_{N,t}\right)}{1+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right) n_{N,t}} \frac{1}{1-n_{N,t}} + \frac{n_{N,t}}{1-n_{N,t}} \right)$$

$$= -a_R \frac{D_t}{L_{N,t}} \frac{n^2_{N,t}}{(1-n_{N,t})\left(1+\left(\frac{1}{g_L}\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}+1\right) n_{N,t}\right)} < 0. \tag{1.A-3}$$

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.

1.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 labour market equation (1.11) for rent-protection workers. From equation (1.17), it follows that D_t grows at the same rate. Then, from the free-entry-in-innovation condition (1.16), it follows that $v^I_{N,t}$ must also grow at rate g_L. Finally, for a constant ι^*, it follows from equation (1.6) that R_t also grows at rate g_L.

The steady state n^*_N in equation (1.54) satisfies $0 < n^*_N < 1$ under two conditions:

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

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX}} > \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \mu + \rho - g_L, \tag{1.A-4}$$

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

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} < \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} < \mu + \rho - g_L. \tag{1.A-5}$$

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

To analyse the local stability of the differential equation (1.47), its derivative with respect to n_N, evaluated at the interior steady state $n^*_N = \frac{\tilde{\beta}_1}{\tilde{\beta}_2}$, is

$$\left.\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N}\right|_{n_N=\frac{\tilde{\beta}_1}{\tilde{\beta}_2}} = \left.\frac{\tilde{\beta}_1 - 2\tilde{\beta}_2 n_N - 2\tilde{\beta}_2 n_N^2}{(1+2n_N)^2}\right|_{n_N=\frac{\tilde{\beta}_1}{\tilde{\beta}_2}} \tag{1.A-6}$$

$$= \frac{-\tilde{\beta}_1 - 2\frac{\tilde{\beta}_1^{\,2}}{\tilde{\beta}_2}}{\left(1+2\frac{\tilde{\beta}_1}{\tilde{\beta}_2}\right)^2}. \tag{1.A-7}$$

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

$$2\mu - \frac{\tau_N g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} > \mu + \rho - g_L, \tag{1.A-8}$$

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 $\tilde{\beta_1} > 0$,

$$\left.\frac{\mathrm{d}\dot{n}_N}{\mathrm{d}n_N}\right|_{n_N=0} = \frac{\tilde{\beta_1}}{(1+2n_N)^2} > 0, \tag{1.A-9}$$

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

$$1 - s \geq \frac{\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{S,t}} + g_L - \mu - \rho}{2\mu - (\Lambda + \tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}} \left(\frac{L_{S,t}}{L_{N,t}}\frac{1}{\lambda} + a_{RX}\frac{s}{g_L}\mu\right). \tag{1.A-10}$$

1.A.3 Proof of Proposition 3

In equation (1.54), 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 (1.54). 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 (1.54). 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

$$\frac{\partial \iota^*}{\partial \mu} = \frac{-\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}(\Lambda + \tau_N)(\frac{\Lambda g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}} + g_L - \mu - \rho) - \mu(2\mu - (\Lambda + \tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}})}{\left(2\mu - (\Lambda + \tau_N)\frac{g_L L_{S,t}}{\bar{w} s a_{RX} L_{N,t}}\right)^2}. \quad (1.A\text{-}11)$$

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.

1.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,

$$\frac{\partial u_{N,t}}{\partial \tau_S} = -a_R \frac{D_t}{L_{N,t}} \frac{1}{1 - n_{N,t}} \frac{\partial \dot{n}_{N,t}}{\partial \tau_S}. \quad (1.A\text{-}12)$$

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

$$\frac{\partial \dot{n}_{N,t}}{\partial \tau_S} = \frac{\partial \Gamma_{1,t}}{\partial \tau_S} \Gamma_{2,t} n_{N,t} + \Gamma_{1,t} \frac{\partial \Gamma_{2,t}}{\partial \tau_S} n_{N,t}. \quad (1.A\text{-}13)$$

For the first term, we have

$$\begin{aligned} \frac{\partial \Gamma_{1,t}}{\partial \tau_S} =& n_{N,t}\left(\frac{-(1+\tau_N)(1-n_{N,t})}{(1+\tau_S - n_{N,t}\tau_S)^2} \Lambda_N \frac{L_{S,t}}{\bar{w} a_R D_t}\right) \\ &+ (1-n_{N,t})\frac{n_{N,t}}{(1+\tau_S - n_{N,t}\tau_S)^2}\Lambda_S \frac{L_{S,t}}{\bar{w} a_R D_t} \\ &+ (1-n_{N,t})\frac{1}{1+\tau_S - n_{N,t}\tau_S}\frac{-1}{1+\tau_S}\frac{L_{S,t}}{\bar{w} a_R D_t}. \end{aligned} \quad (1.A\text{-}14)$$

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

$$\frac{n_{N,t}}{1+\tau_S - n_{N,t}\tau_S}\left(\frac{1}{1+\tau_S} - \frac{\bar{w}}{\lambda}\right) - \frac{1}{1+\tau_S}, \quad (1.A\text{-}15)$$

which is negative since

$$\frac{n_{N,t}}{1+\tau_S - n_{N,t}\tau_S} < 1. \quad (1.A\text{-}16)$$

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

For the second term of equation (1.A-13), we have

$$\frac{\partial \Gamma_{2,t}}{\partial \tau_S} = \frac{-n_{N,t}(1-n_{N,t})}{\left(1 + \left(\frac{1}{g_L}\frac{\dot{v}_{N,t}^I}{v_{N,t}^I} + 1\right) n_{N,t}(1 + \tau_S(1 - n_{N,t})) + (1 - n_{N,t}^2)\tau_S\right)^2}, \quad (1.A\text{-}17)$$

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 $n_{N,t} \leq n_N^*$.

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

Relating to Appendix 1.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 (1.68) with respect to τ_N is

$$\frac{\partial \dot{n}_{N,t}}{\partial \tau_N} = \frac{\partial \Gamma_{1,t}}{\partial \tau_N} \Gamma_{2,t} n_{N,t}, \tag{1.A-18}$$

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

$$\frac{\partial \Gamma_{1,t}}{\partial \tau_N} = n_{N,t} \frac{1}{1 + \tau_S - n_{N,t}\tau_S} \Lambda_N \frac{L_{S,t}}{\bar{w} a_R D_t} + n_{N,t} \frac{1}{1 + \tau_S - n_{N,t}\tau_S} \frac{\bar{w}}{\lambda(1+\tau_N)} \frac{L_{S,t}}{\bar{w} a_R D_t}, \tag{1.A-19}$$

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 (1.68) with respect to $L_{S,t}$ is

$$\frac{\partial \dot{n}_{N,t}}{\partial L_{S,t}} = \frac{\partial \Gamma_{1,t}}{\partial L_{S,t}} \Gamma_{2,t} n_{N,t}, \tag{1.A-20}$$

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

$$\frac{\partial \Gamma_{1,t}}{\partial L_{S,t}} = n_{N,t} \frac{1+\tau_N}{1 + \tau_S - n_{N,t}\tau_S} \Lambda_N \frac{1}{\bar{w} a_R D_t} + (1 - n_{N,t}) \frac{1+\tau_S}{1 + \tau_S - n_{N,t}\tau_S} \Lambda_S \frac{1}{\bar{w} a_R D_t}, \tag{1.A-21}$$

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:

$$\begin{aligned}
\frac{\partial \iota_t}{\partial \mu} &= \frac{\partial \dot{n}_{N,t}}{\partial \mu} \frac{1}{1 - n_{N,t}} + \frac{n_{N,t}}{1 - n_{N,t}} \\
&= \frac{\partial \Gamma_{1,t}}{\partial \mu} \Gamma_{2,t} \frac{n_{N,t}}{1 - n_{N,t}} + \frac{n_{N,t}}{1 - n_{N,t}} \\
&= \left((-n_{N,t} - 1)\Gamma_{2,t} + 1\right) \frac{n_{N,t}}{1 - n_{N,t}}
\end{aligned} \tag{1.A-22}$$

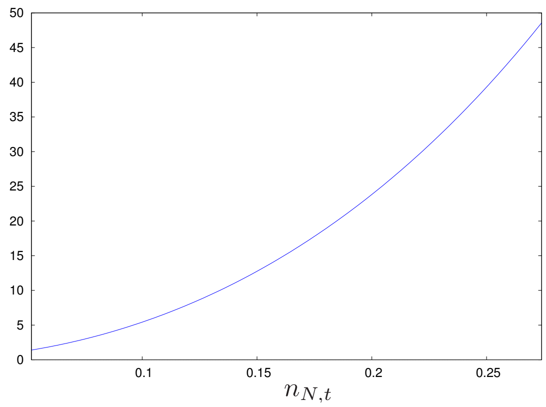
For the term in parentheses, we have

$$
\begin{aligned}
-(1+n_{N,t})\Gamma_{2,t}+1 &= \frac{-(1+n_{N,t})(1+\tau_S(1-n_{N,t}))}{1+2n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n_{N,t}^2)\tau_S}+1 \\
&= n_{N,t}\frac{1+2\tau_S(1-n_{N,t})}{1+2n_{N,t}(1+\tau_S(1-n_{N,t}))+(1-n_{N,t}^2)\tau_S},
\end{aligned} \tag{1.A-23}
$$

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.

1.A.6 Feasible Range of Industry Shares

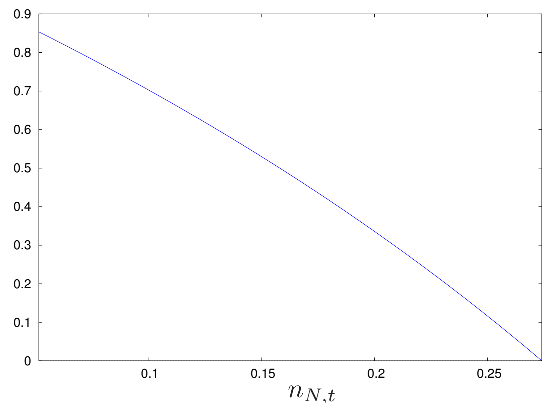
Figure 1.A.1 displays the wage of rent-protection workers for the range of $n_{N,t}$ in which $\bar{w} \leq w^{RP}$ and $0 \leq u_{N,t}$, using the calibration in Section 1.3.3. The wage is obviously increasing with $n_{N,t}$.



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

Figure 1.A.1. Wage of rent-protection workers.

Figure 1.A.2 displays the Northern unemployment rate of general-purpose workers for the same range of $n_{N,t}$. The unemployment rate is obviously decreasing with $n_{N,t}$.



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

Figure 1.A.2. Northern unemployment rate.

1.B Steady State of Extended Model

Equation (1.68) 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:

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

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

which could be solved by the well-known formula

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

However, this yields no analytically tractable solution.

1.C Growth Rate and Level of R&D Difficulty

The growth rate of D_t is equal to g_L when t becomes arbitrarily large. We have from equations (1.41) and (1.6) that

$$\lim_{t\to\infty} \frac{\frac{s}{a_X} L_{N,t}}{D_0 + \frac{s}{a_X g_L}\left[L_{N,t} - L_{N,0}\right]} = \lim_{t\to\infty} \frac{\frac{s}{a_X} L_{0,t} e^{g_L t}}{D_0 + \frac{s}{a_X g_L}\left[L_{0,t} e^{g_L t} - L_{N,0}\right]} = g_L, \tag{1.C-1}$$

which follow from L'Hôpital's rule. Similarly, the term $\frac{L_{S,t}}{D_t}$ converges for $t \to \infty$

$$\lim_{t\to\infty} \frac{L_{S,t}}{D_0 + \frac{s}{a_X g_L}\left[L_{N,t} - L_{N,0}\right]} = g_L \frac{L_{S,0}/L_{N,0}}{s/a_X}. \tag{1.C-2}$$

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 labour market equation for specialised workers (1.11). 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 (1.11) as

$$D_t = D_0 + \frac{1}{g_L}\left[n_{N,t}X_t - n_{N,0}X_0\right]. \tag{1.C-3}$$

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

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

1.D Household Optimisation

1.D.1 Maximisation 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

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

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

$$\frac{p_{N,t}(b,\omega)}{\lambda^b} = \frac{p_{N,t}(b+1,\omega)}{\lambda^{b+1}}. \tag{1.D-2}$$

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.[40]

Given this result, households maximise the instantaneous utility function (1.3) subject to the instantaneous budget constraint (1.4). The maximisation problem is hence

$$\begin{aligned} \max_{\int_0^1 x_{N,t}(k_t(\omega),\omega)\mathrm{d}\omega} &\int_0^1 \ln\left(\lambda^{k_t(\omega)}x_{N,t}(k_t(\omega),\omega)\right)\mathrm{d}\omega \\ &+ \mu\left(c_{N,t} - \int_0^1 p_{N,t}(k_t(\omega),\omega)x_{N,t}(k_t(\omega),\omega)\mathrm{d}\omega\right), \end{aligned} \tag{1.D-3}$$

[40] 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.

and the first-order condition for any industry ω is

$$\frac{\lambda^{k_t(\omega)}}{\lambda^{k_t(\omega)} x_{N,t}(k_t(\omega),\omega)} - \mu p_{N,t}(k_t(\omega),\omega) \stackrel{!}{=} 0, \tag{1.D-4}$$

such that demand is

$$x_{N,t}(k_t(\omega),\omega) = \frac{1}{\mu p_{N,t}(k_t(\omega),\omega)}. \tag{1.D-5}$$

Plugging this into the budget constraint gives

$$c_{N,t} = \int_0^1 \frac{1}{\mu} \mathrm{d}\omega = \frac{1}{\mu}, \tag{1.D-6}$$

and hence for demand, we have

$$x_{N,t}(k_t(\omega),\omega) = \frac{c_{N,t}}{p_{N,t}(k_t(\omega),\omega)}, \tag{1.D-7}$$

such that instantaneous utility can be rewritten as

$$\begin{aligned}
\ln \nu_{N,t} &= \int_0^1 \ln\left(\lambda^{k_t(\omega)} x_{N,t}(k_t(\omega),\omega)\right) \mathrm{d}\omega \\
&= \int_0^1 \ln\left(\lambda^{k_t(\omega)} \frac{c_{N,t}}{p_{N,t}(k_t(\omega),\omega)}\right) \mathrm{d}\omega \\
&= \ln c_{N,t} + \underbrace{\int_0^1 \ln\left(\frac{\lambda^{k_t(\omega)}}{p_{N,t}(k_t(\omega),\omega)}\right) \mathrm{d}\omega}_{\equiv \Theta_t}.
\end{aligned} \tag{1.D-8}$$

Inserting this into the household's lifetime optimisation problem yields

$$\begin{aligned}
\max_{[c_{N,t}]_{t=0}^{\infty}} U_N &= \int_0^{\infty} e^{-\rho t} L_{N,t} \ln c_{N,t} \mathrm{d}t + \int_0^{\infty} e^{-\rho t} L_{N,t} \Theta_t \mathrm{d}t \\
\text{s.t.} \quad \dot{A}_{N,t} &= r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t},
\end{aligned} \tag{1.D-9}$$

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 maximisation problem reduces to

$$\begin{aligned}
\max_{[c_{N,t}]_{t=0}^{\infty}} U_N &= \int_0^{\infty} e^{-\rho t} L_{N,t} \ln c_{N,t} \mathrm{d}t \\
\text{s.t.} \quad \dot{A}_{N,t} &= r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}.
\end{aligned} \tag{1.D-10}$$

1.D.2 Maximisation of Lifetime Utility

The present value Hamiltonian to this problem is

$$H = e^{-\rho t} L_{N,t} \ln c_{N,t} + \mu_{N,t}(r_{N,t} A_{N,t} + W_{N,t} - c_{N,t} L_{N,t} + T_{N,t}). \tag{1.D-11}$$

The optimality conditions are the maximum condition

$$\frac{\partial H}{\partial c_{N,t}} = e^{-\rho t}\frac{L_{N,t}}{c_{N,t}} - \mu_{N,t}L_{N,t} \overset{!}{=} 0, \tag{1.D-12}$$

the multiplier equation

$$\frac{\partial H}{\partial A_{N,t}} = \mu_{N,t}r_{N,t} \overset{!}{=} -\dot{\mu}_{N,t}, \tag{1.D-13}$$

the equation of motion

$$\frac{\partial H}{\partial \mu_{N,t}} \overset{!}{=} r_{N,t}A_{N,t} + W_{N,t} - c_{N,t}L_{N,t} + T_{N,t}, \tag{1.D-14}$$

the transversality condition

$$\lim_{t\to\infty} \mu_{N,t}A_{N,t} \overset{!}{=} 0, \tag{1.D-15}$$

and the initial condition

$$A_0 > 0. \tag{1.D-16}$$

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

$$\frac{\dot{\mu}_{N,t}}{\mu_{N,t}} = -r_{N,t} \tag{1.D-17}$$

and, integrating over time, results in

$$\ln \mu_{N,t} = -r^c_{N,t} + C_1, \tag{1.D-18}$$

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

$$\mu_{N,t} = e^{-r^c_{N,t}+C_1} = C_2e^{-r^c_{N,t}}. \tag{1.D-19}$$

This can be used in (1.D-13):

$$e^{-\rho t}\frac{1}{c_{N,t}} = \mu_{N,t} = C_2e^{-r^c_{N,t}} \Leftrightarrow \frac{e^{r^c_{N,t}-\rho t}}{C_2} = c_{N,t}, \tag{1.D-20}$$

taking (natural) logs results in

$$\ln c_{N,t} = r^c_{N,t} - \rho t - \ln C_2, \tag{1.D-21}$$

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

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = r_{N,t} - \rho. \tag{1.D-22}$$

1.D.3 Steady-State Utility Growth Rate

Here I derive the growth rate of instantaneous utility, given in (1.58). 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

$$\ln \nu_t = \int_0^{n_N^*} \ln \sum_{j=0}^{\infty} \lambda^j x_{N,t}(j,\omega) \mathrm{d}\omega + \int_{n_N^*}^{1} \ln \sum_{j=0}^{\infty} \lambda^j x_{N,t}(j,\omega) \mathrm{d}\omega. \tag{1.D-23}$$

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

$$\ln \nu_{N,t} = \int_0^{n_N^*} \ln \lambda^{\iota^* t} x_{N,t}(\iota^* t,\omega) \mathrm{d}\omega + \int_{n_N^*}^{1} \ln \lambda^{\iota^* t} x_{N,t}(\iota^* t,\omega) \mathrm{d}\omega. \tag{1.D-24}$$

Using the demand functions, we have

$$\ln \nu_t = \int_0^{n_N^*} \ln \lambda^{\iota^* t} \frac{c_N^*}{\lambda(1+\tau_N)} \mathrm{d}\omega + \int_{n_N^*}^{1} \ln \lambda^{\iota^* t} \frac{c_N^*}{1+\tau_N} \mathrm{d}\omega. \tag{1.D-25}$$

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

$$\ln \nu_t = \iota^* t \ln \lambda + \ln c_N^* - n_N^* \ln \lambda - \ln(1+\tau_N), \tag{1.D-26}$$

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

$$g_\nu^* = \frac{\dot{\nu}_t}{\nu_t} = \iota^* \ln \lambda. \tag{1.D-27}$$

1.E Why Not a Simpler R&D Difficulty?

The focus of this paper is on the analysis of trade liberalisation 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

$$D_t = kL_{N,t}, \tag{1.E-1}$$

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.

1.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 labour market for workers who work either in production or in R&D, and the labour market equation writes as

$$n_{N,t}\left(\frac{c_{N,t}L_{N,t}}{\lambda(1+\tau_N)}+\frac{c_{S,t}L_{S,t}}{\lambda}\right)+a_R R_t+u_t L_{N,t}=L_{N,t}. \tag{1.E-2}$$

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

$$v^I_{N,t}=\frac{\pi_{N,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}, \tag{1.E-3}$$

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

The optimisation 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 maximise their expected gain minus R&D costs, that is

$$\max_{R_{m,t}} v^I_{N,t}\iota_{m,t}-\bar{w}a_R R_{m,t}, \tag{1.E-4}$$

subject to (1.5), which yields

$$v^I_{N,t}\overset{!}{=}\bar{w}a_R D_t. \tag{1.E-5}$$

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

1.E.2 The Model's Solution

Again, the Southern labour market equation (1.12) reduces, using the balanced-trade condition (1.33), 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 (1.39), using the balanced trade condition (1.33) and $c_S=1$ yields

$$v^I_{N,t}=\frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{1.E-6}$$

Using the FEIN condition (1.E-5), we can write

$$\bar{w}a_R D_t = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{r_{N,t}+\iota_t+\mu-\frac{\dot{v}^I_{N,t}}{v^I_{N,t}}}. \tag{1.E-7}$$

Solving for $r_{N,t}$ gives

$$r_{N,t} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + \frac{\dot{v}^I_{N,t}}{v^I_{N,t}}. \tag{1.E-8}$$

Differentiating the FEIN condition with respect to time after taking logs and using the definition of D_t in equation (1.E-1) yields

$$\frac{\dot{v}^I_{N,t}}{v^I_{N,t}} = \frac{\dot{D}_t}{D_t} = g_L. \tag{1.E-9}$$

Using this result in equation (1.E-8), which we plug into the Keynes-Ramsey rule, equation (1.9), we have

$$\frac{\dot{c}_{N,t}}{c_{N,t}} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + g_L - \rho. \tag{1.E-10}$$

Again, we use the dynamic version of the balanced-trade condition, (1.45), to replace the left hand side of equation (1.E-10), yielding

$$\frac{\dot{n}_{N,t}}{n_{N,t}}\frac{1}{1-n_{N,t}} = \frac{L_{S,t}\frac{n_{N,t}}{1-n_{N,t}}\left(\Lambda+\tau_N\right)+\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} - \iota_t - \mu + g_L - \rho, \tag{1.E-11}$$

and the equation for industry flows, (1.31), serves to replace ι_t. We finally obtain

$$\dot{n}_{N,t} = \frac{n_{N,t}}{1+n_{N,t}}\left[\underbrace{\left[\frac{\Lambda L_{S,t}}{\bar{w}a_R k L_{N,t}} + (g_L-\rho-\mu)\right]}_{\equiv\gamma_1} - \underbrace{\left(g_L-\rho-\frac{\tau_N L_{S,t}}{\bar{w}a_R k L_{N,t}}\right)}_{\equiv\gamma_2} n_{N,t}\right] \tag{1.E-12}$$

$$= \frac{n_{N,t}}{1+n_{N,t}}\left(\gamma_1-\gamma_2 n_{N,t}\right). \tag{1.E-13}$$

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

$$\left.\frac{d\dot{n}_N}{dn_N}\right|_{n_N=\frac{\gamma_1}{\gamma_2}} = \underbrace{\left.\frac{1}{(1+n_N)^2}\left(\gamma_1-\gamma_2 n_N\right)\right|_{n_N=\frac{\gamma_1}{\gamma_2}}}_{=0} - \gamma_2 \left.\frac{n_N}{1+n_N}\right|_{n_N=\frac{\gamma_1}{\gamma_2}} > 0, \tag{1.E-14}$$

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 cannot 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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Chapter 2

Routinisation and the Decline of the U.S. Minimum Wage

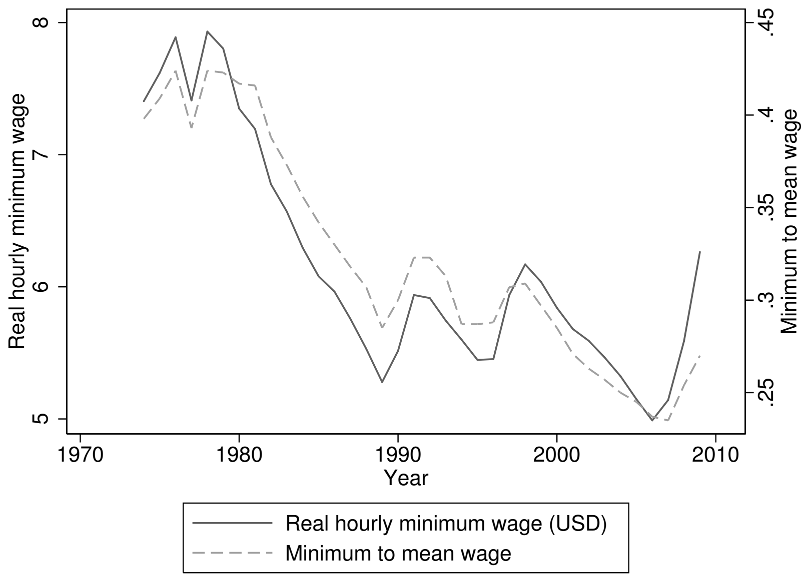
2.1 Introduction

Since the late 1970s, the U.S. legal minimum wage has decreased until the late 2000s in real terms, in particular during the 1980s and since the late 1990s for about a decade. It has also dropped in comparison to the mean wage of full-time workers, as shown in Figure 2.1. Comparing the minimum wage to the mean wage, however, hides that real wages have been diverging for workers with different education levels, as shown in Figure 2.2. In particular, the real wage of the lowest skilled workers, who did not finish high school, has decreased during the 1980s. The mean wage of high school graduates, who mainly have vocational training, has decreased first and increased afterwards again, but remained relatively constant. The mean real wage of the highest skilled workers, who have at least a college degree, has increased.

What is the link between the minimum wage and the diverging real wages of workers with different education levels – that is, how do they affect each other? Given that the college premium rises, how does the decline in the minimum wage affect the education decision? And how can we explain the decrease in the real minimum wage?

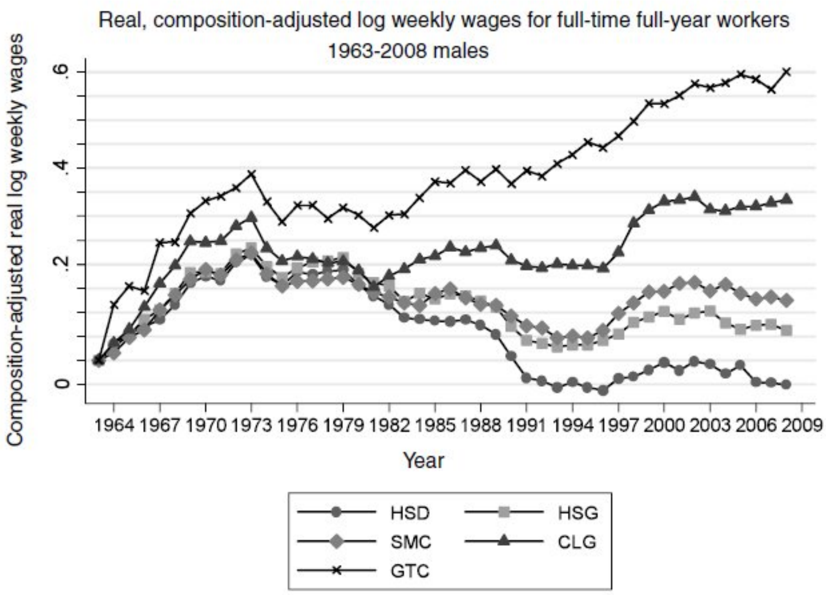
The dominant explanation for changes in wage inequality is a nuanced version of skill-biased technical change, the so-called routinisation hypothesis (Autor et al., 2003; Spitz-Oener, 2006; Goos and Manning, 2007; Autor et al., 2008; Reenen, 2011; Goos et al., 2014). It assumes that a production process consists of several tasks. Some of these tasks, referred to as routine tasks, are easy to code into a computer program and can be done by both workers and machines. As machines become better and cheaper, they replace workers. In other words, labour demand for routine tasks decreases, as capital substitutes workers doing routine tasks and complements workers doing non-routine tasks. Routine tasks are mostly done by low-skilled workers, while non-routine tasks are mostly done by high-skilled workers.

The increased computerisation leads to a polarisation of the labour market, where the de-



Notes: Real hourly minimum wage adjusted by CPI. Mean wage refers to full-time workers.
Source: OECD (2011b).

Figure 2.1. Real minimum wage and minimum to mean wage in the U.S.



Notes: HSD: High school dropouts; HSG: High school graduates; SMC: Some college; CLG: College graduates; GTC: Greater than college.
Source: Acemoglu and Autor (2011).

Figure 2.2. Real wages by education level in the U.S.

mand for medium-skilled workers decreases relative to the demand of low- and high-skilled workers. Goos et al. (2009) show that job polarisation occurred also in most European countries between 1993-2006 and is mostly due to routinisation. Firpo et al. (2011) show that technical change and deunionisation affected wage inequality in the 1980s and 1990s, and offshoring became important from the 1990s on. Engelmann (2014) presents U.K. evidence for effects of technical change on wage inequality. Akcomak et al. (2013) and Goos et al. (2014) argue that technical change is much more important than offshoring in explaining polarisation. They also support the view that routinisation is best modelled as capital-augmenting technical progress.

I use a variant of a model proposed by Acemoglu (2002) as a simple model of routinisation. I modify this model to have three types of skills and endogenous education. High-ability workers jointly work either with low-skilled workers or with capital after having received additional education, which means that they can substitute their low-ability co-workers by machines.

The different skill levels are a stylised version of the education groups that we observed in Figure 2.2 of real wages. As such, the model includes a high school premium and a college premium. The model can account for diverging real wages of high, medium, and low skilled workers. It can also account for an increasing share of high-skilled workers and a rising skill premium. To do so, it does not require a task-based model, as suggested by Acemoglu and Autor (2011).

I add a minimum wage and show how it modifies the effect of technical change on education and on wage inequality. On top of that, I endogenise the minimum wage by a simple objective function of the government. The government opposes unemployment and wage inequality. I calibrate the model to U.S. data. Technical change suggests falling minimum wages.

For the U.S., there is some evidence that labour unions support and small enterprises oppose minimum wages (Silberman and Durden, 1976; Cox and Oaxaca, 1982; Sobel, 1999), while other authors emphasise that ideology is actually much more important (Poole and Rosenthal, 1991; Bartels, 2006), and that the minimum wage is rarely decisive for voting behaviour (Waltman, 2000). Also, the decrease in unionisation and the decline of the minimum wage do not necessarily imply that unions lobby for minimum wages. A decline in unionisation is also correlated with technical change (Dinlersoz and Greenwood, 2013), which is the most important determinant of increasing wage inequality, as mentioned above.[1] Hence, instead of taking a political economy approach, I assume that the government uses the minimum wage to reduce wage inequality.[2]

[1] To explain cross-country differences, Aghion et al. (2011) focus on cultural differences and Boeri (2012) on different setting regimes, that is legislated or bargained minimum wages.

[2] On the normative side, the role of the minimum wage as a redistributive tool has been investigated by the optimal taxation literature. Allen (1987) argues that a minimum wage is desirable under linear income taxation, but never under non-linear income taxation. Marceau and Boadway (1994) show that a minimum wage, combined with unemployment insurance, can be welfare-improving, although a minimum wage increases unemployment. Boadway and Cuff (2001) show that a minimum wage can also be employment-enhancing. Hungerbühler and Lehmann (2009) show that, in a model with search frictions and non-linear income taxes, a minimum wage is desirable if the workers' bargaining power is too low. Even without taxation, a minimum wage is socially desirable if the government values redistribution from high- to low-skilled workers, and this result maintains to hold under non-linear income taxes (Lee and Saez, 2012). While they argue that it is welfare-improving to reduce the before-tax minimum wage and increase tax transfers, such that the after-tax minimum wage remains

To formalise the decomposition of a production process into tasks that can be allocated to different production factors, Acemoglu and Autor (2011) set up a simple task-based model with three skill levels.[3] Yet, all production factors are q-complements in their model, which means that an increase in the productivity of one factor also increases the productivity of all other factors. Hence, technical progress in their model cannot explain the declining real wage of low-skilled workers.

Interacting technical change with minimum wages, Bárány (forthcoming) also focuses on the interaction between the minimum wage, wage inequality, and education. Her interest is more on the effect of the minimum wage on other wages in a general equilibrium model with endogenous technical change. She has only two skill levels and focuses on skill-biased technical change, while I have three skill levels and routine-biased technical change.

2.2 The Model

I use a partial equilibrium model of the labour market similar to Acemoglu (2002, p. 48ff.) with some modifications. Using a partial equilibrium model allows to focus on the effect of changes in the production technology on labour demand.[4] There is a single good that can be produced by two different production technologies. I call them the traditional (T) and the modern (M) technology. There are two groups of workers, the low-ability (L) and the high-ability (H) workers. The total mass of workers is $H + L = 1$. Workers of both abilities can work with the traditional technology. The high-ability workers can choose to undertake costly education, which allows them to work with the modern technology. Low-ability workers cannot work with the modern technology.[5] The model is similar to Acemoglu (2002, p. 48ff.), but I add education costs to have wage inequality between educated and uneducated high-ability workers. It will turn out that education costs make the effect of technical change on wage inequality ambiguous.

The cost of education k is distributed uniformly between 0 and $\bar{k}$ among high-ability workers. Low-ability workers and the uneducated high-ability workers work together with the traditional technology with a Cobb-Douglas production function, $Y_T = L^{\alpha} H_T^{1-\alpha}$.[6] The production function for the modern technology is $Y_M = A \cdot H_M$, where A is an exogenous technology parameter. I assume a constant marginal productivity of educated high-ability workers for tractability. Total production is $Y = Y_T + Y_M$. Figure 2.3 depicts the basic structure of the model.

The interpretation of the production technologies is that low-ability workers perform routine cognitive or manual tasks, while high-ability workers perform rather abstract cognitive or

constant, my results point to a different aspect, such that the higher pressure on low-skilled labour markets led to a decrease in minimum wages.

[3]See Autor (2013) for a shorter presentation of the task-based model.

[4]A partial equilibrium analysis is also in line with, e.g., Acemoglu et al. (2001) and Acemoglu and Autor (2011).

[5]The real world interpretation of this might be that high-ability workers have access to academic education, while low-ability workers have no access to academic education, as their degree of schooling is too low.

[6]That means they are p-substitutes (demand increases with the *relative price* of the other factor) and q-complements (demand and relative wage increases with the *supply* of the other factor) (Sato and Koizumi, 1973).

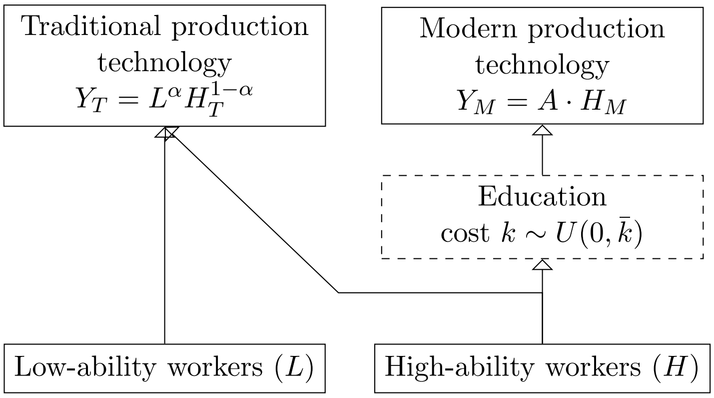


Figure 2.3. Basic structure of the model.

manual tasks. The model reflects the main findings by Spitz-Oener (2006): Occupations today require more complex skills, require education upgrading, and are much more computerised. By assuming two different production technologies, I omit the main weakness of a single production technology, in which all production factors are q-complements as in, e.g., Teulings (2003) and Acemoglu and Autor (2011), such that an increase in the productivity of one factor increases the marginal productivity of all other factors.

2.2.1 Laissez-faire Equilibrium

Before I introduce a minimum wage, I analyse a laissez-faire equilibrium without a minimum wage. This will make clear how the minimum wage affects the model's predictions.

Equilibrium Wages

Labor markets are competitive, so the wage of high-ability workers working with the traditional technology is

$$w_T^H = (1-\alpha)\left(\frac{L}{H_T}\right)^\alpha, \tag{2.1}$$

while the wage of low-ability workers is

$$w_T^L = \alpha\left(\frac{H_T}{L}\right)^{1-\alpha}. \tag{2.2}$$

Both wages depend on the ratio of uneducated high-ability to low-ability workers. If the ratio is higher, there are more high-ability co-workers per low-ability worker, such that their wage is higher, and less low-ability co-workers per high-ability worker, such that their wage is lower.

For educated high-ability workers, who work with the modern technology, the wage is

$$w_M = A. \tag{2.3}$$

It depends only on technology A.

Education Decision

High-ability workers choose education if the higher wage that they earn afterwards, net of education costs, is larger than the wage that they earn from working with the traditional technology, i.e. if

$$A - k > (1-\alpha)\left(\frac{L}{H_T}\right)^{\alpha}. \tag{2.4}$$

In the laissez-faire equilibrium, the threshold value of education costs, $\tilde{k}_c$, determines the worker who is just indifferent between education and staying uneducated. It follows that the share of high-ability workers who choose education is $\frac{\tilde{k}_c}{\bar{k}}$, while a fraction of $1-\frac{\tilde{k}_c}{\bar{k}}$ remains uneducated, as k is uniformly distributed between 0 and $\bar{k}$. So, $H_T = H\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)$. Hence, $\tilde{k}_c$ is given by the no-arbitrage equation,

$$A = \underbrace{\tilde{k}_c + (1-\alpha)\left(\frac{L}{H\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)}\right)^{\alpha}}_{\equiv\Phi}. \tag{2.5}$$

As Φ increases monotonously with $\tilde{k}_c < \bar{k}$, and as $\lim_{\tilde{k}_c\to\bar{k}}\Phi = \infty$, a unique solution exists with $0 < \tilde{k}_c < \bar{k}$ for any value of A under

Assumption 1

$$\lim_{\tilde{k}_c\to 0}\Phi < A \Rightarrow A > (1-\alpha)\left(\frac{L}{H}\right)^{\alpha}.$$

Effect of Skill-Biased Technical Change

If A increases, the wage of educated high-ability workers, w_M, increases unambiguously. In a nutshell, more high-ability workers will choose education because the cost of education now also pays for more high-ability workers. This reduces $\frac{H_T}{L}$ and hence the marginal productivity of low-ability workers and hence their wage w_T^L, but it increases the marginal productivity of high-ability workers who work with them and hence their wage w_T^H.

The share of educated high-ability workers $\frac{\tilde{k}_c}{\bar{k}}$ increases with A, shown by applying the implicit function theorem to (2.5):

$$\frac{d\tilde{k}_c}{dA}\frac{1}{\bar{k}} = \frac{1}{1+\alpha(1-\alpha)\left(\frac{L}{H}\right)^{\alpha}\frac{1}{\bar{k}}\left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right)^{1+\alpha}}\frac{1}{\bar{k}} > 0. \tag{2.6}$$

What happens to wage inequality? The wage of uneducated high-ability workers relative to low-ability workers is

$$\frac{w_T^H}{w_T^L} = \frac{1-\alpha}{\alpha}\frac{L}{H_T} = \frac{1-\alpha}{\alpha}\frac{L}{\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)H}. \tag{2.7}$$

As is clear from the discussion above, the relative wage increases as A increases, because the real wage of high-ability workers increases, while the real wage of low-ability workers decreases.

Comparing the wages of educated to uneducated high-ability workers, we have

$$\frac{w_M}{w_T^H} = \frac{A}{(1-\alpha)\left(\frac{L}{\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)H}\right)^{\alpha}}. \tag{2.8}$$

Wage inequality increases as long as

$$\frac{\bar{k}}{1+\alpha} > \tilde{k}_c, \tag{2.9}$$

and it decreases otherwise.[7] As $\tilde{k}_c$ increases with A, top/median-wage inequality increases with A for low levels of technology A, while it decreases for high levels of A.

Finally, the relative wage of educated high-ability workers compared to low-ability workers is

$$\frac{w_M}{w_T^L} = \frac{A}{\alpha\left(\frac{\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)H}{L}\right)^{1-\alpha}}, \tag{2.10}$$

which increases with A, as w_M increases and w_T^L decreases. We can summarise the results in

Proposition 5

An increase in A

- *increases the share of educated high-ability workers,* H_M*,*
- *increases the wage of educated high-ability workers,* w_M*,*
- *increases the wage of uneducated high-ability workers,* w_T^H*,*
- *decreases the wage of low-ability workers,* w_T^L*,*
- *increases top-bottom wage inequality,* $\frac{w_M}{w_T^L}$
- *increases median-bottom wage inequality,* $\frac{w_T^H}{w_T^L}$
- *increases top-median wage inequality,* $\frac{w_M}{w_T^H}$*, for* $A < \tilde{A}$*, where* $\tilde{A}$ *is implicitly defined as* $\frac{\bar{k}}{1+\alpha} = \tilde{k}_c(\tilde{A})$*, and decreases otherwise.*

[7]See Appendix 2.A.1 for a proof.

Effect of Workforce Composition

If $h = \frac{H}{L}$ increases, the threshold value of education costs increases, which implies less high-ability workers in the traditional sector. Implicitly differentiating equation (2.5), I obtain

$$\frac{d\tilde{k}_c}{dh} = -\frac{\partial\Phi/\partial h}{\partial\Phi/\partial\tilde{k}_c} = \frac{\alpha(1-\alpha)h^{-\alpha-1}\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)^{-\alpha}}{1+\alpha(1-\alpha)h^{-\alpha}\frac{1}{\bar{k}}\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)^{-\alpha-1}} > 0. \tag{2.11}$$

There is obviously no effect on w_M, as it only depends on technology A. The wage of uneducated high-ability workers decreases, as we have just seen that it now pays off for more high-ability workers to engage in education. The intuition is that for a given share of uneducated high-ability workers, there are now less low-ability workers. This reduces the marginal productivity of uneducated high-ability workers. Hence, for a given share H_T, their wage decreases. Therefore, it pays off for more H_T workers to engage in education.

The wage of low-ability workers, w_T^L, increases: The marginal productivity of uneducated high-ability workers decreases, as the ratio of uneducated high-ability to low-ability workers, $\frac{H_T}{L}$, increases. Hence, the marginal productivity of low-ability workers must increase, as it depends positively on $\frac{H_T}{L}$. We can also show this effect more formally: The derivative

$$\frac{\partial w_T^L}{\partial h} = \alpha(1-\alpha)h^{-\alpha}\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)^{1-\alpha} + \alpha(1-\alpha)h^{1-\alpha}\left(1-\frac{\tilde{k}_c}{\bar{k}}\right)^{-\alpha}\left(-\frac{1}{\bar{k}}\frac{\partial\tilde{k}_c}{\partial h}\right) \tag{2.12}$$

is positive as

$$h\frac{1}{\bar{k}}\frac{\partial\tilde{k}_c}{\partial h} < \left(1-\frac{\tilde{k}_c}{\bar{k}}\right). \tag{2.13}$$

The effects on wage inequality follow immediately: $\frac{w_M}{w_T^H}$ increases as w_T^H decreases; $\frac{w_M}{w_T^L}$ decreases as w_T^L increases, and $\frac{w_T^H}{w_T^L}$ decreases, as w_T^H decreases and w_T^L increases.

We can summarise these results:

Proposition 6

An increase in the share of high-ability workers, h,

- *increases the share of educated high-ability workers, H_M,*
- *decreases the wage of uneducated high-ability workers, w_T^H,*
- *increases the wage of low-ability workers, w_T^L,*
- *increases top-median wage inequality, $\frac{w_M}{w_T^H}$,*
- *decreases median-bottom wage inequality, $\frac{w_M}{w_T^L}$,*
- *decreases median-bottom wage inequality, $\frac{w_T^H}{w_T^L}$.*

Having established the properties of the laissez-faire equilibrium, we can introduce an exogenous minimum wage.

2.3 Equilibrium with Minimum Wage

There is a minimum wage $\bar{w}$ that applies to low-ability workers, such that $w_T^L < \bar{w} < w_T^H$. Hence, the wage of low-ability workers in the minimum-wage setting, $w_{T,\bar{w}}^L$, is just equal to the minimum wage,

$$w_{T,\bar{w}}^L = \bar{w}. \tag{2.14}$$

Thus, the minimum wage $\bar{w}$ determines the marginal productivity of low-ability workers, which is

$$\bar{w} = \alpha \left(\frac{H_T}{(1-u_L)L} \right)^{1-\alpha} = \alpha \left(\frac{\left(1 - \frac{\tilde{k}_{\bar{w}}}{k}\right) H}{(1-u_L)L} \right)^{1-\alpha}, \tag{2.15}$$

where u_L is the unemployment rate of low-ability workers, and $1 - \frac{\tilde{k}_{\bar{w}}}{k}$ is the share of uneducated high-ability workers in the minimum wage setting. Uneducated high-ability workers earn just their marginal productivity,

$$w_{T,\bar{w}}^H = (1-\alpha) \left(\frac{(1-u_L)L}{\left(1 - \frac{\tilde{k}_{\bar{w}}}{k}\right) H} \right)^{\alpha}. \tag{2.16}$$

Using (2.14) to substitute the unemployment rate, u_L, the wage $w_{T,\bar{w}}^H$ can be rewritten as

$$w_{T,\bar{w}}^H = (1-\alpha) \left(\frac{\alpha}{\bar{w}} \right)^{\frac{\alpha}{1-\alpha}}. \tag{2.17}$$

Thus, the wage of high-ability workers in the traditional production sector decreases with the minimum wage. This results from a decreasing ratio of uneducated high-ability to low-ability workers, which decreases the marginal productivity of uneducated high-ability workers, while it increases the marginal productivity of low-ability workers as a result of the higher minimum wage.

As the minimum wage should be binding for low-ability workers, not for high-ability workers, we need $\bar{w} < w_{T,\bar{w}}^H$ which leads to

Assumption 2

$$\bar{w} < (1-\alpha)^{1-\alpha} \alpha^{\alpha}. \tag{2.18}$$

The wage in the modern technology sector is still given by $w_M = A$. Hence, the threshold education cost at which workers are just indifferent between working with either technology,

$\tilde{k}_{\bar{w}}$, is determined by

$$w_M - \tilde{k}_{\bar{w}} = w^H_{T,\bar{w}} \Leftrightarrow \tilde{k}_{\bar{w}} = A - (1-\alpha)\left(\frac{\alpha}{\bar{w}}\right)^{\frac{\alpha}{1-\alpha}}, \tag{2.19}$$

which is obviously increasing with the minimum wage.[8]

To determine the share of employed low-ability workers, I substitute $\tilde{k}_{\bar{w}}$ from (2.19) into the equilibrium equation for low-ability workers (2.15) and obtain

$$1 - u_L = \underbrace{\frac{H}{L}\left(\frac{\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}}\left(1 - \frac{A-(1-\alpha)\left(\frac{\alpha}{\bar{w}}\right)^{\frac{\alpha}{1-\alpha}}}{\bar{k}}\right)}_{\equiv L^D/L}, \tag{2.21}$$

where L^D is the demand for low-ability workers.

2.3.1 Feasible Range of the Minimum Wage

The lower limit for the minimum wage to be binding, $\bar{w}_{\min}$, is of course the competitive wage, at which the unemployment rate is zero. So, $\bar{w}_{\min}$ is defined implicitly by

$$u_L = 0 \Leftrightarrow 1 = \frac{H}{L}\left(\frac{\alpha}{\bar{w}_{\min}}\right)^{\frac{1}{1-\alpha}}\left(1 - \frac{A-(1-\alpha)\left(\frac{\alpha}{\bar{w}_{\min}}\right)^{\frac{\alpha}{1-\alpha}}}{\bar{k}}\right). \tag{2.22}$$

The upper bound for the minimum wage, $\bar{w}_{\max}$, is determined either by Assumption 2 which ensures that the minimum wage does not apply to high-ability workers, that is $\bar{w} < w^H_T$, or by the restriction that the minimum wage should be low enough that there are still some low-ability workers employed, that is $1 - u_L > 0$. The second restriction coincides with the restriction that there are high-ability workers working with the traditional technology, that is $\tilde{k}_{\bar{w}} < \bar{k}$.

It depends on the parameters which restriction applies. The first one prevails if $A - \bar{k} < \alpha^\alpha(1-\alpha)^{1-\alpha}$, while the second one applies otherwise, such that the upper threshold $\bar{w}_{\max}$ is

$$\bar{w}_{\max} \equiv \begin{cases} \alpha^\alpha(1-\alpha)^{1-\alpha} & \text{if } A - \bar{k} < \alpha^\alpha(1-\alpha)^{1-\alpha} \\ \alpha\left(\frac{1-\alpha}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}} & \text{otherwise} \end{cases}. \tag{2.23}$$

The second case applies only if $A > \bar{k}$, that is, for a sufficiently large state of technology.

[8] To ensure $0 < \tilde{k}_{\bar{w}} < \bar{k}$, a necessary condition is

$$\alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}} < \bar{w} < \alpha\left(\frac{1-\alpha}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}}, \tag{2.20}$$

but this does not determine the relevant range of minimum wages, as will be discussed in detail in Appendix 2.B.1.

2.3.2 Effect of Technical Change

If there is technical progress, the wage in the modern technology sector, w_M, increases. The wages that arise from the traditional technology do not change, as the minimum wage determines the ratio of low-ability to uneducated high-ability workers and hence the marginal productivity of these workers. Consequently, technical change has no effect on wage inequality between uneducated high-ability and low-ability workers, but it increases wage inequality between educated high-ability workers and the other two groups of workers.

Instead of entailing changes in the wages of workers in the traditional technology, $w^L_{T,\bar{w}}$ and $w^H_{T,\bar{w}}$, technical progress changes the shares of low- and high-ability workers working with the traditional technology. As the higher wage from the traditional technology attracts more high-ability workers, the share of educated high-ability workers increases, as follows immediately from (2.19). As this would decrease the marginal productivity of low-ability workers, some of these become unemployed to balance the decline in the number of high-ability workers: It also follows immediately from (2.21), that the unemployment rate u_L increases with A.

Proposition 7

In an equilibrium with a binding minimum wage, an increase in technology, A,

- *increases the wage of educated high-ability workers, w_M,*
- *has no effect on $w^L_{T,\bar{w}}$ and $w^H_{T,\bar{w}}$,*
- *increases top-bottom wage inequality, $\frac{w_M}{\bar{w}}$,*
- *increases top-median wage inequality, $\frac{w_M}{w^H_{T,\bar{w}}}$,*
- *has no effect on median-bottom wage inequality, $\frac{w^H_{T,\bar{w}}}{\bar{w}}$,*
- *increases the share of educated high-ability workers, $\frac{\tilde{k}_{\bar{w}}}{\bar{k}}$,*
- *increases unemployment of low-ability workers, u_L.*

Note that the wage of uneducated high-ability workers does not change, compared to the laissez-faire equilibrium. This implies that the effect of technical change on the share of educated high-ability workers is stronger than in the laissez-faire equilibrium, where the wage of uneducated high-ability workers would increase with a decreasing share of them.

Last, what is the effect on the relative range of minimum wages? As long as $A - \bar{k} < \alpha^\alpha(1-\alpha)^{1-\alpha}$, it is obvious that $\bar{w}_{\max}$ remains constant, and when $A - \bar{k} > \alpha^\alpha(1-\alpha)^{1-\alpha}$, $\bar{w}_{\max}$ decreases. The lower limit $\bar{w}_{\min}$ decreases, as L^D decreases with $\bar{w}$ and also with A.[9]

[9]See Appendix 2.B.2 for a proof.

2.3.3 Effect of a Higher Minimum Wage

As the minimum wage increases, this increases the share $\frac{\tilde{k}_{\bar{w}}}{\bar{k}}$ of high-ability workers who choose education, which is obvious from equation (2.19) above. As the minimum wage pins down the ratio of uneducated high-ability to low-ability workers, the unemployment rate of low-ability workers has to increase. The unemployment rate is actually monotonously increasing in the minimum wage as long as $u_L < 1$.[10]

The increase in the unemployment rate can be decomposed into two effects: A higher minimum wage requires a lower ratio of low-ability to uneducated high-ability workers. This is the compositional effect. As the share of uneducated high-ability workers decreases with a higher minimum wage, the unemployment rate increases even more. Differentiating the unemployment rate, u_L, with respect to the minimum wage, $\bar{w}$, yields

$$\frac{\partial u_L}{\partial \bar{w}} = \overbrace{\frac{H}{L}\frac{1}{\bar{k}}\frac{\left(\frac{\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}}}{(1-\alpha)}\left(\frac{\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}}}^{\text{educational effect}} + \overbrace{\frac{H}{L}\left(1-\frac{\tilde{k}_{\bar{w}}}{\bar{k}}\right)\frac{\alpha^{\frac{1}{1-\alpha}}\bar{w}^{\frac{-2+\alpha}{1-\alpha}}}{1-\alpha}}^{\text{compositional effect}}. \tag{2.24}$$

The effect on wages is an increase, of course, in the wage of low-ability workers, which is given by the minimum wage, and a decrease in the wage of uneducated high-ability workers, given by (2.17). The wage of educated high-ability workers does not change, as it only depends on technology A.

Consider first the relative wage between high-ability workers:

$$\frac{w_M}{w^H_{T,\bar{w}}} = \frac{A}{(1-\alpha)\left(\frac{\alpha}{\bar{w}}\right)^{\frac{\alpha}{1-\alpha}}} \tag{2.25}$$

It is obvious that the relative wage increases with the minimum wage $\bar{w}$, as $w^H_{T,\bar{w}}$ decreases with $\bar{w}$.

Second, the wage of uneducated high-ability workers relative to the wage of employed low-ability workers,

$$\frac{w^H_{T,\bar{w}}}{w^L_{T,\bar{w}}} = \frac{(1-\alpha)\left(\frac{\alpha}{\bar{w}}\right)^{\frac{\alpha}{1-\alpha}}}{\bar{w}}, \tag{2.26}$$

decreases with the minimum wage. This is obvious as $w^H_{T,\bar{w}}$ decreases and $w^L_T = \bar{w}$ increases. This theoretical finding is also in line with Autor et al. (2008), who find for the U.S. that a decreasing minimum wage contributed to increasing wage inequality at the lower tail, that is at the median/bottom-ratio.

Third, the wage of educated high-ability workers relative to the wage of employed low-ability

[10] See Appendix 2.B.2 for a proof.

workers decreases as well with the minimum wage, which is also obvious:

$$\frac{w_M}{w^L_{T,\bar{w}}} = \frac{A}{\bar{w}} \tag{2.27}$$

The relative wage of median wage earners to the poorest workers does not change with the improving technology. However, it changes the overall wage distribution, as the share of workers earning $w^H_{T,\bar{w}}$ shrinks. As the minimum wage pins down the marginal productivity of both low and uneducated high-ability workers, their ratio has to remain constant. Hence, whenever the number of uneducated high-ability workers decreases, the number of employed low-ability workers must decrease as well to keep the ratio of these workers constant. So the unemployment rate increases. This also reshapes the income distribution.

Proposition 8

An increase in the minimum wage, $\tilde{w}$,

- *increase the share of educated high-ability workers, H_M,*
- *increases the unemployment rate of low-ability workers, u_L,*
- *decreases the wage of uneducated high-ability workers, w^L_T,*
- *decreases top-bottom wage inequality, $\frac{w_M}{w^L_{T,\bar{w}}}$*
- *decreases median-bottom wage inequality, $\frac{w^H_{T,\bar{w}}}{w^L_{T,\bar{w}}}$,*
- *increases top-median wage inequality, $\frac{w_M}{w^H_{T,\bar{w}}}$,*

2.3.4 Effect of Workforce Composition

If $h = \frac{H}{L}$ increases, there are no effects on wages, as these are either determined by technology A or by the minimum wage $\bar{w}$. Also, there is no effect on the share $\frac{\tilde{k}_{\bar{w}}}{k}$ of uneducated high-ability workers, as it is only determined by wages.

The only effect of a higher h is a lower unemployment rate u_L, as the ratio of uneducated high-ability to low-ability workers in the traditional sector increases. This raises the share of employed low-ability workers to readjust the marginal productivity of these back to the level given by the minimum wage.

2.4 Setting the Minimum Wage

As discussed in the Introduction, minimum wages are rarely decisive for the voting behaviour of individuals (Waltman, 2000). So, using a politico-economic approach that connects political decisions to voting behaviour, e.g. to majority voting, might overstate the relevance of minimum wages for elections, and vice versa. Instead, I represent the political decision by an objective function of the government.

The government has a quadratic loss function with two components: the total unemployment rate Lu_L and wage inequality between the top earners and the workers receiving the lowest wage, that is $\frac{A}{\bar{w}}$. Opposition to unemployment should be without discussion, and wage inequality is another topic in the political discussion, see e.g. OECD (2011a). For wage inequality, I take the wage of educated high-ability workers relative to the wage of low-ability workers. This is most closely related to the income gap between rich and poor.

The government takes into account all equilibrium effects of the minimum wage, and its objective function is

$$\max_{\bar{w}} -\gamma \left(Lu_L(\bar{w}) \right)^2 - (1-\gamma) \left(\frac{A}{\bar{w}} \right)^2 , \tag{2.28}$$

where $0 < \gamma < 1$ is the weight for the total unemployment rate $Lu_L(\bar{w})$, and where $u_L(\bar{w})$ is given by equation (2.21). So, the maximisation problem writes

$$\max_{\bar{w}} -\gamma L^2 \left(1 - \frac{H}{L} \left(\frac{\alpha}{\bar{w}} \right)^{\frac{1}{1-\alpha}} \left(1 - \frac{A - (1-\alpha)\left(\frac{\alpha}{\bar{w}} \right)^{\frac{\alpha}{1-\alpha}}}{\bar{k}} \right) \right)^2 - (1-\gamma) \left(\frac{A}{\bar{w}} \right)^2 . \tag{2.29}$$

The first order condition is

$$\gamma u_L(\bar{w}) L^2 \left(\frac{\partial u_L}{\partial \bar{w}} \right) \stackrel{!}{=} (1-\gamma) \frac{A^2}{\bar{w}^3} \tag{2.30}$$

and implies that the marginal loss from the increase in unemployment is equated with the marginal gain from the decrease in wage inequality.

The effect of a change in A on the government's decision about the minimum wage is analytically intractable. To get a reliable answer, I calibrate the model. I compute statistical counterparts for the shares of workers H_M, H_T, and L, the unemployment rate u_L, and the nominal wages w_M^*, w_T^{H*}, $w_T^{L*} = \bar{w}^*$ for five years, where the star denotes nominal values. Then I take the averages of the yearly values, and solve for the model's parameters, that is the elasticity of production with respect to low-ability workers α, the upper bound of education costs $\bar{k}$, and the political preference parameter γ. The derivation of the parameters α, $\bar{k}$, and γ is explained in Appendix 2.C. I keep the parameters α, $\bar{k}$, and γ fixed during the calibration. Varying $A = w_M$ and L, I solve for the optimal minimum wage.

In my analysis, I focus on the 1980s, as the real wage of the least skilled workers declined significantly only in this period, while it did not change much afterwards. This indicates that the hypothesized pressure on the labour market of the least skilled, resulting from technical change, was most intense during the 1980s, but less so afterwards.

To compute the statistical counterparts, I use data from the years 1979-1983, as the minimum wage started to decline in this period. For the minimum wage and the consumer price index, I use data from the OECD, and for all other variables, I use population data from the U.S. March CPS 1980-1984, compiled by IPUMS International (King et al., 2010).[11] A detailed description

[11]The CPS collects data for the previous calendar year, such that, e.g., the CPS 1980 contains data about

of the construction of the statistical counterparts from the U.S. CPS is in Appendix 2.D.

For the population data, I consider males and females aged 24 to 65 who belong to the active labour force, except for the armed forces.[12] According to the model, I divide the remaining sample into three groups. For the share of educated high ability workers H_M, I take the share of full-year fully-employed college graduates. For the share of uneducated high-ability workers H_T, I take full-year fully-employed high-school finishers without college degree. I only take full-year fully-employed workers as I assume that there is no unemployment in these groups of workers. Fully employed workers are those who work at least 40 hours per week.

For the share of low-ability workers L, I take all fully-employed workers who did not finish secondary school.[13] As I assume unemployment in this group of workers, I also include those individuals who are not full-year employed. I compute the unemployment rate of low-ability workers as the average share of the year that each individual was unemployed.

To compute wages, I consider only wage and salary income and compute the hourly wage by dividing the annual wage by weeks worked and hours worked per week.[14] I deflate nominal wages to 1979 values using the CPI from the OECD (2011b).

Input statistics		
Target	Symbol	Value
Average wage of college graduates	w_M^*	\$9.143
Average wage of workers with at most secondary education	w_T^{H*}	\$6.700
Minimum wage	$\bar{w}^*$	\$2.800
Share of workers with at most primary education	L	0.231
Share of fully employed workers with high school graduation	H_T	0.525
Share of fully employed workers with college degree	H_M	0.244
Unemployment rate of workers with less than secondary education	u_L	0.163
Computed parameters		
Elasticity of traditional production w.r.t. low ability workers	α	0.134
Upper bound of education costs	$\bar{k}$	0.870
Government's weight of unemployment rate	γ	0.999

Notes: Determination of the model's parameters using statistics from the OECD (minimum wage) and from the U.S. CPS 1980-1984 (all others).

Table 2.1. Calibration of the model

Table 2.1 shows the statistical counterparts that I use as input and the computed parameters of the model.[15] Figure 2.4 depicts the statistical counterparts of the model's parameters for a period of ten years from the U.S. CPS 1980-1989 in five-year moving averages. The average wage of college graduates proxies the technology parameter A, and the share of high-school drop-outs proxies the share of low-ability workers L. There is clearly an increase in the average

income and work for 1979.

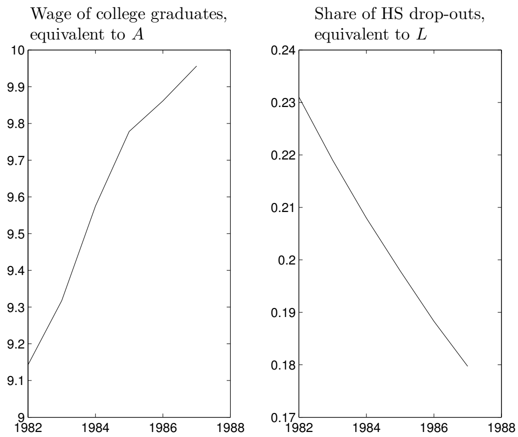
[12] Workers are distinguished as being employed, unemployed, or not in the labour force, and I drop all individuals not in the labour force. The corresponding question in the census refers to the last week before the interview.

[13] Duffy et al. (2004) find evidence for a very low threshold for skilled workers that is just above primary school.

[14] Self-employment income also contains negative values, which are losses. Also, self-employment income is not subject to minimum wages.

[15] Although the value of γ might at first sight put little weight on wage inequality, one should keep in mind that the unemployment rate is below one, while the measure of wage inequality is not restricted to this value. The high value of γ sort of corrects for these imbalances.

wage of college graduates, which motivates to simulate an increase in the technology parameter A. The share of high-school drop-outs steadily declined in this period. I therefore consider a decline in the share of low-ability workers L.



Notes: 5-year moving averages of statistical counterparts of the model's variables A and L from the U.S. CPS 1980-1989. Years give CPS years. Wages in 1979 values, adjusted by CPI.

Figure 2.4. Average wage of college graduates and share of high-school drop-outs.

Given the model's parameters α, γ, and $\bar{k}$, I change the value of technology A, which is equal to the wage of educated high-ability workers, and I change the share of unskilled workers L. Therefore, I take the five-year averages from CPS 1983-1987 as input, as this is the period that is the most distant period from the base period CPS 1980-1984 for which the parameter restrictions of the model still hold. Given these input values, I calculate the minimum wage set by the government. Table 2.2 shows the simulation results. For comparability, I also state the model's outcomes for an exogenous minimum wage. Note that in this case the wage of uneducated high-ability workers, w_T^H, does not change, as it is determined by the constant minimum wage $\bar{w}$.

Symbol	**Data averages**		**Simulation for 1983-1987 averages**				
	1980-1984	1983-1987					
$w_M = A$	\$9.143	\$9.778	Endog. MW			Exog. MW	
L	0.231	0.198	$A\uparrow$	$L\downarrow$	$A\uparrow, L\downarrow$	$A\uparrow$	$L\downarrow$
$\bar{w}$	\$2.800	\$2.589	\$2.669	\$3.174	\$3.032	-	-
$w_{T,\bar{w}}^H$	\$6.700	\$6.888	\$6.750	\$6.572	\$6.619	-	-
u_L	0.163	0.177	0.214	0.175	0.230	0.264	0.022
$L \cdot u_L$	0.038	0.035	0.049	0.035	0.046	0.061	0.004
H_M	0.244	0.265	0.303	0.268	0.330	0.308	0.255
H_M/H	0.318	0.331	0.394	0.334	0.411	0.400	0.318

Notes: The simulation takes the parameters from Table 2.1 as given, computed for the baseline period 1980-1984. It computes the minimum wage that is set by the government and other relevant variables, changing either A or L or both to their respective values for 1983-1987. Years refer to U.S. CPS years.

Table 2.2. Simulation of the minimum wage decision.

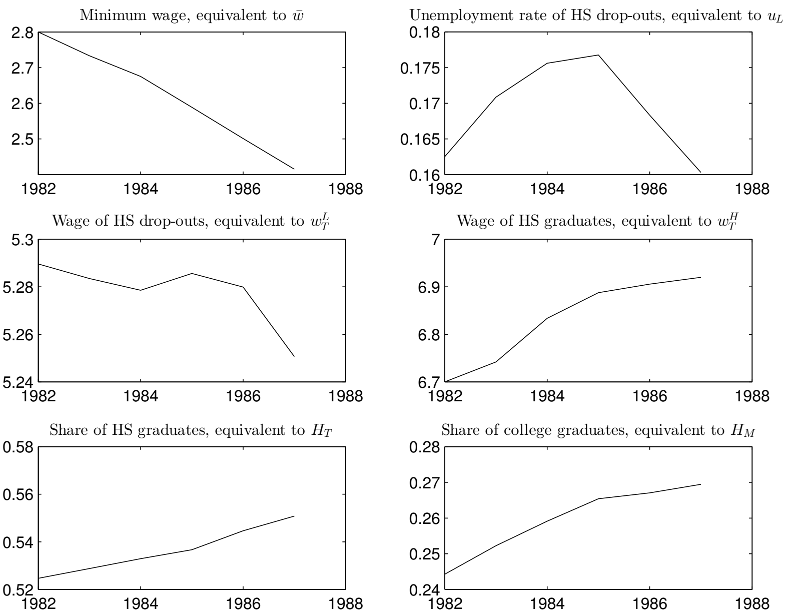
An increase in A leads, ceteris paribus, to a higher unemployment rate among low-ability workers and to higher wage inequality. Endogenising the minimum wage, the government chooses to lower the minimum wage. Therefore, the increase in the unemployment rate is less excessive, but wage inequality even increases. The share of educated high-ability workers still increases, but less than in the case of an exogenous minimum wage. The lower minimum wage leads to a higher wage of uneducated high-ability workers.

A decrease in L leads, ceteris paribus, to a lower unemployment rate. By consequence, the government increases the minimum wage to reduce wage inequality and increase the unemployment rate again to achieve equality in equation (2.30). In this case, it is interesting to note that the unemployment rate u_L increases compared to the baseline calibration. The government focuses instead on the total unemployment rate $L \cdot u_L$, which decreases. Therefore, the government is able to decreases both the unemployment rate and wage inequality. The higher minimum wage also decreases the wage of uneducated high-ability workers.

Changing both A and L to the CPS 1983-1987 values, the decline in L dominates the decision and the government sets a higher minimum wage, which is at odds with the data. The higher minimum wage results in a decline in the wage of uneducated high-ability workers, in an increase in the unemployment rate of low-ability workers, and in an increase in the share of educated high-ability workers.

2.5 Discussion

Given the predictions of this model, what can it explain and where does it fail? Figure 2.5 depicts the development of the statistical counterparts of the model's endogenous variables.



Notes: 5-year moving averages of statistical counterparts of the model's endogenous variables from the U.S. CPS 1980-1989. Wages in 1979 values, adjusted by CPI.

Figure 2.5. Wages, unemployment rate and shares of workers.

Let us first consider the model in the laissez-faire equilibrium. The CPS data reveal a decline in the share of high-school drop-outs and an increase in the share of high-school graduates without a college degree. If the model was correct, we would observe an increase in the wage of high-school drop-outs, w_T^L, and a fall in the wage of high-school graduates, w_T^H. Yet the opposite is the case. The wage of high-school drop-outs declined slightly, while the wage of high-school graduates increased. Thus, this fact does not support the view that both types of workers are q-complements in a joint production function.

Also, viewing all high-school graduates as a homogeneous group of workers is questionable. Instead, if these workers have very differentiated skills, it would be possible to view them as complements in the production function, such that adding an additional worker with a new skill increases the productivity of all other workers. This might explain better the increase in the wage of high-school graduates, yet it still does not explain the decline in the wage of high-school drop-outs.

In the equilibrium with a minimum wage, the model predicts an increase in the unemployment rate of low-ability workers, u_L, in case of an increase in the technology parameter A, ceteris paribus. Yet also the share of high-school drop-outs declined as well as the minimum wage. Both a decrease in the share of low-ability workers, L, and a decrease in the minimum wage reduce the unemployment rate of low-ability workers. The long-term effect on the unemployment rate is unclear. The data show an up-and-down of the unemployment rate of high-school drop-outs. Thus, it is not necessarily at odds with the data to associate increased technical progress with a higher unemployment rate among the lowest skilled workers. Yet the detailed mechanisms are not clear.

Thus, the failure of the model to predict correctly the changes in the minimum wage is one thing, but the failure to predict correctly market wages is even more important. Thus, for future research it would be promising to reconsider the production functions and the complementarity and substitutability of the production factors to get a better understanding of the changes in real wages, as well as the allocation of factors to different sectors.

2.6 Conclusion

I set up a simple partial-equilibrium model of routine-biased technical change, similar to a simple model by Acemoglu (2002). My model features heterogeneous workers with three skill levels. Education, which is necessary to move from medium to high skill levels, is endogenous. This reflects the increasing complexity of occupations which require skill upgrading (Spitz-Oener, 2006).

In the laissez-faire equilibrium without a minimum wage, technical progress leads to diverging real wages, in particular to decreasing real wages of the least skilled workers, and to increasing real wages of medium- and high-skilled workers. Technical progress also increases the share of high-skilled workers. This results from a reallocation of high-ability workers to a modern production technology, where the work previously done by low-ability workers is now done by machines. Thus, less high-ability workers work with low-ability workers, whose marginal productivity declines in consequence.

In the equilibrium with a minimum wage, there are important lessons to be learned from this model. Technical progress also leads to more education, that is a higher share of high-skilled workers. The effect is stronger than in the laissez-faire equilibrium. But technical progress also leads to more unemployment among low-ability workers, as high-ability workers replace them by machines. The government opposes both unemployment and wage inequality. I calibrate the model to U.S. data. As technology improves, the government lowers the minimum wage. It thus gives up wage inequality for more employment among low-ability workers. As also the share of high-school drop-outs decreased, I also analysed the change in the minimum wage resulting from a lower share of low-ability workers. In this case, the government sets a higher minimum wage. Simulating the government's decision by taking into account the changes in both variables for both variables, the model predicts an increase in the minimum wage, which is at odds with the U.S. data.

For future research, several modifications and extensions are interesting. The source of the increased pressure on the labour market of low-ability workers does not seem to stem from changed input shares of workers with different education levels. Therefore, we need to understand better the decrease in the demand for the lowest-skilled workers. Instead of viewing production factors as complements, it might make more sense to focus on the allocation of production factors to different sector. This has so far been treated as exogenous in the literature, see e.g. Autor and Dorn (2013). Yet an endogenous explanation is missing. A model with workers being heterogeneous along a continuous dimension would allow for a continuous distribution of wages. Also, the wages of workers who work with the traditional technology depend solely on the ratio of uneducated high-ability to low-ability workers. It would be appealing to have a general equilibrium framework with different sectors, such that changes in real wages can also be attributed to changes in demand, as the relative price of high-tech consumptions goods decreases with technical progress. The literature also still lacks a task-based theory in which not all production factors are complements, but some are also substitutes, or a task-based theory with multiple sectors that explains not only the allocation of factors to tasks, but also to sectors, such that the effects we observe do not depend on arbitrary assumptions about the production functions.

Appendix to Chapter 2

2.A Appendix for Laissez-faire Equilibrium

2.A.1 Change in Wage Inequality Between High-Ability Workers

The derivative of the relative wage $\frac{w_M}{w_T^H}$ with respect to A is

$$\frac{\partial \frac{w_M}{w_T^H}}{\partial A} = \frac{1 - A\alpha \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right) \frac{1}{\bar{k}} \frac{\partial \tilde{k}_c}{\partial A}}{(1-\alpha)\left(\frac{L}{H}\right)^{\alpha} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right)^{\alpha}}. \tag{2.A-1}$$

As the denominator is positive, the sign depends only on the numerator. It is positive if

$$1 > A\alpha \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right) \frac{1}{\bar{k}} \frac{\partial \tilde{k}_c}{\partial A}, \tag{2.A-2}$$

and using (2.6)

$$1 > A\alpha \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right) \frac{1}{\bar{k}} \frac{1}{1+\alpha(1-\alpha)\left(\frac{L}{H}\right)^{\alpha} \frac{1}{\bar{k}} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right)^{1+\alpha}}, \tag{2.A-3}$$

which can be rewritten[16] as

$$1 > \alpha \frac{1}{\bar{k}} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right) \left[A - (1-\alpha)\left(\frac{L}{H}\right)^{\alpha} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right)^{\alpha}\right]. \tag{2.A-4}$$

Since the term in brackets is equal to $\tilde{k}_c$ from equation (2.5), wage inequality increases if and only if

$$1 > \alpha \frac{\tilde{k}_c}{\bar{k}} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right) \Leftrightarrow \frac{\bar{k}}{1+\alpha} > \tilde{k}_c \tag{2.A-5}$$

and decreases otherwise.

[16] Multiply by $1+\alpha(1-\alpha)\left(\frac{L}{H}\right)^{\alpha} \frac{1}{\bar{k}} \left(\frac{1}{1-\frac{\tilde{k}_c}{\bar{k}}}\right)^{1+\alpha}$ and rearrange.

2.B Appendix for Equilibrium With Minimum Wage

2.B.1 Consistency of Technical Assumptions

There are several restrictions on the minimum wage:

1. $\bar{w} < (1-\alpha)^{1-\alpha}\alpha^{\alpha}$ such that the minimum wage is not binding for high ability workers ($\bar{w} < w^H_{T,\bar{w}}$),
2. $\bar{w} < \alpha\left(\frac{1-\alpha}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}}$ such that the unemployment rate is lower than 1 ($\tilde{k}_{\bar{w}} < \bar{k}$ or $u_L < 1$),
3. $1 > \frac{H}{L}\left(\frac{\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}}\left(1 - \frac{A-(1-\alpha)\left(\frac{\alpha}{\bar{w}}\right)^{\frac{\alpha}{1-\alpha}}}{\bar{k}}\right)$ such that the unemployment rate is positive ($u_L > 0$),
4. $\bar{w} > \alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}}$ for $\tilde{k}_{\bar{w}} > 0$.

- The first and the fourth assumption are consistent, as long as

$$(1-\alpha)^{1-\alpha}\alpha^{\alpha} < A, \tag{2.B-1}$$

  which is derived from rearranging

$$\alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}} < (1-\alpha)^{1-\alpha}\alpha^{\alpha}. \tag{2.B-2}$$

- The first and the second give upper bounds for the feasible range of minimum wages. It depends on the state of technology, A, whether the first or the second is more restrictive. The highest value of the minimum wage that is feasible, i.e. at which $u_L = 1$, decreases with the state of technology and will just be equal to the value at which $\bar{w} = w^H_T$ if

$$A = \bar{k} + (1-\alpha)^{1-\alpha}\alpha^{\alpha}. \tag{2.B-3}$$

  So, the upper limit is given by $(1-\alpha)^{1-\alpha}\alpha^{\alpha}$ if $A < \bar{k} + (1-\alpha)^{1-\alpha}\alpha^{\alpha}$, and it is given by $\alpha\left(\frac{1-\alpha}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}}$ otherwise.

- The third and the fourth state lower bounds for the minimum wage. The third is actually the competitive wage w^L_T, and it is possible to show that it is more restrictive than the forth. If the fourth were more binding than the competitive wage, it would then be that $u_L > 0$. I show by contradiction that this is not possible: Assume that the minimum wage is just equal to $\bar{w} = \alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}}$. Since this is derived from the restriction that $\tilde{k}_{\bar{w}} = 0$, this implies that all high ability workers work in the service sector, since the wage in the tech sector and in the service sector are just the same. Plugging this wage in the right hand side of assumption three, which gives the demand for low ability workers, we get, if we assume $u_L > 0$,

$$\frac{L}{H} > \left(\frac{A}{1-\alpha}\right)^{\frac{1}{\alpha}} \tag{2.B-4}$$

which can be rewritten as

$$\left(\frac{L}{H}\right)^{\alpha}(1-\alpha) > A. \tag{2.B-5}$$

This is obviously at odds with the assumption that $A > (1-\alpha)\left(\frac{L}{H}\right)^{\alpha}$ which is necessary for $\tilde{k}_c > 0$ in the competitive case. So, the assumption that $u_L > 0$ at $\bar{w} = \alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}}$ is wrong, and it must be that $u_L < 0$ if $\bar{w}$ is just equal to $\alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}}$. Since at the competitive wage, we have $u_L = 0$, and since the unemployment rate is increasing in $\bar{w}$, the competitive wage is more restrictive than the minimum wage which is needed for $\tilde{k}_{\bar{w}} = 0$.

- The second and the fourth are consistent, as $\alpha\left(\frac{1-\alpha}{A}\right)^{\frac{1-\alpha}{\alpha}} < \alpha\left(\frac{1-\alpha}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}}$.

2.B.2 Effect of Minimum Wage on Unemployment Rate

The unemployment rate (2.21) increases with the minimum wage $\bar{w}$ if L^D on the right hand side of (2.21) decreases with $\bar{w}$. This is true if

$$\bar{w} < \alpha\left(\frac{(1-\alpha)(1+\alpha)}{A-\bar{k}}\right)^{\frac{1-\alpha}{\alpha}} \tag{2.B-6}$$

Since $(1+\alpha)^{\frac{1-\alpha}{\alpha}} > 1$, the value of $\bar{w}$ at which the sign of the derivative changes is larger than the upper limit of the minimum wage $\bar{w}_{\max}$ defined by (2.23). So for the range of minimum wages that we consider here, the unemployment rate increases monotonously with the minimum wage.

2.C Solving the Model for the Calibration

The value of the parameter L is set equal to the target. To compute the parameter α, I divide equation (2.15) by equation (2.17). Taking relative wages circumvents the fact that the wages from the data are initially in nominal terms. In the resulting equation and by using $H_T = \left(1 - \frac{\tilde{k}_{\bar{w}}}{\bar{k}}\right) H$, I can take H_T, L, u_L, and $\frac{\bar{w}^*}{w^{H*}_{T,\bar{w}}}$ from the data and solve for α. Given α and taking the values for H_T, L, and u_L from the data, I can compute the real wages $\bar{w}$ and $w^H_{T,\bar{w}}$ using equations (2.15) and (2.17), and subsequently the price of the numeraire by dividing the nominal wage from the data by the computed real wage, that is $p = \frac{w^{H*}_{T,\bar{w}}}{w^H_{T,\bar{w}}}$. Next, I compute the real wage of educated high ability workers, $w_M = \frac{w^*_M}{p}$. Having w_M and $w^H_{T,\bar{w}}$, I compute the threshold education cost, $\tilde{k}_{\bar{w}}$, using equation (2.19). Then, I use $H_T = \left(1 - \frac{\tilde{k}_{\bar{w}}}{\bar{k}}\right) H$ to solve for $\bar{k}$. Finally, to compute the policy parameter γ, I solve the government's first order condition (2.30) for γ.

2.D Calibration Details

	CPS Variable	
	Name	Values
Sample selection		
CPS years	Year	$[1980, 1984]$
Age	Age	$[24, 65]$
Age	Age	$[24, 65]$
Employment status	Empstat	$[10, 29]$
Skill groups		
Low-ability workers		
Education level	Educ	≤ 71
Weeks worked per year	Wkswork1	$\in [0, 52]$
Hours worked per week	Uhrswork	$= 0$ or ≥ 40
Uneducated high-ability workers		
Education level	Educ	$[72, 100]$
Weeks worked per year	Wkswork1	$= 52$
Hours worked per week	Uhrswork	≥ 40
Educated high-ability workers		
Education level	Educ	≥ 110
Weeks worked per year	Wkswork1	$= 52$
Hours worked per week	Uhrswork	≥ 40
Other variables used		
Wage income	Incwage	all values

Table 2.D.1. Sample selection from U.S. CPS for the model's statistical counterparts

The unemployment rate u_L is calculated as

$$u_L = \frac{\sum_i \frac{52 - Wkswork1_i}{52} \mathbb{1}_{\leq 71}(Educ_i)}{\sum_i \mathbb{1}_{\leq 71}(Educ_i)}, \tag{2.D-1}$$

where the subscript i denotes an observation in the CPS.

References Chapter 2

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Chapter 3

Diametric Effects of Competition and Rents on Collective Bargaining – Evidence from Germany

3.1 Introduction

While some firms bargain with each worker individually about the wage, other firms bargain with all workers collectively. In Germany, more than two thirds of all firms bargain with workers individually, while more than a quarter of firms bargains collectively at the sectoral level, and only a small share bargains with workers collectively at the firm level (Table 3.1). In most other industrialised countries, sector-level bargaining prevails, but firm-level bargaining is gaining importance (Du Caju et al., 2009). Yet we do not understand very well why firms prefer one type of bargaining to the other. Recently, the theoretical literature has considered less product market competition as being favourable for collective bargaining (Ebell and Haefke, 2006; Boeri and Burda, 2009). Using German establishment data, I show that less competition is detrimental to collective bargaining, but in a non-linear way.

		Collective agreement	
	Individual level	Firm level	Sector level
Establishments (in %)	70	2	28
Employees (in %)	44	8	48

Table 3.1. Establishment and employee coverage of individual or collective wage agreements.

Notes: Data are weighted by sampling weights. (See Section 3.4 for more information.)
Source: IAB Establishment Panel, Wave 2012.

Theory predicts that collective bargaining is more likely under low competition: A firm with market power earns higher rents, and unions try to extract a share of these rents (Ebell and Haefke, 2006). I show that the data do not support this channel. Instead, competition has a u-shaped effect on collective bargaining coverage. The effect is stronger for sector-level than for firm-level collective bargaining. By contrast, firms with higher rents are more likely to opt for collective bargaining. This result is striking as it supports the rent-sharing hypothesis, but it runs against the idea that competition is the channel that drives this effect. Instead, the results emphasise that competition entails a different channel that has so far been neglected by the economic literature. Also, this challenges the empirical literature that has so far used rents as an indicator of competition (Nickell, 1996; Nickell et al., 1997). If rents were a good indicator of competition, we would observe effects in the same direction. We do not.

To shed further light on firm heterogeneity, I also control for the export share and the share of workers with higher education, as both are correlated with higher productivity (Bernard and Jensen, 1999; Delgado et al., 2002; Wagner, 2007; Haltiwanger et al., 1999). Both variables drive firms away from sector-level bargaining towards individual wage setting. Interestingly, the effect on firm-level collective bargaining is mixed: While a higher export share makes firm-level wage setting less likely, a higher share of workers with higher education makes firm-level wage setting more likely. This emphasises how firm-level and sector-level bargaining are structurally different and should be treated as such in the economic literature.

3.1.1 Main Contributions

Using a German cross-section of establishments, I run a multinomial analysis to explain whether establishments bargain with workers individually or collectively at the firm level or at the sectoral level.

The first main contribution is that I consider four different intensities of product market competition separately from a measure of rents. The measure of competition intensity is a subjective rating by the establishment management, ranging from high to no competition. By contrast, the measure of rents is an objective measure of rent per employee, defined as revenue minus wage and material costs (see Section 3.4 for more details). This way, I have both a widely used specific measure of competition – rents – as well as a very broad measure of competition. The latter measure allows not only richer insights than in previous studies which used only an indicator of high or low competition, but the two measures also allow to disentangle the rent of a firm and the degree of competition. Also, the effect of economic turbulence has not been investigated to date. I show that it matters. The share of high-skilled workers has so far been applied in unclear definitions. Using my definition of workers with higher education, I find different or stronger effects than in the existing literature.

The second main contribution is that I distinguish between collective bargaining at the sectoral level and at the firm level. I can show that some of the factors mentioned above are irrelevant for one alternative, but important for the other alternative.

Third, besides an analysis for all establishments in Germany, I also analyse differences between West and East Germany. Using for the first time a multinomial analysis for this question also contributes to this literature. Things work a little bit differently in East Germany: The relationship between product market competition and the probability of sector-level bargaining is only slightly u-shaped, but there is no clear relationship to firm-level or individual bargaining. Economic turbulence does not play a role, but the share of high-skilled workers has a strong positive effect on sector-level and firm-level bargaining.

Fourth, I consider that some establishments apply collective agreements involuntarily, as the German government can declare collective agreements to be binding for all firms in an industry and region. I identify establishments for which this is the case and exclude these from the estimation sample. This issue has also not been considered in the existing empirical literature.

3.1.2 Related Empirical Literature

The empirical literature to which I contribute consists of studies that connect the level of wage bargaining to firm characteristics, mainly the studies by Lehmann (2002); Kohaut and Schnabel (2003); Schnabel et al. (2006); Zagelmeyer (2007); Addison et al. (2013); Hirsch et al. (2014). The focus of these papers is mainly the *decline* in collective bargaining coverage that is observed in Britain and Germany. These papers neither use such rich information on product market competition as I use nor do they use rents. Also, there is no consensus on the effects of the share of skilled workers.

Methodologically, the study closest to mine was written by Lehmann (2002). She distinguishes between individual, firm-level, and sector-level bargaining and also uses a multinomial approach, but controls for other independent variables than I do.

Since then, the multinomial approach has not been used again. Assuming an increasing degree of centralisation from individual over firm-level to sector-level bargaining, Kohaut and Schnabel (2003) and Schnabel et al. (2006) estimate an ordered probit model with German and British firm data, basically using the same explanatory variables as the previous study. First, an ordered probit model restricts the explanatory variables to monotonically in- or decrease the assumed degree of centralisation. Second, the ordered probit estimator is only efficient if the assumptions underlying this estimator are true (Cameron and Trivedi, 2010, p. 529). As the type of wage agreement does not have a natural order, an ordered approach might be inefficient.

The effect of product market competition has only very roughly been investigated by Zagelmeyer (2007), but he does not find robust results comparing only firm-level with sector-level bargaining with British firm data. He includes a dummy for low competition, which is only significant in one out of five cross-sections. He also does not consider firms with individual wage setting, which is in my main interest. Addison et al. (2013) also include a dummy for high competition to explain why firms switched the type of wage agreement between 1998 and 2004, but this is an entirely different question.

The share of high-skilled workers has been included by Lehmann (2002). She finds positive coefficients for firm-level bargaining, such that probably[1] a higher share of high-skilled workers

[1] She does not report marginal effects, but only coefficients.

increases the probability of firm-level bargaining. There is no effect on the probability of sector-level bargaining. She has also not controlled for the share of workers with higher education in a multinomial analysis. Schnabel et al. (2006) include the share of low skilled workers. By contrast to the results by Lehmann, they find statistically significant, but economically insignificant effects for all bargaining levels (an increase in the share of high skilled workers by 10 percentage points increases the probability of sector-level bargaining by 0.005 percentage points). Addison et al. (2013) find that the share of high skilled workers increases the probability of sector-level bargaining, but not of firm-level bargaining, and Hirsch et al. (2014) find a positive, but very small effect on the probability of sector-level bargaining. Thus, there is no robust result in the literature.

The role of exports has recently received increased attention in the empirical literature. Using French firm data, Carluccio et al. (2014) find that exports increase the probability of firm-level agreements, but have little effect on sector-level agreements. By contrast, Capuano et al. (2014) use German establishment data from the manufacturing sector and find that being an exporter decreases the probability of collective bargaining.

I contribute to this literature by using richer data on product market competition together with a measure of ex-post rents and also by including an indicator of idiosyncratic shocks. I apply these new aspects in a multinomial logit regression model to focus on the differences between different types of collective bargaining, on which the existing literature put little weight.

3.2 Theoretical Background

3.2.1 Effect of Collective Bargaining on Economic Outcomes

There is a large and growing literature that studies the effects of collective wage bargaining on economic outcomes. For this question, a particularly active field of research is the search-and-matching theory, as wage bargaining is an essential building block of most of the literature.[2] A first strand of the literature discusses the effects of collective bargaining on unemployment levels. Delacroix (2006) focuses on bargaining coverage and on coordination between unions. He finds substantial effects on the unemployment rate: Less bargaining coverage decreases unemployment, and more coordination between unions also decreases unemployment. As already mentioned, this is supported by evidence that higher union coverage or higher union bargaining power decreases employment (Fiori et al., 2012). Jimeno and Thomas (2013) compare firm-level and sector-level bargaining. Under firm-level bargaining, unemployment is lower. Taschereau-Dumouchel (2014) compares exogenous individual or collective bargaining to endogenous collective bargaining coverage. He emphasises that the pure threat of collective bargaining has substantial effects on unemployment.

[2] Another mechanism of wage formation in the search-and-matching literature is wage posting, see Hall and Krueger (2012) for evidence about wage posting and wage bargaining in the U.S. Wage posting complements collective bargaining, as collective agreements define pay scales for a variety of jobs and qualifications, and the firm offers a wage according to the pay scale to newly hired workers.

A second strand of the literature considers efficiency aspects. Bauer and Lingens (2014) argue that collective bargaining can restore efficiency if firms would otherwise over-hire, given that they face concave production functions (Stole and Zwiebel, 1996), as collective bargaining reduces hiring. Cai et al. (2014) consider the trade-off between the efficient allocation of heterogeneous workers to heterogeneous jobs and the business-stealing externality (Gautier et al., 2010). The externality occurs under job-to-job transitions, as workers who switch employers create an output loss for the firm that they leave. The benefit from the job transition is that the worker is better allocated and earns more. Collective bargaining can internalise the business-stealing externality, but it lowers the efficient allocation of workers to jobs. Krusell and Rudanko (2013) analyse the relationship between collective bargaining and firm-specific investments. If the labour union pursues an egalitarian wage policy, hiring is inefficiently low. Introducing a tenure premium allows the union to extract rents, but also to increase hiring to the efficient level. Efficient unemployment levels can also be obtained if the labour union can commit to future wages.

3.2.2 What Might Explain the Bargaining Level?

In the aforementioned literature, collective bargaining is exogenous, apart from the paper by Taschereau-Dumouchel (2014). But firms or workers can actually choose between collective and individual wage bargaining, depending on a country's legislation. So, which aspects drive firms into individual or collective wage setting?

Ebell and Haefke (2006) argue that the bargaining level depends on *product market competition*, as rents and hiring costs vary with product market competition.[3] If product market competition is low, price-markup and therefore rents are high, and the union can extract a high share of rents by collective bargaining. By contrast, rents from individual bargaining are higher under perfect competition, as hiring costs increase – higher competition leads to more output, more jobs, and hence more vacancies compared to unemployed workers. It is therefore harder for the firm to fill a vacancy, and the worker can extract a higher rent. The model predicts that under low competition, collective wage bargaining is a Nash equilibrium, while under high competition, both levels of wage bargaining are Nash equilibria.[4]

The result by Ebell and Haefke (2006) is also supported by Boeri and Burda (2009), who allow for the coexistence of individual and collective bargaining, depending on the skill level of workers. Higher costs for vacancy posting, which they interpret as costs for market entry that lead to less competition, increase union support. Taschereau-Dumouchel (2014) also predicts

[3]The role of product market competition had already been emphasised, though not in a search-and-matching framework, by Danthine and Hunt (1994), who state that the hump-shaped relationship between centralisation of wage bargaining and economic performance (Calmfors and Driffill, 1988) flattens with increasing competition. Abowd and Lemieux (1993) show that product market competition has a strong effect on collective bargaining agreements, and Dobbelaere et al. (2014) use micro data to establish links between product and labour market regulation. Boulhol et al. (2011) show that international competition decreases workers' bargaining power.

[4]In this model, the bargaining power of workers is constant. This can be questioned as there is evidence by Boulhol et al. (2011) that increasing product market competition decreases worker's bargaining power, such that the price-cost margin remains relatively stable over time.

that more productive firms are more likely to be unionised, as unions can get a higher surplus.

While the aforementioned authors have not considered differences between sector-level and firm-level bargaining, Gürtzgen (2009) finds evidence of rent-sharing only in case of firm-level bargaining, but not in case of sector-level bargaining. This emphasises that it is necessary not only to distinguish between firm-level and sector-level bargaining, but also to inspect the driving forces of collective bargaining in more detail. Firms that differ in the intensity of competition that they face do not only differ with respect to price mark-ups, but also along other dimensions. E.g., the goods that they produce are more heterogeneous across firms and less substitutable by products of other firms. The more products are heterogeneous across firms, the more is the input mix different across firms, and the lower is competition on the labour market. So, instead of focusing on a particular channel such as rent-sharing or workforce composition, I focus on the broad category of competition intensity.

Besides product market competition, the worker's *skill level* might also affect the bargaining power and hence preferences for individual or collective bargaining. In the paper by Boeri and Burda (2009), a firm with high-skilled workers prefers collective bargaining, while all workers prefer individual wage bargaining. Hence, collective bargaining fails and individual bargaining prevails for higher skill levels.

Boeri and Burda also analyse changes in economic *turbulence* (Ljungqvist and Sargent, 1998, 2004), modelled as different rates of idiosyncratic productivity shocks for firm-worker matches. It is unclear whether higher turbulence decreases or increases collective bargaining coverage, as both an increase and a decrease of turbulence lead to less collective bargaining coverage.[5]

Firms with higher total factor productivity are also more likely to opt for collective bargaining (Hirsch et al., 2014), and skill-biased technical progress might explain the declining centralisation of wage bargaining in Scandinavian countries (Ortigueira, 2013) or deunionisation in the U.S. (Dinlersoz and Greenwood, 2013). Preugschat (2009) argues that sectors with higher firm entry costs, lower firm death rates and higher organization costs experience higher unionization rates.

3.3 Institutional Background

In Germany, firms and workers can bargain about wages[6] in various forms of aggregation. Firms can either bargain with each worker separately, or they can bargain with one or several labour unions at the firm level (*Firmen-* or *Haustarifvertrag*), or together with other firms at the sectoral level (*Flächen-* or *Branchentarifvertrag*).[7] Workers are free to join a labour union of

[5]All the results by Boeri and Burda rely on calibrations. The mechanisms at work are therefore not completely clear.

[6]They can also bargain about other working conditions, such as workplace security, qualification issues etc., which is neglected here for simplicity.

[7]To bargain at the sectoral level, the firm becomes a member of an employer association. It can also become a member of an employer association without joining the collective agreements, if the employer association allows for such a membership. But membership is a necessary condition to join sectoral level bargaining.

their choice, and firms are free to join an employers' association of their choice. Collective agreements with a labour union usually apply to both unionised and non-unionised workers. A collective agreement sets bottom standards for wages for all participating firms, which can pay more. Some collective agreements contain opt-out clauses, which allow participating firms to pay lower wages under severe circumstances.

The German Federal Ministry for Labour and Social Affairs can decree that particular collective agreements are binding for all firms in an industrial sector in a particular region (*Allgemeinverbindlicherklärung*), although not all firms are initially contractual members of the agreement.[8] In case of such a decree, firms apply the collective agreement involuntarily. To be sure that firms make deliberate decisions on the level of wage bargaining, I exclude establishments that fall under such a decree. Details are discussed in the next Section.

3.4 Empirical Model and Data Description

I estimate the probability that an establishment applies either a sector-level agreement, a firm-level agreement, or no collective agreement by a multinomial logit regression model, as there is no natural order in the level of bargaining. Thus, if there are J types of agreement, the probability that establishment i opts for agreement type j is

$$p_{ij} = \frac{\exp(\mathbf{x}_i' \boldsymbol{\beta}_j)}{\sum_{k=1}^{J} \exp(\mathbf{x}_i' \boldsymbol{\beta}_k)}, \tag{3.1}$$

where $\mathbf{x}_i$ is a $1 \times L$ vector of explanatory variables and $\boldsymbol{\beta}_j$ is the $1 \times L$ vector of coefficients for alternative j. Let me first present the estimation model formally before I explain why I chose these particular variables. The vector of explanatory variables is

$$\mathbf{x}_i = \begin{bmatrix} 1 \\ EMPL_i \\ EMPL_i^2 \\ \mathbf{COMP}_i \\ RENT_i \\ FLUCT_i \\ EXPORT_i \\ HIGHEDU_i \\ \mathbf{SECTOR}_i \end{bmatrix}, \tag{3.2}$$

where $EMPL_i$ and $EMPL_i^2$ is the number of employees and its square of establishment i. $\mathbf{COMP}_i$ is a vector that indicates the degree of competition. The standard case is high com-

[8] Representatives of both the employers' association and the labour union have to agree to the government decree.

petition, such that

$$\mathbf{COMP}_i = \begin{bmatrix} NO_i \\ LOW_i \\ MEDIUM_i \end{bmatrix}, \tag{3.3}$$

where NO_i, LOW_i, and $MEDIUM_i$ are dummies that indicate whether the establishment faces no, low, or medium competition. $RENT_i$ is the business surplus per employee in thousands, defined as

$$RENT_i = \frac{Return_i - (wage\ costs)_i - (material\ costs)_i}{1{,}000 \cdot EMPL_i}, \tag{3.4}$$

where $(material\ costs)_i$ comprise costs for intermediate goods and third-party costs.[9] Although it would be interesting to measure quasi-rents instead of rents by computing alternative wages, as in Abowd and Lemieux (1993) and Gürtzgen (2009), I use actual wages for simplicity. $FLUCT_i$ is a dummy that indicates whether the establishment faces unpredictable business fluctuations. $EXPORT_i$ contains the export share of the business volume, and $HIGHEDU_i$ is the share of workers that have a degree in higher education, that is a college or university degree. Finally, $\mathbf{SECTOR}_i$ is a vector of eight sectoral industry dummies.

The data are from the IAB Establishment Panel.[10] There is no firm-level data with all required information on collective bargaining in Germany. Therefore, all the aforementioned empirical literature on collective bargaining relies on establishment data. Also, the data set does not contain information on which establishments belong to each other, such that construction of firm data is not possible.

The widely used IAB Establishment Panel is a yearly survey of establishments in Germany with at least one employee and it covers all economic sectors and regions in Germany. Currently, around 15,500 establishments are surveyed. Interviews are mostly conducted face-to-face, and overall response rates vary between 63% and 73%. Data refer to June 30 of each year. For the main analysis, I use Wave 2012, as it is the latest available cross-section. I then make use of the panel structure and use Waves 2009-2012 for robustness checks.[11] I now discuss the variables for the main analysis using Wave 2012. The summary statistics of the estimation sample are in Table 3.2. As in Addison et al. (2013), I use sampling weights which give the inverse sampling probability. Using weights mitigates effects driven by non-random sampling, as e.g. large establishments are overrepresented (Fischer et al., 2009).

[9] The costs used are similar to those in the paper by Gürtzgen (2009). For material costs, the questionnaire enumerates raw materials, auxiliary materials, operating materials, commodities, services from third parties, rents, and any kind of other costs, i.e. advertising costs, agency costs, travelling costs, provisions, license fees, postage costs, insurance premiums, legal costs, consulting costs, inspection costs, bank charges, fees for professional associations etc. More detailed information on costs is not available. If I had firm data, it would be better to use standardised measures from financial resports, such as EBT (earnings before taxes). These data are not available on establishment level.

[10] Data access was provided via remote data access at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB). See Fischer et al. (2008, 2009) and Ellguth et al. (2014) for details on the IAB Establishment Panel.

[11] Although information on product market competition is available from 2008 on, I only use information from Wave 2009 on, as the classification system of economic sectors changes between Waves 2008 and 2009.

	Bargaining level					
	Sector level		*Firm level*		*Individual*	
Variable	Mean	SD	Mean	SD	Mean	SD
Number of employees $\in \mathbb{N}^+$	23.65	63.43	47.98	96.93	10.80	24.94
Competition level						
No competition $\in \{0,1\}$	0.09	0.29	0.08	0.27	0.08	0.28
Low competition $\in \{0,1\}$	0.13	0.34	0.09	0.28	0.18	0.39
Medium competition $\in \{0,1\}$	0.39	0.49	0.32	0.47	0.42	0.49
High competition $\in \{0,1\}$	0.39	0.49	0.52	0.50	0.31	0.46
(Rent per employee)/1000 $\in \mathbb{R}$	54.32	138.05	66.06	70.52	45.11	67.20
Business fluctuations $\in \{0,1\}$	0.53	0.50	0.60	0.49	0.54	0.50
Export share $\in [0,1]$	0.02	0.11	0.04	0.13	0.04	0.13
Share of workers with higher education $\in [0,1]$	0.03	0.10	0.11	0.23	0.06	0.17
Business sector						
Agriculture $\in \{0,1\}$	0.05	0.21	0.02	0.15	0.03	0.17
Manufacturing $\in \{0,1\}$	0.19	0.39	0.20	0.40	0.13	0.34
Construction $\in \{0,1\}$	0.22	0.41	0.14	0.34	0.11	0.32
Retail $\in \{0,1\}$	0.23	0.42	0.28	0.45	0.24	0.43
Traffic $\in \{0,1\}$	0.08	0.28	0.06	0.24	0.12	0.33
Finance/Insurance $\in \{0,1\}$	0.03	0.18	0.01	0.07	0.04	0.21
Services $\in \{0,1\}$	0.01	0.10	0.06	0.24	0.17	0.38
Other services $\in \{0,1\}$	0.18	0.39	0.23	0.42	0.15	0.36
Observations	1,891		407		5,209	

Notes: Data are weighted by sampling weights.
Source: IAB Establishment Panel, Wave 2012.

Table 3.2. Summary statistics for the cross-section analysis.

Establishments indicate whether their wages and salaries are subject either to a sector-level collective agreement or to a firm-level collective agreement, or whether there is no collective agreement. I use this information to construct the dependent variable with these three options.[12]

Competition has no natural value that can be directly measured. In the IAB Establishment Panel, establishments indicate the degree of competition that they face on product markets, which means that it is a subjective measure. There are four categories: no, low, medium, or high competition. These data are particularly interesting, as they allow a very simple non-linear analysis of the degree of competition.[13] For all competition levels and all types of wage agreement, there is a sufficient number of observations. About 8-9% of establishments indicate that they face no competition, which is a surprisingly high number. The share of establishments facing low competition is smallest (9%) among establishments with a firm-level agreement, and highest (18%) among establishments with individual agreements. Equal shares of establishments with a sector-level agreement face medium or high competition. Among establishments with a firm-level agreement, the majority (52%) faces high competition, while among establishments

[12]There is no information available which share of employees is subject to a collective agreement. E.g., employees at the middle management of larger companies might have individual contracts.

[13]A similar indicator of competitiveness has been used by Nickell (1996); Nickell et al. (1997); Blanchflower and Machin (1996) with British establishment data. They set a threshold of five competitors. A detailed threshold is missing in the IAB Establishment Panel.

with no collective agreement, most establishments (42%) report to face medium competition.

I measure rents as defined above.[14] The mean rent per employee is highest (66,060) among establishments with firm-level agreements and lowest (45,110) among establishments with no collective agreement.

In theory, less competition increases profits. If this was the case in the data, it would be difficult to disentangle the effect of the competition level from that of rents. Yet the competition level explains very little of the variation in rents. Columns (1) and (2) in Table 3.3 show OLS estimates, predicting rents per employee by competition level. There is no relation, even if I add sectoral dummies. Thus, using rents and the competition level as explanatory variables does not cause any simultaneity bias.

Similarly, one could argue that the number of employees is also determined by competition. If less competition results from increasing returns to scale, less competition would be associated with a larger number of workers. There is also little relation. Columns (3) and (4) in Table 3.3 shows OLS estimates of the number of employees on the competition level. (To exclude potential outliers, I omitted observations above the 99th percentile of the distribution of employees.) The relation between competition level and the number of employees is statistically significant, but it explains very little of the variation, as the R^2 value of 0.0025 in column (3) is very low. Adding sectoral dummies in column (4) does not change much. Thus, neither the level of rents nor the number of employees capture the heterogeneity between establishments that is driven by competition.

Dependent variable	*(Rent per employee)/1000*		*Employees*	
	(1)	(2)	(3)	(4)
Competition level				
1 = No	7.634	11.887	-7.401***	-8.609***
	(8.758)	(8.700)	(0.706)	(0.760)
1 = Low	0.115	3.497	-6.406***	-7.064***
	(4.108)	(4.151)	(0.647)	(0.677)
1 = Medium	-2.707	-1.907	-3.690***	-3.915***
	(2.149)	(2.128)	(0.576)	(0.581)
Constant	47.780***	61.190***	19.193***	11.617***
	(1.622)	(10.435)	(0.465)	(0.714)
Sectoral dummies	No	Yes	No	Yes
R^2	0.0010	0.0259	0.0025	0.0172
Observations	8,061		13,637	

Notes: OLS estimation. Data are weighted by sampling weights. To exclude potential outliers, the estimation sample for columns (3) and (4) excludes observations above the 99th percentile of the distribution of employees for the unweighted data. Heteroskedasticity-robust standard errors are in parentheses. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Wave 2012.

Table 3.3. OLS regression of rents and number of employees on competition level.

[14] Adding the square of rents, to allow for non-linear and in particular hump- or u-shaped influences, does not change the results. The average marginal effect of rents is not significantly different along the distribution of rents.

As an additional indicator of the economic environment that an establishment faces, the questionnaire in 2012 asks whether there are fluctuations in production and business, and whether the fluctuations are mainly predictable or not. Mainly unpredictable fluctuations indicate economic turbulence, which I indicate by a dummy variable. This variable can capture both the competitive environment, but also some sort of management skills. It thus captures some part of otherwise unobserved variables, which are of course not firm-specific. More than 50% of all establishments report to face unpredictable business fluctuations, and the share is highest (60%) among establishments with firm-level agreements.

To add other measures of competition and productivity, I use the export share as a control. There is much evidence that more productive firms tend to export more (Bernard and Jensen, 1999; Delgado et al., 2002; Wagner, 2007). The mean export share among establishments is between 2-4%.

For the share of high-skilled workers, I take the share of workers with a degree in higher education, that is a college (*Fachhochschule*) or university degree. Workers without higher education have usually accomplished an apprenticeship. As qualifications are highly standardised, the qualifications are relatively easy to define. This also holds for further education. Standardised qualifications make it relatively easy to define pay scales that depend on qualifications. By contrast, workers with higher education might have less standardised professional skills, which makes it harder to define pay scales depending on qualifications. I therefore consider the share of workers with higher education as the share of skilled workers. Its value is highest (11%) among establishments with firm-level agreements, and lowest (3%) among establishments with sector-level agreements.

I stick to a parsimonious set of additional controls. Following the existing literature, I control for the number of employees and its square to allow for a concave effect of firm size (see e.g. Schnabel et al. (2006) and Gürtzgen (2009)) and I also include eight industry dummies, following recommendations by the data provider (IAB, 2012).[15]

I exclude some establishments from the estimation sample. First, I drop establishments from the public sector, as these do not maximise profits and hence have a different rationale. Second, to have only voluntary membership in collective agreements, I drop establishments from industries and regions which are subject to collective agreements on wages or salaries by governmental decree, as explained in the previous Section. I therefore consider all wage agreements according to the registers of generally binding collective agreements from January 1, 2009 to 2012 (BMAS, 2009, 2010, 2011, 2012).[16] Collective agreements on wages are called *Rahmen-*, *Entgelt-*, or *Lohntarifvertrag.* I exclude establishments which are subject to these agreements by governmental decree. Agreements of the type *Manteltarifvertrag* are not considered to be relevant, as they usually exclude wages and salaries or pay scales, but define general working

[15]A more detailed classification would cause empty or small cells for firm-level bargaining.

[16]The register of generally binding collective agreements is published quarterly. The Federal Ministry for Labour and Social Affairs provided historical registers from January 1 and from October 1, 2012. I chose the register from January, as there is little change between January and October. If the governmental decree expires, agreements continue to be effective unless they are replaced by individual arrangements.

conditions, such as hiring and firing conditions, holiday entitlements, or working hours.[17] A detailed listing of all industries excluded is in Appendix 3.C in Table 3.C.2.

Third, outliers are an important concern for the estimation sample. Outliers matter for the number of employees, since the distribution of employees is heavily right-skewed. From the unweighted data for the estimation sample from wave 2012, the median number of employees is 16, the mean is 105 employees and the standard deviation is 810.[18] Most other papers on this topic do not mention how or whether they control for outliers. To keep the sample as large as possible and to avoid truncation problems, but to remove extreme values, I drop observations equal to or larger than the top percentile of the unweighted data.[19]

3.5 Methodology

I estimate a multinomial logit regression model, as there is no natural order in the level of bargaining. Estimating an ordered regression model requires more assumptions on the regression model, and an ordered regression is only efficient if the underlying assumptions are true (Cameron and Trivedi, 2010, p. 529). As the results indicate that some variables have an effect on firm-level bargaining, but not on sector-level bargaining, an ordered approach seems to be inefficient. Tests also show that none of the alternatives is irrelevant, which justifies the multinomial logit approach in contrast to a probit or logit approach.[20] I estimate the model by a pseudo-maximum-likelihood function to account for a non-normal distribution of the parameters.

3.6 Results

My main interest is the degree of product market competition. I therefore start with a simple model in which I only control for establishment size and industry sector as additional covariates. Afterwards, I extend the model and add rents, an indicator for business fluctuations, the export share and the share of workers with higher education as controls. Here, I only present and discuss the average marginal effects of the main covariates of interest.[21]

[17] Many other types of collective agreements exist, e.g. for holidays *(Urlaubstarifvertrag)*, for savings allowances *(Tarifvertrag über vermögenswirksame Leistungen)*, etc. These are also not considered, as they do not define the main reimbursement for the work done by the employee.

[18] For weighted data, the percentiles of the distribution are not available.

[19] The 99th percentile of the estimation sample from wave 2012 is at 1428 employees, and the maximum number of employees is 49011 employees. Keeping the 99th percentile results in iteration steps of the pseudo-likelihood function that are local maxima and which are close to the final iteration. Dropping the 99th percentile shows much more reliable iteration steps; only few iterations are required and the maximum is global.

[20] I excluded each type of collective bargaining and ran a logistic regression for the remaining type with heteroskedasticity-robust standard errors. I tested the null hypothesis that the coefficients for the remaining type of collective bargaining are equal to the coefficients from the multinomial regression. The null was rejected in each case at acceptable p-values.

[21] The marginal effect of variable used in a multinomial logit estimation is computed differently to the marginal effect of a variable used in a linear regression: Here, we are interested in the probability that an individual chooses a specific alternative, and we compute the marginal effect of a variable on the probability of each alternative. If there are J alternatives, the probability that individual i chooses alternative j is $p_{ij} = \frac{\exp(\mathbf{x}_i'\boldsymbol{\beta}_j)}{\sum_{k=1}^{J}\exp(\mathbf{x}_i'\boldsymbol{\beta}_k)}$, where $\mathbf{x}_i$

	Model 1			Model 2		
Bargaining level	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*
Number of employees	-0.0024***	0.0003***	0.0022***	-0.0026***	0.0003***	0.0022***
	(0.0002)	(0.0000)	(0.0001)	(0.0002)	(0.0000)	(0.0001)
Competition level						
1 = No	-0.005	-0.008	0.013	0.010	-0.006	-0.003
	(0.022)	(0.006)	(0.031)	(0.031)	(0.011)	(0.030)
1 = Low	0.078***	-0.017***	-0.060***	0.082***	-0.016***	-0.066***
	(0.022)	(0.005)	(0.021)	(0.022)	(0.005)	(0.022)
1 = Medium	0.051***	-0.013***	-0.038**	0.054***	-0.012**	-0.042**
	(0.017)	(0.005)	(0.017)	(0.017)	(0.005)	(0.017)
(Rent per employee)/1000				-0.0003**	0.00002***	0.0002**
				(0.0001)	(0.00001)	(0.0001)
1 = Business fluctuations				0.025	0.004	-0.028*
				(0.015)	(0.004)	(0.015)
Export share				0.281***	-0.024**	-0.257***
				(0.075)	(0.012)	(0.074)
Share of employees				0.096	0.039***	-0.135**
with higher education				(0.059)	(0.010)	(0.059)
Observations		7,507			7,507	

Notes: Multinomial logit estimation. Data are weighted by sampling weights. Heteroskedasticity-robust standard errors are in parentheses. Effects for competition level dummies give discrete change from base level (high competition). Regressions contain constant and industry sector dummies. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Wave 2012.

Table 3.4. Average marginal effects on the probability of individual or collective wage agreement.

In Model 1, I consider only the role of product market competition with the set of standard controls (Table 3.4). On average, a firm facing low competition is by 6.0 (1.7) percentage points less likely to opt for sector-level (firm-level) bargaining than a firm facing high competition, and hence by 7.8 percentage points more likely to opt for individual wage bargaining.[22] Firms facing medium competition also tend by 3.8 (1.3) percentage points less to sector-level (firm-level) bargaining, and hence by 5.1 percentage points more to individual bargaining. Firms facing no or high competition do not differ significantly in opting for sector-level, firm-level, or individual bargaining. This establishes a u-shaped relationship between competition and the probability of collective bargaining, and a hump-shaped relationship between competition and the probability of individual bargaining. The effect of product market competition on firm-level bargaining is weaker than on sector-level bargaining.

Model 2 in Table 3.4 also contains the other controls. The effect of product market competition does not change much. Firms with higher rents are more likely to opt for collective bargaining.[23] An increase in rents by 10,000 Euros per employee increases the probability of sector-level bargaining by 0.2 percentage points, but the probability of firm-level bargaining increases only by 0.02 percentage points. Thus, as for the competition level, the effect of post-wage rents on collective bargaining is weaker for firm-level than for sector-level bargaining.

Comparing the effect of competition with the effect of rents, the former is much stronger. E.g., to countervail the effect of switching from high to medium competition, rents would need to increase by about 200,000 Euros per employee. Given the summary statistics, this is very unlikely to happen. Thus, the effect of less competition is to reduce the likelihood of sector-level bargaining.

Firms facing unpredictable business fluctuations are by 2.8 percentage points less likely to opt for sector-level bargaining. The effect on firm-level bargaining or individual wage bargaining is not significant. If business fluctuations are an indicator of bad management and low productivity, this might indicate that less well managed firms prefer individual agreements, which allows them to pay wages below sector-level collective agreements.

A higher export share has large consequences. An increase in the export share by 10 percentage points decreases the probability of sector-level bargaining by 2.6 percentage points, while it decreases the probability of firm-level bargaining only by 0.24 percentage points. Thus once again, the effect on firm-level bargaining is weaker. The probability of individual wage bargaining increases by 2.8 percentage points.

is a $1 \times L$ vector of explanatory variables and $\boldsymbol{\beta}_j$ is the $1 \times L$ vector of coefficients for alternative j. The marginal effect of a change in variable x_{il} is $\frac{\partial p_{ij}}{\partial x_{il}} = p_{ij}\left(\boldsymbol{\beta}_{jl} - \sum_{k=1}^{J} \beta_{kl} p_{ik}\right)$, where x_{il} and β_{jl} denote the lth element of $\mathbf{x}_i$ and $\boldsymbol{\beta}_j$. Thus, the marginal effect is different for every individual and it is standard to report average marginal effects. See Cameron and Trivedi (2005, p. 500ff.) for a textbook presentation.

[22] The average effect of a competition level $c \in \{N, L, M, H\}$, which indicates no, low, medium, or high competition, is the average difference between the probability of outcome j, given competition level c, and the probability of outcome j, given the baseline competition level, i.e. high competition. E.g., for $c = L$, the average effect is the average over all i of $p_{ij|c=L} - p_{ij|c=H}$, where p_{ij} is the probability of establishment i to choose bargaining level j.

[23] The effect of rents is also robust to the exclusion of the competition level dummies.

A higher share of workers with higher education pushes firms into firm-level collective bargaining and away from sector-level collective bargaining. The probability to opt for firm-level bargaining increases by 0.39 percentage points if the share of high skilled workers increases by 10 percentage points, and the probability to opt for sector-level wage setting decreases by 1.35 percentage points. As workers with higher education might have much more heterogeneous skills than workers with vocational education, occupations are much more firm-specific and therefore difficult to define across firms.

3.6.1 West and East Germany

In East German states, collective bargaining coverage is much lower, and in many studies, authors exogenously distinguish between establishments in West and East German states, either by sampling from each region (Kohaut and Schnabel, 2003; Schnabel et al., 2006; Hirsch et al., 2014) or by including a dummy for East German states (Gürtzgen, 2009). As I used an estimation sample from all German regions, one can therefore ask whether it makes a difference to sample from all states or to use only West German states, and whether things work similarly or different on West and East Germany. In particular, as collective bargaining coverage is lower in East Germany, and if less competition leads to less collective bargaining, does that mean that East German firms face less competition? Given the severe economic problems in East Germany, indicated by high unemployment rates, one would not expect this.

The distinction between West and East Germany can be justified by historical reasons. A further justification might be that in all East German states, the share of establishments covered by sectoral agreements is below the share of the whole cross-section. Yet this is also true for some West German states, i.e. Schleswig-Holstein, Bremen, and Baden-Wurttemberg. To make my results comparable to the existing literature, I stick to the distinction between West and East Germany. The results are in Table 3.5, and the descriptive statistics for the West German and the East German sample can be found in Appendix 3.A.

In West Germany, things work similarly as we have discovered above for all German establishments. Interestingly, the effect of competition remains valid, but rents have no significant effect. This emphasises even more that the degree of competition affects the type of wage agreement by a different channel than by rents.

Also, the effect of export shares on firm-level bargaining becomes insignificant, and the share of workers with higher education now has a significant effect on individual wage bargaining. Business fluctuations drive firms from sector-level to individual bargaining, and the same holds for firms with a higher export share.

In East Germany, things are a bit different. We now observe almost no relation between product market competition and the probability of any kind of wage determination, except for firms facing medium competition. They are on average by 3.8 percentage points less likely to opt for sector-level bargaining than firms facing high competition. It is unclear whether these firms tend to firm-level or individual wage setting. But higher rents drive firms from individual

	West Germany			East Germany		
Bargaining level	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*
Number of employees	-0.0023***	0.0002***	0.0021***	-0.0031***	0.0007***	0.0024***
	(0.0002)	(0.0000)	(0.0002)	(0.0003)	(0.0001)	(0.0003)
Competition level						
1 = No	0.006	-0.007	0.001	0.007	-0.003	-0.004
	(0.039)	(0.014)	(0.038)	(0.036)	(0.012)	(0.035)
1 = Low	0.090***	-0.020***	-0.070***	0.046	-0.004	-0.042
	(0.027)	(0.006)	(0.026)	(0.029)	(0.008)	(0.029)
1 = Medium	0.058***	-0.019***	-0.039*	0.031	0.007	-0.038*
	(0.021)	(0.006)	(0.021)	(0.021)	(0.008)	(0.020)
(Rent per employee)/1000	-0.00021	0.00002	0.0002	-0.0003**	0.00002	0.0003***
	(0.00012)	(0.00001)	(0.0001)	(0.0001)	(0.00003)	(0.0001)
1 = Business fluctuations	0.032*	0.002	-0.033*	0.004	0.010	-0.013
	(0.019)	(0.005)	(0.019)	(0.018)	(0.007)	(0.018)
Export share	0.281***	-0.015	-0.267***	0.406***	-0.061***	-0.345***
	(0.085)	(0.012)	(0.084)	(0.105)	(0.020)	(0.105)
Share of employees	0.189**	0.042***	-0.231***	-0.114**	0.033**	0.081
with higher education	(0.084)	(0.013)	(0.085)	(0.054)	(0.014)	(0.053)
Observations		4,313			3,193	

Notes: Multinomial logit estimation. Data are weighted by sampling weights. Heteroskedasticity-robust standard errors are in parentheses. Effects for competition level dummies give discrete change from base level (high competition). Regression contains constant and industry sector dummies. */**/*** means significance at 10/5/1% level. *Source:* IAB Establishment Panel, Wave 2012.

Table 3.5. Average marginal effects for West and East Germany.

to sector-level bargaining, which supports the rent-sharing hypothesis. Economic turbulence does not play any role.

The share of workers with higher education has no effect on the probability of sector-level agreements, but it increases the likelihood of firm-level bargaining. By contrast to West German establishments, a higher share of such workers decreases the probability of individual agreements.

The export share is still an important determinant of the type of wage agreement. It still has a negative effect on collective agreements, and it is stronger for sector-level agreements.

3.6.2 Panel Analysis

As a robustness check, I use the panel structure and estimate the model with all available data from 2009 to 2012. As the indicator of business fluctuations is only available in 2012, I omit it here. I estimate the pooled model with both heteroskedastic and clustered standard errors, where I cluster by establishment. Also, I estimate a random effects model, in which the random effects are establishment-specific. All regressions contain, as before, sectoral dummies, but also dummies for each year. For the random effects model, data are not weighted by sampling weights, as the available built-in methods do not offer this possibility. The results are in Table 3.6. To mitigate that I cannot weight the data in the random effects estimation, I estimate the model with additional dummies for the federal state, to account at least partially for the stratification. The marginal effects from these regressions are in Table 3.7.[24] The descriptive statistics for the panel sample are in Appendix 3.A.

Let us first consider the pooled regressions in the first 6 columns of Tables 3.6 and 3.7. The pooled regressions broadly confirm the u-shaped relationship between competition and the probability of collective bargaining, and the hump-shaped relationship between competition and individual bargaining. The marginal effects in the columns with heteroskedastic and clustered standard errors are of course the same.

With or without dummies for the federal state, there is no positive relationship between less competition and the probability of collective bargaining. Establishments facing medium competition levels are still less likely to opt for collective bargaining. An establishment that faces low competition tends to individual bargaining and away from firm-level bargaining, but without dummies for federal states, this holds only for heteroskedastic standard errors, albeit not for clustered standard errors. If dummies for federal states are included, this holds for both types of standard errors.

Higher rents still drive establishments into sector-level bargaining, and a higher export share still drives establishments from sectoral collective into individual bargaining. In contrast

[24] I estimate only a random effects model, as fixed effects estimation of multinomial logit models is to date not provided by Stata, which has to be used for remote data access. Nevertheless, I ran a fixed effects estimation using code by Pforr (2013). As the competition level of an establishment is mostly constant overtime, the estimation relies on 1/8 of the sample and is therefore of little value. Also, the estimates can be very imprecise (Wooldridge, 2002, p. 326).

	Pooled Regression						Random Effects Estimation		
	Heteroskedastic S.E.			*Clustered S.E.*					
Bargaining level	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*
Number of employees	-0.0028***	0.0003***	0.0024***	-0.0028***	0.0003***	0.0025***	-0.0011***	0.0003	0.0012***
	(0.0001)	(0.0000)	(0.0001)	(0.0002)	(0.0000)	(0.0002)	(0.0002)	(0.0000)	(0.0002)
Competition level									
1 = No	-0.010	-0.007	-0.003	0.010	-0.007	-0.003	-0.009	-0.0007	-0.010
	(0.020)	(0.006)	(0.020)	(0.025)	(0.009)	(0.025)	(0.019)	(0.0005)	(0.019)
1 = Low	0.028**	-0.007**	-0.021	0.028	-0.007	-0.021	0.008	-0.0005	-0.008
	(0.014)	(0.003)	(0.014)	(0.018)	(0.004)	(0.017)	(0.009)	(0.0004)	(0.009)
1 = Medium	0.033***	-0.007***	-0.025**	0.033***	-0.007**	-0.025**	0.010	-0.0006	-0.010
	(0.010)	(0.003)	(0.010)	(0.012)	(0.003)	(0.012)	(0.006)	(0.0004)	(0.006)
(Rent per employee)/1000	-0.0004***	-0.0000	0.0004***	-0.0003***	0.00000	0.0004***	-0.0001***	-0.006	0.0001***
	(0.00009)	(0.00001)	(0.0000)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0000)	(0.0000)
Export share	0.180***	-0.012	-0.168**	0.180**	-0.012	-0.168**	-0.0007	-0.0005	0.001
	(0.047)	(0.010)	(0.046)	(0.072)	(0.014)	(0.069)	(0.025)	(0.0001)	(0.025)
Share of employees with higher education	0.132***	0.033***	-0.165**	0.132***	0.033***	-0.165**	0.071*	0.004	-0.075**
	(0.037)	(0.007)	(0.037)	(0.049)	(0.008)	(0.049)	(0.038)	(0.003)	(0.039)
Federal state dummies		No			No			No	
Observations		23,846			23,846			23,846	

Notes: Multinomial logit estimation. Data are weighted by sampling weights in the pooled regression and unweighted in the random effects estimation. Standard errors are in parentheses. Clustered standard errors are clustered by establishment. Random effects are establishment-specific. Effects for competition level dummies give discrete change from base level (high competition). Regressions contain constant and dummies for the industry sector and for each year. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Waves 2009-2012.

Table 3.6. Average marginal effects on the probability of individual or collective wage agreement. Estimation with panel data.

	Pooled Regression						Random Effects Estimation		
	Heteroskedastic S.E.			*Clustered S.E.*					
Bargaining level	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*	*Individual*	*Firm level*	*Sector level*
Number of employees	-0.0027***	0.0003***	0.0024***	-0.0027***	0.0003***	0.0024***	-0.0004***	0.00009	0.0004***
	(0.0001)	(0.0000)	(0.0001)	(0.0002)	(0.0000)	(0.0002)	(0.00005)	(0.00001)	(0.00005)
Competition level									
1 = No	-0.011	-0.008	-0.003	0.011	-0.008	-0.003	0.002	-0.0068***	-0.005
	(0.020)	(0.006)	(0.020)	(0.025)	(0.009)	(0.025)	(0.014)	(0.0022)	(0.015)
1 = Low	0.030**	-0.008**	-0.022	0.030*	-0.007*	-0.022	0.010	-0.0048***	-0.005
	(0.014)	(0.003)	(0.014)	(0.018)	(0.004)	(0.017)	(0.008)	(0.0019)	(0.009)
1 = Medium	0.034***	-0.008***	-0.025***	0.034***	-0.008**	-0.025**	0.014**	-0.0032**	-0.011*
	(0.010)	(0.003)	(0.010)	(0.012)	(0.003)	(0.012)	(0.006)	(0.0014)	(0.006)
(Rent per employee)/1000	-0.0003***	-0.0000	0.0003***	-0.0003***	0.00000	0.0003***	-0.0001***	-0.00006	0.0001***
	(0.00001)	(0.00001)	(0.0001)	(0.0001)	(0.00001)	(0.0001)	(0.00002)	(0.0000)	(0.00002)
Export share	0.195***	-0.007	-0.188***	0.195***	-0.007	-0.188***	-0.013	-0.0001	0.013
	(0.047)	(0.010)	(0.046)	(0.071)	(0.013)	(0.069)	(0.020)	(0.0044)	(0.021)
Share of employees	0.084**	0.032***	-0.116***	0.084	0.032***	-0.116**	0.015	0.024***	-0.009
with higher education	(0.036)	(0.007)	(0.037)	(0.049)	(0.008)	(0.048)	(0.020)	(0.007)	(0.020)
Federal state dummies		Yes			Yes			Yes	
Observations		23,846			23,846			23,846	

Notes: Multinomial logit estimation. Data are weighted by sampling weights in the pooled regression and unweighted in the random effects estimation. Standard errors are in parentheses. Clustered standard errors are clustered by establishment. Random effects are establishment-specific. Effects for competition level dummies give discrete change from base level (high competition). Regressions contain constant and dummies for the industry sector, for the federal state, and for each year. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Waves 2009-2012.

Table 3.7. Average marginal effects on the probability of individual or collective wage agreement. Estimation with panel data and additional dummies for the federal state.

to the cross-section analysis, the negative effect on the probability of firm-level bargaining is not confirmed. A higher share of workers with higher education drives establishments away from sector-level bargaining and into firm-level bargaining, similar to the cross-section analysis, but it also drives firms into individual bargaining, similar to the cross-section of West German establishments in Table 3.5.

The results from the random effects estimation have to be considered with care, as these estimations rely on the assumption that the random effects are uncorrelated with all regressors. If this assumption is violated, the estimates are inconsistent (Cameron and Trivedi, 2005, p. 701f.).

In the random effects estimation without federal state dummies (Table 3.6), there is no effect of the competition level on the type of wage agreement. Including federal state dummies (Table 3.7), less competition now leads establishments away from firm-level bargaining. The lower the degree of competition, the stronger is the effect, but not as strong as in the cross-section and pooled regressions: Establishments that face no competition are only by 0.7 percentage points less likely to opt for firm-level agreements.

By contrast, higher rents increase the probability of sector-level bargaining, while reducing the probability of individual wage setting. This holds independent of the inclusion of federal state dummies, and the effect of rents is qualitatively, but not in size, in line with the cross-section and pooled panel analysis.

The effect of the export share vanishes in the random effects estimation. Whether the share of workers with higher education matters, changes with the inclusion of federal state dummies, but broadly confirms the predictions from the cross-section and pooled estimation.

3.6.3 Discussion

The results do not support the nexus of low competition and rent-sharing as an explanation for collective bargaining. If it was true, we would observe an increasing probability of collective bargaining with a decreasing degree of competition.

The results should be considered with some care, as the competition level might be subject to an omitted variable bias or measurement error. As long as the omitted variable bias hinges on unobserved variables, the bias cannot be resolved, but only mitigated. To give an example for an omitted variable bias, the competition level might be correlated with some other unobserved variable captured by the error term, e.g., management skills. If good management leads to high profitability, the firm considers competition to be lower than it actually is. In this case, the effects of the competition level are overstated and its absolute values should be interpreted as an upper bound. However, rents might capture some of the management skills, as good management usually leads to profitable firms.

Some part of management skills might also be captured by the indicator of business fluctuations. Important as this aspect is, it gives only a very rough and dichotomous indication of management skills. In addition, the share of high-skilled workers is correlated with productivity (Haltiwanger et al., 1999), such that this variable also captures some of the possible omitted variable bias.

Endogeneity could also be mitigated by an individual fixed effect to account for unobserved heterogeneity. However, it is impossible to compute the marginal effects as in the cross-section analysis, since the individual fixed effect is unobserved, but needs to be known for the marginal effect. Also, estimation of a fixed-effects model is problematic as the main variable of interest is a categorical variable with little variation over time - only 1/8 of the panel sample would be used. Thus, a fixed effects estimation is of little value, and a cross-section analysis is the preferred approach.

How do the results relate to the existing literature? Compared to the theoretical literature, I contradict the predictions by Ebell and Haefke (2006) and by Boeri and Burda (2009). While Ebell and Haefke predict that under low competition, collective bargaining is a Nash equilibrium, I find that firms tend more to individual wage setting if competition is at low or medium values than firms facing high competition. Firms facing high competition are more likely to opt for sector-level collective bargaining, while Ebell and Haefke predicted a tendency to individual wage setting. Even more, Ebell and Haefke model collective bargaining as firm-level bargaining. I show that product market competition play a minor role for this type. My results also contradict Boeri and Burda, who predict higher union support in case of less competition.

Compared to the existing empirical literature, the results are also opposite to Addison et al. (2013). They found a negative effect of high competition on the probability of sector-level bargaining. My results also challenge the results by Zagelmeyer (2007), who found no difference between firm-level or sector-level bargaining for several cross-sections. My multinomial analysis, combined with a richer distinction between different levels of product market competition, reveals that it is the decision between individual and sector-level bargaining that is mainly affected by competition.

Concerning the share of high-skilled workers, I can also not confirm the results by Addison et al. (2013), who find a positive effect on the probability to bargain at the sectoral level for skilled workers. He might use a different definition of skilled workers. Regarding the paper by Boeri and Burda (2009), I can also not confirm that the skill level plays a role for sector-level bargaining, but only for firm-level bargaining. My results also contrast the results by Hirsch et al. (2014), who find that a higher share of skilled workers drives firms into sector-level bargaining. My results are also much stronger than those reported by Lehmann (2002).[25] This might also be due to a different definition of the share of skilled workers, as she also includes workers with an apprenticeship.

As for the export share, my results are opposite to the results by Carluccio et al. (2014) and in line with the results by Capuano et al. (2014). Carluccio et al. (2014) report a positive association between exports and firm-level agreements, which I cannot confirm. Instead, I find a negative effect in the cross-section analysis, but no effect in the panel analysis. This is in

[25] Although she only reports regression coefficients, I find much higher coefficients than her.

line with results by Capuano et al. (2014), who find a negative effect of exports on collective bargaining.

Economic turbulence has so far not been analysed empirically in this context. As the predictions of Boeri and Burda (2009) were inconclusive, I could show that business fluctuations affect the decision about individual or sector-level collective bargaining.

How can we potentially explain the main finding of a u-shaped relationship between competition and collective bargaining? As both firm-level and sector level bargaining show the u-shaped relationship, this might indicate that workers are less interested in unionisation for medium competition levels. As the share of workers with higher education has different effects on firm-level and sector-level bargaining, we need to consider other aspects, not necessarily related to worker heterogeneity. A possible argument could be that in case of less competition, jobs are safer than in case of high competition, as firm entry and exit rates might be lower (Asplund and Nocke, 2006). Less firm turnover leads to a lower threat of an unemployment spell and longer job durations. Thus, firm and employee engage in relatively long-term relations such that the employer supports individual career plans. Thus, the employees organizes themselves within the firm rather than within a labor union. As unions also provide support in periods of unemployment, there are hence less incentives to become a union member.

Looking at the firm side, another explanation would be benefits from coordination between firms, such as a reduction of the business-stealing externality (Cai et al., 2014). If firms agree to pay similar wages, this reduces competition of firms for workers, at least between low-productivity firms. But firms facing high competition produce homogeneous or highly substitutable goods within an industry, while firms that face less competition produce more different and less substitutable goods across firms. The more the goods differ, the more is the input mix different, that is the set of qualifications of the firm's employees. Firms have hence less advantage from coordination. So far, the costs and advantages of coordination have not been explicitly considered in the theoretical literature.

3.7 Conclusion

I have asked why some firms prefer individual wage setting to collective bargaining at the firm level or at the sectoral level. Several theories have come up, most importantly in the search-and-matching literature, which makes heavy use of wage bargaining and is therefore a useful source of explanations. The type of wage bargaining is a strategic device that might depend on the degree of product market competition, the skill level of workers, and the degree of fluctuations in business that the firm faces (Ebell and Haefke, 2006; Boeri and Burda, 2009). The main mechanism of the degree of competition is that less competition leads to higher firm rents, which enhances collective bargaining to get a higher share of the rents for the workers. The more intense competition is, the more firms are competing for workers, who can hence get a higher rent from individual bargaining.

The contributions of this paper are fourfold: First, less competition does not support collective bargaining. Second, the existing theory distinguishes insufficiently between firm-level and sector-level bargaining. My results show that these types of collective bargaining are entirely different. Third, things work differently in West and East Germany. Fourth, I take into account that the German government can declare collective agreements to be generally binding for all firms in a particular economic sector or region. I exclude these establishments from the estimation sample, as they do not apply the collective agreement voluntarily.

I find that there is a u-shaped relationship between product market competition and the probability to opt for collective wage bargaining. Establishments facing no competition and firms facing high competition are equally likely to opt for collective or individual wage setting. Establishments facing low or medium competition have, by contrast, a lower probability of collective bargaining, and a higher probability of individual bargaining. The effect is weaker for firm-level than for sector-level bargaining.

Higher rents drive establishments into collective bargaining, but the effect is not very strong. Therefore, it seems that the degree of competition entails a different channel than so far considered by the theoretical literature.

In East Germany, there is almost no relation between product market competition and the type of wage setting. By contrast, higher rents make collective bargaining more likely. It therefore seems that the rent-sharing explanation holds in East Germany, but the results still do not support the idea that the degree of competition is the causal channel.

My findings shed new light on the effect of product market competition on employment. Fiori et al. (2012) showed that product market regulation and bargaining coverage reduce employment. But if more competition increases bargaining coverage, and as higher bargaining coverage decreases employment, the employment-increasing effect of product market deregulation might be reduced.

An interesting empirical extension of my research would be to use linked employer-employee data to consider quasi-rents instead of rents. As rents are affected by actual wages and the type of bargaining, this would resolve potential problems of reverse causality. Also, this would allow a more detailed insight into differences between estabslishments of different competition levels concerning the composition of the workforce. In particular, a much richer insight than only a distinction between so-called low- and high-skilled workers is necessary. Rather, the type of occupations seems much more relevant. If the required set of occupations differs between firms with decreasing competition, the incentive reduces to opt for sector-level collective agreements to avoid the business-stealing externality.

The results also open a lot of questions for theoretical research. Why is there no difference between firms facing no or high competition? Why are the effects of competition and rents weaker for firm-level than for sector-level bargaining? There is so far only one theoretical study that focuses on firm-level vs. sector-level bargaining (Jimeno and Thomas, 2013), but it considers the level of wage bargaining to be exogenous.

What about policy research? One policy intervention in collective bargaining is, as explained before, that the government declares collective agreements to be generally binding. It would be interesting to learn more about the cause and the effect of this intervention. Besides further research that helps more to understand these findings, there are also further research questions. Connecting my findings with the literature that focuses on the decline of collective wage bargaining, it would be interesting to check whether this is due to a change in product market competition.

Appendix to Chapter 3

3.A Summary Statistics

	Bargaining level					
	Sector level		*Firm level*		*Individual*	
Variable	Mean	SD	Mean	SD	Mean	SD
Number of employees $\in \mathbb{N}^+$	23.65	63.43	47.98	96.93	10.80	24.94
Competition level						
No competition $\in \{0,1\}$	0.09	0.29	0.08	0.27	0.08	0.28
Low competition $\in \{0,1\}$	0.13	0.34	0.09	0.28	0.18	0.39
Medium competition $\in \{0,1\}$	0.39	0.49	0.32	0.47	0.42	0.49
High competition $\in \{0,1\}$	0.39	0.49	0.52	0.50	0.31	0.46
(Rent per employee)/1000 $\in \mathbb{R}$	54.32	138.05	66.06	70.52	45.11	67.20
Business fluctuations $\in \{0,1\}$	0.53	0.50	0.60	0.49	0.54	0.50
Export share $\in [0,1]$	0.02	0.11	0.04	0.13	0.04	0.13
Share of workers with higher education $\in [0,1]$	0.03	0.10	0.11	0.23	0.06	0.17
Business sector						
Agriculture $\in \{0,1\}$	0.05	0.21	0.02	0.15	0.03	0.17
Manufacturing $\in \{0,1\}$	0.19	0.39	0.20	0.40	0.13	0.34
Construction $\in \{0,1\}$	0.22	0.41	0.14	0.34	0.11	0.32
Retail $\in \{0,1\}$	0.23	0.42	0.28	0.45	0.24	0.43
Traffic $\in \{0,1\}$	0.08	0.28	0.06	0.24	0.12	0.33
Finance/Insurance $\in \{0,1\}$	0.03	0.18	0.01	0.07	0.04	0.21
Services $\in \{0,1\}$	0.01	0.10	0.06	0.24	0.17	0.38
Other services $\in \{0,1\}$	0.18	0.39	0.23	0.42	0.15	0.36
Observations	1,891		407		5,209	

Source: IAB Establishment Panel, Waves 2009-2012. Data are weighted by sampling weights.

Table 3.A.1. Summary statistics for the panel estimation.

	West Germany						East Germany					
	Sector level		*Firm level*		*Individual*		*Sector level*		*Firm level*		*Individual*	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of employees $\in \mathbb{N}^+$	24.72	75.22	48.62	110.60	11.16	26.10	21.39	43.53	43.99	72.48	9.63	21.03
Competition level												
No competition $\in \{0,1\}$	0.09	0.29	0.09	0.28	0.08	0.27	0.10	0.30	0.05	0.21	0.09	0.28
Low competition $\in \{0,1\}$	0.14	0.34	0.09	0.28	0.19	0.39	0.13	0.34	0.09	0.29	0.16	0.37
Medium competition $\in \{0,1\}$	0.39	0.49	0.24	0.43	0.41	0.49	0.37	0.48	0.50	0.50	0.44	0.50
High competition $\in \{0,1\}$	0.39	0.49	0.58	0.49	0.31	0.46	0.40	0.49	0.35	0.48	0.32	0.47
(Rent per employee)/1000 $\in \mathbb{R}$	54.28	142.43	74.07	78.68	47.37	70.70	54.66	103.33	46.15	38.23	38.26	54.72
Business fluctuations $\in \{0,1\}$	0.53	0.50	0.59	0.49	0.54	0.50	0.50	0.50	0.64	0.48	0.54	0.50
Export share $\in [0,1]$	0.03	0.11	0.05	0.14	0.04	0.14	0.01	0.07	0.02	0.10	0.03	0.11
Share of workers with higher education $\in [0,1]$	0.02	0.08	0.11	0.23	0.06	0.17	0.08	0.19	0.12	0.22	0.08	0.19
Business sector												
Agriculture $\in \{0,1\}$	0.05	0.22	0.03	0.16	0.03	0.16	0.02	0.15	0.02	0.13	0.04	0.20
Manufacturing $\in \{0,1\}$	0.20	0.40	0.21	0.40	0.13	0.34	0.16	0.36	0.18	0.38	0.13	0.33
Construction $\in \{0,1\}$	0.21	0.41	0.16	0.37	0.10	0.30	0.27	0.45	0.07	0.26	0.15	0.36
Retail $\in \{0,1\}$	0.23	0.42	0.23	0.42	0.25	0.43	0.20	0.40	0.41	0.49	0.21	0.41
Traffic $\in \{0,1\}$	0.09	0.29	0.05	0.22	0.12	0.32	0.05	0.22	0.08	0.27	0.12	0.33
Finance/Insurance $\in \{0,1\}$	0.03	0.17	0.002	0.04	0.04	0.20	0.04	0.20	0.01	0.11	0.05	0.22
Services $\in \{0,1\}$	0.01	0.10	0.09	0.28	0.18	0.39	0.01	0.09	0.01	0.08	0.14	0.35
Other services $\in \{0,1\}$	0.17	0.38	0.24	0.43	0.15	0.35	0.24	0.43	0.22	0.41	0.15	0.36
Observations	1,396		214		2,703		503		189		2,501	

Source: IAB Establishment Panel, Wave 2012. Data are weighted by sampling weights.

Table 3.A.2. Summary statistics for East and West Germany.

3.B Regression Results

In a multinomial logistic regression, one of the choice categories is chosen as base category. Its coefficients are normalized to zero to identify the coefficients of the other categories (Greene, 2010, p. 763). Here, the base category is individual bargaining. The choice of the base category does not make a difference for the marginal effects reported in Section 3.6.

	Model 1		**Model 2**	
Bargaining level	*Firm level*	*Sector level*	*Firm level*	*Sector level*
Number of employees	0.022***	0.014***	0.023***	0.016***
	(0.002)	(0.001)	(0.001)	(0.001)
(Number of employees)^2	-0.00002***	-0.00001***	-0.00002***	-0.0000***
	(3.8e^{-06})	(1.7e^{-06})	(3.9e^{-06})	(1.8e^{-06})
Competition level				
1 = No	-0.350	0.062	-0.288	0.034
	(0.527)	(0.179)	(0.542)	(0.184)
1 = Low	-1.091***	-0.432***	-1.049***	-0.468***
	(0.312)	(0.147)	(0.315)	(0.150)
1 = Medium	-0.719***	-0.267**	-0.699***	-0.290***
	(0.236)	(0.107)	(0.233)	(0.109)
(Rent per employee)/1000			0.002**	0.002**
			(0.001)	(0.001)
1 = Business fluctuations			0.140	-0.179*
			(0.209)	(0.099)
Export share			-1.834***	-1.731***
			(0.672)	(0.484)
Share of employees with higher education			1.813***	0.804**
			(0.532)	(0.384)
Constant	-3.599***	-0.704***	-3.848***	-0.628***
	(0.720)	(0.216)	(0.780)	(0.239)
Sectoral dummies	yes		yes	
Observations	7,507		7,507	
Pseudo-R^2	0.0912		0.1012	
χ^2 (df)	490.42*** (24)		514.77*** (32)	

Notes: Multinomial logit estimation, base category is individual wage agreement. Marginal effects in Table 3.4. Data are weighted by sampling weights. Heteroskedasticity-robust standard errors are in parentheses. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Wave 2012.

Table 3.B.1. Regression results

	West Germany		East Germany	
Bargaining level	*Firm level*	*Sector level*	*Firm level*	*Sector level*
Number of employees	0.018***	0.014***	0.039***	0.027***
	(0.002)	(0.001)	(0.004)	(0.003)
(Number of employees)^2	-0.0000***	-7.6e^{-06}***	-0.00008***	-0.00006***
	(2.9e^{-06})	(9.6e^{-07})	(0.00001)	(9.9e^{-06})
Competition level				
1 = No	-0.305	-0.006	-0.172	-0.042
	(0.662)	(0.216)	(0.619)	(0.311)
1 = Low	-1.346***	-0.473***	-0.286	-0.435
	(0.400)	(0.171)	(0.442)	(0.305)
1 = Medium	-1.134***	-0.270**	0.190	-0.356*
	(0.299)	(0.126)	(0.340)	(0.192)
(Rent per employee)/1000	-0.001*	0.001	0.001	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
1 = Business fluctuations	-0.024	-0.110*	0.396	-0.114
	(0.269)	(0.114)	(0.279)	(0.177)
Export share	-1.406*	-1.663***	-3.410***	-3.620***
	(0.751)	(0.515)	(0.747)	(1.043)
Share of employees with higher education	-2.032***	-1.330***	1.630***	0.893*
	(0.765)	(0.511)	(0.617)	(0.533)
Constant	-3.317***	-0.175	-5.353***	-2.773***
	(0.977)	(0.274)	(0.705)	(0.529)
Sectoral dummies	yes		yes	
Observations	4,313		3,193	
Pseudo-R^2	0.1094		0.1221	
χ^2 (df)	352.58*** (32)		373.94*** (32)	

Notes: Multinomial logit estimation, base category is individual wage agreement. Marginal effects in Table 3.5. Data are weighted by sampling weights. Heteroskedasticity-robust standard errors are in parentheses. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Wave 2012.

Table 3.B.2. Regression results for West and East Germany

	Pooled Regression				Random Effects	
	Heteroskedastic S.E.		*Clustered S.E.*			
Bargaining level	*Firm level*	*Sector level*	*Firm level*	*Sector level*	*Firm level*	*Sector level*
Number of employees	0.022***	0.017***	0.022***	0.017***	0.006***	0.023***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
(Number of employees)^2	-0.00002***	-0.00001***	-0.00002***	-0.00001***	-3.8e^{-06}*	-0.00001***
	(1.8e^{-06})	(1.1e^{-06})	(2.5e^{-06})	(1.8e^{-06})	(2.1e^{-06})	(2.7e^{-06})
Competition level						
1 = No	-0.391	-0.031	-0.391	-0.031	0.367	0.159
	(0.376)	(0.120)	(0.594)	(0.151)	(0.273)	(0.230)
1 = Low	-0.434**	-0.147	-0.434*	-0.147	0.292*	-0.135
	(0.202)	(0.090)	(0.260)	(0.112)	(0.160)	(0.161)
1 = Medium	-0.461***	-0.176***	-0.461**	-0.176**	0.320***	-0.172
	(0.154)	(0.063)	(0.192)	(0.075)	(0.113)	(0.111)
(Rent per employee)/1000	-0.001	0.002***	-0.001	0.002***	0.001*	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Export share	-1.000*	-1.096***	-1.000	-1.096**	-0.277	0.021
	(0.577)	(0.294)	(0.801)	(0.448)	(0.387)	(0.446)
Share of employees	-1.549***	-0.988***	-1.549***	-0.988***	2.046***	-1.328**
with higher education	(0.355)	(0.235)	(0.458)	(0.306)	(0.728)	(0.688)
Constant	-4.232***	-0.791***	-4.232***	-0.791***	-6.767***	3.616***
	(0.337)	(0.142)	(0.424)	(0.216)	(0.610)	(0.325)
Sectoral dummies	yes		yes		yes	
Year dummies	yes		yes		yes	
Federal state dummies	no		no		no	
Observations	23,846		23,846		23,846	
Pseudo-R^2	0.0869		0.0869		-	
Wald χ^2 (df)	1221.79*** (32)		564.65*** (32)		-	

Notes: Multinomial logit estimation, base category is individual wage agreement. Marginal effects in Table 3.6. Data are weighted by sampling weights in the pooled regression and unweighted in the random effects estimation. Standard errors are in parentheses. Clustered standard errors are clustered by establishment. Random effects are establishment-specific. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Waves 2009-2012.

Table 3.B.3. Regression results for panel estimation.

	Pooled Regression				Random Effects	
	Heteroskedastic S.E.		*Clustered S.E.*			
Bargaining level	*Firm level*	*Sector level*	*Firm level*	*Sector level*	*Firm level*	*Sector level*
Number of employees	0.021***	0.017***	0.021***	0.017***	0.020***	0.008***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
(Number of employees)^2	-0.00002***	-0.00001***	-0.00002***	-0.00001***	-0.00002***	-1.4e^{-06}
	(1.7e^{-06})	(1.2e^{-06})	(2.4e^{-06})	(1.8e^{-06})	(2.2e^{-06})	(1.1e^{-06})
Competition level						
1 = No	-0.457	-0.037	-0.457	-0.037	-0.673***	0.051
	(0.377)	(0.122)	(0.597)	(0.155)	(0.253)	(0.252)
1 = Low	-0.465**	-0.160*	-0.465*	-0.160	-0.485***	-0.112
	(0.200)	(0.091)	(0.257)	(0.113)	(0.185)	(0.162)
1 = Medium	-0.502***	-0.182***	-0.502***	-0.182**	0.356***	-0.232**
	(0.154)	(0.065)	(0.192)	(0.077)	(0.120)	(0.109)
(Rent per employee)/1000	-0.001	0.002***	-0.001	0.002***	0.001*	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Export share	-0.786	-1.243***	-0.786	-1.243***	-0.085	-0.250
	(0.572)	(0.301)	(0.788)	(0.457)	(0.385)	(0.384)
Share of employees with higher education	-1.589***	-0.695***	-1.599***	-0.695**	2.152***	-0.025
	(0.357)	(0.237)	(0.462)	(0.312)	(0.553)	(0.387)
Constant	-5.015***	-0.582***	-5.015***	-0.582*	-6.956***	-2.696***
	(0.414)	(0.202)	(0.531)	(0.315)	(0.770)	(0.551)
Sectoral dummies	yes		yes		yes	
Year dummies	yes		yes		yes	
Federal state dummies	yes		yes		yes	
Observations	23,846		23,846		23,846	
Pseudo-R^2	0.1074		0.1074		-	
Wald χ^2 (df)	1832.32*** (32)		887.57*** (32)		-	

Notes: Multinomial logit estimation, base category is individual wage agreement. Marginal effects in Table 3.7. Data are weighted by sampling weights in the pooled regression and unweighted in the random effects estimation. Standard errors are in parentheses. Clustered standard errors are clustered by establishment. Random effects are establishment-specific. */**/*** means significance at 10/5/1% level.
Source: IAB Establishment Panel, Waves 2009-2012.

Table 3.B.4. Regression results for panel estimation with federal state dummies.

3.C Excluded Sample

	Sector level	
Variable	Mean	SD
Number of employees $\in \mathbb{N}^+$	17.92	56.28
Competition level		
No competition $\in \{0,1\}$	0.09	0.28
Low competition $\in \{0,1\}$	0.13	0.33
Medium competition $\in \{0,1\}$	0.38	0.49
High competition $\in \{0,1\}$	0.40	0.49
(Rent per employee)/1000 $\in \mathbb{R}$	43.07	46.94
Business fluctuations $\in \{0,1\}$	0.67	0.47
Export share $\in [0,1]$	0.01	0.03
Share of workers with higher education $\in [0,1]$	0.02	0.06
Business sector		
Agriculture $\in \{0,1\}$	0.003	0.05
Manufacturing $\in \{0,1\}$	0.29	0.45
Construction $\in \{0,1\}$	0.48	0.50
Retail $\in \{0,1\}$	0.04	0.21
Traffic $\in \{0,1\}$	0.04	0.20
Finance/Insurance $\in \{0,1\}$	0.00	0.00
Services $\in \{0,1\}$	0.00	0.00
Other services $\in \{0,1\}$	0.14	0.34
Observations	417	

Source: IAB Establishment Panel, Wave 2012. Data are weighted by sampling weights.

Table 3.C.1. Summary statistics of the excluded sample

Industry	Industry Code	Region	2009	2010	2011	2012
Gardening, landscaping, sports field construction	81301	Germany	X	X	X	X
Silviculture	2100	North Rhine-Westphalia	X	X	X	X
Manufacture of bricks and tiles	23320	Bavaria	X	X	X	X
Manufacture of ceramics	23200-23500	Rhineland-Palatinate: Districts of Koblenz, Trier, Alzey-Worms, Mainz-Bingen, Cities of Mainz and Worms		X	X	X
Cutting, shaping and finishing of stone	23700	Germany	X	X	X	X
Electric installation	43210	Eastern Berlin and Brandenburg	X			
Weaving of textiles	13200	North Rhine-Westphalia	X	X	X	X
Manufacture of grain mill products	10610	North Rhine-Westphalia	X	X	X	X
Manufacture of breads	10710	Schleswig-Holstein				X
		Hamburg	X	X	X	X
Construction	41201, 41202, 42110, 42120, 42130, 42210, 42220, 42910, 43110, 43120, 43130, 43291, 43330, 43912, 43992, 77320	Germany	X	X	X	X
Painting and laquering	43341	Germany	X	X	X	X
Erection of roofs, roof covering and related plumbing works	43911	Germany	X	X	X	X
Glazing	43342	Lower Saxony	X	X	X	X
Scaffolds and work platforms erecting and dismantling	43991	Germany	X	X	X	X
Wholesale	45310, 46200-47000	North Rhine-Westphalia	X	X	X	X
Accomodation and food service activities	55101-57000	Lower Saxony				X
		North Rhine-Westphalia	X	X		
General cleaning of buildings	81201	Germany	X	X	X	X
Hairdressing	96021	Schleswig-Holstein				X
		Bremen, Lower Saxony, North Rhine-Westphalia, Hesse, Baden-Wurttemberg, Bavaria, Thuringia, Rhineland-Palatinate: District South, except Mainz, Worms, Mainz-Bingen, Alzey-Worms	X	X	X	X
Hairdressing, except cooperatives		Saxony	X	X	X	X
Private security activities	80100	Berlin, Brandenburg, Baden-Wurttemberg, Bavaria, Hesse, North Rhine-Westphalia	X	X	X	X
		Hamburg	X	X		X
		Lower Saxony, Saxony	X	X		
		Bremen, Saarland, Schleswig-Holstein	X			
		Saxony-Anhalt, Mecklenburg-West Pomerania				X
		Thuringia	X	X	X	

Notes: Establishments were excluded if they applied sector-level collective agreements and if they belonged to industries for which the government declared declared collective agreements of the types *Rahmen-*, *Entgelt-*, or *Lohntarifvertrag* to be generally binding, based on the registers of generally binding collective agreements from January 1, 2009 – 2012. Industry code refers to the German classification WZ2008 of economic sectors.

Table 3.C.2. List of industries excluded from estimation sample

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