Globalization and Labor Market Outcomes: Applying Schumpeterian Growth Models

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Contents

Abstract

This dissertation examines the impact of international trade and FDI on the skill premium and on welfare of different skill groups. Four related North-North Schumpeterian growth models capturing different aspects of the issue are employed. CGE simulations test the models' performance for European data.

Dinopoulos and Segerstrom (1999) present a 2x2x2 dynamic general-equilibrium model of endogenous innovation with structurally identical countries (the "benchmark" model), offering a trade-based explanation for rising wage inequality. The two goods are manufactures and R&D services. Firms are either producers ("quality leaders" earning monopoly profits from sales in both countries) or innovators ("quality followers" trying to outstrip the leaders). Quality leaders' profits increase when (iceberg) trade costs fall as they earn higher profits abroad. Since quality followers increase their R&D efforts when profit opportunities rise, falling trade costs create a greater incentive to innovate. With R&D being the skilled-labor-intensive activity, this increases the relative demand for skilled labor and thus the relative wage.

The benchmark model is extended in three ways. First, the possibility of unskilled-labor unemployment is introduced. Trade liberalization, inducing a higher rate of innovation, produces frictional unemployment due to increased job turnover. In this first extension, trade liberalization still increases the demand for skilled labor, but on the other hand the effective supply of unskilled labor falls, which depresses the relative wage. Hence, unemployment "absorbs" a portion of the increase in the relative wage. However, the unemployment-adjusted relative wage increases unambiguously.

The second extension introduces the possibility of horizontal FDI, which can be performed by firms once they bear a cost that depends on the FDI level. Firms save trade costs but pay higher FDI costs when increasing FDI activity. The impact of falling trade costs is now twofold. First, the wage gap is widened due to increased innovation, as described above. Second, falling trade costs diminish the incentive to perform horizontal FDI as the "jumping" motive partially erodes. Therefore, the impact of falling trade

costs is smaller than in the benchmark model. As opposed to that, a decrease in FDI costs increases both the FDI level and the relative wage.

Third, we account for the fact that skilled and unskilled households have different consumption patterns: unskilled households consume relatively more tradables when comparing consumption expenditure shares. Extending the benchmark model by introducing a novel type of household preferences and a non-tradables sector, the different consumption patterns imply that trade liberalization has a different impact on households' real income, depending on how much tradables they consume. In the presence of non-tradables, the increase in wage inequality is smaller.

Calibrating and simulating the benchmark model yields that trade liberalization explains about 5 percent of the increase in the relative wage. For the model with unemployment, the fraction of the unemployment-adjusted relative wage explained is even smaller, but the fraction of unemployment explained is about 40 percent. In the model with FDI, the impact of a combined decrease in trade cost and FDI cost leads to a greater increase in the relative wage than before. Introducing FDI enhances the explanatory power of international trade by about one third. In all model variants, welfare increases by 4 to 20 percent, depending on model specification and skill group, thus all households gain in the long run. In the model with non-tradables, unskilled households gain even more than skilled households.

The results confirm the finding of the literature that trade explains only a small fraction of increasing wage inequality. Simulating technological change or institutional reform, however, reveals that the models are apt to reproduce real-world outcomes. In reality, these phenomena are closely related to trade. The different effects are isolated and their relative importance is determined.

List of Tables

List of Abbreviations

BTD	Bilateral Trade Database
CES	constant elasticity of substitution
CEX	Consumer Expenditure Survey
CGE	computable general equilibrium
EPO	European Patent Office
FDI	foreign direct investment
FOC	first-order condition
GTAP	Global Trade Analysis Project
ISCED	International Standard Classification of Education
JPO	Japanese Patent Office
LIS	Luxembourg Income Study
MNE	multinational enterprise
NLS	non-linear least squares
OECD	Organisation for Economic Co-Operation and Development
OLS	ordinary least squares
PPML	Poisson pseudo maximum likelihood
R&D	research and development
STAN	Structural Analysis
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
USPTO	United States Patent and Trademark Office

Chapter 1

Introduction

The wage distribution is essential for the structure of a society. It determines who consumes what and how much, who becomes poor, and whether a society drifts apart due to dwindling social coherence. It has an important influence on people's educational decisions, on firms' hiring and training policy, and also on the aggregate saving rate and therefore on investment decisions. It also has an impact on the technology employed and therefore on productivity as well as on the institutional framework and on most political decisions. There are many reasons why it is worthwhile taking a closer look at the issue, and economists as early as Adam Smith were eager to examine the roots of wage inequality. Smith (1776) identifies five factors that influence the remuneration of a job: "first, the agreeableness or disagreeableness of the employments themselves; secondly, the easiness and cheapness, or the difficulty and expense of learning them; thirdly, the constancy or inconstancy of employment in them; fourthly, the small or great trust which must be reposed in those who exercise them; fifthly, the probability or improbability of success in them" (p. 112). Of particular interest for this dissertation is the second point: "the difficulty and expense" means that becoming skilled earns an individual a pecuniary compensation, or as Smith (1776) puts it, the wage "will replace to him the whole expense of his education" (p. 113). What Smith describes verbally is an endogenous skill decision as well as an endogenous skill premium, where skilled workers earn more than unskilled since they have forgone income in the past while undergoing training. The third point from Smith is also of great interest for this dissertation. The "constancy or inconstancy of employment," in other words, job security, strongly affects the actual wage structure as an individual's employment status decides whether he has an income or not and thus his expected wage. This interaction of wage inequality and unemployment is nowadays often called the "Krugman hypothesis."

Skill premia have increased considerably over the past few decades in most countries around the world. There are several different reasons for the ongoing trend of an increase in wage inequality (or, with rigid wages, an increase in the unemployment rate of unskilled labor). The two main competing explanations are globalization, with Leamer and Wood being two of the most prominent exponents[1], and skill-biased technological change, which has more advocates than the trade explanation, among them such renowned economists like Phelps, Tinbergen, or Krugman[2]. We will show, however, that the two explanations are closely related in such a way that trade provides a reason for skill-biased technological change to happen. Moreover, it is reasonable to assume that technological change facilitates trade. As Acemoglu (2002b) puts it, “technology itself is no more than an endogenous actor” (p. 13) instead of an explanation of its own right. A profit-based incentive for skill-biased technological change is required. Another oft-cited cause of wage dispersion is institutional change, manifesting itself in the erosion of union power or minimum-wage regimes.

The aim of this dissertation is to explore the relationship between globalization and labor market outcomes by means of endogenous-growth models. However, globalization appears in many different guises: trade liberalization, international outsourcing and offshoring, increased migration of labor and capital, cultural globalization, or faster transmission of international shocks and trends. The general feeling we have about this phenomenon is that countries, firms, or people move closer together, hence the notion of the “global village.” One of the major causes for this increased global integration are falling costs of communication, transport, or the abolition of tariff barriers. Here we summarize these cost reductions as falling trade costs, either in the form of iceberg transport costs or as iceberg costs of foreign direct investment (FDI), as we shall see.

The most famous trade model that is able to explain changes in relative wages is probably the Heckscher-Ohlin model, which has a North-South country structure. Assuming that the North manufactures a skill-intensive good while the South produces a non-skill-intensive good, it offers an explanation by means of the Stolper-Samuelson theorem: from the Northern perspective, the relative price of (unskilled-labor-intensive) imports declines, therefore the wage of unskilled workers compared to skilled workers must decline as well. The problem is that import prices in terms of exports actually did not decline (much) over time, hence the change in the relative wage (defined as the wage of skilled vs. unskilled labor) cannot be explained by North-South trade (alone). Furthermore, North-North trade is by far more important than North-South trade.

[1] Cp. Leamer (1993, 1994) and Wood (1995).

[2] Cp. Nelson and Phelps (1966), Tinbergen (1975), and Krugman (1995).

A version of the model from Dinopoulos and Segerstrom (1999) we employ here has a structure that fixes relative goods prices in equilibrium. Hence the channel that changes the relative wage is somewhat different but of a Stolper-Samuelson kind, too. The authors call this the "Schumpeterian version" of the Stolper-Samuelson theorem: there are two activities (manufacturing and innovation) and two factors (unskilled and skilled labor). When trade costs fall, profit opportunities increase due to better market access. Since R&D (research and development) effort is the basis of making profits in the first place, innovative activity will rise. As innovation is assumed to be skilled-labor-intensive, the factor price of skilled labor rises relative to unskilled labor. We explore the impact of falling trade costs on the relative wage in one country. For these purposes, we use a so-called North-North model. As the name suggests, it assumes symmetric countries trading with each other.

The term "Schumpeterian" refers to the notion of "creative destruction," i.e., the constant industrial transformation through innovation, resulting in the weakening of the positions of monopolists and thus sustaining long-run growth. It was first formulated by Joseph Schumpeter (1942). This class of models is also often named the (R&D-based) "new growth theory." Central to these models, although differing in many respects, is the common idea that firms conduct R&D to reap temporary monopoly profits. Hence, as opposed to models of exogenous growth, these models draw a clear picture of the deeper reasons for innovation by formalizing an explicit incentive structure. An important difference to the Heckscher-Ohlin model is that trade does not occur on the basis of endowment differences. In the Schumpeterian model, the trade pattern is determined by differences in knowledge. Due to ongoing innovation, the pattern of comparative advantage is constantly changing: each country manufactures half of the goods available, but which of the goods it produces depends on the success of its innovators in the past.

Apart from the term "globalization" in the title, which we tried to clarify above, the expression "labor market outcomes" is very comprehensive. In our context, the meaning is twofold: we refer to the relative wage, i.e., the wage of skilled labor relative to unskilled labor as well as the unemployment rate. The idea that wages and unemployment rates are just "different sides of the same coin"[3] will be accounted for as well. In our basic (or "benchmark") model, we examine and quantify the impact of globalization on the relative wage in one country, and later on we add the possibility of unemployment.

The word "applying" appears in the title since our focus is not only upon the theoretical model implications, but on application to real-world data as well. In fact, we formulate the different model variations as computable general equilibrium (CGE) mod-

[3]Krugman (1994), p. 62.

els so that we can explore the qualitative and quantitative results of changes in model parameters such as falling trade costs. As opposed to other CGE models applied to actual data (one of the most prominent examples being the Global Trade Analysis Project, GTAP), our models are highly stylized. This demands some deliberation about how appropriate data might look like in order to feed the models.

Apart from the relative wage, our second goal is to examine the impact on employment by allowing for non-clearance of labor markets due to a time-consuming search process. The second question uses the same model, but modifies it drawing upon Sener (2001) in many parts. Increased innovation induces greater fluctuations and thus labor turnover, which results in a higher rate of unemployment. We will see that the unemployment-adjusted relative wage still increases when trade is liberalized, but the unadjusted relative wage may decline. The reason is that increased "Schumpeterian" unemployment due to innovation reduces the *effective* supply of unskilled labor, introducing scarcity that may lead to unskilled workers (only those who still have a job) being better off.

Third, we try to understand the impact of horizontal FDI, performed in order to save transport costs. The main reason is that FDI is now the dominant channel through which firms serve foreign customers: according to UNCTAD (1999), the total value for foreign affiliate sales was 11 trillion dollars already in 1998 while the value of worldwide exports was 7 trillion dollars. In a North-South context, there would be an incentive to fragment production, accruing from lower wages in the South (vertical FDI). However, we want to stick with the North-North structure since our empirical aim is Western Europe where countries are relatively homogeneous compared to all other countries in the world. Moreover, North-North FDI is quantitatively far more important than North-South FDI, thus we employ a model of horizontal FDI instead of vertical FDI. A model of vertical FDI would not make sense in a North-North context as there are by definition no factor price differences to be exploited. Apart from iceberg transport costs, we assume the presence of another cost component that depends on the volume of FDI (FDI cost). Therefore, firms face a trade-off when increasing their FDI level: they save trade costs but bear higher FDI costs. This model variant has three novel features. First, the model extends an existing theoretical framework to the case of horizontal FDI, thereby shedding new light on the role of falling transport costs. Second, the notion of "trade liberalization" in this context is generalized by introducing a second cost component, namely FDI costs. Third, the total impact of both components on the skill premium is quantified by simulating the model for a sample of European countries (Germany, France, the United Kingdom, and the Netherlands).

The pertinent literature does not examine the welfare implications of shocks in this kind of models. We therefore develop an appropriate welfare measure, both for the entire economy and for the different skill groups. This is particularly interesting for the case of unskilled workers since it is a priori unclear whether their short-run nominal wage loss is offset by long-run real wage increases as implied by Schumpeterian growth models.

A point that has been neglected by our models so far is the presence of non-tradable services. Empirically, unskilled households spend a greater share of their consumption expenditure on tradable goods than skilled households do. The implication in this model context is that, since the economic development in Schumpeterian growth models can be interpreted as a continuous increase in real income (or a continuous decline in tradables prices), the benefits from international trade depend on how much tradables a household consumes—and since unskilled households consume relatively more tradables, they benefit more from the decline in tradables prices. We therefore develop a measure of the real relative wage that fits our model context and check by how much changes in real relative wages differ from their nominal counterparts. Then we incorporate the household-specific consumption pattern into the model and introduce a non-tradables sector. We assume a novel type of household preferences which we try to justify empirically by using data on household expenditure. The non-tradables sector offers partial protection from the forces of globalization for unskilled workers, which weakens the impact of trade liberalization. Moreover, the impact on welfare changes.

Model Property	Dinopoulos & Segerstrom (1999)	Sener (2001)	Glass & Saggi (2001)	Sayek & Sener (2006)
Competition	Cournot	Bertrand	Bertrand	Bertrand
Number of Factors	2	2	1	2
Endogenous Factors	yes	yes	no	no
Used in Both Activities	yes	no	n.a.	no
Trade Costs	yes	yes	no	no
Unemployment	no	yes	no	no
FDI	no	no	yes (vertical)	yes (vertical)
Structure	North-North	North-North	North-South	North-South

Table 1.1: Comparison of Some Relevant Schumpeterian Growth Models.

It is true that the relationship between increased global integration and wage disparities has often been studied before empirically. However, what has only been done to a lesser extent so far is the empirical application of Schumpeterian models to labor-market-related issues, especially in a CGE framework. Furthermore, there is no empirical work yet dealing with these different labor market issues in a unified treatment. Appropriate models are available only for certain aspects. The main problem is, however, that relevant models differ with respect to crucial model assumptions. Table 1.1 shows the major differences of some models that are relevant for our topic but are too different from each other and thus too hard to compare to be applied one-to-one to the data. There is no common basis for quantitative comparisons of model outcomes since available models differ with respect to their foundations (e.g., type of competition, incorporation of trade costs, country structure). Defining a common basis—Bertrand competition, endogenous factor supplies, two factors, incorporation of trade costs, North-North structure—and extending this benchmark model in three steps (unemployment, horizontal FDI, non-tradables) is one of the tasks we are going to solve. One contribution of this dissertation is to establish a basic framework that is extended in a stepwise fashion in order to examine how different extensions influence the model outcomes.

This dissertation is structured as follows. The next chapter gives an overview of the development of wage inequality and unemployment in OECD (Organisation for Economic Co-Operation and Development) countries since the 1980s. It then offers an extensive literature overview about the reasons for increasing wage inequality, both from a theoretical and empirical perspective. In Chapter 3 all three model variants are presented. Whenever there is original content, this will be highlighted in the course of the dissertation. First, we will exhibit the benchmark model in detail. We slightly modified the paper from Dinopoulos and Segerstrom (1999) and incorporated some new ideas. Our goal was to present the model in a CGE-applicable form that allows for unemployment and horizontal FDI to be added. Moreover, we address welfare issues, both economy-wide and for different skill groups. Next, the framework is extended by allowing for unemployment. Some important modifications of the model from Sener (2001) were necessary to make the model operational, comparable to the benchmark model, and the results interpretable. Last, the benchmark model is enriched by introducing the possibility of horizontal FDI. This is a feature that does not appear in the literature yet. Chapter 4 describes the empirical strategy, i.e., the data used as well as the model calibration. Most parts of that chapter are new contributions. Chapter 5 discusses the simulation results from all three model variants. In Chapter 6, all of which is a new contribution, we take account of the different consumption patterns of skilled and unskilled households and present a suitable model extension and simulation results. Chapter 7 concludes.

Chapter 2

Trends and Determinants of Wage Inequality

Between 1949 and 1996, the U.S. skill premium of college relative to non-college education has increased from about 1.35 to 1.8. There were, however, periods of decreasing skill premia, namely at the beginning of the 1960s and during the 1970s. As opposed to these temporary fluctuations against the secular trend of rising college premia, the relative supply of college skills is pointing upwards virtually all the time and increased from about 1.2 to 2.0. This means that skill premia and skill supplies moved in the same direction most of the time, but there were also periods where they ran in opposite directions.[1] Apart from years of schooling, professional experience is also an indicator of skill and has a strong impact on the wage rate.[2]

Contrary to the U.S. experience, German wage inequality has been "unbearabl[y]"[3] stable until the mid-1990s. One reason could be relatively high training levels of German youths without college education. Moreover, the growth of the highly educated labor force was stronger in Germany than in the U.S. in the 1980s.[4] Finally, wage inequality started to increase, which is mostly attributed to declining union power.[5] Germany had (and still has) a high level of unemployment, and the unemployment rate of unskilled workers is a particularly tough problem. Given that unemployment rates are part of the story of wage inequality (Krugman hypothesis, see below), the recent trend of declining

[1] Cp. Katz and Murphy (1992), Murphy and Welch (1992), and Bound and Johnson (1992) as well as Katz and Autor (2000) and Acemoglu (2002b) for surveys.

[2] Cp. Juhn et al. (1993).

[3] Prasad (2004), p. 1.

[4] Cp. Abraham and Houseman (1993).

[5] Cp. Kohn (2006), Möller (2006), and Gernandt and Pfeiffer (2006).

unemployment rates due to less wage rigidity might have put upward pressure on the relative wage, as has been observed in other countries as well (in the United Kingdom or the Netherlands during the 1990s, for instance). Another reason for rising wage inequality during the last years may be the German educational system that increases educational inequality due to early tracking.

The experience of these two different countries—the United States and Germany—does not allow for an explanation of changing skill premia by means of supply changes—alone they would dictate a narrowing of the wage gap. Hence, there must be other influences that govern the development of the skill premium. One explanation are declining costs of international trade, the topic of this dissertation. Apart from trade liberalization, which empirically explains only a small fraction of rising wage inequality, there are competing explanations, the most widespread of them being skill-biased technological change. After an overview of the evolution of inequality in the "North," i.e., OECD countries (Section 2.1), we will describe theoretically and empirically what reasons for the weakening of the relative position of unskilled labor are conceivable and how these different explanations are intertwined (Section 2.2).

It is realistic to assume that relative labor supply does not react quickly enough to fully compensate for changes in relative labor demand since education takes a lot of time.[6] Thus, the relative wage either rises or, with a fixed relative wage, unskilled-labor unemployment increases. Rising wage inequality especially in the United States and rising unemployment, particularly of unskilled workers, in many (continental) European countries can be considered a direct consequence of a fall in the relative demand for unskilled labor. Regarding wage dispersion and unemployment as two sides of the same coin is often referred to as the "Krugman hypothesis" in the literature. Among others, Puhani (2003) tests it for the United States, Britain, and Western Germany and finds some support. We do not consider Krugman's hypothesis the ultimate truth, but for this dissertation it has some value. Relative wages can easily be adjusted by unemployment rates, reflecting the fact that an increased probability of becoming unemployed has a certain equivalent in terms of changing wages. The reasonable assumption that unskilled labor is much more affected by changes in aggregate unemployment than skilled labor[7]

[6] E.g., cp. Acemoglu (2003).

[7] There is an extensive literature on job security and job stability, depending on, inter alia, educational attainment. E.g., Rose (1995) reports that for the United States, high school dropouts were much more likely to be employer changers (having changed employers in more than four years over a 10-year period) in the 1970s and 1980s. Similarly, Aaronson and Sullivan (1998) find that displacement rates of non-graduates vs. college graduates and blue-collar vs. white-collar workers were about twice as high (for workers with five or more years of tenure). The same holds for the likelihood of job loss, and the reverse figures for the likelihood of finding comparable employment. For Germany, Schmidt (1999) reports

due to the fact that unskilled workers are easier to replace entails the following. Define the *adjusted* relative wage $\tilde{w}$ as the relative wage w weighted by the respective probability of unskilled and skilled labor, L and H, of having a job: $\tilde{w} \equiv [w_H(1-u_H)]/[w_L(1-u_L)]$ with unemployment rates u_H and u_L. With u_L being affected more than u_H by changes in the aggregate unemployment rate u_A, increases in u_A are directed against unskilled labor.

It is true that wage inequality and unemployment are two different things with different consequences for the persons concerned. For our purposes, however, aimed at explaining the weakening of the relative *position* of unskilled labor (changes in $\tilde{w}$), relative wage trends can tell a lot. Unemployment figures sometimes even support the evidence of a weaker position of unskilled labor (when both w and u_A increase), sometimes they run contrary to it (different signs of the change in w and u_A). But the overall picture of deterioration of the position of unskilled labor is very pronounced. Hence, this chapter will mainly focus on wage inequality instead of unemployment, but some unemployment figures will be presented as well.

2.1 Measurement Issues and Developments in the OECD

Wage dispersion in general describes the distribution of wages among the labor force of an economy. There are many different inequality measures such as the Gini coefficient or the Theil index.[8] Our goal is, however, to examine the relationship between an individual's educational attainment and his working experience (in short: his skills) and his wage. Data on relative wages differentiated by skill level are by far not as readily available as data on wages of different deciles. The most widespread decile relations are the relative wage of the 9th-decile worker[9] and the 5th-decile worker (i.e., the median worker), abbreviated as $\frac{D9}{D5}$, as well as the ratios $\frac{D5}{D1}$ and $\frac{D9}{D1}$, where $D1$ represents the 1st-decile worker. $\frac{D5}{D1}$ and $\frac{D9}{D5}$ measure inequality at the lower and upper tail of the distribution, whereas $\frac{D9}{D1} = \frac{D9}{D5} \cdot \frac{D5}{D1}$ measures overall inequality. For the purpose of this subsection—giving an overview of inequality developments in most OECD countries—it is adequate to assume that a higher skill level leads to a higher wage. This is actually one of the fundamentals of this thesis: the assumption that one earns more when one

much higher unemployment rates among unskilled than among skilled workers as well as higher relative employment-to-unemployment flows of the unskilled. Bergemann and Mertens (2004) find a significantly negative relationship between the risk of becoming unemployed and a college degree. Both studies for Germany use data from the German Socio-Economic Panel from the 1980s and 1990s.

[8] Cp. Sen (1997) for a comprehensive treatment of different inequality measures.

[9] This worker earns more than 90 percent of the population.

has forgone income in the past in order to accumulate human capital to reach higher income levels in the future. “Skill” is partly a subjective measure, but the hard evidence about the objectively measurable features of a worker such as years of schooling and working experience draws a clear picture: more schooling and more work experience lead to higher wage levels. Hence, this subsection will only report figures for $\frac{D9}{D1}$ instead of relative wages differentiated by educational attainment.

Table 2.1 presents wage inequality and aggregate unemployment figures for most OECD countries during the 1980s, 1990s up to 2005.[10] As one can easily see, the general trend of the wage differential is going upwards and the effect is most pronounced for the United Kingdom and the United States. For the former communist countries Hungary and Poland, inequality has also been increasing sharply. The Scandinavian countries experience the lowest levels of inequality but exhibit a slight upward trend as well. Germany’s figure virtually stagnated in the 1980s and started to slightly increase since then. The results in Table 2.1 are on the whole comparable to Sanders and ter Weel (2000), who summarize several different studies on wage inequality, examining the 1970s, 1980s, and 1990s.

One problem of the data presented in Table 2.1 is that relative wages sometimes refer to hourly, sometimes to weekly, monthly, or yearly wages, in most cases without but in some cases including fringe benefits. Neglecting fringe benefits leads to an underestimation of inequality since higher-paid workers usually earn higher fringe benefits.[11] Another problem is the gross-net difference. All figures quoted refer to gross wages, which neither reflect the workers’ incentives nor the employers’ actual cost, but data availability is in favor of using them. Moreover, the more progressive the tax system the more do gross wages overestimate wage dispersion.

Unemployment soared during the 1980s in most countries except for the United States and most Scandinavian countries. In the 1990s, it generally decreased although many European countries saw their rates rising considerably. Since 2000 the overall picture is mixed with some tendency to rise again until 2005.

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[10] The $\frac{D9}{D1}$ figures have been calculates as follows. OECD (2004), p. 141 shows average $\frac{D9}{D1}$ values for five periods: 1980–84, 1985–89, 1990–1994, 1995–99 and 2000-01, while OECD (2007) has numbers for 2005. Averaging the numbers for 1980–84 and 1985–89 yields, for instance, the values that can be found in our Table 2.1 under “1980s.” Our numbers in the “percentage change” column are the percentage changes between the 1980-84 and 1985-89 figures. The values for the other decades have been calculated correspondingly. For the (seasonally adjusted) unemployment rates we used data from the OECD website, calculating simple averages for all numbers given in a decade. The change in percentage points is always computed as the difference between the beginning and the end of a decade (2005 for the last decade).

[11] Cp. Brown (1980) for an early survey on this and other related issues.

Country	1980s				1990s				2000s			
	$\frac{D9}{D1}$		u_A		$\frac{D9}{D1}$		u_A		$\frac{D9}{D1}$		u_A	
	value	p. ch.	value	p.p. ch.	value	p. ch.	value	p.p. ch.	value	p. ch.	value	p.p. ch.
Australia	2.86	-1.74	7.52	-0.10	2.88	4.26	8.59	0.20	3.10	1.63	5.97	-1.20
Austria	3.47	1.16			3.56		4.11	-0.10			4.28	1.60
Belgium	2.40		9.29	0.40	2.28		8.47	1.90			7.67	1.50
Canada			9.38		3.65		9.55	-0.50	3.73	0.81	7.22	0.00
Czech Republic					2.86		5.21	4.20	2.71		8.00	-0.80
Denmark	2.18	0.46	6.65	-1.00	2.16		6.92	-2.10	2.64		4.85	0.50
Finland	2.50	0.40	5.40	-2.20	2.38	-1.26	11.89	7.10	2.42	0.41	9.00	-1.30
France	3.19	0.31	8.55	3.10	3.14	-4.36	10.60	2.00	4.01		9.17	0.60
Germany	2.87	-0.69	5.81	3.00	2.83	2.87	7.57	3.10	3.13		8.45	2.20
Hungary	2.83				3.85	16.90	9.68	-3.10	4.69	-9.35	6.18	0.80
Ireland			15.43	1.80	4.02	-2.22	12.05	-7.70	3.57		4.38	0.00
Italy	2.29		7.81	4.90	2.38	2.13	10.26	2.00			8.65	-2.40
Japan	3.12	2.27	2.50	0.30	3.03	-2.61	3.05	2.60	3.12		4.92	-0.30
Korea	4.42	-7.41	2.60	2.60	3.76	0.53	3.30	4.20	4.51		3.78	-0.70
Netherlands	2.51	3.24	7.31	2.30	2.73	9.62	5.42	-2.70	2.91		3.47	1.90
New Zealand	2.90		4.24	5.20	3.17	7.19	7.93	-1.00	3.49		4.78	-2.30
Norway			2.85	3.70	1.96		5.15	-2.60	2.12	8.87	4.07	1.20
Poland	2.62	2.32			3.27	15.51	13.89	-2.90	4.31		18.42	1.60
Portugal	3.56		7.59	-2.90	3.76		5.68	-0.30			5.60	3.60
Sweden	2.05	3.98	2.61	-0.60	2.17	5.69	7.20	5.00	2.32	1.30	5.77	1.70
Switzerland					2.70	-0.74	3.43	3.00	2.61		3.60	1.80
United Kingdom	3.20	6.80	9.47	1.30	3.42	1.77	8.00	-1.00	3.46	3.24	4.97	-0.50
United States	4.07	8.18	7.27	-1.80	4.49	4.56	5.75	-1.40	4.75	4.74	5.18	1.10

Table 2.1: Data on Wage Dispersion and Unemployment Rates in OECD Countries. Source: own calculations based on OECD (2004), OECD (2007), and OECD website. "p. ch.": percentage change in the respective decade, "p.p. ch.": change in percentage points in the respective decade.

2.2 The Causes of Wage Inequality

Since international trade is the focus of this dissertation, we take the trade explanation as the guideline of the following literature overview from which the other explanations are derived. This does not necessarily mean that we regard the trade explanation as more convincing—it is rather a method to get through the thicket of competing explanations and simultaneously not to digress from the leitmotif of this thesis.

In general these reasons can be classified into those concerning trade between developed and developing countries (North-South trade), trade between developed countries only (North-North trade), and reasons that do not directly refer to trade (but nevertheless are likely to interact with trade in some way). The focus of this dissertation is North-North trade, but in order to understand the main mechanisms regarding the impact of North-South trade on labor market outcomes, we will discuss both country structures. Moreover, we will discuss the (only seemingly) trade-independent causes of rising wage inequality. As Goldberg and Pavcnik (2004) state in their survey, there is no conclusive evidence on the effects of globalization on employment and wages. The problem of the causes under consideration is that they are not independent. For instance, trade is a channel for technology diffusion and adoption, indirectly influencing the relative wage through technological change. Likewise, technological progress may foster trade. Furthermore, trade policy cannot be considered exogenous since labor market outcomes determine the degree of trade liberalization.[12] We intend to separate the different mechanisms at work from each other, and point out later on how they are linked. Instead of listing countless models without going into the details of one of them, we rather describe a few models in some more detail of which we think they are representative to illustrate the important mechanisms. Understanding the underlying mechanisms is easier when a single model is fully understood. Naturally, this comes at the cost of omitting some model variations and also other mechanisms that might be at work.

Section 2.2.1 describes the impact of globalization on the labor market, viewed as a phenomenon isolated from technological change or other causes. The next step combines the effects of globalization and skill-biased technological change (Section 2.2.2) in order to enhance the explanatory power of trade with respect to labor market outcomes.[13] Thereafter, we examine globalization and institutional change such as a decline in unionization (Section 2.2.3), where market imperfections due to minimum wages or

[12] Cp. Hoekman and Winters (2005).

[13] Naturally, one could as well take technological change as the starting point from with globalization and other issues are derived, as the survey from Acemoglu (2002b) does, but we rather follow the trade-oriented approach since it is more appropriate to our topic.

union power have an impact on both the wage gap and the rate of unemployment. Given this classification, our actual Schumpeterian growth model we work with throughout this thesis and that is described in Section 3 is a model that uses the interaction of globalization and skill-biased technological change as an explanation of the increasing wage gap.

There are various other explanations such as the repercussions of gender wage inequality on overall wage inequality[14] or the role of changing tax progression after tax reforms[15]. Since they are of minor importance we do not discuss them in this thesis. Moreover, the triad of the three major explanations we deal with fits our empirical framework best, since for all explanations we have parameters at hand that can be shocked, as we will demonstrate soon.

2.2.1 Globalization

As already mentioned in the introduction of this thesis, the term "globalization" has different meanings, but all of them refer to a process that alleviates or facilitates overcoming invisible borders of some form. Therefore, in Section 2.2.1.1 we first describe what constitutes this invisible border and point at some studies that try to quantify it. The insights yielded there will also be useful later on when we have to estimate trade costs ourselves. Section 2.2.1.2 then reviews how the labor market is influenced by North-South trade through three obvious channels: liberalization of trade in goods, the possibility of vertical FDI, and migration. Section 2.2.1.3 exposes in some more detail how North-North trade affects a country's labor market. Here we discuss two different channels in models that employ a continuum of worker skills.

2.2.1.1 The Border Effects of Trade

Even in an increasingly coalescing world it remains costly to deliver a good from producer to consumer. There are various impediments that make "trade," in the broadest sense the movement of goods or services from one economic agent to another, costly, both on the intra- and international level. Border-related trade barriers include tariffs, transport costs, or language[16] and currency barriers[17]. Barriers that are related to both intra- and international trade are local distribution costs, costs of law enforcement, regulation, or information. Those non-border-dependent costs are, however, certainly even higher

[14] E.g., cp. Fortin and Lemieux (2000).
[15] E.g., cp. Bishop et al. (1998).
[16] Cp. Hummels (2001) for the impact of different languages on trade costs.
[17] Cp. Rose and van Wincoop (2003) for the impact of national currencies on trade costs.

when a border separates the agents. Since we are interested in the costs of *international* trade rather than in the broad definition of trade costs, we abstract from any costs incurred on the national level as well as from costs on the international level, given that the border has already been crossed. For the broadest measure of trade costs encompassing anything that exceeds the pure cost of production, Feenstra (1998) reports that the trade cost for a Barbie doll amounts to 900 percent: from the retail price of $10 Mattel earns $1; the difference is the cost of transportation, marketing, wholesaling, and retailing. Such a broad definition of trade costs is not appropriate for our puposes, thus we concentrate only on border-related trade costs since the reduction of the latter is what actually epitomizes "globalization." A policy-induced reduction of trade costs comprises abolition of tariffs or tariff-equivalent barriers (e.g., quotas), promoting infrastructure investment, or adopting a common currency.

Anderson and van Wincoop (2004), who provide a well-known survey on trade costs, distinguish three sources to obtain trade cost figures: direct evidence, inference from trade flows (gravity equation), and inference from prices (comparison of national retail and import prices). Compared to deduced trade cost measures, direct evidence is relatively scarce. For measurement issues in this thesis we will only consider inference from trade flows. Comparing our measures to other studies is much easier then since the majority of trade costs estimates is based on some form of the gravity equation. The reason seems to be that gravity is much more entrenched theoretically than inference from prices.

Even for very similar countries, intranational trade volumes by far exceed cross-border trade. An oft-cited study is McCallum (1995), who compares trade volumes between U.S. states and Canadian provinces, controlling for importers' and exporters' GDP and distance. He finds that intranational trade is more than 20 times larger than cross-border trade. This is called the "home bias" in the literature: domestic goods are preferred to foreign goods. Wei (1996), examining the extent of the home bias for OECD countries, controlls for exporter and importer sizes, distance, geographic position to the rest of the world[18], and possible linguistic ties. His result is that trade with itself is two and a half times larger than trade with an otherwise identical country. Anderson and van Wincoop (2003), however, detect that the gravity equation normally used in empirical applications does not have sufficient theoretical foundation and thus suffers from a bias due to omitted variables. In particular, these variables are multilateral resistance terms.

[18] For instance, Australia and New Zealand are more likely to trade with each other than Germany and Portugal since the latter trading partners are surrounded by many other countries whereas the former are very remote.

They modify the equations for estimation accordingly and find national borders to reduce trade by 20–50 percent, a smaller number than found by other authors. Evans (2003) emphasizes that strong border effects (high intranational relative to international trade volumes) can either stem from high trade costs or the fact that domestic and foreign goods are bad substitutes (i.e., the elasticity of substitution between them is high).

Head and Mayer (2004) examine a model of monopolistic competition and consumers with CES (constant elasticity of substitution) love-of-variety preferences. Given that internal trade is costless and two countries i and j face symmetric iceberg trade costs τ, the "freeness of trade" φ, a measure inverse to trade cost, is

$$\varphi \equiv (1+\tau)^{1-\sigma} = \sqrt{\frac{M_{ij}M_{ji}}{M_{ii}M_{jj}}}, \tag{2.1}$$

where M_{ij} and M_{ji} are trade flows from i to j and vice versa (i.e., imports and exports) whereas M_{ii} and M_{jj} are the volumes of "imports from self" ("exports to self"), i.e., total industry output minus exports (imports). $\sigma > 1$ is the elasticity of substitution between differentiated varieties produced in an industry as well as between domestic and foreign goods. In order to get a ballpark figure of trade barriers, (2.1) delivers a good starting guess if one has a reasonable estimate of the elasticity of substitution. We will come back to the issue of trade cost measurement in Section 4.2.

2.2.1.2 North-South Trade

In this subsection on North-South trade, we do not explicitly model trade costs but rather compare autarky with free trade, which implies a reduction of trade costs from a prohibitively high level to zero. First, we explain the impact of free trade in the classic Heckscher-Ohlin-Samuelson model. Second, we allow for the possibility of production sharing, also referred to as international outsourcing. Third, we examine the influence of migration on the relative wage.

2.2.1.2.1 The Heckscher-Ohlin-Samuelson Framework The Heckscher-Ohlin model, later often dubbed the Heckscher-Ohlin-Samuelson model after the formalization of the original model by Samuelson (1948), is a model with two countries (North and South), two factors, in our case skilled and unskilled labor, H and L, and two goods (each of them being produced with one the factors intensively, e.g., computers and textiles). Later on, Vanek (1968) extended the model to the multigood, multifactor case, which is often called the Heckscher-Ohlin-Vanek model. The Heckscher-Ohlin theorem is as simple as it is intuitive: when the two countries trade with one another, each country will export the good that uses its abundant factor intensively.[19] Hence, countries must have different endowments to provide a reason for trade.

The model assumes identical technologies across countries, thus comparative advantage cannot arise from different technologies but only from different factor prices due to different factor abundances. The technology is linearly homogeneous and both factors are essential, i.e., without using both factors nothing can be produced. Goods can always be ordered according to their factor intensity: for all possible relative factor prices (i.e., relative wages), computers remain the skill-intensive good (there are no factor intensity reversals). Tastes are identical and homothetic across countries. Trade in goods is free, but factors are only mobile between sectors, not between countries.

Apart from the Heckscher-Ohlin theorem itself, there are three main theorems that follow from the Heckscher-Ohlin-Samuelson model. First, although factors cannot cross international borders, trade in goods will equalize factor prices as long as no factor intensity reversals occur and as long as there is incomplete specialization. This result is called the factor price equalization theorem and was first formulated by Samuelson (1948, 1949). Second, given our context, when the supply of skilled labor increases, the relative production of computers increases as well since more computer firms make use of skilled labor now. Since they also require unskilled labor, textile production shrinks as resources are drawn away from the textile industry. This is called the Rybczynski (1955) theorem. Third, an increase in the relative price of computers will drive up the relative wage (defined as the wage of skilled labor over unskilled labor), which is the Stolper and Samuelson (1941) theorem. Moreover, not only the relative factor reward will increase, but factors will be affected in absolute terms as well: skilled labor will be better off while unskilled labor will be worse off. Hence, apart from overall welfare gains, free trade has important distributional consequences.

Although the Heckscher-Ohlin-Samuelson model is easily tractable and provides some major insights into the mechanics of international trade, North-South trade due to endowment differences does not seem to be a major cause of increasing wage inequality, for several reasons. First, North-South trade plays only a minor role in total world trade and in the trade balance of Northern nations in particular. Krugman (1995) reports that in 1990, imports from Newly Industrializing Economies[20] accounted for only 1.3 (1.9) percent of the GDP of the European Union (the United States). He concludes

[19]There are several textbooks on international trade, all of them dealing with the Heckscher-Ohlin-Samuelson model. Parts of this subsection rely on the textbook from Feenstra (2004).

[20]Hong Kong, Taiwan, mainland China, Singapore, Korea, Indonesia, Malaysia, Thailand, and the Philippines.

that such small trade shares can hardly have caused the observed changes in the relative wage and/or unemployment rates. Freeman (1995) suggests that there is some truth to the notion that Northern wages are "Set in Beijing" (p. 1), but the effect is probably overrated. Borjas et al. (1997) emphasize that it is very difficult to estimate the impact of North-South trade since realistic counterfactuals—how would workers and firms have behaved without growing world trade?—are hard to specify. Borjas et al. (1992) and Katz and Murphy (1992) find that the amount of low-skilled labor reaching the U.S. labor market through imports and the amount of high-skilled labor leaving the labor market through exports can hardly account for the large changes in the skill premium.[21]

Second, according to the Stolper-Samuelson theorem, a decrease in the price of unskilled labor would imply a decrease in the price of unskilled-labor-intensive goods, i.e., imports from the Northern perspective (see next subsection for a discussion of the role of imported intermediates). The evidence on relative prices (of imported in terms of exported goods), however, does not permit a final conclusion on that. Lawrence and Slaughter (1993) find no change in relative prices while Sachs and Shatz (1994) report a small decline in relative prices of unskilled-labor-intensive goods, which is in accordance with the Stolper-Samuelson meachnism (both studies refer to the United States). The latter point out that not observed prices, but prices adjusted by total factor productivities have to be considered to account for huge technological improvements, thus they introduce a dummy for the computer sector. Lawrence (1994) tests for the existence of a Stolper-Samuelson effect by examining relative import prices for the United States, Germany, and Japan. Neither wholesale nor import prices of unskilled-labor-intensive goods have seen relative declines.

Third, if the Heckscher-Ohlin-Samuelson model were a good mirror image of the real world, trade liberalization would benefit the locally abundant factor: Northern specialization in skilled-labor-intensive goods and Southern specialization in unskilled-labor-intensive goods would lead to an increase in the wage gap in the North (as observed) and a decrease in inequality in the South. The general experience in the South, however, is quite different: trade liberalization rather leads to more inequality. It is true that the Asian tigers (Singapore, Hong Kong, Korea, Taiwan), the first two with ratios of exports over GDP in 1990 of 174 and 144 percent[22], respectively, experienced some wage compression when opening up in the 1960s and 1970s. Wood (1997) remarks that in many cases it was rather skill expansion than free trade that caused wage compression in the

[21] We quote these relatively old studies since they focus on the 1980s, a period of excessively high increases in the relative wage and thus of special interest for our topic.

[22] Cp. Krugman (1995).

1970s and 1980s in these countries. For most (former) developing countries, however, the evidence is very much in favor of wage dispersion in the South, as can be seen from the survey by Arbache et al. (2004). The authors conclude that the increase in the wage gap in the South is probably largely due to imports of Northern technology by the South, which entails skill-biased technological change in these countries.

Fourth, the Heckscher-Ohlin-Samuelson model predicts factor movements from the skilled-labor-intensive to the unskilled-labor-intensive sectors when the relative factor price (i.e., the relative wage) falls. What we observe, however, are not interindustry but mostly intraindustry movements: trade seems to change the skill pattern of production and thus its productivity. Berman et al. (1994) find that in the 1980s, employment shifts in favor of skilled labor in U.S. manufacturing mainly occurred within (as opposed to between) industries. Using plant level data and decomposing changes in wages and employment into changes between and within plants, Bernard and Jensen (1997) show that more than half of the change in employment and wages can be attributed to changes within plants in the 1980s. In order to understand how shifts internal to the firm take place, we present a model of international outsourcing in the next section.

2.2.1.2.2 International Outsourcing A clearly visible feature of increased integration of global markets is a sharply rising degree of international production sharing, e.g., cars "Made in Germany" containing parts manufactured in many other different countries.[23] The phenomenon of fragmentation of production, also called "vertical specialization," "intra-product specialization," "offshoring," or "international outsourcing"[24] in the literature, has been viewed from different angles, one of them being its impact on labor markets and distributional consequences on them in particular.[25]

If we allowed for production to be split up into different stages, with production of intermediates differing in their skill intensity, the Heckscher-Ohlin-Samuelson model would lead to Northern specialization in skilled-labor-intensive intermediates and Southern specialization in unskilled-labor-intensive intermediates as well as a rise in the relative wage in the North and a drop in the South. A simple yet sufficiently rich model in order to explain rising skill premia in the North *and* the South is developed by Feenstra and

[23] There is a huge variety of papers examining the developments of international production sharing, e.g., Audet (1996), Campa and Goldberg (1997), Hummels et al. (2001), and Yeats (2001). Those view trade in intermediate inputs or parts and components as an indicator for international production sharing.

[24] "International outsourcing" is not to be confused with simple "outsourcing" since the latter only refers to production sharing on the national level. However, since this thesis deals with international trade, "outsourcing" might be used on occasion, but always refers to the international level.

[25] E.g., cp. Kohler (2003, 2004).

Hanson (1996, 1997), using a continuum of intermediate inputs produced with different skill intensities. In their model, capital flows from North to South lead to a shift of the less skilled-labor-intensive activities from North to South, which increases the average skill intensity in both countries and thus both relative wages.

There are three primary factors, namely unskilled labor L, skilled labor H, and capital K. Labor is mobile only between sectors while capital is mobile between countries as well. The world consists of two countries, where the North is skill-abundant while the South (marked with an asterisk) is abundant in unskilled labor. Moreover, the capital intensity is higher in the North than in the South before FDI liberalization takes place. Reflecting these scarcities, we assume that the relative wage of skilled labor, $w \equiv w_H/w_L$, is higher in the North while the return on capital is higher in the South:

$$w > w^* \quad \text{and} \quad r < r^*. \tag{2.2}$$

Intermediate input $\iota(\omega)$ with index $\omega \in [0,1]$ is produced using both types of labor in a Leontieff fashion and combining the labor input in a Cobb-Douglas fashion with capital:

$$\iota(\omega) = \mathcal{A}\left[\min\left\{\frac{L(\omega)}{a_L(\omega)}, \frac{H(\omega)}{a_H(\omega)}\right\}\right]^a K^{1-a}, \quad \omega \in [0,1], \tag{2.3}$$

where $\mathcal{A}$ is a constant and $a_L(\omega)$ and $a_H(\omega)$ are the amounts of unskilled and skilled labor, respectively, needed to produce one unit of intermediate ω. The Southern production technology is the same except for a different productivity paramater ($\mathcal{A}^*$ instead of $\mathcal{A}$). Intermediates are ordered such that the ratio $a_H(\omega)/a_L(\omega)$ is nondecreasing in ω, i.e., ordered by increasing skill intensity. The dual unit-cost function is given by

$$A(w_L, w_H, r, \omega) = \mathcal{B}[w_L a_L(\omega) + w_H a_H(\omega)]^a r^{1-a}, \tag{2.4}$$

where $\mathcal{B}$ is a constant and a is the input coefficient of labor. The final good Y is assembled costlessly, thus we do not keep track of the location of final assembly since there is zero value added and zero labor demand in this activity. It takes place using all inputs in a Cobb-Douglas manner ($\nu(\omega)$ are the weights):

$$\log Y = \int_0^1 \nu(\omega) \log \iota(\omega)\, \mathrm{d}\omega \quad \text{with} \quad \int_0^1 \nu(\omega)\, \mathrm{d}\omega = 1. \tag{2.5}$$

If unit costs for all inputs of the continuum of $\omega \in [0,1]$ were lower in the North than in the South, all production would take place in the North. Since we are interested in international production sharing we assume that there is at least one intermediate, call it ω^*, for which

$$A(w_L, w_H, r, \omega^*) = A(w_L^*, w_H^*, r^*, \omega^*). \tag{2.6}$$

For this intermediate, it does not matter whether it is produced in the North or in the South. Due to our assumption of different relative wages across countries it follows that an activity with a slightly higher skill intensity, $\omega' > \omega^*$, will be produced in the North since the higher skill requirement will have a greater impact on Southern than on Northern costs. Hence, $A(w_L, w_H, r, \omega') < A(w_L^*, w_H^*, r^*, \omega')$. Similarly, $A(w_L, w_H, r, \omega') > A(w_L^*, w_H^*, r^*, \omega')$ for $\omega' < \omega^*$. We conclude that there is *exactly* one ω^* for which (2.6) holds true. The whole continuum of intermediates can be separated into a less skill-intensive fraction whose production takes place in the South and a more skill-intensive fraction whose production takes place in the North.

We now examine the impact of a capital flow from North to South, which is reasonable since $r^* > r$ at the beginning. Moving capital away from Northern production increases the Northern return on capital (i.e., the cost of capital) while it decreases the return in the South. Consequently, the unit-cost of production increases in the North while it decreases in the South. Since the fraction of intermediates for which Southern production is cheaper than Northern production has increased, more (less) intermediates are produced in the South (North) than before capital was flowing across borders: the product range in the North has contracted in favor of the South. Kenney and Florida (1994) report that as TV manufacturing shifted from the United States and Japan to Mexico, first the construction of chassis, later of electronic circuits and picture tubes was shifted there. Both countries become more skill-intensive, thus globalization here takes the form of international technology upgrading or, as Feenstra and Hanson (1996) put it, "the transfer of activities acts as a form of 'endogenous technical change'" (p. 18).

A higher skill intensity in both countries widens the wage gap. We have pointed out how a capital flow from North to South increases ω^*. The relative demand for skilled labor in the North depending on ω^* is given by

$$\frac{\int_{\omega^*}^{1} \frac{\partial A}{\partial w_H} \iota(\omega)\, \mathrm{d}\omega}{\int_{\omega^*}^{1} \frac{\partial A}{\partial w_L} \iota(\omega)\, \mathrm{d}\omega}. \tag{2.7}$$

Since the unit labor requirement $\partial A/\partial w_H$ ($\partial A/\partial w_L$) is decreasing (increasing) in the relative wage, the entire expression given in (2.7) is decreasing in the relative wage, as expected (the more expensive a factor the lower the demand for it). Moreover, the relative demand curve (in an diagram of relative factors supplies and relative wage) shifts upwards when ω^* in increased. Given exogenous skill supplies, an increase in the relative demand for skilled labor increases the relative wage.

The change in the relative wage naturally has a feedback effect on ω^*, which implies endogenous factor prices, but Feenstra and Hanson (1996) prove that the increase in w is unambiguous in their model. Moreover, they show that unskilled workers need not necessarily lose in real terms. It is true that Southern labor (superscript S) wins relative to Northern labor (superscript N) in terms of the total wage bill. In the South, both skill groups win in absolute terms, and Northern unskilled workers clearly experience a drop in their absolute wage. It can be shown that

$$\hat{w}_H^S > \max\{0, \hat{w}_L^S\} \quad \text{and} \quad \hat{w}_L^N < \min\{0, \hat{w}_H^N\}, \tag{2.8}$$

where hats denote relative changes. However, Northern unskilled workers do not lose necessarily in real terms since they can be more than compensated by a falling price of the final good. If the range of production shifted abroad, $\Delta\omega^*$, is sufficiently small, both skill groups in both countries win.

What does not follow from the model of Feenstra and Hanson (1996) is an answer to the question by how much trade between countries increases due to a reduction in trade and FDI barriers. When countries specialize in certain inputs, small shifts of the unit-cost curves could potentially entail large changes in the borderline activity ω^* and international outsourcing volumes. Usually one would expect the increase in trade volumes to be closely related to tariff declines. Tariff reductions, however, were much larger before the mid-1980s than after, but trade growth was much smaller before than after. This leads to the conclusion that trade cost reductions and trade volume expansions do not follow a linear relationship. One convincing explanation for this phenomenon is international outsourcing, as the Ricardian trade model by Yi (2003) shows. In his model, production sharing can explain more than 50 percent of the growth in U.S. trade since 1962.

Another way to model the influence of vertical FDI on relative wages is by means of innovation and imitation in a product cycle model.[26] For these purposes, the usual approach is a North-South model where products are developed in the North, production techniques are perfected there, then production is shifted to the South, new products are developed in the North and so on. The cycle is reignited whenever an innovation occurs in the North. This model class takes a look at innovation incentives in the North when the South is assumed to be an imitator and hence threatens profit margins in the North.

[26] The original idea of the product cycle stems from Vernon (1966).

The incentive to fragment production accrues from lower wages in the South. Higher profit opportunities due to lower production costs increase the incentive to innovate. Glass and Saggi (2001) offer a one-factor (i.e., there is only "labor") Schumpeterian growth model of international fragmentation of production in a North-South setting. They describe the substitution between Northern and Southern labor instead of skilled and unskilled labor. Their result is that the wage of Northern relative to Southern workers declines when international outsourcing becomes cheaper. As innovation takes place in the North, the intuition is that the incentive to innovate can only be maintained when the Northern wage declines. Hence, closing ranks through production sharing means closing the wage gap between countries. Different from that, Sayek and Sener (2006) provide a model of the same kind, but with two factors. In their model, cheaper outsourcing raises the Northern skill premium unambiguously. In the South, however, the skill premium is only raised if the skill intensity of outsourced production is higher than that of local Southern production, a result that corresponds to the idea of the Feenstra and Hanson (1996) model.

Yet another interpretation is by means of the Stolper-Samuelson theorem. An increase in intermediate trade through trade liberalization can be interpreted as a rise in the degree of international fragmentation of production. Since unskilled labor and intermediates are more substitutable than skilled labor and intermediates[27], a decline in the price of intermediates due to lower production costs abroad changes relative labor demands and hence relative wages.

2.2.1.2.3 Migration Apart from globalization through trade in goods or intermediates, migration is another channel that can have an impact on the relative wage in both countries. To see this, we make use of a very simple framework.[28] We employ a CES production function:

$$Y = \left[(aL)^{\frac{\sigma-1}{\sigma}} + ((1-a)H)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{2.9}$$

where $\sigma > 0$ is the elasticity of substitution. Note that the two factors are gross substitutes when $\sigma > 1$ and gross complements when $\sigma < 1$. Moreover, $\sigma = \infty$ represents the special case of perfect substitutes and $\sigma = 0$ yields a Leontieff production function (perfect complements). Another special case occurs when $\sigma = 1$, namely the Cobb-Douglas case. (2.9) can either be interpreted as an economy that produces only one good with

[27] Falk and Koebel (1997) and Koebel (1997) support this hypothesis.
[28] The following thoughts are adopted from Acemoglu (2002b).

unskilled and skilled labor used in production or as an economy with a consumer utility function defined over two goods, where either good is produced with one of the factors only. For the latter interpretation the economy has to be closed.

Assuming competitive labor markets, each factor is paid its marginal product:

$$w_L = \frac{\partial Y}{\partial L} = a^{\frac{\sigma-1}{\sigma}} \left[a^{\frac{\sigma-1}{\sigma}} + (1-a)^{\frac{\sigma-1}{\sigma}} \left(\frac{H}{L} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} \tag{2.10}$$

and

$$w_H = \frac{\partial Y}{\partial H} = (1-a)^{\frac{\sigma-1}{\sigma}} \left[a^{\frac{\sigma-1}{\sigma}} \left(\frac{H}{L} \right)^{-\frac{\sigma-1}{\sigma}} + (1-a)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}. \tag{2.11}$$

Obviously, an increase in the relative skill supply H/L benefits unskilled labor since it becomes scarcer,

$$\frac{\partial w_L}{\partial (H/L)} > 0, \tag{2.12}$$

and harms skilled labor since it becomes more abundant:

$$\frac{\partial w_H}{\partial (H/L)} < 0. \tag{2.13}$$

The relative wage,

$$w = \frac{w_H}{w_L} = \left(\frac{1-a}{a} \right)^{\frac{\sigma-1}{\sigma}} \left(\frac{H}{L} \right)^{-\frac{1}{\sigma}}, \tag{2.14}$$

is therefore decreasing in the relative skill supply:

$$\frac{\partial \log w}{\partial \log(H/L)} = -\frac{1}{\sigma} < 0. \tag{2.15}$$

(2.15) shows that for a given skill bias of technology, $(1-a)/a$, the relative demand curve for skill is downward sloping with elasticity $1/\sigma$. Two substitution effects are conceivable when H/L is increased. First, assume that skilled and unskilled workers produce the same good but perform different functions. In this case some of the tasks previously performed by unskilled workers will now be performed by skilled workers. Second, assume that skilled and unskilled workers produce different goods. In this case there will be a substitution of the unskilled good by the skilled good. Either way, the relative wage of skilled labor is depressed.[29]

[29] In the short run, a relative increase in skill supply may decrease the relative wage. In the long run, however, it may create a greater market for skill-complementary technologies and thus induce skill-biased technological change, which would lead to the opposite result of what we just described; cp. Acemoglu

Angrist (1995) examines the impact of an increase in relative skill supply in the West Bank and Gaza Strip in the 1980s. There were no Palestinian institutions of higher education before 1972, and when they began to open, college premia declined from 40 percent to less than 20 percent. Furthermore, unemployment among college graduates began to rise, indicating a decrease in the (unemployment-adjusted) relative wage. In addition, Schiff and Ya'ari (1991) observed that only one in eight college graduates performed a task generally associated with skilled labor. The rest worked as unskilled laborers, many of them in the construction industry.

What we have considered by example so far is an increase in H/L. The more realistic case for immigration from the South to the North, however, is probably a decrease in H/L since Southern workers are usually less skilled than Northern workers. In this framework, the issue of changes in H/L due to immigration from the South is trivial. Immigration leads to a drop in Northern relative skill supply if the relative skill supply of the immigration flow from the South is lower than the relative skill supply in the North without immigration. It is not clear, however, whether Northern unskilled workers gain or lose in real terms since we have not considered changes in goods prices here.

From this model it seems theoretically clear that an influx of Southern unskilled workers harms wages of Northern unskilled workers. The empirical evidence, however, is far less clear. There is a number of "natural experiments" from which one can conclude whether immigration actually has an impact on the relative wage in the North. One famous example is the "Mariel boatlift": in April 1980, Fidel Castro had allowed his people for the first time to leave Cuba (from Mariel Harbor). Between April and October, when the exodus ended by mutual agreement of both the U.S. and the Cuban government, about 125,000 Cubans had arrived in Miami. The total local labor force was increased by 7 percent, and the share of unskilled labor even by about 30–40 percent, which is a huge supply shock. Card (1990) observes that this shock "had virtually no impact on the wage rates of less-skilled non-Cuban workers" (p. 256), nor did unskilled-labor unemployment increase. According to him, the local industries were able to absorb the larger labor force quite rapidly. Going back to the Heckscher-Ohlin-Samuelson model, this could be explained by an expansion of unskilled-labor-intensive industries, which actually took place. Hence, the impact of the enlarged unskilled workforce is canceled out by a Rybczynski-like effect that avoids a decline in the relative wage. Another explanation one could conceive of is compensating immigration of native skilled workers (or emigration of native unskilled workers), balancing the skill ratio again. A later study by Card (1997), however, shows that this was not the case.

(1998). This and other related topics will be discussed in Section 2.2.2.

The Mariel boatlift can be considered representative for the U.S. experience in general: with the inflow of immigrants having a lower skill level than the native population[30] (although there are exceptions to this, see below), most authors[31] find that immigration to the United States has not contributed much to a wider wage gap, although there are a few authors who disagree[32]. The evidence is similar for Germany. Bauer (1998) finds that the impact of immigration on German wages is quantitatively very small and slightly negative. He further finds that it is not appropriate to treat natives and foreigners of the same occupational status as similar inputs. Gang and Rivera-Batiz (1994), using education, experience, and unskilled labor as inputs, find no clear impact on the wage of different skill groups due to immigration. Pischke and Velling (1997) even find immigration to lower unemployment and increase wages, as do Haisken-DeNew and Zimmermann (1996). Sometimes it is argued that the impact of immigration might be underestimated since inflows occur mainly locally concentrated and mainly to prospering regions that can more easily absorb changes in the skill composition. Moreover, temporary increases in unemployment may sometimes obscure a weakening in the relative position of unskilled labor.

As opposed to the idea that immigration lowers the overall skill level, there is also the notion that people who make the effort to emigrate to another country a generally "more able, ambitious, aggressive, entrepreneurial, or otherwise more favorably selected than similar individuals who choose to remain in their place of origin"[33]. This is aggravated by some countries' immigration policy aimed at attracting skilled instead of unskilled workers. For South-North migration, this can lead to the oft-cited "brain drain" that makes developing countries even more skill-scarce. However, following Borjas (1987), who states that immigrants from countries with a low (high) degree of inequality have a relatively high (low) average skill level, this type of migration might not be too relevant for migration from the South to the North. Therefore migration of skilled workers might be more applicable to North-North than to North-South migration. Contrary to this view, Chiquiar and Hanson (2002) find that Mexican immigrants to the United States have a relatively high skill level compared to the Mexican population as a whole, although on average they are less skilled than natives in the United States. Thus the

[30] Polgreen and Simpson (2006) find that for immigration flows between 1972 and 1987, the average years of schooling sank from 12.88 to 12.43, while the native population increased its skill level. Due to a share of immigrants in the total population of only 9 percent in the United States and skill upgrading of the native population, the total years of schooling increased.

[31] Important contributions in this field are Grossman (1982), Altonji and Card (1991), or LaLonde and Topel (1991). For surveys on the issue cp. Borjas (1994) or Topel (1997).

[32] E.g., cp. Borjas et al. (1997).

[33] Chiswick (2000), p. 1.

negative-selection hypothesis of Borjas (1987) that in poor countries the individuals with the strongest incentive to emigrate are the unskilled does not come true in the case of Mexico and the United States, but still might be correct for other countries.

To sum it up, empirically it is neither clear what skill level immigrants have compared to natives nor what the qualitative and quantitative impacts of immigration on local labor markets are. It is thus necessary to watch out for other causes of labor market outcomes.

2.2.1.3 North-North Trade

Unlike our Schumpeterian growth model we are going to apply later on, forming a combined explanation of the wage gap by North-North trade and endogenous technological change, the models we present here can arguably be classified as an explanation of the wage gap by trade alone. We resume two approaches, both of them dealing with heterogeneous workers. Section 2.2.1.3.1 outlines a model whose structure one could call "semi-symmetric," which is why we put it at the beginning of our North-North discussion, as a transitional case between North-South and North-North models. In this model, countries are identical and differ only with respect to their skill *distribution*, i.e., in some countries ability is more dispersed while it is more concentrated in others, but the average skill *levels* are equal across countries. Given specific assumptions about the production technology, different skill distributions provide an independent source of comparative advantage and thus a novel cause for trade. There are two goods and for one of them it is more advantageous to be produced in a relatively dispersed country while the other one is better produced in the more homogeneous country. Trade benefits the most talented individuals in the former whereas it benefits the less skilled in the latter country. The model also draws a connection between organizational change (which is related to institutional change, cp. Section 2.2.3) and globalization.

In contrast, Section 2.2.1.3.2 presents a model with absolutely symmetric countries, and is closely related to the recently emerged literature on firm heterogeneity à la Melitz (2003). What we discuss here, however, is a model where firms per se are homogeneous, but they can employ different technologies and workers differ in terms of skill. The outcome is an increase in wage dispersion and in aggregate firm productivity as a consequence of trade liberalization. Due to the latter result, this model could as well be classified as belonging to "Globalization and Skill-Biased Technological Change," but we classify it as a "pure" trade explanation since no new technologies are invented—what changes is only the relative extent to which existing technologies are used.

2.2.1.3.1 Different Skill Distributions Kremer and Maskin (1996) and Acemoglu (1999) report for U.S. firms that the weight of the lower and upper industry-occupation cells (i.e., job types paying relatively low or high wages) relative to the center has increased during the 1980s and 1990s. Therefore, not only the relative wage increased but the spread of skills inside a firm, too. This can be interpreted as evidence for an increasing relevance of single individuals performing tasks whose remuneration becomes more and more independent of the productivity of unskilled workers. Moreover, anecdotal evidence suggests that firms devote more resources to carefully selecting their workforce than years ago, which also manifests itself nowadays in the importance of elaborate choice procedures by means of assessment centers and the like. Murnane and Levy (1996) quote a Ford manager from 1967, describing their hiring strategy: "[W]e would look outside in the plant waiting room to see if there were any warm bodies standing there. If someone was there and they looked physically OK and weren't an obvious alcoholic, they were hired" (p. 19). Today firms spend a lot more time and effort to recruit workers. The model we are going to discuss examines the decision of skilled workers to perform tasks in a common firm with unskilled workers, or rather leave the firm so they can reap the full benefits of their own productivity. Since both groups' productivities are interdependent in the common firm, skilled workers may want to leave the firm when their own productivity is depressed too much by the unskilled workers' productivity.

Grossman (2004) presents a model where two countries are identical in all respects except for their distribution of skill. Both countries have workers with an average skill level of θ_0 and skill is uniformly distributed across the continuum of households (i.e., workers). In the Home country, skill ranges from $\theta_0 - e$ to $\theta_0 + e$ while it ranges between $\theta_0 - e^*$ and $\theta_0 + e^*$ in the Foreign country. We assume that $e > e^*$, thus the Home country is more dispersed. The skill distribution is common knowledge, but workers have private information about their own ability. Hence, labor contracts are imperfect, which is the crucial feature of this model in order for trade to occur. Unproductive workers can "hide" their true productivity behind the above-average performance of others.

There are two perfectly competitive activities with a continuum of firms in each industry, one of them performed in teams ("automobile production") and the other one alone ("software"). Due to labor market imperfection, less skilled workers will self-select into automobile production since they anticipate that they will be paid the average wage every worker in this industry receives as the employer does not know the actual skill level of whom he employs. More skilled individuals will avoid the automobile sector, thus there is adverse selection. These individuals will produce software and reap the full benefits of their own talent.

In the automobile sector, production is a collective enterprise with a team of workers performing a set of indivisible tasks. The output of a team is $Y(\theta_1, \theta_2)$, where θ_i is the contribution of the team member who performs task $i = 1, 2$.[34] Moreover, the tasks are symmetric. In the other industry, output is produced by one worker alone and the single worker's output is measurable and verifiable. Both industries produce with constant returns to skill[35], thus the software output by an individual with ability θ is $\kappa\theta$, where $\kappa > 0$ is a parameter defining one unit of skill. $Y(\cdot)$ as well as production in the software sector are homogeneous of degree one.

Another important property of $Y(\cdot)$ is that both team members must have a non-zero level of competence. A higher quality of each team member raises the marginal product of the other; they are complementary inputs with both inputs being essential. As Grossman and Maggi (2000) put it, "failure at any task destroys the entire value of the project" (p. 1256).

If there was perfect information, wages in the automobile industry would be linked to individual productivity and each individual would be indifferent about his occupation. With imperfect information, however, less skilled workers have an incentive to self-select into the automobile industry since they are paid the average wage that all automobile workers receive. Concerning welfare, adverse selection leads to a suboptimal level of automobile production since skilled individuals do not take into account that they create a positive externality in terms of additional national income when entering team production. Private and social incentives diverge. Grossman (2004) argues that a subsidy to the automobile sector would increase national income by more than the cost of the subsidy.

Individuals in both countries have identical and homothetic preferences and are risk neutral; their utility function is homogeneous of degree one. Define $Y_1 \equiv Y(1, 1)/2$ and recall that $Y(\cdot)$ has constant returns to skill. The potential output of a pair of workers of skill level θ is thus $2Y_1\theta$, whereas they could produce $2\kappa\theta$ in the software industry. Each country has therefore a linear production possibility frontier with a slope of $-Y_1/\kappa$. In a Walrasian equilibrium, market-clearing contracts paying each worker a wage proportional to his ability would emerge. The relative price of software in terms of automobiles would be $p = Y_1/\kappa$. Since technologies are identical across countries, perfect information would imply that there is no trade. This is why imperfect contracts are required for non-zero trade volumes.

[34] One could also assume that a team consists of more than two team members, but the qualitative model mechanisms can be exposed with two members as well.

[35] As opposed to that, Rosen (1981) presents a model where "superstars" self-select into activities with increasing returns to skill such as TV shows, serving large audiences at virtually no additional cost.

Hiring and paying workers is assumed to be costless, thus some workers can become "managers," hiring one worker each. These firm owners have to pay their employees and gain property rights to the firm's output in return. Equilibrium wages must make managers indifferent between the various teams they could possibly assemble. Each individual chooses its industry in a first stage (software or automobiles) and participates in an auction ("hiring hall") in a second stage. The labor force consists of $L = L_a + L_s$ individuals of which L_a choose the automobile industry and L_s the software industry. Of those who choose to work in the automobile industry, each individual makes a bid in the form of an unconditional wage offer. The highest 50 percent of the bids win and their bidders become managers. Each manager hires one of the remaining loosing bidders, the "workers," who earn a fixed wage afterward. Workers are randomly assigned to firms. The result of the auction are teams in the automobile sector consisting of two individuals each, namely one manager and one worker.

Individuals sort themselves into the different industries and roles (i.e., manager or worker) in the equilibrium with imperfect contracts. An individual entering the automobile industry and expecting to become a worker there earns a wage w irrespective of his skill level. A manager's income depends negatively on the wage he has to pay his team partner (the worker) and positively on his own ability since he is one of the team members himself. He faces uncertainty with respect to the skill level of the worker he is matched with. $Y(\cdot)$ has constant returns to skill, but each of its functional arguments has decreasing returns, thus the manager's expected income will be a concave function of his own skill level. Given the commonly known cumulative skill distribution $G(\theta)$ with θ taking values between $\theta_{\min}$ and $\theta_{\max}$, there is a threshold θ_w where individuals are just indifferent about becoming workers or managers in the automobile industry. This threshold is defined by

$$w = \frac{1}{G(\theta_w)} \int_{\theta_{\min}}^{\theta_w} Y(\theta_w, \theta) \, \mathrm{d}G(\theta) - w, \tag{2.16}$$

where the right-hand side is the probability-weighted output sum resulting from all possible worker matches minus the wage that has to be paid by the manager. Note that the individual with threshold skill level θ_w will be matched with a partner who has a skill level less than or equal to θ_w, therefore the upper bound of the integral is θ_w. For an employee in the software industry ("entrepreneur"), the income depends linearly on his skill level. Similarly, there is a skill level θ_m where individuals are just indifferent about becoming managers or entrepreneurs:

$$\kappa p\theta_m = \frac{1}{G(\theta_w)} \int_{\theta_{\min}}^{\theta_w} Y(\theta_w, \theta)\, \mathrm{d}G(\theta) - w, \tag{2.17}$$

where the right-hand side is exactly the same as in (2.16). All individuals with ability between θ_w and θ_m opt to become managers. Consequently, those with ability higher than θ_m (lower than θ_w) become entrepreneurs (workers). Since the number of managers has to equal the number of workers,

$$G(\theta_w) = G(\theta_m) - G(\theta_w) \tag{2.18}$$

must hold in equilibrium.

Suppose the hiring hall for the automobile industry attracts the least skilled individuals L_a of the labor force and $\tilde{\theta}(L_a)$ denotes the median skill level among the L_a least skilled workers. Then each individual with $\theta > \tilde{\theta}(L_a)$ bids a wage that makes an individual with $\theta = \tilde{\theta}(L_a)$ indifferent between becoming a manager or worker. Moreover, each individual with $\theta < \tilde{\theta}(L_a)$ bids the wage that makes him personally indifferent between the two choices, given the remaining labor pool he can possibly be matched with. Grossman (2004) shows that there exists an equilibrium where θ_w and θ_m are uniquely determined and entrepreneurs earn more than managers who in turn earn more than workers.

The question is now which of the two countries specializes in which activity. Grossman (2004) shows that in both countries, $\mathrm{d}\theta_m/\,\mathrm{d}e < -1$, i.e., automobile employment shrinks when the range of skills is expanded, and the decrease is more than proportional. A highly skilled individual would not want to enter into team production since he anticipates the risk of being matched with a low skilled worker. The large skill spread in the Home country creates a greater disincentive for the skilled individuals to produce automobiles since they would share the disadvantage of low productivity in the automobile sector stemming from the relatively large left tail of the skill distribution. It is true that in the Home country, a manager would pay lower wages to automobile workers since productivity in the automobile sector is lower than in the more homogeneous Foreign country, but the expected loss in productivity outweighs the cost savings of wage reductions. The Home (Foreign) country thus produces relatively more software (automobiles). With identical and homothetic preferences, the Home country exports software and imports automobiles in the free-trade equilibrium.

Compared to autarky, the price of software in the free-trade equilibrium is higher in the Home country and lower in the Foreign country. Software engineers in the Home country unambiguously benefit from this change in relative prices, while automobile workers are harmed. There might be a small group of managers, however, that benefits as well since automobile wages have declined. Altogether, the wage gap in the Home country is widened. The logic is just the opposite for the Foreign country, where the wage distribution is compressed. The United States, for instance, can be thought of as a relatively individualistic society, which results in a comparative advantage in products such as software. Likewise, there are relatively homogeneous societies such as Japan or Germany who are better at fabricating products requiring long sequences of production such as high-end electronics or automobiles.

2.2.1.3.2 Heteregeneous Workers Recently, a new strand of literature dealing with heterogeneous firms has evolved.[36] In these models, firms are assumed to be heterogeneous with respect to their productivity. Empirical evidence suggests that exporting firms are more productive than non-exporters, earn higher revenues, and most importantly to our topic, pay higher wages.[37] These stylized facts are what the heterogeneous-firms models aim to reflect. The firms in these models, after a random productivity draw, decide whether or not to export. The result of trade liberalization is that the most productive firms self-select into export markets, less productive firms serve their domestic market only, and the least productive firms leave the market. Hence, aggregate firm productivity is increased. This is also a result of the model by Yeaple (2005) we are going to outline here. An important difference to the heterogeneous-firms models is, first, that firms per se are homogeneous and, second, there is a continuum of worker skill whereas there is only one type of labor in the heterogeneous-firms models. The Yeaple (2005) model thus allows for examination of the impact of trade liberalization on the wage distribution.

The economy consists of two identical countries of which we only have to consider one. Two goods are produced, namely a non-tradable homogeneous good (domestic services), Y, which is the numéraire, and a tradable composite differentiated good, X, with first-tier Cobb-Douglas and second-tier CES consumer preferences:

$$U(Y, X) = (1 - a) \log Y + a \log X, \tag{2.19}$$

[36] Melitz (2003) and Bernard et al. (2003) are two of the seminal papers of this strand of literature.
[37] Cp. Bernard and Jensen (1997, 1999), among many others.

where

$$X = \left[\int_0^N x(\omega)^{\frac{\sigma-1}{\sigma}} \, \mathrm{d}\omega \right]^{\frac{\sigma}{\sigma-1}} \quad \text{with} \quad \sigma > 1. \tag{2.20}$$

$x(\omega)$ is the amount of variety ω and N is their range. According to the well-known Dixit and Stiglitz (1977) framework, an aggregate price index for X as well as total demand for any variety can be determined.

The distribution of worker skills is given by $G(\theta)$ with support $\theta \in [0, \infty)$. There is only one technology for production of Y, but two competing technologies for production of X: a high-unit-cost, low-fixed-cost (L-technology, "low-tech") and a low-unit-cost, high-fixed-cost technology (H-technology, "high-tech"). Π_j with $j = Y, L, H$ represents an index of productivity for the three different technologies. Highly skilled workers have a comparative advantage in high-technology production of X over moderately and low-skilled workers:

$$\frac{\partial \Pi_H(\theta)}{\partial \theta} \frac{1}{\Pi_H(\theta)} > \frac{\partial \Pi_L(\theta)}{\partial \theta} \frac{1}{\Pi_L(\theta)} > \frac{\partial \Pi_Y(\theta)}{\partial \theta} \frac{1}{\Pi_Y(\theta)} > 0. \tag{2.21}$$

Moreover, the productivity indices are one for zero skill:

$$\Pi_H(0) = \Pi_L(0) = \Pi_Y(0) = 1. \tag{2.22}$$

The H-technology has thus lower unit costs than the L-technology for all but the least skilled workers. There is free entry in both sectors. In order to employ technology L or H, a firm must bear a fixed cost of F_L or F_H, respectively. The fixed cost takes the form of output that must be produced but cannot be sold, thus it has an "iceberg" character. This is modeled by stating that total revenue of a firm in the X-sector employing technology $j = L, H$ equals $R_j = A_j(x_j + F_j)$, where A_j are the unit costs for production with technology $j = L, H$. It is assumed that $F_H > F_L$.

We first consider the closed economy. It can easily be derived that all firms in the X-sector charge a price equal to a constant markup over unit cost (in order to cover the fixed cost of production; profits are zero) and a price equal to unit cost (= 1) in the Y-sector. Like the goods market, the labor market is perfectly competitive. It follows that the wage distribution adjusts such that firms using the same technology face the same unit cost. One can determine a skill threshold θ_Y for which holds that all workers with skill level $\theta < \theta_Y$ work in the Y-sector. Analogously, all workers with $\theta_Y < \theta < \theta_L$ work in the L-sector, and those with $\theta > \theta_L$ work in the H-sector. Each worker employed with one of the three technologies is paid a technology-specific efficiency wage:

$$w(\theta) = \begin{cases} A_Y \Pi_Y(\theta) & \text{if} \quad 0 \leq \theta \leq \theta_Y \\ A_L \Pi_L(\theta) & \text{if} \quad \theta_Y \leq \theta \leq \theta_L \\ A_H \Pi_H(\theta) & \text{if} \quad \theta \geq \theta_L \end{cases} . \tag{2.23}$$

Normalizing the price of Y to one, it follows that $A_H < A_L < A_Y = 1$. Moreover, if a worker is assigned to the "wrong" technology, i.e., a technology he has no competitive advantage in, he will earn less than with a correct assignment. The more advanced the technology, the greater the (required) skill of the worker who uses it in the respective firm. Moreover, according to (2.21), $\Pi_H(\theta)$ reacts more sensitively on changes of θ than $\Pi_L(\theta)$ and $\Pi_Y(\theta)$. Hence, if both L- and H-firms appear in equilibrium, H-firms pay higher wages than L-firms. The model also implies that firms that are larger in terms of revenue pay higher wages, a model feature consistent with empirical studies such as Davis and Haltiwanger (1991).

When allowing for international trade with an iceberg transport cost $\tau > 0$, revenues in the foreign market are reduced by a factor $(1+\tau)^{1-\sigma} < 1$. Firms employing technology $j = L, H$ earn revenues R_j at home and $R_j(1+\tau)^{1-\sigma}$ abroad. In addition, when serving the foreign market, a firm has to bear a fixed cost of F_X in order to become acquainted with the foreign market, establish new distribution channels etc. If

$$F_H > F_X(1+\tau)^{\sigma-1} > F_L \tag{2.24}$$

holds true, H-firms export and L-firms do not. In the following we will assume that (2.24) is satisfied. This corresponds to the stylized fact that exporters use more advanced technologies and are more productive. It is not clear whether L-firms exist in equilibrium, but it becomes more likely if the share spent on the composite good, a, and the fixed cost of H-production, F_H, are sufficiently large.

We consider changes in τ rather than in F_X since these are easier to measure and more common in the literature. Moreover, the economic implications of changes in F_X are similar. We first examine how falling trade costs affect the skill thresholds θ_Y and θ_L. A decrease in τ is like a technological improvement for an exporter, i.e., for an H-firm. Since firms must continue earning zero profits, an H-firm must employ some of the moderately skilled workers formerly employed by L-firms. Hence, employment in the export sector increases while θ_L declines to θ'_L. Furthermore, since workers in the X-sector earn more in terms of the numéraire after trade liberalization (which is implied by a higher unit cost in the X-sector), total expenditure increases as well, raising the demand for Y, which in turn increases Y-sector employment and thus θ_Y to θ'_Y. Altogether, the volumes of domestic services and exported goods increase while the volume of goods produced with moderately skilled workers declines: the L-sector is "compressed" from both sides, i.e., $\theta_Y < \theta'_Y < \theta'_L < \theta_L$.

The shift of workers across industries has of course an impact on the wages of the different skill groups. The least skilled workers, $\theta < \theta_Y$, see their wage unchanged since they use the same technology before and after trade liberalization. Moderately skilled workers who have worked in the L-sector before and now work in the Y-sector ($\theta_Y < \theta < \theta'_Y$) see their wage decline since they have to use an inferior technology now. Real wages of these moderately skilled workers, however, may either have declined or risen, as Yeaple (2005) shows. The same holds for workers who are employed in the L-sector before and after trade liberalization ($\theta'_Y < \theta < \theta'_L$). Workers in the H-sector are better off afterward, regardless whether they have worked in the L-sector ($\theta'_L < \theta < \theta_L$) or H-sector before ($\theta > \theta_L$).

The wage increase for highly skilled workers is in accordance with empirical observation, as is the increase in the average level of education in both the non-traded and the traded sector. What does not necessarily conform to reality are the unchanged wage of the least skilled workers and the wage drop for the moderately skilled workers. To cure this drawback, Yeaple (2005) suggests to interpret θ as unobserved heterogeneity after controlling for formal criteria like years of schooling or work experience. Using this interpretation, the model predicts that workers in the export sector, having some unobservable features that are valuable to the firm, benefit from greater export volumes. The moderately-skilled workers obviously do not exhibit these unobservable qualities to the same degree. Bernard and Jensen (1999) find that there are large within-industry premia paid by exporting firms to both production and non-production workers.

This model induces firms to switch from one existing technology to another, leading to a higher wage premium for the most skilled workers and a lower wage premium for the moderately skilled workers. Since this form of technological change favors the most skilled workers, it is some form of skill-biased technological change, but it only makes use of existing technologies and shifts workers from one industry to another. When we refer to "globalization and skill-biased technological change" in this dissertation, we rather mean the endogenous evolution of new technologies through forces that are connected to trade liberalization. We will discuss that in the next section.

2.2.2 Globalization and Skill-Biased Technological Change

"Skill-biased technological change" is the technologically motivated increase in the (relative) demand for skilled labor, increasing the skill premium and thus weakening the position of unskilled workers. New technology often requires a skill such as the ability to grasp new things quickly, therefore it seems reasonable to assume a complementary relationship between skill and technology. Moreover, robots and computers more and more perform tasks formerly done by unskilled workers. These machines are operated by workers who are on average more skilled than workers some decades ago. When technological improvements favoring skilled labor become more profitable than unskilled-labor-biased technology, the relative productivity of unskilled labor is reduced. Note that "technological change" is not necessarily the same as "technological progress" as the latter term can also refer to a Hicks-neutral technological change that enhances total factor productivity but does not hurt either factor. Naturally, if new technologies tend to be skill-biased, then skill-biased technological change and technological progress can be used synonymously. In principle, there are three technology-related explanations for the rise in wage inequality.[38] First, the "steady-demand hypothesis"[39] states that the demand for skill increases at a constant pace. Until the 1970s, when the rate of skill accumulation, i.e., the supply side, developed as rapidly as the demand side in the United States, inequality remained largely stable. The widening of the wage gap thereafter is explained by slower growth on the supply side. The second explanation, summed up to the "acceleration hypothesis,"[40] purports that the speed of skill-biased technological change has increased in the last decades, mainly due to the invention of the microchip. Given a constant growth rate of relative skill supply, the result is the same as for the steady-demand hypothesis. Both explanations are two sides of the same coin since they refer to an exogenous change of supply and demand, leading to new equilibrium wages. The problem with this approach is assuming that a "technological revolution" just happened for the sake of it is not a particularly convincing hypothesis. It is much more likely that new inventions where spurred by other developments. Hence, a third explanation is offered by focusing on the endogeneity of technology, examining the interaction of skill-biased technological change, trade, and other factors.

As the heading suggests, this section focuses on the interaction of skill-biased technological change and trade. We refer to both symmetric and asymmetric countries, but we will make clear what structure we are dealing with in the respective case. To understand

[38] Authors supporting this classification include Katz and Autor (2000) and Acemoglu (2002b).
[39] Acemoglu (2002b), p. 10.
[40] Acemoglu (2002b), p. 11.

the role of technology, however, it is useful to first take a look at (exogenously given) technology alone, which will be done in Section 2.2.2.1. We then outline a simple framework where trade increases the market size and thus provides an incentive to endogenously bias technology toward skilled labor (Section 2.2.2.2). Finally, we describe a relatively new Schumpeterian framework of "defensive" skill-biased innovation, where firms produce endogenously more skill-intensive in order to prevent competitors from imitating or leapfrogging (Section 2.2.2.3). In a sense, that approach combines the two notions of new technology being skill-biased by nature (exogenous explanation) and technology being skill-biased as a result of trade liberalization (endogenous explanation). Moreover, it provides a new channel in a North-North framework through which the skill premium is increased. Our Schumpeterian growth model that we use as a workhorse later on falls in this category of trade interacting which technology as well, but we will not describe it in this literature review since it will be presented in detail in Section 3.

2.2.2.1 Technology as an Independent Cause

Going back to our simple one-sector, two-factor economy that we already examined when we tried to shed light on the role of migration in Section 2.2.1.2.3, we restate (2.14):

$$w = \left(\frac{1-a}{a}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{H}{L}\right)^{-\frac{1}{\sigma}}, \tag{2.25}$$

where we now assume that a is not constant anymore. An increase in the factor intensity of skilled labor, i.e, $(1-a)/a$, increases the relative wage as long as the relative skill supply remains constant and the elasticity of substitution is greater than one:

$$\frac{\partial \log w}{\partial \log[(1-a)/a]} = \frac{\sigma - 1}{\sigma} > 0 \quad \text{if} \quad \sigma > 1. \tag{2.26}$$

Most estimates for σ are between one and two, thus the positive relationship between the skill-complementary technology and the relative wage can be taken for granted here.[41] An increase in skilled-labor productivity increases the *effective* supply of skilled workers. If σ were below one—consider the Leontieff case as an extreme one, thus input proportions being fixed—this "excess supply" would put downward pressure on the relative wage. But this is merely a theoretical possibility, at least in this simple framework. Under normal circumstances, w should be increasing in the skill intensity of production.

[41] Note that the dependence of the expression in (2.26) on σ hinges on the way the skill bias is defined by (2.9). Employing a production function where a is written outside the round brackets of (2.9) yields a sign of (2.26) independent of σ.

A non-recurring increase in the skill intensity of production causes a non-recurring increase in the relative wage, but cannot explain its steady increase over decades. Skill-biased technological change has to accelerate in order to account for that, and this acceleration is likely to be endogenous as we shall see in Section 2.2.2.2, where we allow for the relative skill supply to change. For the sake of this exercise, however, we fix H/L. Here we just take the accelerated technological change as given by introducing a growth rate g of (factor-neutral) technological progress. Acemoglu (2002b), adopting a simplified version of Galor and Moav (2000), outlines what happens to the relative wage if the rate of technological progress is not constant anymore. Galor and Moav (2000) distinguish two effects: the "erosion effect," meaning that workers (of both kinds) become less productive over time as their human capital depreciates with each new innovation. Moreover, there is a "productivity effect," enhancing total factor productivity, and this effect by assumption benefits the skilled workers more than the unskilled.[42] We assume that the factor intensity of unskilled labor, a, is a decreasing function of technological progress, g:

$$a = \Gamma_L(g) \quad \text{with} \quad \Gamma_L' < 0. \tag{2.27}$$

This is somewhat ad hoc but the justification is that unskilled workers become less useful when technology advances since skilled workers and technology complement each other better than unskilled workers and technology do. (2.27) implies that the skill intensity of production, $(1-a)/a$, must be increasing in g. Rewriting (2.25) as

$$w = \left(\frac{1-\Gamma_L(g)}{\Gamma_L(g)}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{H}{L}\right)^{-\frac{1}{\sigma}} \tag{2.28}$$

reveals that the relative wage must increase in the growth rate of technological progress. Acceleration of technological change by definition refers to a change in the growth rate: g increases over time, inducing a steady increase in the relative wage.

2.2.2.2 Market Size and Endogenous Technology

So far we assumed that technological change was skill-biased by nature, thus the increase in the relative wage happened rather exogenously. A different approach is the idea of a demand pull, i.e., new profit incentives from using a technology due to a changed environment.[43] For instance, increased purchases of railroad equipments entailed rapid

[42] A third effect mentioned by Galor and Moav (2000) is the "composition effect," meaning the endogenous reaction of the workforce to labor requirements, which changes the composition of skill supply. We will deal with endogenous labor supply in later sections.

[43] The following train of thoughts is based upon Acemoglu (2002a,b).

innovation in railroads in the past. Hence, the profitability of a new technology depends crucially on the market size. “Market size” in this context refers to the size of the skilled labor force since more skilled workers allow for new technology to be used to a greater extent. A larger market can make it worthwhile using a new technology due to economies of scale. The increased demand for skill is therefore induced by an increased supply of skill. This in turn raises the question why the skill supply increases. One could either argue that it rises as a response to the increased skill premium, resulting in a circle of mutually re-enforcing skill supply and demand increases, or just take the increase in skill supply as given. We will take the second approach here since we will deal with endogenous skill supply later on. Here we just study the impact of an exogenous increase in skill supply on skill demand and thus on the relative wage.

The application of such a mechanism makes sense in a North-South scenario. Trade liberalization makes the North an exporter of the skill-intensive good while the South becomes an importer of this good. Thus, the Northern market size for the skill-intensive good increases since the North produces more of that good now. This in turn makes innovations toward skill more profitable and increases the relative wage in the North (while it drops in the South).

Suppose consumer utility, defined over the final good Y, is of the CES type, with two goods Y_L and Y_H, both being produced with one of the factors:

$$Y = \left(Y_L^{\frac{\sigma-1}{\sigma}} + Y_H^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}. \tag{2.29}$$

Here $Y_L = N_L L$ and $Y_H = N_H H$, where N_L and N_H can be interpreted as the numbers of specialized machines used with unskilled and skilled workers, respectively. Utility maximization yields a relative price of the two goods of

$$p \equiv \frac{p_H}{p_L} = \left(\frac{N_H H}{N_L L}\right)^{-\frac{1}{\sigma}}. \tag{2.30}$$

Specialized machines are developed and sold by profit-maximizing monopolists. Development of a new machine costs a certain fraction of the final good Y, and the marginal cost of producing these machines is assumed to be zero once they have been developed. Taking the derivatives of $p_L Y_L$ and $p_H Y_H$ with respect to N_L and N_H, respectively, yields the marginal willingness to pay for an additional machine:

$$\frac{\mathrm{d}(p_L N_L L)}{\mathrm{d}N_L} = p_L L \quad \text{and} \quad \frac{\mathrm{d}(p_H N_H H)}{\mathrm{d}N_H} = p_H H. \tag{2.31}$$

These two derivatives reflect the marginal increase in profits in both sectors as well as the marginal cost of innovation (since producers have to buy the machines from monopolists).

There are two effects fostering the development of new technologies. First, goods using the scarce factor (unskilled labor in Northern countries) fetch higher prices, which favors innovation directed at unskilled labor. This is called the "price effect." Second, a larger workforce able to use a new technology encourages innovation toward the abundant factor (skilled labor). This is the "market size effect." In equilibrium, both effects have to be balanced, which means that the marginal increase in profits is equal to the marginal cost of innovation in both sectors:

$$\frac{p_H H}{p_L L} = 1. \tag{2.32}$$

With H/L fixed, (2.32) can only hold if the relative price p adjusts, which requires a change in N_H/N_L according to (2.30). Using these two equations yields

$$\frac{N_H}{N_L} = \left(\frac{H}{L}\right)^{\sigma-1}. \tag{2.33}$$

The market size effect is stronger than the price effect if the two goods are gross substitutes, i.e., if $\sigma > 1$. Combining (2.30) and (2.33) and calculating the factor rewards as $w_L = p_L(\partial Y_L/\partial L) = p_L N_L$ and $w_H = p_H(\partial Y_H/\partial H) = p_H N_H$ gives the skill premium:

$$w = \frac{p_H N_H}{p_L N_L} = \left(\frac{H}{L}\right)^{\sigma-2}. \tag{2.34}$$

In this simple model, (2.34) implies that for values of $\sigma > 2$, the relative wage increases in relative skill supply (this condition need not generalize to more complex environments). The long-run demand curve—technology adoption takes time—for skill would thus be upward-sloping. The endogenous mechanism just described can explain part of the acceleration in skill bias during the 1980s in the United States, but empirically it is difficult to separate exogenous and endogenous technological change. Since the exact size of σ is empirically unclear it is probably a combination of both mechanisms—exogenous and endogenous technological change—that accounts for the skill bias of technology.

2.2.2.3 Defensive Innovation

In the model of Thoenig and Verdier (2003), firms can endogenously bias the direction of technological change. Quality leaders aspire to maintain their technological competitiveness. It is assumed that the degree of tacitness depends on the specific knowledge embodied in production. Technology handled by skilled workers is less codifiable or, put differently, less codified technologies necessitate greater learning efforts, thus more skilled labor is required to handle the technology. Either way, using skill-intensive technology can be considered defensive in the sense that quality followers cannot easily copy the existing technology due to large uncodified (or tacit) portions. Firms face the following trade-off: they incur higher unit costs when using more skill-intensive technology but are better protected from leapfrogging by other firms. Being leapfrogged would erode their profit basis since they can only extract monopoly rents as long as they are quality leaders. The model thus reconciles the exogenous approach of technological progress being skill-biased per se (once the trade-off is decided in favor of skill-biased defensive innovation, one observes exactly this) as well as the idea that there is some endogenous mechanism underlying the skill bias.

Thoenig and Verdier (2003) is a dynamic general-equilibrium quality-ladder model in continuous time with a continuum of final goods. Skilled and unskilled labor are used in the production of final goods with unit cost of skill-intensive production being higher than the unit cost of non-skill-intensive production. A third factor, research-specific labor, is used for innovation activities. Research labs sell their innovations as monopoly patents to firms in the final goods sector. Each innovation reduces the cost of production by a constant factor. It is assumed that the non-skill-intensive technology is subject to instantaneous and complete informational spillovers while the skill-intensive technology does not generate any spillovers at all. Moreover, the technology for the next generation can only be developed by quality followers if the information about the current generation has become publicly available. Hence, non-skill-intensive technologies can be leapfrogged while skill-intensive cannot. Furthermore, once an innovation is made, a firm that has filed a patent can change the underlying (non-skill-intensive) technology on its own ("in-house"), making it skill-intensive.

Neutral technological change is a priori always more efficient since the skill-biased technology comes at a higher unit cost. In the presence of the outside threat, however, the situation is more complex. Suppose the old quality leader (incumbent) uses the non-skill-intensive technology. Now the new quality leader enters, making the incumbent its closest rival. The new quality leader engages in limit pricing. In the first case the new quality leader uses the non-skill-intensive technology. Here the leader is threatened by further innovation, destroying his monopolistic rents. In the second case, when using the skill-intensive technology, there is no threat from further innovation, but the unit cost of production is higher. If the discounted firm value[44] is higher in the first case of no skill bias, then the fraction of goods produced with skill-intensive technology remains constant. If, however, biasing technology towards skill should result in a higher firm value, the fraction of skill-intensive goods will increase. In particular, it will grow at the same rate as the rate of innovation.

Relative labor demand depends on the relative wage and on the fraction of skill-intensive goods. Therefore, with exogenous labor supplies, the relative wage is increasing in the fraction of skill-intensive goods. Economic integration of symmetric countries[45] increases technological competition since there are more firms active now. Increased R&D activity and thus an increased degree of creative destruction in non-skill-intensive technologies induces quality leaders to undertake defensive skill-biased innovations. This in turn reduces knowledge spillovers, increases the demand for skilled labor, and drives up the relative wage.

2.2.3 Globalization and Institutional Change

The third major explanation apart from trade and technological change (as well as their interaction) is the role of organizational and institutional change. The two concepts overlap in the sense that both refer to the proximity of skilled and unskilled workers, either with regard to performing production together or separately (organizational change) or with regard to being members of a common trade union or not, to cite just one of many aspects of institutional change. Since organizational change has already been discussed in the context of team vs. individual production in Section 2.2.1.3.1, we constrain ourselves to institutional change here. This also includes the role of minimum wages and labor market flexibility in general.

The impact of minimum wages on inequality is both theoretically and empirically unclear. On the one hand, minimum wages compress the wage distribution from below, making wages more equal. Evidence on the impact of minimum wage increases on the average wage comes from DiNardo et al. (1996) for the United States or Möller (2006) for Germany. The result is that the increase in the average wage is far less than proportional, thus the impact on lower wage groups is much stronger than on higher wage groups. This

[44] Cp. Section 3 for the value of the firm and its interaction with the capital market.

[45] Thoenig and Verdier (2003) consider the case of an arbitrary number of symmetric countries, multiplying all labor supplies by the number of countries.

is the famous "accordion effect." On the other hand, Grossman (1983) finds that two years after raising the minimum wage in a certain occupational group, the ratio between minimum and regular wages was restored. Hence, transferring this observation to the wage structure as a whole, minimum wages rather drive up inflation since the wage gap between the different occupations is dictated by the market and will be sustained in the long run, regardless of the level of minimum wages. This view is supported by Card and Krueger (1994), who find that prices in U.S. fast food restaurants rose in proportion to minimum wages.

Yet another aspect is the impact of minimum wages on unskilled-labor unemployment. The evidence on this is unclear, too.[46] For teenagers, the empirical relation seems to correspond to economic intuition: an increase in the minimum wage makes it less attractive to hire unskilled workers, forcing them into unemployment. When adjusting the relative wage for skill-specific unemployment, it becomes obvious that increased unskilled-labor unemployment has an impact on the adjusted relative wage (Krugman hypothesis). If the increase in the rate of unskilled-labor unemployment is stronger than the decrease in the wage gap of the still active workers due to minimum wages, the unemployment-adjusted wage gap widens nevertheless. Card and Krueger (1995) argue in a meta-analysis that many studies have been biased in favor of the standard theory and that the evidence of a negative relationship between employment and minimum wages is less clear. To sum it up, minimum wages have either a negative or no effect at all on the relative wage of those who work, and a negative, neutral, or even slightly positive effect on employment. The overall impact of minimum wages on inequality is ambiguous but probably only of minor empirical relevance, given the small fractions of the labor force that are eligible for minimum wages.

The influence of union power on inequality is unclear theoretically but clearer empirically, thus we present a simple model of institutional change and relative wages in this section. One line of argument is that sectors with high degrees of unionization pay higher wages than non-union sectors. This tends to decrease employment in union sectors and raises labor supply in non-union sectors, depressing wages of non-union workers. Given that high-wage sectors are more unionized than low-wage sectors (which of course depends on how one defines "skilled"), the influence of trade unions increases inequality.[47] Apart from considerations of union power that explain the outcome of higher wages in unionized firms, another reason may be that these firms are forced to become more

[46]Cp. Brown et al. (1982) for an early but still valuable survey on the issue.

[47]This rationale is taken from Johnson (1975). Lewis (1986) and Jarrell and Stanley (1990) show that unionized sectors pay significantly higher wages (they find union premia between 9 and 16 percent).

productive, allowing them in turn to pay higher wages.[48] In this sense, productivity and higher wages are mutually enhancing. Other theoretical arguments in favor of a positive impact of unions on productivity are productivity gains through reduced negotiation costs as well as opening up a new communication channel through increased employee representation in organs such as the shop council. Altogether, this reasoning advocates a positive relationship between union density and wage inequality.

The other line of argument is similar to minimum wages: unions compress the wage distribution from below, which either causes less inequality[49] or just inflation[50]. Bowdler and Nunziata (2007) show for 20 OECD countries that union membership increased from about 38 percent in 1965 to its peak in 1979 at 46 percent and then declined to its 1965 level in the middle of the 1990s. A rise in wage inequality took place in the 1970s in some countries already, but was much more pronounced since the 1980s. One could argue that the decline in union membership contributed to the rise in wage inequality. A drawback of this conclusion is, however, that it is unclear for how large a proportion of workers collective labor agreements are binding. In Germany for instance, trade unions are not permitted to discriminate between members and non-members in their labor agreements, thus there is a freeloader problem. Nevertheless, declining union power across industrialized countries might be viewed as part of the reason for the widening wage gap. This view is supported by the majority of authors today, including Freeman (1993), DiNardo et al. (1996), Card (2001), and Gosling and Lemieux (2004). The general goal of trade unions to equalize the wages of different groups seems to have some influence on the actual wage distribution achieved in the presence of unions. This is also confirmed by the observation that potentially relevant characteristics such as education and professional experience exhibit lower correlations with wages for union workers than for non-union workers.[51]

The simple model we are going to present here works in favor of the leveling effect of union power. It argues that skill-biased technological change, either of an exogenous kind or induced by globalization, can destroy the coalition between skilled and unskilled workers as skilled workers become more productive and union-induced wage compression becomes more costly to skilled workers.[52] The idea is that decision making within

[48] The meta-analysis from Doucouliagos and Laroche (2003) finds that studies for OECD countries—the majority of studies is for the United States—give a mixed picture of the impact of unions on productivity, although the overall evidence is slightly in favor of a positive relationship. The correlation is, however, strongly country-, industry-, and time-specific.

[49] E.g., cp. Freeman (1980).

[50] E.g., cp. Bowdler and Nunziata (2007).

[51] Cp. Freeman (1980).

[52] The framework outlined here stems from Acemoglu (2002b), who presents a simplified version of

a union is geared to the median voter who might be unskilled, thus the union tries to increase wages of unskilled workers at the cost of skilled workers.[53] Moreover, union members might be willing to compress wages since they draw some benefit from ideological fulfillment of higher equality as well as social cohesion. Whatever the reason for the union's behavior, it is impossible to attract skilled workers without offering them an extra utility, denoted $\bar{\beta} > 0$. This parameter can be interpreted as some benefit each worker draws from being a union member, for instance an increase in firm productivity, leading to higher wages of unionized firms. Let a_L and a_H be the marginal products of unskilled and skilled labor, respectively. Non-union workers earn their marginal products, therefore the relative wage would be the ratio of marginal products. With union-induced wage compression, however, the relative wage amounts to

$$w = \frac{w_H}{w_L} = \bar{\gamma}\frac{a_H}{a_L}, \tag{2.35}$$

where $\bar{\gamma} < 1$ is the wage-compression parameter. $\bar{\beta}$ can be interpreted as additional productivity whose monetary equivalent can be subtracted from the wage bill. Then firms are just indifferent about hiring union workers and opening up a non-union plant (paying just the marginal revenue products) if

$$(w_L - \bar{\beta})H + (w_H - \bar{\beta})L = a_H H + a_L L \tag{2.36}$$

is fulfilled. The left-hand side of (2.36) is the productivity-adjusted wage paid to union workers while the right-hand side is the wage paid to non-union workers. Combining (2.35) and (2.36) yields an expression for the wage of skilled workers:

$$w_H = \frac{(a_H + \bar{\beta})H + (a_L + \bar{\beta})L}{a_H H + \bar{\gamma}^{-1} a_L L} a_H. \tag{2.37}$$

It is attractive for skilled workers to join the trade union if w_H given by (2.37) is greater than a_H, which depends on the relative size of $\bar{\beta}$ and $\bar{\gamma}$. As the factor relating w_H and a_H decreases in a_H (or in the ratio a_H/a_L), skill-biased technological change makes it less attractive for skilled workers to stay in the union. Skill-biased technological change, be it exogenous or induced by globalization, increases the productivity of skilled workers

Acemoglu et al. (2001).

[53]Note that this union behavior is different from what we assumed before when arguing in favor of a positive relationship between unionization and firm productivity. This makes clear that the model outcome depends crucially on the assumption whether the union acts more in favor of skilled or unskilled workers and again on how one defines "skilled."

and thus creates a more credible threat for them to leave. Whether they actually leave the union or just enforce a decrease in wage-compression tendencies (i.e., an increase in $\bar{\gamma}$) does not really matter since both leads to an increase in the relative wage. This simple framework demonstrates how globalization can drive a wedge between both skill groups by destroying their coalition.

Once the trade union has dissolved, unskilled workers lose in absolute terms. Their wage under unionization is

$$w_L = \frac{(a_H + \bar{\beta})H + (a_L + \bar{\beta})L}{\bar{\gamma} a_H H + a_L L} a_L, \tag{2.38}$$

which is clearly greater than a_L, therefore they are better off under union protection. Given that unions usually support minimum wage regimes (although they implicitly make themselves partly superfluous by doing so), erosion of union power may also offset equality gains based on minimum wages.

Globalization and/or technological change do not only widen the wage gap but also change the institutional framework of wage determination. This triple connection between the three explanations demonstrates that they are well compatible. The next section documents the Schumpeterian growth model we are going to work with in the rest of this dissertation. The model focuses mainly on globalization and its interaction with skill-biased technological change. There are, however, model parameters that can be interpreted as reflecting the institutional framework, and shocking them might be regarded as institutional change, although only of an exogenous rather than endogenous kind.

Chapter 3

Schumpeterian Growth Models

Following our literature review, the workhorse presented here is a North-North model, where trade results from the fact that both countries have a comparative advantage in production of exactly half of the goods. Trade liberalization fosters technological progress, and this progress is in favor of skilled labor. Therefore, it offers an explanation for rising wage inequality through trade and skill-biased technological change.

The basic model ("benchmark model") we present in Section 3.1 includes two factors of production and endogenous factor supplies. Here we draw heavily upon Dinopoulos and Segerstrom (1999). Their model includes an ad valorem tariff for manufacturing goods, which we replace by an iceberg transport cost. In Section 3.2, this framework is extended by allowing for unemployment by means of a job-matching mechanism, partly adopted from Sener (2001). Next, we introduce the possibility of production taking place in both countries. The incentive for horizontal FDI stems from trade cost reductions: firms "jump" the trade barrier (Section 3.3). This second extension is a novel feature of this dissertation.

3.1 The Benchmark Model

Dinopoulos and Segerstrom (1999) develop a 2x2x2 dynamic general-equilibrium model of endogenous innovation with two structurally identical countries. The two factors of production are skilled and unskilled labor, and the two goods produced are manufactures and R&D services. There is a continuum of tradable goods, and the trade pattern is determined by differences in knowledge. Due to ongoing innovation, the pattern of comparative advantage is constantly changing: each country manufactures half of the goods from the continuum, but which goods it produces depends on the success of its innovators in the past, i.e., is determined by chance. The model offers a North-North explanation for increasing wage inequality through trade liberalization. The authors develop what they call a "Schumpeterian version" of the Stolper-Samuelson theorem. Stolper and Samuelson (1941) state that increased trade between the unskilled-labor-abundant South and the skilled-labor-abundant North leads to a decline in the relative wage of unskilled labor due to a decline in the relative price of the unskilled-labor-intensive good—which is the imported good from the Northern perspective. With two structurally identical countries facing the same iceberg trade cost for all imported goods, domestic relative prices of imported in terms of exported goods remain fixed. This feature excludes changes in relative goods prices as an explanation for changes in the relative wage.

Therefore, the trade explanation for increasing wage inequality can only be justified when there is another mechanism at work apart from changes in relative goods prices. Firms have an incentive to innovate since consumers are willing to pay a higher price for higher-quality products, which grants temporary monopoly profits to the firms. Innovation is the skilled-labor-intensive activity, and the reward to innovation rises when trade is liberalized since profits earned abroad rise as well. Thus falling trade costs lead to a rise in the "price of innovation," which in turn increases the price of the factor used intensively in innovation (as opposed to the other activity, manufacturing, which is unskilled-labor-intensive). Hence the expression "Schumpeterian version": changes in the relative price of innovation lead to changes in the relative wage. Moreover, labor supplies are endogenously determined, depending on the relative wage. By means of Figure 3.1 we have endeavored to display the model mechanism graphically. In the following subsections we will derive the model formally and in all necessary detail.

Apart from some minor changes, Sections 3.1.1 to 3.1.4 mainly reproduce the model from Dinopoulos and Segerstrom (1999), while 3.1.6 presents a test simulation. New contributions are Sections 3.1.5 (CGE formulation), 3.1.7 (welfare measurement), and 3.1.8 (welfare by ability level).

3.1.1 Utility Maximization and Human Capital Accumulation

In each country, there is a continuum of households indexed by ability $\theta \in [0, 1]$.[1] Each household, modeled as an infinitely-lived dynasty, has the same number of members

[1] There is a distinction between "ability" and "skill": the first term refers to a household's *draw* from the ability distribution and does not change (like intelligence or other given features). The second term, as we shall see in a moment when it comes to endogenous skill upgrading, refers to a household's *decision* to become "skilled" (undergoing a costly training).

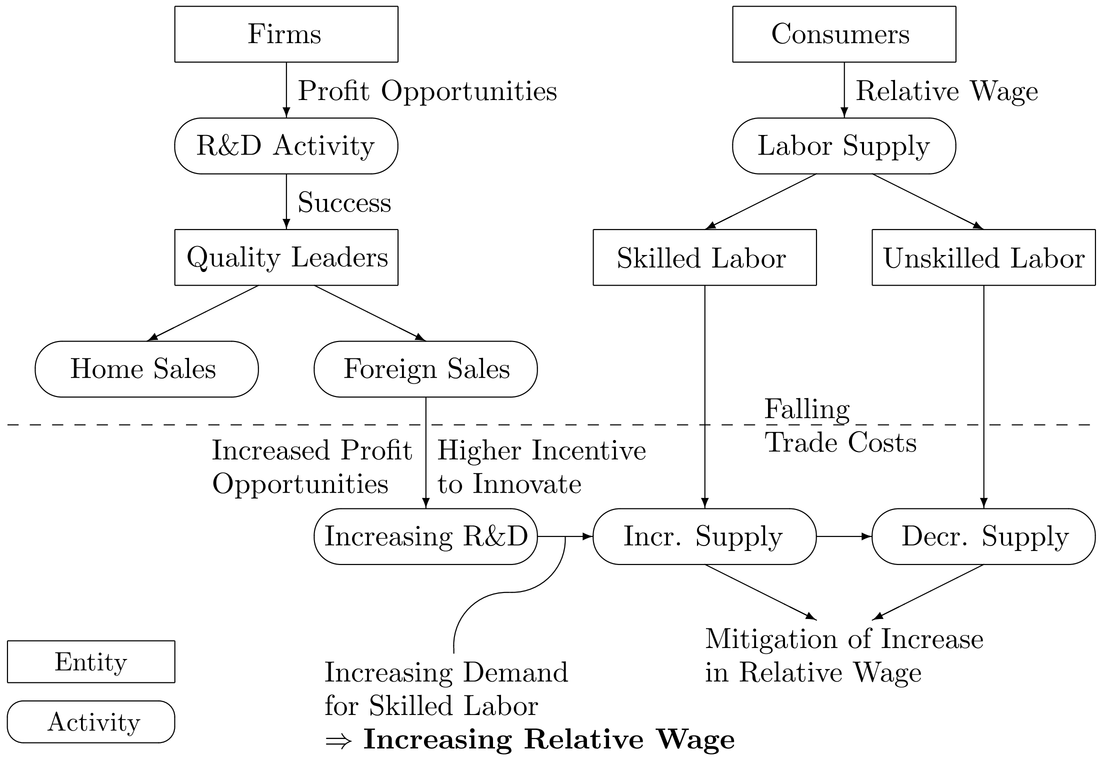

Figure 3.1: Flowchart of the Benchmark Model.

and the entire offspring of each individual household has the same ability θ (children are assumed to be no different from their parents). Household size grows over time at an exogenous rate $n = \beta - \delta$ with birth rate β and death rate δ. The time-dependent population size is $N(t) = N_0 e^{nt}$, where N_0 denotes the number of members of each household at time $t = 0$. With each individual living for an exogenous period of time D, it follows that $\delta = n/(e^{nD} - 1)$ and $\beta = (ne^{nD})/(e^{nD} - 1)$ when equating the number of births at time t and the number of deaths at time $t + D$.

In a standard fashion[2], households with ability θ maximize utility

$$U_\theta \equiv \int_0^\infty N_0 e^{-(\rho-n)s} \log u_\theta(s)\,\mathrm{d}s, \tag{3.1}$$

where the individual time discount factor ρ has to be greater than n to make the integral converge, subject to a quality-based definition of instantaneous utility u_θ (quality augmentation is described by multiplication with parameter λ, indicating the arrival at the next step on the "quality ladder"),

$$\log u_\theta(s) = \int_0^1 \log \Big[\sum_j \lambda^j q_\theta(j,\omega,s)\Big]\,\mathrm{d}\omega \tag{3.2}$$

with number of improvements j and industry index $\omega \in [0, 1]$. Moreover, per capita consumption expenditure c_θ,

$$c_\theta(s) = \int_0^1 \Big[\sum_j p(j,\omega,s) q_\theta(j,\omega,s)\Big]\,\mathrm{d}\omega, \tag{3.3}$$

is the product of price p and quality-adjusted quantity q_θ. The budget constraint,

$$W_\theta(t) + Z_\theta(t) = \int_t^\infty N_0 c_\theta(s) e^{ns} e^{-[R(s)-R(t)]}\,\mathrm{d}s, \tag{3.4}$$

equates the sum of discounted wage income from time t on, $W_\theta(t)$, and the asset value at time t, $Z_\theta(t)$, to the discounted consumption value, where $R(t) \equiv \int_0^t r(s)\,\mathrm{d}s$ is the market discount factor with interest rate $r(s)$. The representative consumer's problem can be split up into three steps: allocating lifetime wealth across time, allocating expenditure at

[2]Basically, there are two different ways of modeling changes in the product space. The first one is a continuous increase in the number of products, which raises consumer utility through increased variety. Second, the number of products is held constant but the quality of each product is steadily increased, which again yields higher consumer utility. This second approach is what we are going to follow throughout this thesis. However, Grossman and Helpman (1991), chapters 3 and 4 show that both approaches lead to similar results.

each instant across products, and allocating expenditure at each instant for each product across available quality levels. The familiar result is the Keynes-Ramsey rule,

$$\frac{\dot{c}_\theta}{c_\theta} = r(t) - \rho, \tag{3.5}$$

stating that the growth rate of consumption is the higher the greater the interest rate relative to the discount factor. The reason is that a high interest rate makes it more attractive to postpone consumption to the future since saving money yields a high return. Much more consumption tomorrow than today entails a high consumption growth rate. In steady state, per capita consumption expenditure is constant over time, hence

$$r(t) = \rho, \tag{3.6}$$

which implies that the subjective household discount factor equals the market discount factor.

An individual can either join the labor force as an unskilled worker and earn wage w_L or become skilled by undergoing training for an exogenous period of time T. He then earns a wage $(\theta - \gamma)w_H$, where γ is a parameter governing the wage distribution, as we shall see below.

The incentive to become skilled only exists if the discounted wage income is greater than in the case of not becoming skilled:

$$\int_t^{t+D} e^{-[R(s)-R(t)]} w_L(s)\,\mathrm{d}s < \int_{t+T}^{t+D} e^{-[R(s)-R(t)]}(\theta - \gamma)w_H(s)\,\mathrm{d}s. \tag{3.7}$$

An implicit assumption of the model is that all unskilled workers earn the low wage whereas skilled workers earn the high wage, which need not necessarily be the case in reality. Since we focus on steady-state outcomes where consumption expenditure and wages do not change over time any more, (3.7) holds as an equality, which results in a certain level of θ where individuals are just indifferent about becoming skilled or not, θ_0. This level determines the number of individuals remaining unskilled (those with ability lower than θ_0) and those who undergo training and become skilled. The steady-state value of this skill threshold equals

$$\theta_0 = \frac{\varsigma}{w} + \gamma, \quad \text{where} \quad \varsigma \equiv \frac{1 - e^{-\rho D}}{e^{-\rho T} - e^{-\rho D}} > 1 \quad \text{and} \quad w \equiv \frac{w_H}{w_L}. \tag{3.8}$$

ς can be interpreted as a measure of the ratio of discount factors for unskilled and skilled labor. The relative wage w must be greater than one because workers accumulating human capital have to be compensated for their effort by a higher wage. (3.8) makes clear why γ has been introduced in the first place.[3] First suppose that $\gamma > 0$. This ensures that $w = \varsigma/(\theta_0 - \gamma)$ will not fall below $\varsigma/(1-\gamma)$, which means that the wage distribution is bounded from below. Moreover, it implies that even for very high values of w, θ_0 will not become smaller than γ, i.e., not all workers become skilled. Alternatively suppose that $\gamma < 0$. Now w cannot exceed a value of θ_0/γ, bounding the wage distribution from above. Moreover, as w cannot fall below one, $\gamma < 0$ also implies that θ_0 will not exceed $\sigma + \gamma$, which implies that not all workers become unskilled. To sum it up, the role of $\gamma > 0$ (< 0) is to constrain θ_0 and w from below (above).

Another advantage of introducing γ becomes obvious when we turn to model calibration in Section 4.2, where γ works as an additional degree of freedom: (3.8) filled with real-world data for θ_0, w, and ς is unlikely to hold in the absence of γ (i.e., $\theta_0 = \varsigma/w$ being satisfied would be pure coincidence).

Now the supplies of unskilled labor $L(t)$ and skilled labor $H(t)$ have to be determined. The first equals the number of individuals that remain unskilled:

$$L(t) = \theta_0 N(t). \tag{3.9}$$

The subpopulation $(1-\theta)N(t)$ comprises those individuals who either work as skilled workers or undergo training. The skilled workers are born between $t - D$ and $t - T$, hence the amount of skilled workers who already have undergone training (the older part of the subpopulation) equals

$$\int_{t-D}^{t-T} \beta(1-\theta_0)N(s)\,\mathrm{d}s = (1-\theta_0)\phi N(t), \quad \text{where} \quad \phi \equiv \frac{e^{n(D-T)} - 1}{e^{nD} - 1} < 1. \tag{3.10}$$

ϕ stands for the fraction of skilled workers with acquired skills. The θ of skilled workers varies between θ_0 and 1, thus the average skill level of individuals that have finished training equals $[(\theta_0 - \gamma)/2] + [(1-\gamma)/2] = (\theta_0 + 1 - 2\gamma)/2$. Therefore the supply of skilled labor, measured in efficiency units, is

$$H(t) = \frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1-\theta_0)N(t). \tag{3.11}$$

(3.9) and (3.11) together with (3.8) show that factor supplies depend positively on their

[3] This is a point not touched by Dinopoulos and Segerstrom (1999); they only consider the case of $\gamma > 0$ and do not go into the details of the parameter's effect.

respective wage. With θ_0 constant over time (in the absence of parameter shocks), each country's factor supplies grow at the same rate n.

3.1.2 Product Trade, Trade Costs, and Profits

We now derive the equilibrium quantities sold in the Home and the Foreign country (marked by an asterisk) by Home and Foreign producers as well as the respective profit flows. In each country, there is a continuum of industries, producing final consumption goods with both skilled and unskilled labor and constant returns to scale. The unit-cost function $A(w_L, w_H)$, based on a constant-returns-to-scale production function, is the numéraire:

$$A(w_L, w_H) = 1. \tag{3.12}$$

Firms producing the state-of-the-art quality are named "quality leaders," indexed by ℓ, and firms that are one step behind on the "quality ladder" are called "quality followers," indexed by f, trying to replace the leaders. Leaders produce the manufactured good but do not innovate anymore while followers innovate but do not produce yet. Winning an R&D race grants a firm a patent and the right to sell its product to consumers in both countries. The patent expires when further innovation occurs in the industry. Products not protected by patents can be produced competitively by firms in both countries. A common iceberg trade cost τ is faced when exporting in either direction. In order to prevent the trade cost from being prohibitive, it is assumed that $0 \leq \tau \leq \lambda - 1$.

Unlike Dinopoulos and Segerstrom (1999), we consider the case where quality leaders and followers engage in Bertrand competition with each other by setting prices.[4] Moreover, Dinopoulos and Segerstrom (1999) assume that all imports are subject to an ad valorem tariff and tariff revenues are distributed to consumers in a lump-sum fashion. Their approach is not the same as our iceberg cost since our concept does not imply any revenue being collected. We take the iceberg approach (which is more reasonable in a North-North setting anyway) and assume that a fraction of the shipment "melts away": when $(1 + \tau)$ units are shipped from one country to the other, only one unit reaches its destination.

[4] The model presented in Dinopoulos and Segerstrom (1999) employs Cournot quantity competition. However, since most models make use of Bertrand price competition and modifications are easier to perform under that behavioral assumption, we do the same here. The outcome of Bertrand competition is that prices are pushed down to the level of marginal cost even in a duopoly setting whereas Cournot competition predicts that prices will be higher than marginal cost due to the assumption of the Cournot model that firms do not lose their entire market share when raising prices, as opposed to the Bertrand model. Hence, Bertrand competition can be viewed as "tougher" than Cournot competition. The qualitative model results, however, do not depend on the competitive behavior assumed.

Suppose a Home quality leader exports its product to the Foreign market. Since all followers bear identical unit costs (equal to one), any positive trade cost will prevent Home followers from entering the Foreign market (since followers do not have a quality advantage that puts them in a position to charge a higher price that could cover the trade cost). By this logic, which due to symmetry naturally holds for trade in both directions, an exporting Home quality leader competes with Foreign followers only. Each product is manufactured by a single firm only.

Due to international arbitrage, the price paid by Foreign consumers for the state-of-the-art product, denoted by P_ℓ^*, has to equal the "cif" (cost, insurance, freight) price the Home leader receives from selling to Foreign consumers, p_ℓ^*, augmented by the trade cost: $p_\ell^*(1+\tau) = P_\ell^*$. Consumers consider goods identical when adjusted for quality, thus $P_\ell^* = \lambda p_f^*$ with $p_f^* = A(w_L, w_H) = 1$ due to perfect competition. The price that Foreign consumers pay for the state-of-the-art imported good is equal to λ times the price of the good produced by Foreign followers: $p_\ell^*(1+\tau) = \lambda = P_\ell^*$. Due to trade costs on imported goods, Foreign followers cannot undercut the prices of Home followers in the Home market and vice versa. Demanded quantities do not depend on the trade cost. In equilibrium, followers can break even at best and thus do not produce: $Q_f = Q_f^* = 0$, i.e., only state-of-the-art qualities are manufactured. The asterisk indicates that a quantity is sold in the Foreign market. Home leaders face a unitary elastic demand and sell $Q_\ell = \big[c(t)N(t)\big]/\lambda$ in the Home market. For the Foreign market, however, they have to produce $Q_\ell^* = \big[c(t)N(t)(1+\tau)\big]/\lambda > Q_\ell$ to deliver Q_ℓ as a portion of the shipment melts on the way. The actual amounts *delivered* to the Home and the Foreign country by a quality leader are the same, but since we argue from a source perspective here we need to consider the amounts *produced*, and this leads to $Q_\ell^* > Q_\ell$ for $\tau > 0$. This producer perspective is necessary as we need to establish the profits earned at home and abroad in the next step. In the Home market, the Home leader earns profits

$$\pi_\ell = p_\ell Q_\ell - Q_\ell = c(t)N(t)\frac{\lambda - 1}{\lambda}. \tag{3.13}$$

In the Foreign market, the Home leader's profits depends on τ since $p_\ell^* = \lambda/(1+\tau)$:

$$\pi_\ell^* = p_\ell^* Q_\ell^* - Q_\ell^* = c(t)N(t)\frac{\lambda - 1 - \tau}{\lambda}. \tag{3.14}$$

The global profit flow of a Home leader (and of a Foreign leader as well due to symmetry) amounts to

$$\pi = \pi_\ell + \pi_\ell^* = c(t)N(t)\frac{2(\lambda - 1) - \tau}{\lambda}. \tag{3.15}$$

In the product market equilibrium, only state-of-the-art products are produced and traded. Moreover, all leaders charge the same price λ in both countries. Most important, however, is the fact that in this model, trade liberalization does not have any impact on relative goods prices. The channel through which changes in the relative wage occur, namely the price of innovation, is discussed in the next subsection.

3.1.3 R&D Races and Factor Markets

Sequential and stochastic R&D races in each industry lead to the discovery of higher-quality final products. Arrival of innovations is governed by a Poisson process with intensity $I(\omega,t)+I^*(\omega,t)$, i.e., the sum of the instantaneous probabilities of innovation success in both countries, where returns to R&D investment are independently distributed across firms, industries, and over time: $I(\omega,t)=\sum_i I_i(\omega,t)$ and $I^*(\omega,t)=\sum_i I_i^*(\omega,t)$, where i denotes the firm index.[5] A firm i engaging in R&D incurs the cost flow

$$[B(w_H)X(\omega,t)]I_i(\omega,t), \tag{3.16}$$

where $B(w_H)$ is the unit-cost function[6] derived from a constant-returns-to-scale production function and $X(\omega,t)$ is the R&D difficulty. Specifically we assume here that it becomes more difficult to replace old products by inventing new ones when the market becomes larger, i.e., $X(\omega,t)$ depends on the population size:

$$X(\omega,t)=kN(t), \tag{3.17}$$

where $k>0$ is a constant.[7]

[5]Innovations arriving with a Poisson process imply that the time until the next innovation occurs is exponentially distributed. The expectation of the exponential distribution is the inverse of the underlying intensity, i.e., $1/[I(\omega,t)+I^*(\omega,t)]$. With symmetric countries in steady state, $I=I^*$, the average time until an innovation occurs is $1/(2I)$. For instance, with a rate of innovation of five percent in each country, it takes on average ten periods of time until the next innovation occurs.

[6]R&D activity makes use of skilled labor only. We could also assume that both factors are used in both activities as in Dinopoulos and Segerstrom (1999). However, in the model with unemployment, this would result in model complications that hamper model calibration severely and do not yield any new insights. The crucial model assumption—R&D being the skilled-labor-intensive activity—is fulfilled with our own simplifying assumption as well. Moreover, the actual amount of unskilled labor used by the innovation sector is negligible anyway.

[7]The specification given in (3.17) is called the PEG model, since trade liberalization has "permanent effects on growth." The other specification employed by the authors is the so-called TEG model, standing for "temporary effects on growth," where $\dot{X}(\omega,t)/X(\omega,t)=\mu[I(\omega,t)+I^*(\omega,t)]$ with $\mu>0$. However, since for the TEG version a positive rate of innovation I in the long run only occurs for positive population growth rates ($I=n/(2\mu)$ in steady state), we prefer the PEG version. Population growth should not be a necessary condition for innovation in our model. An important feature of both the PEG and TEG specification is that there is neither explosive growth nor scale effects, i.e., the growth rate does not

In order to interpret k, we first identify its dimension.[8] The cost flow in (3.16) has the dimension "monetary units per time unit," for instance "euros per year." As $B(w_H)$ has the dimension "euros per year per worker" and I has the dimension "per year," X must have the dimension "years times workers" or simply "man years." Taking this result and using the fact that N in (3.17) has the dimension "workers," k has the dimension "years." E.g., a value of $k = 2$ means that one additional worker adds two man years to the R&D difficulty, given that all time-related values are measured in years (and not in hours or days), of course.

A global stock market channels consumer savings to R&D firms. Complete risk diversification due to the industry continuum assumption guarantees that investing in such a firm yields exactly the market interest rate $r = \rho$. With an efficient stock market, the market interest rate equals the sum of the rate of return on the stock value, the profit per share (i.e., the dividend), and the monopolist's risk of being driven out of the market by a new innovation, which would completely erode the profit basis of the firm under consideration:

$$r(t) = \frac{\dot{v}(\omega,t)}{v(\omega,t)} + \frac{\pi(t)}{v(\omega,t)} - [I(\omega,t) + I^*(\omega,t)], \tag{3.18}$$

where the expected discounted profits of a quality leader are denoted by $v(\omega, t)$. Solving for $v(\omega, t)$ shows that profit flows are discounted with the market interest rate and the instantaneous probability of being driven out of the market as well as the negative relative change of the firm value:

$$v(\omega,t) = \frac{\pi(t)}{r(t) + I(\omega,t) + I^*(\omega,t) - [\dot{v}(\omega,t)/v(\omega,t)]}. \tag{3.19}$$

Formally, (3.19) can also be derived by the following reasoning. The product's lifetime is equal to the length of the time period between two innovations and is represented by a random variable η distributed with the global rate of innovation $2I$ (given that $I = I^*$). The arrival of new products follows a Poisson process and therefore η is exponentially distributed. The discounted profits expected by a successful innovator are given by

$$v(\omega,t) = \int_0^\infty 2I(\omega,t)e^{-2I(\omega,t)\eta} \left(\int_0^\eta \pi(t)e^{-[r(t)-\dot{v}(\omega,t)/v(\omega,t)]s}\,\mathrm{d}s \right) \mathrm{d}\eta, \tag{3.20}$$

depend on country size as in the "first-generation" endogenous-innovation models.

[8] Dinopoulos and Segerstrom (1999) do not provide a useful interpretation of k, thus we make up for that here.

where the inner integral represents the discounted profits of the quality leader for the duration of the product, η. Solving the integrals in (3.20) yields (3.19) as well.

Firm i chooses its R&D intensity to maximize

$$v(\omega,t)I_i(\omega,t)\,\mathrm{d}t - B(w_H)X(\omega,t)I_i(\omega,t)\,\mathrm{d}t. \tag{3.21}$$

Free entry ensures that (3.21) is equal to zero in equilibrium. The "relative price" of innovation,

$$S(\omega,t) \equiv \frac{v(\omega,t)}{X(\omega,t)} = B(w_H), \tag{3.22}$$

is the ratio of the reward for innovating and its difficulty. It is not difficult to show that in the absence of factor intensity reversals, an increase in the relative price of innovation S raises w_H and lowers w_L if and only if R&D is the skilled-labor-intensive activity. Moreover, the fraction of skilled workers is increased as well. These two results are what Dinopoulos and Segerstrom (1999) call the "Schumpeterian version" of the Stolper-Samuelson theorem.[9]

The last missing step in order to arrive at the general equilibrium is factor market clearance. Wages are assumed to be fully flexible and factors are perfectly mobile across industries and activities, hence factor markets are cleared at every moment in time. Relative R&D difficulty, $x \equiv X(t)/N(t)$, is equal to k according to (3.17). The "average" quantity of final output produced in each industry, q, equals half of the sum of output produced by Home followers, Q_f $(= 0)$, the quality leader's output sold at Home, Q_ℓ, the leader's output sold to Foreign consumers, Q_ℓ^*, and the output of Foreign followers, Q_f^* $(= 0)$:

$$q = \frac{Q_f + Q_\ell + Q_f^* + Q_\ell^*}{2} = \frac{c(t)N(t)}{2\lambda} + \frac{c(t)N(t)(1+\tau)}{2\lambda} = c(t)N(t)\frac{2+\tau}{2\lambda}. \tag{3.23}$$

Unskilled labor is used in manufacturing only, therefore the per capita version of the full-employment condition for unskilled labor is

$$\theta_0 = A_L(w_L, w_H)\frac{q}{N(t)}, \tag{3.24}$$

where $A_L(w_L, w_H) = \partial A/\partial w_L$ denotes the unskilled-labor requirement per unit of output

[9] The authors check for the empirical relevance of their "Schumpeterian version" by examining whether there is a correlation between the skill premium of college graduates compared to high school graduates and the relative price of innovation, measured by real asset prices divided by an index of R&D difficulty; data are for the United States between 1963 and 1989. Indeed, they find their hypothesis to be highly relevant empirically.

in the manufacturing sector. Defining $A_H(w_L, w_H) = \partial A/\partial w_H$ and $B_H(w_H) = \partial B/\partial w_H$, using the skilled-labor supply given by (3.11), and assuming that skilled labor is used in both activities, the corresponding condition for skilled labor is

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) = A_H(w_L, w_H)\frac{q}{N(t)} + B_H(w_H)Ix. \tag{3.25}$$

3.1.4 Steady-State Equilibrium

The model structure is similar to the Heckscher-Ohlin-Samuelson model producing R&D services Ix and final output q/N, although the Heckscher-Ohlin-Samuelson model assumes asymmetric countries. The relative price of R&D investment is expressed in terms of final goods (and equals S). Factor supplies are completely inelastic for a given θ_0. From (3.15) and (3.22) it follows that $\dot{v}/v = \dot{X}/X = n$. Calculating the steady-state value of $v(t) = \pi/(\rho + 2I - n)$ (since $I = I^*$ due to symmetry) from (3.19) and plugging in π from (3.15) allows to solve for $c(t)N(t)$. The resulting expression is inserted into (3.23) using (3.22). This yields

$$q = B(w_H)(\rho + 2I - n)\Psi(\tau)X, \quad \text{where} \tag{3.26}$$

$$\Psi(\tau) \equiv \frac{q}{\pi} = \frac{2 + \tau}{4(\lambda - 1) - 2\tau}.$$

$\Psi(\tau)$ is an increasing function of τ and a decreasing function of λ. Hence, Ψ can be interpreted as a measure for the distance of competitive advantage through innovation and trade costs. Together with the PEG model given by (3.17), (3.26) can be substituted into the per capita full-employment conditions (3.24) and (3.25), which leads to

$$\theta_0 = A_L(\theta_0)B(\theta_0)\Psi(\tau)(\rho + 2I - n)k \tag{3.27}$$

and

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) = A_H(\theta_0)B(\theta_0)\Psi(\tau)(\rho + 2I - n)k + B_H(\theta_0)Ik, \tag{3.28}$$

where $B(\cdot)$ and the derivatives of $A(\cdot)$ and $B(\cdot)$ depend on θ_0 due to (3.8). The equilibrium in the (θ_0, I) space can the determined from (3.27) and (3.28). The right-hand sides of both (3.27) and (3.28) increase in I since they reflect factor demands which naturally grow with increasing R&D investment. The respective left-hand sides have opposite signs with respect to θ: (3.27) rises while (3.28) falls (θ_0 represents the share of unskilled labor, thus the left-hand side of (3.28) is the supply of skilled labor). Hence, there must be a unique equilibrium.[10]

There are three important implications of trade liberalization, i.e., a reduction in τ: the relative wage, $w \equiv w_H/w_L$, increases, the fraction of workers that remain unskilled, θ_0, decreases, and the global rate of technological change, $2I$, increases. These effects can be explained as follows. First we consider the case where factor supplies remain constant. Falling trade costs raise the profitability of R&D investment due to better market access, therefore the relative price of innovation S rises. The rise in the non-production activity Ix (R&D) goes along with a fall in the production activity q/N (manufacturing). Workers move from one activity to the other in each industry. With R&D being the skilled-labor-intensive activity, a rise in the price of innovation reduces the demand for unskilled labor and increases the demand for skilled labor. When endogenous skill upgrading is allowed for, the following Rybczynski-type[11] effect is generated: according to (3.8), a higher relative wage leads to a fall in θ_0, i.e., there are more skilled workers than before trade liberalization. This results in rising supply of R&D services and thus a falling price of the latter. The impact of trade liberalization is reduced through this factor-supply-based general-equilibrium channel, but not completely canceled out, only mitigated.[12]

3.1.5 CGE Formulation

In order to make make the model operational, we assume explicit functional forms for $A(\cdot)$ and $B(\cdot)$, namely Cobb-Douglas unit-cost functions: $A(w_L, w_H) = w_L^a w_H^{1-a}$ and $B(w_H) = w_H$.[13] It follows that $A_L(w_L, w_H) = a\left(\frac{w_H}{w_L}\right)^{1-a}$, $A_H(w_L, w_H) = (1-a)\left(\frac{w_H}{w_L}\right)^{-a}$, and $B_H(w_H) = 1$. There are four endogenous variables: w_H, w_L, I, and θ_0. The CGE model consists of (3.12), (3.8), (3.27), and (3.28) and looks as follows:

$$A(w_L, w_H) = w_L^a w_H^{1-a} = 1, \tag{3.29a}$$

[10] Such an equilibrium with $I > 0$ and $\theta_0 > 0$ (i.e., in the positive orthant) exists for sufficiently low values of k or $(\rho - n)$.

[11] The Rybczynski theorem states that an increase in the supply of one of two factors induces a relative increase in the production of the good using it intensively in production. This in turn leads to a reduction in the relative price of that good.

[12] If manufacturing and R&D were equally skill-intensive, the increase in the relative wage would be completely offset by adapting factor supplies; only the rate of innovation would increase.

[13] We could also write $B(\cdot)$ as a function of both wages: $B(w_L, w_H) = w_L^b w_H^{1-b}$. With our assumption of no unskilled labor used in R&D, $b = 0$, this yields $B(w_H) = w_H$ as well.

$$\theta_0 = \varsigma \frac{w_L}{w_H} + \gamma, \tag{3.29b}$$

$$\text{where} \quad \varsigma \equiv \frac{1 - e^{-\rho D}}{e^{-\rho T} - e^{-\rho D}} > 1,$$

$$\theta_0 = A_L(w_L, w_H) B(w_H) \Psi(\tau)(\rho + 2I - n)k, \tag{3.29c}$$

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) = A_H(w_L, w_H) B(w_H) \Psi(\tau)(\rho + 2I - n)k + B_H(w_H) I k, \tag{3.29d}$$

$$\text{where} \quad \Psi(\tau) \equiv \frac{q}{\pi} = \frac{2 + \tau}{4(\lambda - 1) - 2\tau}, \quad \phi \equiv \frac{e^{n(D-T)} - 1}{e^{nD} - 1} < 1.$$

3.1.6 Test Simulation[14]

Dinopoulos and Segerstrom (1999) employ the TEG model to run a simulation. According to the modifications of their original model (Cournot instead of Bertrand competition, iceberg trade cost, no unskilled labor in R&D) and making use of the PEG model instead, we perform a test simulation that shows how the model behaves. We apply the following parameter values (the same values as in their paper, except for k, which does not appear in the TEG model, and γ, which we changed for reasons of convergence of the model extensions in the following sections): $D = 40$, $T = 4$, $n = 0.01$, $\rho = 0.03$, $\lambda = 1.35$, $k = 1$, $\gamma = 0.1$, $a = 0.85$. Detailed interpretations of parameters and variables will follow when it comes to model calibration in Section 4.2. Only that much for now: the economic lifetime is assumed to be 40 years and the training duration 4 years; the population grows with 1 percent per year and discounting takes place with 3 percent per year; the step size on the quality ladder is 35 percent (which is also the price markup charged by the monopolist); each additional worker adds one year to the R&D difficulty; w does not fall below $\sigma/(1-\gamma) \approx 1.19/(1-0.1) = 1.33$ (cp. (3.8)) and θ_0 is at least 0.1; the share of unskilled labor used in manufacturing is 85 percent. When shocking trade costs τ from an initial level of 20 percent to a new level of 10 percent, endogenous variables change as shown in Table 3.1.

As one can see from the table, all variables move in the expected direction. While the wage levels and the relative wage (which is naturally greater than 1) as well as the

[14] All simulations were performed with the AMPL solver KNITRO, which is designed for non-linear optimization. Cp. www.ampl.com and www.ziena.com.

Variable	$\tau = 0.2$	$\tau = 0.1$	Relative Change [%]
w_H			3.3
w_L			-0.6
w	1.837	1.909	3.9
θ_0	0.739	0.725	-1.9
I	0.099	0.118	18.8
q/N			-3.8

Table 3.1: Results of Test Simulation for the Benchmark Model. Parameter values: $D = 40$, $T = 4$, $n = 0.01$, $\rho = 0.03$, $\lambda = 1.35$, $k = 1$, $\gamma = 0.1$, $a = 0.85$.

skill level change moderately, the rate of innovation is subject to considerable change of about 19 percent. Output per capita decreases since more resources are used for innovation, hence less is left for production of manufactured goods. Note that it does not make sense to report absolute values for any variables except w, θ_0, and I.

If one fixes θ_0 (not in the table) at its initial level of 0.739, the mitigating impact of changing labor supplies does not come into play. The relative wage reaches a level of 2.122, i.e., rises by about 15.5 percent while the rate of innovation reaches a lower level of 0.109 due to more expensive skilled labor than in the case of adapting labor supplies. However, it is hardly realistic to assume that labor supplies do not react to changes in factor prices.

3.1.7 Total Welfare and Average Real Wage

The approach taken by Sener (2001) in order to measure welfare is to calculate the discounted dynastic utility given by (3.1). The problem with his approach is, however, that due to the logarithmic utility function, simulated values for the relative change in utility cannot reasonably be compared to real-world equivalents. We lack a cardinal utility measure. The usual approach to measure welfare is the equivalent variation EV, asking what income change at the current prices would be equivalent to the change in terms of its impact on utility. To the best of our knowledge, the literature has not addressed the issue of the equivalent variation for this specific type of utility function. We therefore develop a measure at this point in order to be able to compare the simulated equivalent variation to actual data.

As a prerequisite, we need to derive a closed-form solution of the utility integral in (3.1), and this is already provided by Sener (2001). By using $q/N = c/[(2+\tau)/2\lambda]$ from

(3.23), instantaneous utility from (3.2) can be written as

$$\log u(t) = \log c(t) - \log \lambda + \log(1+\tau/2) + \int_0^1 \log \lambda^{j(\omega,t)}\,\mathrm{d}\omega, \tag{3.30}$$

where $j(\omega, t)$ is the number of quality improvements in industry ω at time t. The value of the integral, $\int_0^1 \log \lambda^{j(\omega,t)}\,\mathrm{d}\omega = \log \lambda \int_0^1 j(\omega,t)\,\mathrm{d}\omega$, is $2It \log \lambda$ since $\int_0^1 j(\omega,t)\,\mathrm{d}\omega = 2It$ is the expected value of $j(\omega, t)$ and $2I$ is the steady-state intensity of the Poisson process of innovation. Given

$$\log u(t) = \log c(t) - \log \lambda + \log(1+\tau/2) + 2It \log \lambda, \tag{3.31}$$

we can calculate the growth rate of instantaneous utility:

$$g \equiv \frac{\dot{u}}{u} = 2I \log \lambda, \tag{3.32}$$

thus utility grows proportionally with the rate of innovation. Plugging this result into lifetime utility (3.1) yields

$$U = N_0 \int_0^\infty e^{-(\rho-n)t}[\log c - \log \lambda + \log(1+\tau/2) + gt]\,\mathrm{d}t, \tag{3.33}$$

dropping the time index of c. Normalizing the initial population to one, $N_0 = 1$, the integral becomes

$$U = \int_0^\infty e^{-(\rho-n)t}[\log c - \log \lambda + \log(1+\tau/2)]\,\mathrm{d}t + \int_0^\infty e^{-(\rho-n)t} gt\,\mathrm{d}t. \tag{3.34}$$

If $\rho > n$, both integrals in (3.34) converge.[15] Solving (3.34) yields

$$U = \frac{1}{\rho - n}\left(\log c - \log \lambda + \log(1+\tau/2) + \frac{g}{\rho - n}\right). \tag{3.35}$$

With falling trade costs, manufacturing output per capita declines since more resources are devoted to innovation, whereas the rate of innovation (and thus the growth rate) rises, hence the total impact on welfare is undetermined: people forgo consumption today but achieve higher consumption in the future due to increased growth. As one can see from (3.35), g is divided by $(\rho - n)$, a very small number, hence the second term in the squared brackets changes considerably even for small changes in g. This

[15] $\rho > n$ can be written as $\rho + g > n + g$, which states that the real interest rate must be greater than the total growth rate. This is the condition for dynamic efficiency.

in turn makes the relative change of the second term in the squared brackets likely to be greater than the relative change of the first term, hence the change in utility due to trade liberalization is likely to be positive.

Now we can determine the equivalent variation. We aim at finding the value c^* that generates the same utility under g^0 (the initial growth rate) that final expenditure c^1 generates under the final growth rate g^1. For these purposes, we make use of (3.35):

$$\frac{1}{\rho - n}\left(\log c^* - \log\lambda + \log(1+\tau/2) + \frac{g^0}{\rho - n}\right) = \frac{1}{\rho - n}\left(\log c^1 - \log\lambda + \log(1+\tau/2) + \frac{g^1}{\rho - n}\right). \tag{3.36}$$

Solving (3.36) yields c^*:

$$c^* = c^1 \cdot \exp\left(\frac{g^1 - g^0}{\rho - n}\right). \tag{3.37}$$

Finally we can calculate the relative equivalent variation:

$$EV^R \equiv \frac{c^*}{c^0} - 1 = \underbrace{\frac{c^1}{c^0}}_{<1} \cdot \underbrace{\exp\left(\frac{g^1 - g^0}{\rho - n}\right)}_{>1} - 1, \tag{3.38}$$

which is expressed as the share of the equivalent variation that comes on top of initial expenditure c^0. The gist of (3.38) is that welfare measured by the equivalent variation can either rise or fall, depending on the relative impact of the change in c (or q/N) and the change in g. However, since the growth rate enters (3.38) through the exponential function, chances are that EV^R will be positive. This becomes clearer when rewriting the inequality $EV^R > 0$ as

$$g^1 - g^0 > (\rho - n) \cdot \log\left(\frac{c^0}{c^1}\right). \tag{3.39}$$

Knowing that c^0/c^1 is the relative change in c plus one[16] and given that $\log(1 + \hat{x}) \approx \hat{x}$ for small $\hat{x}$, (3.39) can be written as

$$g^1 - g^0 > (\rho - n) \cdot \hat{c}, \tag{3.40}$$

where the hat denotes the relative change. (3.40) states that the difference in the utility growth rates must be greater than the (absolute value of the) relative change in c times the small factor $(\rho - n)$.

[16]This is not entirely true. Recall that c decreases, thus c^0/c^1 from (3.39) is greater than one and denotes the relative change from the point of view of a jump from c^1 to c^0 (and not vice versa, as it actually happens).

Another measure of interest is the average real wage $\bar{w}$. This is the factor-share-weighted average of the wages of unskilled and skilled labor divided by the product price[17]:

$$\bar{w} = \frac{\theta_0 w_L + (1-\theta_0)\phi w_H}{\lambda}, \tag{3.41}$$

where the multiplication by ϕ is necessary since only those skilled individuals that already have undergone education earn a wage. The average real wage can either rise or fall when trade costs decline. This depends on whether the gain of the entirety of skilled workers, $(1-\theta_0)\phi w_H$, overcompensates the loss of the entirety of unskilled workers, $\theta_0 w_L$, which would result in a rise in $\bar{w}$. We will return to our welfare measure and the average real wage when it comes to model simulation with actual data.

3.1.8 Welfare by Ability Level

We consider three ability groups, namely those workers skilled before and after the shock, those unskilled before and after the shock, and those unskilled before but skilled after the shock. The third group of "skill switchers" is induced by trade liberalization to upgrade its skill level. It is true that there is a continuum of abilities, but we shall see that this distinction is sufficient.

According to the budget constraint faced by each dynasty, (3.4), total discounted wage income $W_\theta(t)$ plus asset holdings $Z_\theta(t)$ has to equal discounted consumption expenditure at each point in time. This is equivalent to stating that total discounted wage income from zero to infinity, $W_\theta(0)$, plus initial asset holdings, $Z_\theta(0)$, has to equal discounted consumption expenditure from zero to infinity. Using the equation representing the skill-specific wage earned, (3.7), the following result holds for skilled workers:

$$W_\theta(0) + Z_\theta(0) = \int_T^\infty e^{-(\rho-n)t}(\theta-\gamma)w_H(t)\,\mathrm{d}t + Z_\theta(0) = \int_0^\infty e^{-(\rho-n)t}c_\theta(t)\,\mathrm{d}t. \tag{3.42}$$

Recall that skilled workers do not earn a wage until they have undergone training for a duration of T. Asset holdings can only stem from positive firm profits. Without loss of generality, we assume that at the instant zero, there are no assets, thus $Z_\theta(0) = 0$. Solving (3.42) and multiplying by $(\rho - n)$ we get

$$e^{-(\rho-n)T}(\theta-\gamma)w_H = c_\theta, \tag{3.43}$$

which must hold in order to guarantee that all income has been spent on goods once

[17] This measure can be found in Sener (2001).

infinity is "reached." (3.43) states that consumption expenditure is proportional to wage earnings. Since $e^{-(\rho-n)T}(\theta-\gamma)$ cancels out we can immediately set up the relative equivalent variation of skilled workers, using (3.38):

$$EV_H^R = \frac{w_H^1}{w_H^0} \cdot \exp\left(\frac{g^1 - g^0}{\rho - n}\right) - 1, \tag{3.44}$$

which is unambiguously greater than zero since both the wage of skilled workers and the growth rate increase due to trade liberalization. Note that EV_H^R is independent of θ but only depends on whether workers have an ability level above the threshold that separates the skilled from the unskilled, θ_0.

The reasoning for workers unskilled before and after the shock is the same: they earn $w_{L,0}$ before and $w_{L,1}$ after trade liberalization. The respective welfare change is thus

$$EV_L^R = \frac{w_L^1}{w_L^0} \cdot \exp\left(\frac{g^1 - g^0}{\rho - n}\right) - 1. \tag{3.45}$$

EV_L^R is either greater or smaller than zero, depending on the relative influence of w_L and g. As in the case of skilled workers, it is independent of θ.

As opposed to workers who do not change their skill level, welfare of skill switchers depends on the ability level since $e^{-(\rho-n)T}(\theta-\gamma)$ does not cancel out here:

$$EV_{LH}^R = \frac{e^{-(\rho-n)T}(\theta-\gamma)w_H^1}{w_L^0} \cdot \exp\left(\frac{g^1 - g^0}{\rho - n}\right) - 1, \tag{3.46}$$

which can be greater or smaller than zero when trade is liberalized.

3.2 First Extension: Unemployment

Apart from the relative wage, the other determinant of the labor market we seek to examine is the unemployment rate. Sener (2001) presents a model that combines a framework similar to that presented in Section 3.1 and a matching process on the market for unskilled labor, but comprises some major differences to Dinopoulos and Segerstrom (1999) with respect to the model assumptions.[18] Since these deviations result in different model equations and would make it difficult to compare the CGE results of Sections 3.1 and 3.2, we stick to the framework presented in Section 3.1. Any modification made has the single goal of accounting for the possibility of unemployment and its implications for the model outcome.

[18] Cp. Table 1.1 for the major differences between the papers.

Our contribution with respect to the unemployment extension is fourfold. First, we make the Sener (2001) model comparable to the framework presented in Section 3.1. When having a look at the paper from Sener (2001), the general-equilibrium equations look quite different since he follows a different approach in order to formulate the equilibrium. For the sake of comparability to Section 3.1, we derive general-equilibrium conditions analogous to those above when applying the additional model content of Sener (2001). Second, we discuss the possiblity of trade liberalization decreasing the relative wage (as opposed to the benchmark model, where it unambiguously increases), and provide an explanation why this can happen in the presence of unemployment. Third, the matching function has not been specified explicitly, therefore we assume a specific functional form, which yields a new parameter that demands interpretation. Moreover, we make the model operational in such a way that a CGE version can be run. Fourth, we discuss the interaction of endogenous variables and model parameters in much greater detail than Sener (2001), which also leads to new insights in terms of the interpretation of parameters of the unemployment model (search time and matching efficiency).

When enriching the model by allowing for unskilled-labor unemployment, the economic intuition is as follows. The job reallocation due to factor shifts from manufacturing to R&D generates unemployment in the presence of search costs. Moreover, only unskilled labor is assumed to suffer from unemployment; skilled labor is fully employed at each moment in time. A high frequency of innovations causes a high turnover rate of unskilled labor. This is what Sener (2001) calls "Schumpeterian unemployment" (p. 119). However, as skill is determined endogenously, the *aggregate* unemployment rate—the product of the unemployment rate of unskilled labor and the aggregate skill level—can either rise or fall due to falling trade costs, depending on whether the labor-turnover effect or the skill-upgrading effect mitigating unemployment is stronger. Furthermore, when the rate of population growth is positive, there is "biological unemployment" (p. 123) as well: newly-born workers must go through a period of search for a job.

The assumption that only unskilled labor is affected by frictional unemployment due to increased innovation might seem awkward as it does not necessarily correspond to empirical observation (skilled workers are laid off as well). The technical reason for that assumption is that the model would become more complex and less tractable with two rates of unemployment, i.e., one for unskilled one for skilled labor. Probably no qualitatively new insights would be yielded; quantitatively, unskilled workers would be better off in relative terms as skilled workers would be affected by unemployment, too. The fundamental idea behind the assumption of full employment of skilled labor but not of unskilled labor is that unskilled workers are easier to replace, thus they are assumed to lose their jobs when creative destruction takes place while skilled workers have fewer problems finding a new job. Nevertheless, real-world skilled workers often need a long time to find a job; the assumption is therefore certainly quite simplistic.

3.2.1 Model Structure

The model structure without the matching mechanism is similar to what was presented in Section 3.1. The household sector optimizes according to Section 3.1.1, hence $r = \rho$ continues to hold. However, due to the possibility of unemployment, the equation determining the skill decision, (3.7), becomes

$$\int_t^{t+D} e^{-[R(s)-R(t)]} w_L(s)(1-u)\,\mathrm{d}s < \int_{t+T}^{t+D} e^{-[R(s)-R(t)]} (\theta - \gamma) w_H(s)\,\mathrm{d}s, \tag{3.47}$$

where u is the unemployment rate of unskilled labor. This leads to a change of (3.8):

$$\theta_0 = \frac{\varsigma}{w}(1-u) + \gamma. \tag{3.48}$$

$w > 1$ does not necessarily hold anymore: the new condition is $w > 1 - u$, i.e., the *expected* earning per efficiency unit of skilled labor, w_H, is greater than that of of unskilled labor, $w_L(1-u)$. Moreover, since only a fraction $(1-u)$ of the total amount of unskilled labor is supplied, the per capita labor-market-clearance conditions (3.27) and (3.28) have to be modified as well, as we will show in the next subsection (we cannot show it here since we have not introduced the search process yet).

3.2.2 Job Matching

We will now describe the job-matching mechanism between unskilled workers and manufacturing firms, being the element that adds new insight to the underlying framework of Section 3.1. We take a different course of action when deriving the equilibrium in order to arrive at conditions directly comparable to the benchmark model. The entire workforce of unskilled labor is seeking jobs regardless of being employed. Firms, however, only start searching when they have gained access to the state-of-the-art technology. Hence, only quality leaders engage in vacancy creation. Moreover, firms can create vacancies, replace dying workers, and expand employment without incurring any cost.

The aggregate flow of completed job matches is given by the matching function $m(Z(t), L(t))$, where $Z(t)$ is the number of vacancies and $L(t)$ is the number of unskilled workers (as above). Defining $z(t) \equiv Z(t)/L(t)$ as the vacancy rate, $f(z(t)) \equiv m(z(t), 1)$

is the aggregate job-finding rate. Sener (2001) does not formulate his model in CGE form and thus does not specify his matching function $m(\cdot)$ explicitly. He requires, however, that it be concave, homogenous of degree one, and increasing in both its arguments. $f(\cdot)$ is required to satisfy $f(0) = 0$ and $f(\infty) = \infty$. A straightforward way to specify $m(\cdot)$ is

$$m(Z, L) = Z^{\varepsilon} L^{1-\varepsilon}, \tag{3.49}$$

where $0 < \varepsilon < 1$ is a parameter governing the matching efficiency.[19] The higher ε, the more efficient are workers matched with vacancies. From this functional form, the aggregate job-finding rate can be derived:

$$f(z) = z^{\varepsilon}. \tag{3.50}$$

The function specified in (3.49) satisfies all requirements.

The search process takes time $y > 0$ which means that a firm that has won the R&D race in t recruits workers between t and $t + y$ and has to forgo a production period of y (but can make up for this when a rival with superior technology faces the same situation in a later period in time). At time $t + y$ the newly emerging leader has completed the search process and replaces the incumbent firm. The former leader has to lay off its workers that are then unemployed. The discounted profits expected by a successful innovator are derived as in the benchmark model with the only difference that they are discounted with the search time y:

$$v(t) = e^{-\rho y} \left[\int_0^{\infty} 2I e^{-2I\eta} \left(\int_0^{\eta} \pi(t) e^{-(\rho - n)s} \, \mathrm{d}s \right) \mathrm{d}\eta \right]. \tag{3.51}$$

Solving the integrals yields

$$v(t) = e^{-\rho y} \frac{\pi(t)}{\rho + 2I - n}, \tag{3.52}$$

which is the same as (3.19) from the benchmark model, but extended by the discount factor represented by the exponential.

As promised above, we can now state the modified general-equilibrium conditions replacing (3.27) and (3.28), i.e., the labor market clearing conditions. Two new elements have to be included: the unemployment rate of unskilled labor, u, and the discount factor

[19] A reason why the extra parameter ε is introduced is that this adds one more degree of freedom when it comes to model calibration. Moreover, there is another possible interpretation of ε, as we shall see when it comes to the simulation results in Section 5.2.

due to search time y:

$$(1-u)\theta_0 = A_L(w_L, w_H)B(w_H)\Psi(\tau)(\rho + 2I - n)ke^{\rho y} \tag{3.53}$$

and

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1-\theta_0) = A_H(w_L, w_H)B(w_H)\Psi(\tau)(\rho + 2I - n)ke^{\rho y} + B_H(w_H)Ik. \tag{3.54}$$

(3.53) and (3.54) are derived analogously to (3.27) and (3.28): (3.15) is plugged into (3.52) which again allows to solve for $c(t)N(t)$. This is inserted into (3.23) using (3.22) so that (3.26) becomes $q = B(w_H)(\rho + 2I - n)\Psi(\tau)Xe^{\rho y}$ (the minus sign in $e^{-\rho y}$ vanishes as we divide by this expression). By using (3.24) and (3.25) once again, this yields (3.53) and (3.54).

Next, the steady-state flows of vacancies and unemployment have to be derived. The expected demand for unskilled labor from manufacturing is $(A_L q)/N(t+y)$. During the search period between t and $t+y$, each firm sees product demand increase according to the population growth rate. Therefore it posts vacancies at time t equal to its expected labor demand in $t+y$, which is equal to twice the value of $(A_L q)/N(t+y)$ since a quality leader supplies both countries, i.e., $(2A_L q)/N(t+y)$. Because of symmetric countries, one half of the Home firms must create positions growing with a rate $\beta - \delta$ due to the expansion in demand and compensate for the loss of jobs due to employed workers dying with a rate δ. Thus, the rate of job openings is $\beta - \delta + \delta = \beta$. The steady-state flow of vacancies consists of three terms: the inflow of vacancies due to innovations by Home firms, the job openings by Home firms that expect to operate after a period of y, and the vacancy fillings represented by the matching function:

$$\dot{Z}\,\mathrm{d}t = I\,2A_L q(t+y)\,\mathrm{d}t + \frac{1}{2}\beta\,2A_L q(t+y)\,\mathrm{d}t - m(Z(t), L(t))\,\mathrm{d}t, \tag{3.55}$$

where all variables except N, Z, and L are constant. In steady state, the vacancy growth rate is fixed and equals the rate of population growth, $n = \beta - \delta$. Using $L = \theta_0 N$ and $q = [(1-u)L]/A_L$ from (3.53) and recalling that $m(Z(t), L(t)) = f(z(t))L(t)$, $N(t) = N_0 e^{nt}$, and $z = Z(t)/L(t)$ yields the balanced-growth condition,

$$\frac{\dot{Z}}{Z} = \frac{(2I + \beta)(1-u)e^{ny} - f(z)}{z} = \beta - \delta. \tag{3.56}$$

(3.56) states that the growth rate of the vacancy pool is equal to the population growth rate in steady state.

For the steady-state unemployment rate, the flow consists of four terms: the inflow into the unemployment pool U due to innovations, the newly-born unskilled workers instantly joining the unemployment pool, the jobless workers that die, and the matched workers:

$$\dot{U}\,\mathrm{d}t = \frac{1}{2}\,2A_L q(t)\,2I\,\mathrm{d}t + \beta L(t)\,\mathrm{d}t - \delta u L(t)\,\mathrm{d}t - m(Z(t), L(t))\,\mathrm{d}t. \tag{3.57}$$

In steady state, this becomes

$$\frac{\dot{U}}{U} = \frac{2I(1-u) + \beta - \delta u - f(z)}{u} = \beta - \delta. \tag{3.58}$$

Solving (3.58) for u,

$$u = 1 - \frac{f(z)}{2I + \beta}, \tag{3.59}$$

and inserting (3.59) into (3.56) yields an expression from which the equilibrium vacancy rate can be determined:

$$\frac{f(z)(e^{ny} - 1)}{z} = \beta - \delta. \tag{3.60}$$

With $f(z) = z^{\varepsilon}$ and $\beta - \delta = n$, (3.60) can be solved for z:

$$z = \left(\frac{e^{ny} - 1}{n}\right)^{\frac{1}{1-\varepsilon}}. \tag{3.61}$$

At first glance, the constancy of z—(3.61) depends on parameters only—contradicts the Beveridge curve theory[20] stating that there is a negative relationship between vacancy and unemployment rate. From (3.59), however, the negative relationship between z and u—many vacancies imply little unemployment and vice versa—can immediately be seen. Consider the case of an increase in the search time y. (3.61) shows that the vacancy rate increases when the search time y is extended[21], which is intuitive since it takes longer to fill the vacancies then. Moreover, the vacancy rate depends negatively on ε, which is reasonable since a higher matching efficiency leads to fewer vacancies.[22]

The interpretation of the unemployment equation (3.59) is the core element of this first model extension. First, u is increasing in the rate of innovation, I. This mechanism

[20] E.g., cp. Blanchard et al. (1989) or Mortensen and Pissarides (1994).

[21] Given $\varepsilon < 1$ it follows that

$$\frac{\partial z}{\partial y} = \frac{e^{ny}}{1-\varepsilon}\left(\frac{e^{ny} - 1}{n}\right)^{\frac{\varepsilon}{1-\varepsilon}} \geq 0.$$

[22] Given a strictly positive population growth rate, $n > 0$, this relationship only holds for $y < 1$ (which

of creative destruction that pushes firms with inferior technology out of the market and forces them to lay off workers generates "Schumpeterian unemployment." Second, u is increasing in the birth rate β. Newly-born workers must go through a search process and are thus unemployed for a while before they start working, which is termed "biological unemployment." Increases in I or β speed up labor turnover. However, biological turnover itself should not be sufficient to generate unemployment; a strictly positive level of innovation is required. Suppose that no innovation takes place ($I = 0$) and $f(z) < \beta$. In that case, u would become negative according to (3.59). Hence, $f(z) > \beta$ is assumed in order to ensure that even in the case of no innovation there is a useful interpretation for u.

From $L(t) = \theta_0 N(t)$ and $U(t) = uL(t)$, it follows that aggregate unemployment $u_A = U(t)/N(t)$ is the product of the unskilled-labor share and the unskilled-labor unemployment rate:

$$u_A = u\theta_0. \tag{3.62}$$

Trade liberalization increases the fraction of skilled workers $(1 - \theta_0)\phi$ as well as the unemployment rate of unskilled workers (Schumpeterian unemployment), both independently of model parameters. The aggregate unemployment rate u_A increases or decreases, depending on whether the decrease in θ_0 or the increase in u is stronger. Furthermore, the level of innovative activity increases for the same reason as in the benchmark model, i.e., increased profit opportunities from innovating. Depending on model parameters, it can lead to a rise or fall in the relative wage w. The reason for the rise in the relative wage has already been explained in the benchmark model: an increase in the price of innovation raises the price of the factor used intensively in innovation.

The outcome of freer trade, however, can also be a decline in the relative wage, but the explanation is quite different. This case is not addressed by Sener (2001), thus all that follows is a new contribution. Trade liberalization undoubtedly leads to more unskilled-labor unemployment in this model, thus less skilled labor is effectively available to be used in production. With unskilled labor being scarcer now, its price increases relative to the price of skilled labor. Intuitively speaking, the unemployment rate "absorbs" part of the wage differential; additional unemployment can more than compensate the rise in

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is satisfied by our data):

$$\frac{\partial z}{\partial \varepsilon} = \frac{1}{(1-\varepsilon)^2}\left(\frac{e^{ny}-1}{n}\right)^{\frac{1}{1-\varepsilon}} \log\left(\frac{e^{ny}-1}{n}\right) < 0 \Longleftrightarrow \log\left(\frac{e^{ny}-1}{n}\right) < 0 \Longleftrightarrow y < \frac{\log(1+n)}{n} < 1$$

for $n > 0$ (for $n < 0$, $\frac{\log(1+n)}{n} > 1$).

the wage gap. For the case of $\partial w/\partial\tau > 0$ (trade liberalization leads to a decline in the wage gap), more wage equality is paid for by more unemployment.

The total effect of trade liberalization on the relative wage depends on model parameters. For large n, large T and small D, or large k, $\partial w/\partial\tau$ is more likely to be negative (as in the model without unemployment). The economic intuition is that with a high population growth rate, trade liberalization does not produce as much *additional Schumpeterian* unemployment because biological unemployment is already on a relatively high level (high n leads to high β which causes high biological unemployment). Less additional unemployment produced implies an approximation to the model without unemployment, i.e., a negative relationship between w and τ. When people are trained for a long period (high T relative to D), skilled labor is relatively scarce since individuals undergoing training are not available for the work force yet, which in turn leads to increased scarcity of skilled labor and hence an increase in w becomes more likely. The reason of high k, i.e., a difficult R&D process, being in favor of a negative impact of τ on w is that with much skilled labor needed in innovation, the demand for skilled labor increases and thus w rises.

When dealing with actual data, however, n, T, or D cannot be set arbitrarily since they are constrained by the data (and k by model calibration). The only two variables where we have at least some leeway are λ and ρ. A higher markup λ tends to be beneficial to skilled labor, therefore the impact of trade liberalization on the relative wage tends to be positive. A high discount factor ρ has two opposing effects. First, it tends to benefit unskilled labor as a high discount factor makes it more attractive to consume now instead of in the future (by performing R&D), therefore making unskilled labor better off. Second, through its positive impact on ς (the ratio of discount factors for unskilled and skilled labor in the qualification decision), a large value for ρ tends to increase the relative wage. In our simulations, the second effect is stronger, therefore we can postulate a positive relationship between ρ and w. We will check for the sensitivity of the results with respect to λ and ρ when it comes to the test simulations.

In models with unemployment, the additional leisure gained when becoming unemployed often enters the utility function and therefore the welfare measure. In order to be consistent with the qualification decision that does not incorporate leisure (cp. (3.7)), we abstract from any disutility of labor, thus the welfare measure is the same as in the benchmark model. The average real wage, however, is slightly different from (3.30) since the wage of unskilled labor has to be corrected for the share of those unskilled workers who are employed, $(1-u)$, and thus earn a wage:

$$\bar{w} = \frac{(1-u)\theta_0 w_L + (1-\theta_0)\phi w_H}{\lambda}. \tag{3.63}$$

Depending on parameter values and hence on the weight of increases in unskilled-labor unemployment compared to increases in the relative wage, $\bar{w}$ can either rise or fall.

3.2.3 CGE Formulation

The endogenous variables are w_H, w_L, I, θ_0, z, u, and u_A. The system consists of (3.12), (3.48), (3.53), (3.54), (3.59), (3.60), and (3.62) and looks as follows:

$$A(w_L, w_H) = w_L^a w_H^{1-a} = 1, \tag{3.64a}$$

$$\theta_0 = \varsigma \frac{w_L}{w_H}(1-u) + \gamma, \tag{3.64b}$$

$$(1-u)\theta_0 = A_L(w_L, w_H)B(w_H)\Psi(\tau)(\rho + 2I - n)ke^{\rho y}, \tag{3.64c}$$

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1-\theta_0) = A_H(w_L, w_H)B(w_H)\Psi(\tau)(\rho + 2I - n)ke^{\rho y} + B_H(w_H)Ik, \tag{3.64d}$$

$$u = 1 - \frac{f(z)}{2I + \beta}, \tag{3.64e}$$
$$\text{where} \quad f(z) = z^{\varepsilon},$$

$$\frac{f(z)(e^{ny} - 1)}{z} = n, \tag{3.64f}$$

$$u_A = u\,\theta_0. \tag{3.64g}$$

3.2.4 Test Simulation

The matching-function parameter is set to $\varepsilon = 0.7$ and the search time parameter to $y = 0.4$; all other parameters are the same as for the simulation of the benchmark model. Having a look at the matching function, $m(Z, L) = Z^{\varepsilon} L^{1-\varepsilon}$, the value for ε means that

70 percent of all matches can be attributed to the presence of vacancies, the remaining 30 percent to the presence of unskilled workers. The interpretation for y is that the matching duration is 0.4 years. Simulation results are presented in Table 3.2.

Variable	$\tau = 0.2$	$\tau = 0.1$	Relative Change [%]
w_H			-9.2
w_L			1.7
w	1.618	1.444	-10.8
θ_0	0.751	0.727	-3.2
I	0.098	0.116	18.9
q/N			-15.4
z	0.100	0.100	*n.ch.*
u	0.117	0.242	105.8
u_A	0.088	0.176	99.1
$\tilde{w}$	1.833	1.904	3.9

Table 3.2: Results of Test Simulation for the Model with Unemployment. Parameter values: $D = 40$, $T = 4$, $n = 0.01$, $\rho = 0.03$, $\lambda = 1.35$, $k = 1$, $\gamma = 0.1$, $a = 0.85$, $\varepsilon = 0.7$, $y = 0.4$. "n.ch.": no change compared to starting value.

We consider the case where the parameter constellation leads to $\partial w/\partial\tau > 0$, i.e., trade liberalization closes the wage gap. The reason for this course of action is simple. Theoretically, the (unadjusted) relative wage w could be increased when τ falls, as in the benchmark model. For realistic parameter constellations, however, the contraction of effective labor supply depressing the relative wage weighs stronger than the innovation channel that drives up the relative wage. The two parameters that we have changed in order to check for model sensitivity are λ and ρ. For conceivable values of ρ (0.01–0.1), λ would have to be above 2, which implies a markup of more than 100 percent. Since this is not compatible with actually observed markups (as we will show when it comes to real-world data), we state that this model produces a positive relationship between trade costs and the unadjusted relative wage. It can be concluded that parameter values that make the model with unemployment qualitatively the same as the benchmark model are unrealistic. For realistic parameter constellations, the unadjusted relative wage declines. Both wage levels move in different directions than without the possibility of unemployment.

As one can see, both rates of unemployment rise. For unskilled labor this can partially be interpreted as the price paid by unskilled workers for a closing wage gap. The economic reason is that with less unskilled labor employed (since u has risen), the remaining unskilled workers still participating earn relatively higher wages since their marginal product compared to skilled labor has increased as well. For aggregate unemployment the rise is similarly high since the skill composition has not been altered much. The steady-state vacancy rate does not change at all since it is independent of τ. Moreover, what is worth mentioning is that the job finding rate, $f(z) = z^{\varepsilon} = (0.100)^{0.7} \approx 0.1995$, is greater than the birth rate, $\beta = (ne^{nD})/(e^{nD} - 1) = (0.01e^{0.4})/(e^{0.4} - 1) \approx 0.0303$. The latter condition is required by our model assumptions in order to guarantee that unemployment cannot stem from birth alone.

For the unemployment-adjusted relative wage $\tilde{w}$, the impact is naturally still the same as before: trade liberalization leads to more wage dispersion. As the relative demand for innovation has increased, skilled workers must be better off. The relative position of unskilled workers is weakened in this model as well, but for another reason than in the benchmark model: unskilled workers lose more from increased unemployment than they win from an increase in their wage. This can be seen by an increase in $\tilde{w}$ of 3.9 percent. Note that the relative increase of w in the benchmark model was exactly the same. Moreover, the levels of $\tilde{w}$ in this model are almost the same as the levels of w in the benchmark model. As before, the rate of innovation increases and the share of unskilled workers decreases.

3.3 Second Extension: Horizontal FDI

There are various possible motives for production abroad, either by means of vertical or horizontal FDI. In a North-South model with lower wages in the South than in the North, the most obvious reason for shifting a fraction of production abroad are lower factor prices in the South. “Fraction” in this context refers to one *stage* of production, reasonably the unskilled-labor-intensive stage, which means that production can be fragmented in this type of models (vertical FDI). In a North-North model, however, the motivation for FDI is quite different. Due to symmetric countries, no factor price differentials can be exploited. Hence, vertical FDI does not make much sense in our model, so we examine the impact of horizontal FDI. The arguably most evident reason for producing a fraction (in this context referring to a *share* of the manufactured good) abroad is the incentive to save trade costs: goods produced abroad do not have to be shipped costly to sell them to foreign consumers. Saving trade costs by producing abroad is often referred to as “jumping” the trade barrier.[23] There are other conceivable reasons for horizontal FDI such as receiving knowledge spillovers on purpose by producing

[23] The textbook from Markusen (2002) gives an overview of the decision criteria for FDI and exports.

abroad.[24] But since the mechanism of our model extension works without any further complications, we assume that saving trade cost provides the only incentive for firms to produce abroad.

Given another cost component that depends on the volume of FDI (FDI cost), firms face a trade-off when increasing their FDI level: they save trade costs but bear higher FDI costs. The impact of falling trade costs is now twofold. First, the wage gap is widened due to increased innovation, as in the benchmark model. Second, falling trade costs diminish the incentive to perform horizontal FDI as the jumping motive partially erodes. The amount of trade costs borne by a firm rises, which in turn makes profits decline. This leads to less innovation and thus a smaller increase in the skill premium than without the possibility of horizontal FDI. Hence, the impact of falling trade costs on the skill premium is smaller than in the benchmark model. However, decreasing not only trade costs but FDI costs as well reveals that the impact of the combined decrease of both cost components leads to a stronger increase in the skill premium than in the benchmark model. The reason is that profits increase by more than in the case of falling trade costs alone. Since increasing profits (or profit opportunities, to be precise) are the sole engine of additional innovation and thus increasing wage inequality in this model, an even higher skill premium is the outcome. Introducing the possibility of FDI therefore enhances the explanatory power of international trade with respect to rising wage inequality.

This second extension has three novel features. First, the model extends an existing theoretical framework to the case of horizontal FDI, thereby shedding new light on the role of falling trade costs. Second, the notion of "trade liberalization" in this context is generalized by introducing a second cost component, namely FDI costs, using a similar iceberg approach as in the case of goods transport. Third, the total impact of both components on the skill premium is quantified, evaluating whether the model with FDI can enhance the explanatory power of trade liberalization with respect to the relative wage.

In the rest of this section we will first derive formally the incentive for quality leaders to engage in horizontal FDI (quality followers do only perform R&D and they have no motivation for R&D activity in both countries at the same time). We then show how the general-equilibrium conditions change. To the best of our knowledge, there is no Schumpeterian growth model with a symmetric country structure allowing for horizontal FDI, so we develop one here by extending the benchmark model accordingly.

[24] Cp. Branstetter (2006) for Japanese foreign affiliates receiving knowledge spillovers from U.S. domestic firms.

3.3.1 Optimization by Quality Leaders

This subsection derives the optimal FDI decision of the quality leader in the presence of trade costs. Once a firm has become a quality leader, its total production, consisting of domestic production Y and production abroad Y^*, is fixed and equals the total quantity sold in both countries: $Y + Y^* = Q + Q^*$. We define $\alpha \equiv Y^*/(Y + Y^*)$ as the share of production that takes place abroad. The incentive to conduct FDI accrues from the potential to save trade costs (cp. Figure 3.2).

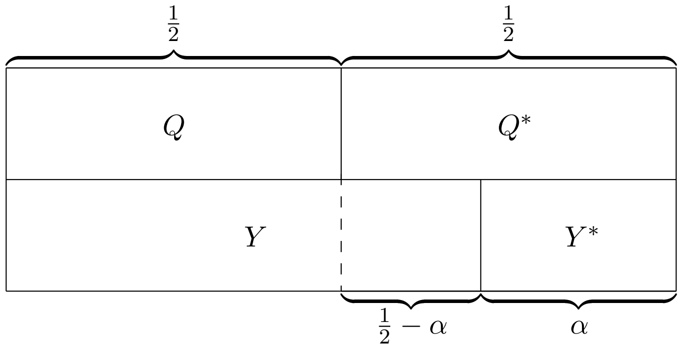

Figure 3.2: Trade Costs with Horizontal FDI.

It is straightforward to derive the trade cost borne by the firm in the presence of FDI. For the following reasoning, suppose that $\alpha \leq \frac{1}{2}$. A leader supplies both the domestic and the foreign market with half of its total production, independent of trade costs. Furthermore, he does neither have to bear trade costs for domestic sales nor for foreign sales congruent with foreign production. The remaining fraction of total production that is subject to trade costs is the quantity sold abroad less the quantity produced there, i.e., $\frac{1}{2}-\alpha$. This has to be divided by $\frac{1}{2}$ to account for the fact that only half of total sales takes place abroad. Thus the FDI-adjusted trade cost a firm faces is $\tau_\alpha = (1 - 2\alpha)\tau$, which is decreasing in α. With FDI shares $\alpha > \frac{1}{2}$, however, trade costs have to increase again since congruence of sales and production becomes worse. To account for this (merely theoretical) possibility of $\alpha > \frac{1}{2}$, FDI-adjusted trade costs make use of the absolute value of $1 - 2\alpha$ and amount to

$$\tau_\alpha = \text{abs}(1 - 2\alpha)\tau \geq 0. \tag{3.65}$$

From the one-sided viewpoint of saving trade costs, $\alpha = \frac{1}{2}$ would be the optimal choice, but this neglects the cost of FDI.

Analogously to the cost of goods trade, we operationalize the cost of FDI by means of an iceberg share that "melts away" from total output. This share has to depend on α, thus we assume that the share of output that gets lost on the way is $b\alpha$, which can be interpreted as the cost of building up production facilities abroad with FDI cost parameter $b \geq 0$. Output would therefore be multiplied by $(1 - b\alpha)$. This setup cost does not have to be borne by purely domestic producers since we assume that firms already own plants in their home country when they start production. When starting production abroad, they have to build a second plant in the other country, which only comes at a cost.

One might argue that the "beachhead cost" of setting up production facilities in another country are fixed and do not depend on production volumes abroad—as it is modeled by Melitz (2003) or Yeaple (2005), for instance. Apart from the fact that the dependence on α is necessary for our aspired model behavior, there is also an economic justification for this course of action. What we think of here is rather a cost of communication between the two countries' production facilities. Maintaining a durable connection between both parts of the firm and fine-tuning what amount of production to sell in which country costs resources. Among others, Portes and Rey (2005) find that trade costs have a strongly depressing impact on cross-border equity flows, controlling for goods trade. Not surprisingly, this shows that there is a border effect in investment abroad just as there is one in goods trade. This fact is captured by our "cost-of-FDI" measure.

Basically, a firm that wants to sell its products abroad through an affiliate can either start from scratch, building a new plant without any cooperation with local incumbents ("greenfield" FDI). Alternatively, it can acquire a foreign firm. Supplying the foreign market with the firm's own product requires deep restructuring of the acquired plant. This second mode is often called "brownfield" FDI.[25] Our model implicitly assumes greenfield FDI only since firms do neither acquire incumbents nor engage in mergers.

It is desirable to make the FDI model comparable to the benchmark model. For these purposes, we normalize output levels to one at the initial instant (i.e., before the shock) by multiplying output by $(d - b\alpha) = 1$ instead of $(1 - b\alpha) < 1$. Here $d \geq 1$ is a parameter that is determined when it comes to model calibration (cp. Section 4.2.3). Given the additional equation in the calibration process, $(d - b\alpha) = 1$, an extra degree of freedom is required anyway. This is the role of d. Outputs produced at home and abroad amount to

$$Y = F(d - b\alpha) \tag{3.66}$$

[25] Cp. Meyer and Estrin (2001) for an overview of the different modes of entry.

and

$$Y^* = F^*(d - b\alpha), \tag{3.67}$$

where F and F^* are the factor inputs in both countries.

According to (3.13) and (3.14), profits of quality leaders at home and abroad are

$$\pi_\ell = cN\mathcal{K} = \lambda Q\mathcal{K} = \lambda\frac{1}{2}(Y + Y^*)\mathcal{K} \tag{3.68}$$

and

$$\pi_\ell^* = c^*N^*\mathcal{K}^* = \lambda Q^*\mathcal{K}^* = \lambda\frac{1}{2}(Y + Y^*)\mathcal{K}^*, \tag{3.69}$$

where $\mathcal{K} \equiv (\lambda - 1)/\lambda$ is a constant and $\mathcal{K}^* \equiv (\lambda - 1 - \tau_\alpha)/\lambda$ depends on α through changes in τ_α. Total firm profits are given by

$$\pi = \pi_\ell + \pi_\ell^* = \lambda\frac{1}{2}(F + F^*)(\mathcal{K} + \mathcal{K}^*)(d - b\alpha). \tag{3.70}$$

Maximizing total profits with respect to Y and Y^* is equivalent to maximizing them with respect to α since $\alpha = Y^*/(Y+Y^*)$. Maximization simplifies to the term $(\mathcal{K}+\mathcal{K}^*)(d-b\alpha)$, therefore

$$\alpha = \arg\max_\alpha\{(\mathcal{K} + \mathcal{K}^*)(d - b\alpha)\}, \tag{3.71}$$

which can be explicitly solved for α. Note that in order to obtain a profit maximum, concavity of (3.71) is sufficient. (3.71) is indeed concave, as becomes evident in a moment. Assuming that $\alpha \leq 0.5$ in order to get rid of the absolute value, α can be determined as

$$\alpha = \arg\max_\alpha\{M_0 + M_1\alpha + M_2\alpha^2\}, \tag{3.72}$$

where

$$M_0 = \frac{2d}{\lambda}\left(\lambda - 1 - \frac{\tau}{2}\right) > 0, \tag{3.73}$$

$$M_1 = \frac{2b\tau}{\lambda}\left(\frac{1}{2} + \frac{d}{b} - \frac{\lambda - 1}{\tau}\right) > 0 \quad \text{for} \quad \frac{1}{2} + \frac{d}{b} > \frac{\lambda - 1}{\tau}, \tag{3.74}$$

$$M_2 = -\frac{2b\tau}{\lambda} < 0. \tag{3.75}$$

Solving (3.72) yields the optimal α:

$$\alpha = -\frac{M_1}{2M_2} = \frac{1}{2}\left(\frac{1}{2} + \frac{d}{b} - \frac{\lambda - 1}{\tau}\right), \tag{3.76}$$

which is increasing in τ as the jumping motive partially erodes when trade costs fall. Moreover, it is decreasing in b since a higher cost of FDI discourages FDI activity.

Since (3.72) represents the solution of a quadratic equation, M_2 must be negative to ensure a concave function (which is the case) and hence M_1 must be positive in order to guarantee a positive solution for α. M_1 is indeed very likely to be positive: going back to the respective condition,

$$\frac{1}{2} + \frac{d}{b} > \underbrace{\frac{\lambda - 1}{\tau}}_{\geq 1}, \tag{3.77}$$

and given that $d \approx b$ is the result of all our model calibrations, (3.77) is likely to hold, ensuring a positive level of FDI activity.

A decrease in trade costs has now two opposing effects. First, it works through the usual innovation-enhancing channel of the benchmark model, increasing firm profits and therefore the relative wage. Second, it unambiguously decreases α, which decreases firm profits since the total volume of trade costs borne by the firm increases (they have to transport more when they reduce their production volume abroad). The overall impact of a falling τ on firm profits must of course be positive, as firms are always optimizing and it is by construction of the model impossible to harm them by liberalizing trade. But compared to the benchmark model, profits increase by less and thus the increase in the relative wage is smaller.

As opposed to falling τ, decreases in b have a purely trade-cost-reducing effect and thus a purely positive impact on firm profits. This increases the incentive of outsiders to innovate even more since increased profit opportunities make it even more worthwhile investing in R&D activity. As a consequence, the aggregate rate of innovation increases and thus the relative demand for skilled labor, driving the relative wage upwards. Note that exports and FDI are substitutes since the total volume sold abroad remains at one half of total production, which is due to country symmetry.[26] With more FDI taking place, exports shrink.

The total effect of a *combined* decrease in τ and b is very likely to increase the relative wage by more than the decrease of τ alone in the benchmark model (cp. the simulations in Section 5.3). Hence, adding a formerly neglected feature of international trade to the benchmark model enhances its explanatory power in terms of changes in the skill premium.

[26]Empirically, the question whether trade and FDI are complements or substitutes depends on whether one considers intermediates or final goods. Exports of intermediates and sales of affiliates are complements. For the case of final goods only, as in our model, there exists a rather substitutional relationship; cp. Blonigen (2001). For an overview of the issue also cp. the survey from Saggi (2002).

In order to determine the steady state, q/N is derived as in the benchmark model and takes the same value as in (3.26), except for dividing it by $(d - b\alpha)$:

$$\frac{q}{N} = \frac{B(w_H)(\rho + 2I - n)\Psi(\tau)k}{d - b\alpha}.$$

Furthermore, $\Psi(\tau)$ is now given by

$$\Psi(\tau) \equiv \frac{q}{\pi} = \frac{(2 + \tau_\alpha)}{4(\lambda - 1) - 2\tau_\alpha}.$$

3.3.2 CGE Formulation

Compared to the benchmark CGE model (cp. Section 3.1.5), there is one additional equation and the full-employment conditions have slightly changed due to the change in q/N and $\Psi(\tau)$. The model contains one additional endogenous variable, namely α, and looks as follows:

$$A(w_L, w_H) = w_L^a w_H^{1-a} = 1, \tag{3.78a}$$

$$\theta_0 = \varsigma \frac{w_L}{w_H} + \gamma, \tag{3.78b}$$

$$\theta_0 = A_L(w_L, w_H) \cdot \frac{B(w_H)(\rho + 2I - n)k}{d - b\alpha} \cdot \Psi(\tau), \tag{3.78c}$$

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) = A_H(w_L, w_H) \cdot \frac{B(w_H)(\rho + 2I - n)k}{d - b\alpha} \cdot \Psi(\tau) + B(w_H)Ik, \tag{3.78d}$$

$$\alpha = \frac{1}{2}\left(\frac{1}{2} + \frac{d}{b} - \frac{\lambda - 1}{\tau}\right). \tag{3.78e}$$

Chapter 4

Empirical Strategy and Data

As stated in the introduction of this thesis, we aim at applying our models to Europe. The justification for European data in Section 4.1 is a new contribution, just as virtually all the thoughts about what real-world equivalent the different variables and parameters have (Section 4.2).

4.1 Applying the Model to Europe

In the models, the entire world economy consists of only two countries that are symmetric with respect to size, preferences, technology, factor endowments, in short: they are identical. Obviously there are no two countries in the world nor in Europe that fulfill this condition. We make the following thought experiment. Suppose it was possible to divide the entire European continent into two identical halves, not necessarily divided by a single border, by finding a partitioning scheme with a very fine regional breakdown that leaves two (almost) identical regional entities.[1] If this were possible, the application of our model would be appropriate if this system of two artificial "countries" could (approximately) be viewed as a closed economy. It is clear that only disproportionally large efforts would make an imaginery division of Europe into two identical halves possible. Luckily this is not necessary. We can just assume that it *were* possible and that these two halves traded with each other. What we do have to check, however, is the question whether it is justified to consider Europe a closed system, a "world economy" of its own.

[1] The first approach to achieve such a division would be to put countries one after another in one of two country baskets. If, for instance, Germany were put in the first basket, the second would receive France and some other smaller countries, e.g., the Benelux. Then we would proceed until both baskets had the same weight, regardless of countries' geographical location, only with respect to relevant country features. The fine-tuned method of filling the baskets would take very small regions instead of countries.

It is common knowledge that Europe is anything but a closed economy. However, in the context of our model, we identify two criteria as important when it comes to evaluation of the openness of Europe. The first is the question how large a share of the trade volume of European countries can be attributed to trade with other European countries, i.e., the share of intra-European trade relative to trade between Europe and the rest of the world. If trade with non-European countries played a major role for European countries, then innovation incentives would be very different from what our model suggests since profits could also be reaped by engaging in trade activity that our model does not account for (since this would be trade "outside our world"). For the EU-25, data from the Eurostat website for the year 2005 reveal that about two thirds of EU-25 exports are directed at EU-25 countries. Similarly, about two thirds of EU-25 imports stem from EU-25 countries. This shows that intra-European trade is very important for Europe, although a fraction of trade that our model does not deal with is left. One could argue that intra-European trade is not subject to tariffs and therefore our model does not fit this case. Nevertheless, intra-European trade is costly as any other international trade and is certainly affected by economic integration.

The second criterion for our closed-system assumption to be justified is the question how strongly innovation activities in Europe are affected by non-European influences. This leads to the question of how important non-Europe-to-Europe knowledge spillovers are compared to intra-European knowledge spillovers. If the former were highly relevant, then large portions of the innovation activity, crucial to all other variable changes in our model, would be unexplained. Note that our model implicitly assumes perfect cross-border knowledge spillovers: each quality follower has full access to all former quality steps of all goods developed in both countries. A commonly accepted approach to measure international knowledge spillovers are patent citations: when a patent application is filed, the responsible examiner from the patent office searches for references that the respective patent is based upon. Moreover, the patent applicant has usually already cited some references himself since the patenting system is based on the idea that knowledge grows by further elaborating existing inventions. If a patent filed in Germany cites a patent filed in the United States, then one can assume that there is a knowledge spillover from the United States to Germany. Of course, this is a very rough approach and it has been doubted that it is appropriate.[2] Nevertheless, we will regard it as sufficient for our purposes. Some support also comes from Jaffe et al. (2000), who ask the question whether citing a patent is perceived as being conducive to innovation, using data from a survey of inventors: the likelihood of a knowledge spillover is significantly greater in

[2] E.g., cp. Duguet and MacGarvie (2005).

the presence of a patent citation than without one. In addition, there are many studies examining the link between geographical proximity and citation frequency.[3] They all conclude that there is a strong causality between the two measures. A large portion of knowledge is tacit (as opposed to codifiable) and difficult to transport across long distances. This leads to the hypothesis that proximity fosters knowledge spillovers. If patent citations proxy for spillovers, then they are likely to be more numerous for neighboring countries, which is actually the case. It is true that patents represent codifiable knowledge, but referring to another patent is much more likely when some verbal communication has taken place between persons, which in turn requires some degree of proximity.

Most countries have their own patent office, but for our purposes it is more suitable to have a look at the three most frequented patent offices: the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO), and the Japanese Patent Office (JPO). For obvious reasons, countries have a strong "home bias" when filing patents.[4] Both the proximity-citation link and the filing home bias point at knowledge spillovers being mainly of a local scale. Duguet and MacGarvie (2005), who present a cited-vs.-citing-region matrix with EPO data between 1978 and 1997, support this view. Of all patents cited by European applicants about two thirds stem from Europe. This leads to the conclusion that the majority of knowledge generated within Europe can be attributed to itself. These two figures—two thirds of trade with itself and two thirds of knowledge from itself—might justify to view Europe as a closed system in our sense.

4.2 Model Calibration

Calibrating a model means to adjust its parameters in such a way that a model simulation yields endogenous variables that correspond to realistic values at a certain point in time, the starting point. This is called the "benchmark case" (not to be confused with "benchmark model"). Since each of our three models has more parameters than variables, many parameters have to be fixed according to real-world values before calibration takes place. When determining values the endogenous variables shall arrive at (i.e., the variables are being fixed), some parameters are left and hence can be considered

[3] Jaffe et al. (1993) is one of the seminal papers on this field of research. Studies for Europe stem from Maurseth and Verspagen (1999) or Verspagen and Schoenmakers (2000), for instance.

[4] 54.7 percent of all patents granted at the USPTO stem from U.S. applicants (data are for 2003), while 44 percent granted at the EPO are from applicants from the EU (2003). For the JPO, the number of patent applications is even more distinct: 78 percent of the applicants are Japanese. Cp. OECD (2006).

free. These are the parameters that are calibrated by running the model "the other way round": the free parameters are now the "endogenous variables." Obviously, it makes sense to regard those parameters as free that cannot be found in the empirical literature and/or have a very abstract meaning, such as the difficulty of the R&D process, k.

4.2.1 Benchmark Model

4.2.1.1 Skill Level θ_0 and Relative Wage w

We first have to define what differentiates "unskilled" from "skilled" labor. The idea is to separate the group from the entire workforce that is often considered the "losers" of globalization. As Steedman and McIntosh (2001) show, the United Nations International Standard Classification of Education, last updated in 1997 (ISCED 1997), can be used as a basis to make that distinction. The ISCED system defines seven categories:

- ISCED 0: pre-primary education,
- ISCED 1: primary education or first stage of basic education,
- ISCED 2: lower secondary or second stage of basic education,
- ISCED 3: (upper) secondary education,
- ISCED 4: post secondary non-tertiary education,
- ISCED 5: first stage of tertiary education,
- ISCED 6: second stage of tertiary education.

Steedman and McIntosh (2001) present surveys of educational performance demonstrating that the lower three groups (ISCED 0-2) score rather poorly in terms of qualifications needed to find a job. Moreover, many empirical studies apply the same cutoff point.[5] We therefore define workers as "unskilled" if they have an ISCED level of 2 or less and as "skilled" otherwise.

The second criterion of separation is data availability. It is easy to find data about the qualification level and the wage gap for *one* year for the EU-27 (e.g., Eurostat Structure of Earnings Survey or European Union Labor Force Survey), but comparable data are not available for a different year, and two distinct points in time are required to check

[5]However, some authors differentiate between ISCED 0-4 and 5-6 when talking about the skill premium of high-skilled labor, e.g., Acemoglu (2003) or Mitchell (2005). Then the value for θ_0 is close to what was achieved in the test simulations (about 75 percent).

whether the model can reproduce real-world outcomes appropriately. Instead of using data for the entire European Union, we limit ourselves to some data that include only four countries (Germany, France, the United Kingdom, and the Netherlands). These countries represent about 57 percent of the EU-27 GDP in 2006 (GDP data from the Eurostat website). More importantly, the datasets of both points in time are consistent. Data are taken from de Grip and Nekkers (2001) and are from 1992 and 1998.[6] It is better to have just a ballpark figure of the data required with possibly just a few countries in it but comparable initial and final values than having a larger country sample but hardly comparable data. It is essential to be able to check the model's empirical validity with two consistent datasets. Table 4.1 gives the values for θ_0 (share of unskilled workers) and w (relative wage of skilled vs. unskilled labor) for the four countries in our sample. θ_0 declines from 0.29 to 0.23 and the relative wage w rises from 1.37 to 1.44. Note that only households that actually earn a labor income are included in the sample (otherwise the numbers given here would be relative wages that have already been adjusted for the risk of becoming unemployed).

A striking feature of the data is that the share of unskilled workers in the United Kingdom is much larger than for the other three countries. In fact, the entire skill distribution in the United Kingdom is rather atypical: the fraction of medium-skilled workers (ISCED 3) in 1992 is only 13 percent as opposed to 46 (72, 50) percent in Germany (France, the Netherlands); the share of high-skilled workers (ISCED 5 and above) is 32 percent in the United Kingdom while it is only 22 (17, 23) percent in Germany (France, the Netherlands).

	1992		1998	
Country	θ_0	w	θ_0	w
Germany	0.11	1.28	0.11	1.49
France	0.27	1.27	0.20	1.30
United Kingdom	0.55	1.64	0.44	1.55
The Netherlands	0.32	1.28	0.21	1.31
Population-Weighted Average	0.29	1.37	0.23	1.44

Table 4.1: Data on Labor Supplies and Relative Wages. Source: own calculations based on de Grip and Nekkers (2001), p. 9ff.

[6]The authors present relative wages of unskilled to medium-skilled and high-skilled to medium-skilled labor as well as incidence of skill categories. We had to convert these numbers into an appropriate measure for the relative wage for our purposes. Data stem from household panels with about 60,000 observations in total. For Germany data stem from the German Socio-Economic Panel, for France from the Enquête sur l'Emploi, for the United Kingdom from the British Household Panel Survey, and for the Netherlands from the Socio-Economic Panel of Statistics Netherlands.

4.2.1.2 Population Growth Rate n, Lifetime D, and Training Duration T

The population growth rate can easily be calculated from Eurostat population figures. Weighting the population growth rates of the four countries with their respective population size in all seven years (1992–1998) and taking the overall average population growth rate over the entire sample period yields a value of $n = 0.00378$ with country averages ranging from 0.00261 (United Kingdom) to 0.00602 (the Netherlands). These numbers include natural reproduction and immigration since it does not matter for the model where new individuals come from. It is true that immigration is likely to change the skill distribution. One model requirement is, however, that population growth (be it due to "organic" growth or immigration) is skill-neutral, which is certainly not the case in reality. But since the change in the skill composition due to immigration is very small compared to the change due to skill decisions of the native population, as already discussed, we will assume that immigration does not significantly distort the skill distribution.

In order to calculate an individual's average *economic* lifetime, D, we need two figures. The first one is the population-weighted average number of years in order to attain ISCED level 2, which our model refers to as the decision not to become skilled. The numbers can be taken from the United Nations Educational, Scientific and Cultural Organization's (UNESCO) database[7], where so-called "education expectancies" for many countries are stated.[8] These are the expected years of education under current conditions, excluding education for children under the age of five, separated by ISCED stages. One can see from this table how old an individual is on average when she or he achieves a certain ISCED level. The number for ISCED 2 is 14.7 years (including the five years that had been subtracted before). The second figure in order to calculate D is the average retirement age. Blöndal and Scarpetta (1999) provide the average age of transition to inactivity for our four countries for the year 1995, separated by male and female workers. Weighting these figures with labor-force participation rates of males and females and again by country populations yields an overall average of 59.7 years. Hence, $D = 59.7 - 14.7 = 45.0$.

Next we are going to compute the average training duration in order to become skilled, D. Average training durations for ISCED levels 3, 4, and 5–6 (data from the UNESCO) are weighted by the shares of the population that already have attained the respective levels (data from de Grip and Nekkers (2001)). The problem with this

[7]Cp. www.uis.unesco.org.

[8]Figures are for the year 2003 since consistent data for 1992-1998 are not available.

methodology is, however, that we have to assume that the skill distribution does not change over time, which is of course not true. To be precise, we would need data on the training duration as well as the highest ISCED level reached by a specific cohort, which is not available. Thus our methodology is a second-best solution. The population-weighted average of time spent to undergo ISCED stages 3–6 is 7.63 years. Weighting stages 3, 4 and 5–6 with data on educational attainment, it turns out that the population-weighted average training time is $T = 4.25$. This means that the average time to reach the average skill level of a skilled worker is about four years and three months.

4.2.1.3 Time Discount Factor ρ

According to (3.6), the subjective discount factor ρ is equal to r. Dinopoulos and Segerstrom (1999) as well as Sayek and Sener (2006) use the observed real interest rate as the real-world equivalent of ρ. However, this neglects utility growth and is therefore inappropriate. In the model, instantaneous utility grows with rate g, and utility growth can be considered the equivalent of real income growth (which in turn is equivalent to goods becomimg cheaper with rate g, although goods prices itself are constant in the model). Denote the observed real interest rate $\bar{\rho}$. In order to obtain data on the real interest rate we have to adjust data on nominal interest rates by the rate of inflation. The OECD website provides data on long-term nominal interest rates and consumer price indices for our time period (1992–1998). The GDP-weighted average over all years is $\bar{\rho} = 0.0448$. The appropriate value to be used for ρ is then

$$\rho = \bar{\rho} - g, \tag{4.1}$$

where g is the steady-state growth rate and will be determined in Section 4.2.1.6.

4.2.1.4 Relative Discount Factor ς, Wage Dispersion Parameter γ, and Fraction of Skilled Workers with Acquired Skills ϕ

With ρ, D, and T known, it follows from (3.8) that $\varsigma \approx 1.17$. This means that unskilled workers discount by 17 percent more since their respective time span is longer as they do not undergo training.

With θ_0 and w fixed and ς known, γ cannot be a free parameter either. For our benchmark year 1992, (3.8) leads to $\gamma \approx -0.567$. This value can be interpreted as follows. Rearranging the skill decision (3.8) so as to isolate w, $w = \varsigma/(\theta_0 - \gamma)$, and assuming that $\gamma < 0$, it follows that $w \leq \varsigma/(0 - \gamma)$ (since $\theta_0 \geq 0$). Given our values of

ς and γ, it follows that the relative wage cannot exceed 2.06, thus the wage dispersion is bounded from above. (For positive values of γ, w would be bounded from below.) Moreover, θ_0 is bounded from above to $\theta_0 < \varsigma/1+\gamma = 0.603$ (since $w > 1$).

Since we know n we can determine ϕ from (3.10) as $\phi \approx 0.898$. Hence, about 90 percent of all skilled workers have undergone training and are available for the labor market.

4.2.1.5 Trade Cost τ, Quality Improvement λ, and Distance Measure Ψ

4.2.1.5.1 Preliminaries for Trade Cost Measurement As opposed to McCallum (1995) and many other authors, we take a regression approach that avoids specification problems in the gravity equation. Three regressors are included: an exporter fixed effect a_i, an importer fixed effect b_j, and a dummy c_{ij} that takes the value one for trade flows within a country ($i = j$) and zero otherwise. The ordinary least squares (OLS) regression looks as follows:

$$\log M_{ij} = a_i + b_j + c_{ij} + \epsilon_{ij} \tag{4.2}$$

with error term ϵ_{ij} and a set of first-order conditions (FOCs)

$$\sum_{i=1}^{n} \left[\log y_i - x_i\hat{\beta}\right] x_i = 0 \tag{4.3}$$

with dependent variable y_i, regressors x_i, and estimator $\hat{\beta}$. (4.2) has the advantage that a_i and b_j capture all country-specific features and c_{ij} captures the effect of within-country versus cross-border trade flows ("border effect"). The regression shows that what is actually measured by the border effect is the ratio of external and internal trade frictions. The assumption of costless internal trade is therefore just a normalization that does not affect the regression results. The exponential of the border-effect coefficient (since the left-hand side of (4.2) is measured in logs) shows by how much more countries trade with themselves than with other countries. This is the value McCallum (1995) found a magnitude of 20 for (but he used a different regression, as described above). Going back to (2.1) and using $\sigma = 10$ for instance, a value of 20 translated to trade costs implies that $\tau = 20^{1/(\sigma-1)} - 1 \approx 0.395$.

One disadvantage of the OLS approach is, however, that it neglects the fact that the expectation of the log of a random variable is different from the log of its expected value. Therefore, taking logs can be misleading in the presence of heteroskedasticity. Heteroskedasticity in turn is likely to occur as the magnitudes of trade flows vary considerably across countries; the mere variance of trade flows of a large country is in some instances greater than trade flows alone of a small country. One way to overcome this problem is to estimate the constant-elasticity model, $y_i = \exp(x_i\beta)$, directly, using non-linear least squares (NLS).[9] The FOCs are

$$\sum_{i=1}^{n} \left[y_i - \exp(x_i\hat{\beta})\right] \exp(x_i\hat{\beta})x_i = 0. \tag{4.4}$$

Due to the exponential term behind the squared brackets, observations with large $\exp(x_i\hat{\beta})$ have a higher weight. These are usually the observations with larger variances, thus the NLS estimator gives more weight to noisier observations. A common approach to circumvent this problem is to assume that the variance is proportional to the expectation: $E[y_i|x] = \exp(x_i\hat{\beta}) \propto V[y_i|x]$. This yields the so-called Poisson pseudo-maximum-likelihood estimator (PPML) with FOCs

$$\sum_{i=1}^{n} \left[y_i - \exp(x_i\hat{\beta})\right] x_i = 0, \tag{4.5}$$

which does not suffer from the problem of overemphasizing observations with large $\exp(x_i\hat{\beta})$. Note the similarity to the OLS estimator in (4.3). We will apply and compare the three different estimators when it comes to finding suitable values for τ in Section 4.2.1.5.2.

4.2.1.5.2 Finding Suitable Values We have only two equations left in order to calibrate the model—the per capita full-employment conditions (3.29c) and (3.29d)—but five parameters that have not been fixed yet (τ, λ, Ψ, a, and k), thus we have to fix three parameters before model calibration can take place. We fix λ and τ (and thus Ψ) in order to guarantee that the condition for non-prohibitive trade costs, $0 \leq \tau \leq \lambda - 1$, is fulfilled since for some values of w and θ_0, τ can become greater than $\lambda - 1$ when fixing a and/or k, hence the latter two parameters stay free.

Although the relative size of τ and λ is more important than the single values alone, we aspire to work with reasonable values for both parameters. Concerning λ, there are two promising ways to access data. First, there is an extensive literature on price markups.[10] One widespread approach to estimate a markup is an equation making use of the Solow residual. Under perfect competition, the growth rate of technical innovation

[9] The following thoughts are based upon Silva and Tenreyro (2006).
[10] Cp. Norrbin (1993), Roeger (1995), or Basu (1996).

(i.e., the Solow residual) is equal to the growth rate of output minus the sum of the (elasticity-weighted) growth rates of the input shares. If the Solow residual were truly exogenous it would be uncorrelated with aggregate input demand variables. If there is a correlation, however, the remaining "wedge" between the observed Solow residual and input growth rates must be explained by means of something else, namely market power due to imperfect competition. Estimates for different countries vary largely across industries, but on average the authors find values between 1.1 and 1.2.

Second, we could make use of the expression for total firm profits (3.15) in order to determine λ and τ.[11] Dividing (3.15) by total consumption expenditure cN yields

$$\xi \equiv \frac{\pi}{cN} = \frac{2(\lambda - 1) - \tau}{\lambda}. \tag{4.6}$$

Data on π and cN can be obtained from the OECD website: we use "Gross operating surplus and mixed income" and "Final consumption expenditure," respectively. Thus we can calculate ξ for 1992 and 1998, using data on all four countries in our sample. Rearranging (4.6) allows us to infer τ when λ is known:

$$\tau = \lambda(2 - \xi) - 2. \tag{4.7}$$

Assuming constant markups over time, rising relative firm profits (ξ increased from 0.4359 in 1992 to 0.4582 in 1998) would allow for the conclusion that τ has fallen. However, this approach assumes that changes in relative firm profits are caused exclusively by changing trade costs, which is certainly not the case in reality. If we nevertheless regard this approach as valid it turns out that λ has to be greater than $\lambda = 2/(2 - \xi)$ in order to get a strictly positive value for τ (rearranging (4.7) with $\tau = 0$). For $\xi = 0.4359$ (1992) this yields a λ-value of at least 1.28 and at least 1.30 for $\xi = 0.4582$ (1998). These figures are higher than the numbers found by the price-markup literature, and for realistic τ-values λ has to be even greater. Hence, inferring λ and τ from ξ may be a theoretically feasible idea. In practice, however, it does not correspond to empirical values of λ found by other methods. Therefore, we stick with the markup literature and employ a value of $\lambda = 1.2$, the upper bound of what can be justified empirically.

[11] In the model of Dinopoulos and Segerstrom (1999), a country's openness, measured as the value of exports (imports) as a percentage of consumption expenditure, depends on both τ and λ due to the assumption of Cournot competition. In their model, the consequence of Cournot competition is that quality followers produce strictly positive quantities. Since followers produce but do not export, trade openness varies with the relative importance of leaders and followers and hence with trade costs. In our Bertrand specification, openness is always equal to one, hence we have to make use of another equation in order to determine τ and λ, namely (3.15).

In order to get a value for τ we make use of our three estimators presented in Section 4.2.1.5.1 (OLS, NLS, PPML).[12] There are 16 observations of the dependent variable (4×4 countries and thus 16 trade flows, including the intranational flows). We use data on bilateral trade flows as well as on industry outputs from the Worldbank COMTRADE database.

	OLS		NLS		PPML	
	1992	1998	1992	1998	1992	1998
Coefficient	2.50	1.93	2.71	2.40	2.56	2.24
Border Effect	12.2	6.9	15.0	11.0	13.0	9.4
τ ($\sigma = 5$)	0.869	0.621	0.968	0.822	0.899	0.751
τ ($\sigma = 10$)	0.320	0.239	0.351	0.306	0.330	0.283
τ ($\sigma = 20$)	0.141	0.107	0.153	0.135	0.145	0.125

Table 4.2: Data on Trade Costs. Source: own calculations based on Worldbank COMTRADE database.

Table 4.2 presents the coefficient estimates from the three regressions (all of them significant at the 1-percent level) as well as their exponentials, i.e., the border effects. Estimates for the elasticity of substitution σ can be obtained from many authors[13]; most figures are in the range of 5 and 10. The general picture emerging from Table 4.2 is that trade cost estimates do not react very sensitively to changes in the estimation method but very sensitively to changes in the elasticity of substitution. In our case low values of σ would lead to prohibitively high trade costs: $(1+\tau)$ must not be greater than $\lambda = 1.2$, thus $\sigma = 5$ and $\sigma = 10$ would be too low. As Wei (1996) states, trade between similar countries is probably subject to a relatively high elasticity of substitution (he employs a value of 20).

In order to satisfy the constraint of non-prohibitive trade costs, we use $\sigma = 20$. This leads to $\tau = 0.145$ ($\tau = 0.125$) in 1992 (1998), implying a decrease in τ of 13.4 percent in six years. It is true that a value for σ as large as 20 does not seem to be very realistic since this comes close to the case of perfect substitutability. What is important for the explanatory power of the model, however, is the relative change in τ rather than its absolute size. Considering the PPML results, the relative change in τ is -16.4 percent, -14.2 percent, and -13.4 percent for a σ of 5, 10, and 20, respectively. Therefore, the exact value chosen for σ is not essential for our purposes.

[12] All regressions have been performed with MATLAB.

[13] E.g., Harrigan (1993), Hummels (2001), Head and Ries (2001), Baier and Bergstrand (2001), or Eaton and Kortum (2002) estimate gravity equations and use information about tariffs and/or transport costs.

We use the PPML estimate for two reasons. First, it is the theoretically most convincing method of the three to estimate the border effect. Second, coefficients as well as trade costs are about halfway between the OLS and the NLS estimate. The latter property does not come unexpected when looking at the FOCs for the respective estimators: NLS tends to overestimate the border effect due to higher weight of large observations while OLS tends to underestimate it. PPML appears to find a compromise between both methods.[14]

Due to our restriction of non-prohibitive trade costs, τ must not exceed 0.2. Consequently, our values are a little smaller than trade cost estimates of many other authors. What distinguishes our country sample from many other samples, however, is that all countries share common borders (except for the United Kingdom) and are EU members. Trade costs of 14.5 or 12.5 percent, respectively, thus seem to be fairly realistic. Using (3.26), Ψ takes values of 4.21 and 3.86 in 1992 and 1998, respectively. As Ψ is defined as q/π, a value of 4.21 (3.86) means that firm profits make up about 24 (26) percent of all output in value terms. Compared to OECD data, these numbers are too small: dividing "Gross operating surplus and mixed income" by "Gross domestic product (income approach)" yields values of 34 and 36 percent, respectively. Hence, in order to reach the actual Ψ values, τ would have to be reduced and/or λ increased.

4.2.1.6 Rate of Innovation I and Utility Growth Rate g

There are no appropriate data on our rate of innovation since this is an abstract concept. However, when fixing λ, one can infer I from (3.32) when g is known. We assume that "utility" can be measured by real GDP for which growth rates are available from Eurostat. I unambiguously rises when trade is liberalized, but it does not make much sense to fix growth rates at the initial and the final instant since growth rates fluctuate according to movements of the business cycle that are too much influenced by factors other than trade cost to justify an explanation of changes in I solely by trade liberalization. Instead, we take the GDP-weighted average over all four countries and all years as the value for both points in time. The data reveal that $g = 0.02$, which leads to

[14]Rather a footnote than something we are actually going to use is the development of trade costs within the entire EU-27, just to get a comparative figure. Running the same PPML regression for 25 countries (Estonia is excluded as no COMTRADE data are available; Belgium and Luxembourg are merged into one country) yields higher values for τ, as expected: the numbers are 1.247, 0.433, and 0.186 in 1992 for a σ of 5, 10, and 20, respectively. In 1998 they decreased to 1.023, 0.368, and 0.160. Although the absolute values for τ and therefore the change in percentage *points* is higher than for our four-country sample, the *relative* change in τ is about the same, although slightly larger (-18.0, -15.1, and -14.0 percent for the three different values of σ).

$I = 0.02/(2 \log 1.2) \approx 0.0548$. The result for g can in turn be used to determine the discount factor: $\rho = 0.0448 - 0.02 = 0.0248$.

4.2.1.7 Unskilled-Labor Share in Manufacturing a and Relative R&D Difficulty k

With two equations and two parameters left, model calibration yields $a = 0.237$ and $k = 1.629$. It is straightforward why k is calibrated: its meaning is very abstract and there is no data available for this kind of parameter. The interpretation for this value is that R&D difficulty grows by 1.629 man years for each newly-born worker.

Variables			Parameters		
w	1.37	de Grip and Nekkers (2001)	n	0.00378	Eurostat
θ_0	0.29	de Grip and Nekkers (2001)	D	45.0	UNESCO, Blöndal and Scarpetta (1999)
g	0.02	Eurostat			
I	0.0548	(inferred)	T	4.25	UNESCO, Blöndal and Scarpetta (1999)
			ρ	0.0248	OECD
			τ	0.145	(own estimate)
			λ	1.2	markup literature
			a	0.237	(calibrated)
			k	1.629	(calibrated)
			γ	-0.567	(calibrated)

Table 4.3: Calibration of the Benchmark Model. Note: All variables are for the initial year (1992).

It is true that factor shares in the production function, a and $(1 - a)$, can be found in the literature. For our specific definition of skilled and unskilled labor, however, it is difficult if not impossible to find appropriate data, thus we calibrate a as well. One could pose the question which parts of the data mainly influence the size of a (since CGE calibration rarely yields to a one-to-one correspondence of data and calibrated parameters). The answer would be that θ_0 is the most important determinant of a (as can be seen from their similar sizes), but naturally other parts of the data have an impact on a as well. Table 4.2 provides an overview of variables and parameters (fixed and calibrated), their values as well as their sources.

4.2.2 Model with Unemployment

Instead of two there are now four free parameters: a, k, the search time y, and the matching-function parameter ε. It is true that data on average unemployment durations for different skill groups can be found, but hardly for our exact skill definition and our specific country sample and observation period. With two additional equations for calibration—(3.59) and (3.60)—, the two additional free parameters can be calibrated. In order to do so, we need data on unemployment and vacancies. Since it is easier to get data on u_A than on factor-specific u, we fix u_A and determine u from (3.62) since we have already fixed θ_0. Seasonally adjusted aggregate unemployment figures are available from the OECD. The "standardized" unemployment rate is defined as the number of unemployed persons as a percentage of the civilian labor force. The civilian labor force in turn consists of civilian employees, the self-employed, unpaid family workers, and the unemployed. The main problem with unemployment figures is that they depend heavily on the business cycle, which is not part of our model. In order to get a general tendency of the different rates in 1992 and 1998, we take five-year moving averages when quoting figures for both years. Furthermore, we only use unemployment figures for West Germany since there was a significant structural break of unemployment data for the whole of Germany after reunification. The civilian-labor-force-weighted[15] moving average for u_A is 0.0764 in 1992. This value rises to $u_A = 0.0895$ in 1998. However, there are significant cross-country differences, as presented in Table 4.4. Moreover, γ has changed since we employ (3.48) instead of (3.8) now: $\gamma = -0.342$.

Country	1992	1998
West Germany	0.0656	0.0896
France	0.0914	0.1140
United Kingdom	0.0818	0.0772
The Netherlands	0.0610	0.0562
Civilian-Labor-Force-Weighted Average	0.0764	0.0895

Table 4.4: Data on Aggregate Unemployment Rates, 5-Year Moving Averages. Source: own calculations based on OECD and German Federal Bank websites.

There are two problems connected with the vacancy rate of unskilled labor. First, we only have consistent data for the *aggregate* vacancy rate that includes skilled-labor vacancies as well. This is tackled by deriving z_A analogously to u_A: with $L = \theta_0 N$ and $Z = zL$ it follows that $z_A = Z/N = z\theta_0$ and hence $z = z_A/\theta_0$. Second, actual data reveal that z_A (aggregate vacancy rate) fluctuates considerably over time, just like the unemployment rate (increases in z_A between 15 percent for Germany and 211 percent for the United Kingdom for 1992–1998, OECD data), but our model demands z to be constant and independent of trade costs since it only depends on exogenous parameters.

[15]Weights are obtained from the OECD as well.

This problem of fluctuating real-world values due to a strong dependence on the business cycle is solved in the same fashion as for the growth rate g: we take the average over all years and countries and fix it. This yields $z_A = 0.00764$ and hence $z = 0.0302$.[16] New calibration results for the model with unemployment are given in Table 4.5.

Variables			Parameters		
u_A	0.0764	OECD, Eurostat	a	0.218	(calibrated)
u	0.2634	(inferred)	k	1.289	(calibrated)
z	0.0302	OECD	γ	-0.342	(calibrated)
			y	0.306	(calibrated)
			ε	0.662	(calibrated)

Table 4.5: Calibration of the Model with Unemployment. Notes: All variables are for the initial year (1992). Variables and parameters not listed have not changed compared to the benchmark model.

A value of $y = 0.306$ means that the search duration is a little longer than three and a half months. This is much shorter than the number reported by the German Federal Employment Office, for instance: in 2006, the average duration of unemployment was 41.4 weeks[17], which is about nine and a half months. Our model assumes the presence of frictional unemployment only. The figure from the unemployment statistics, however, includes all other kinds of unemployment such as cyclical and structural unemployment. Therefore, our calibrated y has to be lower than numbers found in pertinent publications.

The other parameter, $\varepsilon = 0.662$, governs the efficiency of the matching process. Recalling the Cobb-Douglas nature of the matching function, $m(Z, L) = Z^{\varepsilon}L^{1-\varepsilon}$, this value can be interpreted such that about two thirds of all matches are "produced" by the presence of vacancies while the remaining third is due to the size of the unskilled labor force, i.e., labor supply.

4.2.3 Model with Horizontal FDI

Compared to the benchmark model, there are now two additional free parameters, namely the FDI cost parameters b and d. The first equation is the condition for the optimal α, (3.78e). The second one ensures comparability with the benchmark model at the initial instant: firms performing horizontal FDI (all quality leaders in equilibrium) do not produce more output than without the possibility of FDI, therefore the total

[16] In order to calculate z from z_A, θ_0 is needed. Values for θ_0 are available from de Grip and Nekkers (2001) for 1992, 1995 and 1998. $\theta_{0,1992}$ and $\theta_{0,1995}$ are used to linearly interpolate values for 1993 and 1994, and $\theta_{0,1995}$ and $\theta_{0,1998}$ interpolate values for 1996 and 1997.

[17] Cp. BA (2006).

output is multiplied by a factor equal to one:

$$d - b\alpha = 1, \tag{4.8}$$

which must hold in 1992 but not necessarily in 1998.

It is difficult to differentiate between horizontal and vertical FDI empirically.[18] Moreover, neither data on FDI flows nor on FDI stocks would be in accordance with our model. The reason is that capital inputs do not necessarily reflect production volumes. In addition, capital formation is a process that refers to the long run, and we do not know the lag between capital formation and actual production taking place with the capital invested before.

What we need instead are production volumes of affiliates of multinational enterprises (MNEs) and according sales in order to reflect our model appropriately. Alternatively, we might use employment figures of foreign affiliates, assuming that production volumes are closely related to employment. There are some problems connected to this "market share" approach as well. First, production is not congruent with sales, but this is what our model assumes. Second, foreign affiliates are unlikely to use factors of the same skill intensity as domestic firms because they are much more productive on average.[19] Third, it is unclear whether foreign production has a vertical goal (i.e., intermediates are produced abroad and re-imported) or a rather horizontal aim. Despite these discrepancies of our model and the data available, we choose to make use of sales and employment data as a proxy for the share of horizontal FDI.

The United Nations Conference on Trade and Development (UNCTAD) offers data on sales and employment (World Investment Directory) of foreign affiliates on a country-

[18] In a recently published paper, Alfaro and Charlton (2007) report that a large share of vertical FDI has been mistaken for horizontal FDI as the level of aggregation (usually two digits) has been too rough to get a realistic picture. The authors find that multinationals tend to own stages of production proximate to their final production ("intra-industry" FDI), thus a large share of North-North FDI is vertical instead of horizontal, but this can only be seen when using a fine classification (four digits, as they do). They examine data for 650,000 multinational subsidiaries in 90 countries and 400 industries—which comes close to a comprehensive picture of the issue—and find that about half of all FDI is horizontal, both with regard to North-South and North-North FDI (the lion's share of FDI is North-North FDI anyway).

[19] It is undoubted that firms performing FDI are more productive than those staying at home or even those serving the foreign market via exports only (cp. Helpman et al. (2004) for a model with heterogeneous firms separating these three types (domestic firms, exporters, multinationals) as well as an empirical application of their theory). However, this is not a trivial issue since it is neither empirically nor theoretically clear whether firms produce abroad as a consequence of their above-average productivity or whether they are productive because they produce abroad, or both is true. Among many others, Bernard and Jensen (1999) examine the direction of causality for U.S. firms. Several studies of that kind find that firms rather become active abroad (either by means of FDI or exports, or both) because they already have an above-average productivity than vice versa.

by-country basis. For instance, we get figures on how much affiliates of German MNEs *in France* sold to *French* customers (but unfortunately not how much they produced in France for purely horizontal purposes). Moreover, we get data on total employment of these affiliates in France (both figures refer to industry sales only). These numbers are available for all of our 12 country pairs.[20] In order to arrive at "FDI shares," we divide the sum of affiliate sales (or affiliate employment, respectively) by total manufacturing production minus manufacturing exports in all four countries (or total industry employment, respectively), using figures from the OECD.[21] On a sales basis, α increased from 0.15 in 1992 to 0.23 in 1998. On an employment basis, however, both the levels as well as the relative increase in α were much smaller; the share increased from 0.05 to 0.06.[22]

Variables		Parameters		
α	0.15	a	0.241	(calibrated)
τ_α	0.1015	k	1.912	(calibrated)
		b	0.972	(calibrated)
		d	1.146	(calibrated)

Table 4.6: Calibration of the Model with Horizontal FDI. Notes: All variables are for the initial year (1992). Variables and parameters not listed have not changed compared to the benchmark model.

When presenting the outcome of the model calibration, we use data from the sales approach since this is closer to our model than the employment approach. However, when is comes to the simulations results, we will also present some figures for the employment approach. Table 4.6 gives a data overview for the model with horizontal FDI. As one can see, the effective transport cost rate, τ_α, is smaller than τ since $\alpha > 0$. The values for b and d can be interpreted as follows. The production functions in the presence of FDI, (3.66) and (3.67), imply that output amounts to $(F + F^*)(d - b\alpha)$. This can be split up into gross output, $(F + F^*)d$, and FDI cost, $(F + F^*)b\alpha$. The firm therefore bears an FDI cost in the form of an iceberg share of $(b\alpha)/d = 0.127$ of its gross production.

[20] Sales data for France are available from 1996 to 1998 only, and for the United Kingdom from 1995 to 1998 only. We solve the problem by assuming a linear time trend, extrapolating figures to 1992. This seems to be justified since in general, there appears to be a mostly positive trend for affiliate sales over time. For the Netherlands, data are only available for 1997, and we use them in both periods. Concerning employment figures, French data are available from 1996 to 1998, Dutch from 1995 to 1998, and U.K. figures from 1992 to 1997 only. Due to huge fluctuations in these figures, however, we do not extrapolate anything here since this does not appear to be a justified strategy in this case. Instead, we just take the earliest year available.

[21] Annual average exchange rates used to convert dollars and Dutch guilders to euros are provided by the German Federal Bank.

[22] Using employment figures based on extrapolated data (as we did with the sales figures) does not change this result much.

Possibly just coincidentally, this figure is very close to our iceberg transport cost τ for goods shipments. The latter calculation shows, however, that the calibrated values for d and b are of reasonable size.

Chapter 5

Results

Employing all three model variants from Section 3 and using the data documented in Section 4, we will now present the results for each of the three model simulations and comment on them as well.

5.1 Benchmark Model

Probably the most significant result is that no matter which of the three model variants we employ, the explanatory power of trade liberalization with respect to wage inequality is rather small. The possible reasons will be discussed below. Table 5.1 presents the results for a trade cost reduction from 0.145 in 1992 to 0.125 in 1998.[1] As opposed to the test simulation, the relative change in the wage of unskilled labor is greater than the relative change in the wage of skilled labor. The reason is that the test simulations assumed a high share of unskilled labor used in manufacturing production ($a = 0.85$) while this is not the case for our real-world data ($a = 0.237$). With only little unskilled labor employed at all, shifting output away from manufacturing in favor of R&D implies that the *relative* change in unskilled-labor demand is higher than with a lot of unskilled labor employed. Therefore, the change in the wage of unskilled labor compared to the change in skilled labor has to be greater than in the test simulation.

Had international trade explained 100 percent of the rise in wage inequality, w would have risen from 1.37 to 1.44 instead of merely 1.3734. The fraction explained by a fall in τ is thus about 4.9 percent, whereas the fraction explained of skill upgrading (θ_0 was supposed to decrease to 0.23) is about 3.5 percent.

[1]Note that the heading of the last column, "Relative Change," is not quite appropriate in the case of EV. What we exactly mean here is the value of EV^R (relative equivalent variation as a share of initial consumption expenditure).

Variable	$\tau = 0.145$	$\tau = 0.125$	Relative Change [%]
w_H			0.06
w_L			-0.19
w	1.37	1.3734	0.25
θ_0	0.29	0.2879	-0.73
g	0.02	0.0219	9.29
q/N			-0.92
EV			8.24
EV_H			9.31
EV_L			9.04
EV_{LH}			17.29
$\bar{w}$			0.04

Table 5.1: Simulation Results for the Benchmark Model. Parameter values: $D = 45$, $T = 4.25$, $n = 0.00378$, $\rho = 0.0248$, $\lambda = 1.2$, $k = 1.629$, $\gamma = -0.567$, $a = 0.237$.

The increase in the growth rate by about 9 percent can be interpreted as evidence of the growth-enhancing effect of free trade through knowledge spillovers, as observed by studies such as Ben-David and Loewy (1998) or Frankel and Romer (1999). The size in the increase should, however, not be taken as a measure of the model performance since the growth rate reacts quite sensitively on changes in τ, although an increase by 0.2 percentage points seems to be a reasonable figure.

The decrease in q/N (i.e., manufacturing output per capita) reflects the ongoing process of de-industrialization. The change in q/N ought to be compared to the actual change in manufacturing production as a share of total production. Using data from Eurostat, the manufacturing production share in our four countries decreased from 0.737 in 1992 to 0.638 in 1998, which implies a decrease of more than 13 percent. Therefore, our figure of less than one percent strongly underestimates the impact of falling trade costs on q/N, as in the case of w and θ_0. Using actual employment shares instead yields the same picture: manufacturing employment as a share of total employment[2] fell from 0.288 to 0.255, a decrease of more than 11 percent.

Wages in the industrial and service sector measured in purchasing power parities increased by 4.2 percent between 1995 and 1998 (data from Eurostat, available only for Germany, France, and the Netherlands) and probably twice as much between 1992 and 1998. Our simulation result of 0.04 percent again considerably underestimates that number.

A suitable real-world analog for our welfare measure is the growth rate of real GDP per capita. According to OECD data, real GDP increased by 12.5 percent during the

[2]Data on manufacturing employment for the United Kingdom are only available for 1993, not 1992.

observation period. Since the population grew by 2.1 percent, real GDP per capita rose by 10.2 percent. Our result of a welfare change of about 8 percent is therefore in the same ballpark. It is interesting to see that although the sign of EV is not clear a priori, we get a clearly positive result. Thus the model performance in welfare terms is alright. Moreover, it turns out that workers of all abilities gain from trade liberalization. Although unskilled workers lose in a static sense they gain in the long run. When calculating the equivalent variation for a worker who is induced by trade liberalization to change his skill level, EV_{LH}, we have to choose some value for θ since EV_{LH} depends on the worker's ability. There is only a small range of suitable values, namely all values of θ_0 before and after the shock, i.e., values between 0.29 and 0.2879. We use $\theta = (0.29 + 0.2879)/2 = 0.2890$ to calculate EV_{LH}, yielding the average gain a "skill switcher" achieves (recall that there is a uniform ability distribution). The skill switchers benefit most from trade liberalization.

At first glance in seems odd that all skill groups gain more in welfare terms than is gained by the entire population, i.e., $EV < EV_i$, $i = H, L, LH$. When relating the figures, however, one finds that EV divided by a weighted average of EV_H, EV_L, and EV_{LH} has the same value as ϕ. Recalling that ϕ is the fraction of skilled workers that have already undergone education (about 90 percent), it becomes clear why EV is smaller than the three group-specific welfare measures: the overall welfare measure includes all *living* individuals while EV_H, EV_L, and EV_{LH} include only *working* individuals. Those who undergo training do not receive a wage income.

The overall model performance is (partly by construction) qualitatively in accordance with reality, but not quantitatively. This result is robust even for lower values for the elasticity of substitution ($\sigma = 10$) and thus much higher trade cost levels: decreasing τ from 0.330 to 0.282 yields an increase of w to 1.3775, thus about 10.7 percent of the change in w are explained. This fraction is about twice as large as before, but still relatively small.

We now take a quite different approach from what was done before. We do not strive to shock τ in such a way that real-world data are reflected appropriately. Instead, we run counterfactual simulations (cp. Table 5.2). The first experiment is a reduction of trade costs to zero. As presented in the first column of Table 5.2, a complete elimination of trade costs would be able to explain about 36 (28) percent of the change in the relative wage (skill composition) in this model, which is still far away from 100 percent. Hence, without the change of other parameters, the real-world outcomes cannot be reproduced, given our trade cost estimates.

As argued above, skill-biased technological change plays a very important role, too. This is why we run two more counterfactual simulations, both of them implying skill-

Variable	Starting Value	$\tau = 0$	$\lambda = 1.461$	$a = 0.194$
w	1.37	1.3952	**1.44**	**1.44**
θ_0	0.29	0.2745	0.2483	0.2483
g	0.02	0.0334	0.1153	0.0198

Table 5.2: Counterfactual Simulations for the Benchmark Model.

biased technological change. First, we increase the price markup λ, which provides greater incentives for innovation and thus increases the relative wage. λ is increased in such a way that $w = 1.44$ is exactly reached, leaving τ at its initial level. The necessary value of $\lambda = 1.461$ means that the markup has to be more than doubled (from 20 to 46 percent) in six years, which is hardly realistic. The growth rate takes an exorbitantly high value. The second experiment referring to skill-biased technological change is an increase in the skill intensity of manufacturing production by decreasing the share of unskilled labor used, a, again leaving τ unchanged. In order to arrive at $w = 1.44$, we need to decrease a by more than four percentage points (from 23.7 to 19.4 percent), which seems much more realistic than the necessary increase in λ, although it is still a huge decrease given the short time span of six years. The growth rate declines slightly since more skilled labor is used in manufacturing, leaving less for R&D.

These experiments have been performed to demonstrate the order of magnitude of parameter changes required to replicate real-world outcomes. Each single parameter change appears to be too large to be realistic, thus only a combination of parameter changes can credibly explain changes in the wage and skill structure. Yet another parameter that can be shocked in order to simulate skill-biased technological change is the R&D difficulty, k. However, decreasing k alone cannot replicate $w = 1.44$, so we have not included it in Table 5.2. Even a decrease of k to 50 percent of its initial value, i.e., from 1.629 to 0.846, leads to an increase of w to only 1.3731, which is a rather small change. Nevertheless, a decrease in k might be used in a combined parameter shock (τ, λ, a, and k) in order to fully explain changes in w.

Another experiment is to fix θ_0 at its initial level of 0.29 (not in the tables). This results in a relative wage of 1.3863 when decreasing τ and thus an explained fraction of 23.3 percent, which is much more than with endogenous labor supplies. However, since it is hardly realistic to assume that labor supplies do not react to changes in the wage structure, we will not pursue this exogenous-supply approach any further.

Although constant relative labor supplies are unrealistic in the long run (and our steady-state view implies that we focus on a long-run scenario), there is a short-run consequence of adapting labor supplies. Suppose the system were in steady state before the shock. Once trade costs have declined, households are induced to upgrade their skill level as there will be a higher skill premium to be earned in the future. Before entering the labor market, however, they have to undergo training for $T = 4.25$ years, a period where the additionally educated workers are not available for the labor market yet. Hence, in the transition phase between the old and the new steady state, the relative wage will overshoot its final level. We do not simulate the transition here but only state the qualitative result that six years after the shock, the model predicts that w lies somewhere between 1.3734 (the new steady state) and 1.3863 (the value for w when θ_0 is fixed at its initial level).

5.2 Model with Unemployment

In the model with unemployment it is the adjusted relative wage that ought to be examined closely. Qualitatively it is predetermined that $\tilde{w}$ has to increase since skilled workers will be better off after trade liberalization. The interesting point is again the order of magnitude of variable changes; the results are displayed in Table 5.3.

Variable	$\tau = 0.145$	$\tau = 0.125$	Relative Change [%]
w_H			-1.52
w_L			5.65
w	1.37	1.2771	-6.78
θ_0	0.29	0.2881	-0.67
g	0.02	0.0219	9.29
q/N			-2.49
z	0.0302	0.0302	*n.ch.*
u	0.2634	0.3155	19.77
u_A	0.0764	0.0909	18.97
$\tilde{w}$	1.8600	1.8658	0.31
EV			6.52
EV_H			7.58
EV_L			15.40
EV_{LH}			15.44
$\bar{w}$			-1.49

Table 5.3: Simulation Results for the Model with Unemployment. Parameter values: $D = 45$, $T = 4.25$, $n = 0.00378$, $\rho = 0.0248$, $\lambda = 1.2$, $k = 1.289$, $\gamma = -0.342$, $a = 0.218$, $y = 0.306$, $\varepsilon = 0.662$. "n.ch.": no change compared to starting value.

Employed unskilled workers gain more than skilled workers lose and the unadjusted relative wage w decreases significantly: the impact of the decrease in effective unskilled-labor supply is stronger than the impact of the increase in the skilled-labor demand on the relative wage. The reason is that changes in τ have a relatively strong impact on unemployment (through changes in the rate of innovation, driving up Schumpeterian unemployment). Since $\tilde{w}$ must rise, w must fall considerably, given the strong rise in u. Had international trade explained 100 percent of the rise in adjusted wage inequality, $\tilde{w}$ would have risen to $1.44/(1 - 0.3868) = 2.3483$ instead of merely 1.8658 (note that 0.3868 is the target value for u). The fraction explained by a fall in τ is thus about 1.2 percent, which is even smaller than the change in w explained by the benchmark model. This is a drawback of the model, but changes in the unemployment rates u and u_A are predicted quite well: the target values would have been 0.3868 and 0.0895, thus the model predicts 42 and 111 percent of the empirical changes. Moreover, the level of unskilled-labor unemployment after shocking τ is very high. On the one hand, this is due to our specific definition of unskilled labor. On the other hand, accounting for the fact that in reality some of the jobs of unskilled workers are merely the result of job-creation measures aimed at glossing over unemployment statistics or government subsidies to low-skilled-labor employment, published figures of unskilled-labor unemployment are likely to be underestimated. Therefore, our estimate is possibly more realistic than it seems to be at first glance. To sum it up, the model behaves satisfactorily in terms of explaining unemployment but rather poorly in terms of adjusted and unadjusted relative wages.

θ_0 decreases by about the same size as in the benchmark model. Moreover, the vacancy rate z remains constant by construction. In addition, compared to the benchmark model, the decline in q/N is stronger. The reason is that the increase in the wage of unskilled labor makes manufacturing production more expensive, leading to output contraction. As opposed to the benchmark model, the average real wage decreases since the increase in u has a strong impact on the total wage bill. As before, welfare increases, but by less than in the benchmark model. Unskilled workers who are still employed gain more than skilled workers (but this welfare measure neglects those who do not earn a wage anymore due to unemployment, thus it does not fully account for the cost inflicted on unskilled households).

We now discuss the counterfactual simulations presented in Table 5.4. Decreasing τ to zero makes the unadjusted relative wage decline below one, which is certainly not realistic. However, it is possible theoretically since it is $\tilde{w} = w/(1 - u)$ that has to be greater than one. Note that unemployment rates become excessively high. With an adjusted relative wage of 1.9030, the fraction of the change explained by trade liberalization increases to 8.8 percent.

We now ask the same question as in the benchmark model: by how much would the skill intensity (in the form of a) have to be changed in order to arrive at the real-world

Variable	Starting Value	$\tau = 0$	$a = 0.191$	$a = 0.097$	$\varepsilon = 0.657$	$y = 0.314$
w	1.37	0.9042	**1.44**	1.7766	**1.44**	**1.44**
θ_0	0.29	0.2757	0.2634	0.1587	*n.ch.*	*n.ch.*
u	0.2634	0.5249	0.2584	0.2435	0.2258	0.2258
u_A	0.0764	0.1447	0.0681	0.0386	0.0655	0.0655
z	0.0302	*n.ch.*	*n.ch.*	*n.ch.*	0.0317	0.0326
$\tilde{w}$	1.8600	1.9030	1.9419	**2.3483**	*n.ch.*	1.8599
g	0.02	0.0334	0.0198	0.0194	*n.ch.*	0.0199

Table 5.4: Counterfactual Simulations for the Model with Unemployment. "n.ch.": no change compared to starting value.

outcomes of w and $\tilde{w}$? Decreasing a by less than three percentage points (from 21.8 to 19.1 percent) is a smaller decrease than in the benchmark model (four percentage points) to achieve the same outcome of $w = 1.44$. The reason is that due to decreased unemployment (since the rate of innovation has slightly decreased), effective supply of unskilled labor has increased, putting downward pressure on the wage of unskilled labor. This in turn leads to a stronger increase in w through a than in the benchmark model. Therefore, skill-biased technological change does not have to be as strong as before in order to fully explain changes in w.

What we take as a yardstick in a second step is the value of $\tilde{w} = 2.3483$ that occurred in 1998. a would have to be decreased by 12.1 percentage points to reach it (from 21.8 to 9.7 percent), which is probably too high to be realistic.

The simulations documented in the last two columns of Table 5.4 refer to parameters of the search process. Both changes in ε and y make the matching process of unskilled labor either more or less efficient. They determine the turnover rate but do not change the fundamentals of the labor market (supply and demand) and therefore do not have an impact on the adjusted relative wage (or hardly any impact in the case of y).

First, ε is decreased, implying a worsened matching technology. The result is that vacancies cannot be filled as quickly as before, hence the vacancy rate rises. This in turn decreases unskilled-labor unemployment. Since the adjusted relative wage has to remain constant, w must increase. The growth rate does not change. What is interesting is that the relative wage reacts very sensitively on a shock of the matching technology. A worsened matching technology means that it has become harder for firms and employees to find each other. One conceivable cause in reality for this increased difficulty are higher skill requirements: it is more difficult to find an employee with certain desired features than without those. A fall in ε can therefore be interpreted as a form of organizational change. Firms increasingly employ specialists with job-specific abilities and become more demanding in terms of what they consider a good match. However, this interpretation has to be taken with a pinch of salt since the search mechanism too simple and stylized to fully account for all facets of the labor market.

The reasoning for y is a little different. Increasing the search duration implies that firms need more time to find suitable employees, which increases the vacancy rate. This again depresses unemployment and raises w, while $\tilde{w}$ remains roughly constant. In order to increase w to 1.44, u and u_A must take the same values as in the case before. In addition and as opposed to the change in ε, however, the growth rate has slightly decreased. This is caused by the fact that firms have to devote more resources (in the form of forgone revenues) to the search process. The additional effort absorbs resources that are not available for R&D purposes. The decrease in the growth rate decreases demand for skilled labor, slightly depressing the adjusted relative wage.

Extending the time of the search process can be interpreted as a decrease in labor market flexibility, for instance through increased union power or labor market legislation. As argued in the literature review, institutional change has an impact on the relative wage. What we simulated here is "reverse" institutional reform since our experiment made the labor market less flexible, increasing the (adjusted) relative wage. To sum it up, both changes in ε and y partly reflect the experience of organizational (ε) and institutional (y) change. Shocking them accordingly yields some new insights into the interplay of vacancies, unemployment, and relative wage in our model.

5.3 Model with Horizontal FDI

As opposed to the other two model variants, we now have an additional variable of trade liberalization, namely FDI cost. We will first shock either variable alone and then in a combined fashion. The simulation results for the model with horizontal FDI are presented in Table 5.5. We only display the relative changes, not the absolute values that result from parameter shocks.

The first experiment is the well-known trade-cost reduction, leaving b unchanged at its calibrated value of 0.972. The result is qualitatively the same as in the benchmark model. Moreover, α decreases by about 74 percent. The reason for this huge decline is that the FDI share reacts very sensitively on changes in τ since saving trade costs is the only incentive to perform FDI at all. The adjusted trade cost τ_α increases as the decrease in α weighs more than the fall in τ. Nevertheless, firm profits must increase as it is by construction impossible to harm firms by trade liberalization. Therefore, the relative wage must rise as well. Compared to the benchmark model, however, the increase in

Variable	$\tau = 0.145$, $b = 0.972$	Rel. Ch. [%] for $\tau = 0.125$	Rel. Ch. [%] for $b = 0.855$	Rel. Ch. [%] for $\tau = 0.125$, $b = 0.734$
w_H		0.04	0.03	0.08
w_L		-0.12	-0.08	-0.26
w	1.37	0.16	0.11	0.35
θ_0	0.29	-0.48	-0.33	-1.02
g	0.02	5.15	3.52	10.83
q/N		-0.61	-0.42	-1.28
α	0.15	-73.56	53.33*	53.33*
τ_α	0.1015	13.39	-22.86	-33.50
EV		4.39	2.98	9.44
EV_H		5.07	3.44	10.95
EV_L		4.89	3.32	10.57
EV_{LH}		12.79	11.07	19.00
$\bar{w}$		0.03	0.02	0.06

Table 5.5: Simulation Results for the Model with Horizontal FDI. Parameter values: $D = 45$, $T = 4.25$, $n = 0.00378$, $\rho = 0.0248$, $\lambda = 1.2$, $k = 1.912$, $\gamma = -0.567$, $a = 0.241$, $d = 1.146$. "*" indicates that b is shocked in such a way that the actual value of $\alpha = 0.23$ is reached.

w is ceteris paribus smaller (0.16 vs. 0.25 percent) due to the partial mitigation of the effect through α. This result shows that in the presence of FDI and constant FDI costs, the wage-dispersing effect of trade liberalization is smaller, which is a new finding.

The problem of the first simulation is that the FDI share did actually increase during our observation period. We thus run a second simulation changing b in such a way that $\alpha = 0.23$ is reached, holding τ fixed, which implies a drop to $b = 0.855$. Again, the relative wage rises and the other variable changes have the same direction as before. The only exception is that τ_α falls through the increase in α. Quantitatively the changes are even smaller than before.

Neither simulation performed so far was very realistic: the first neglected that α has risen (through falling FDI costs) while the second disregarded the fall in τ. What we have to do now is a combined decrease of both cost components. A drop in trade costs alone decreases α, therefore b has to decline by more than in the second simulation in order to reach $\alpha = 0.23$, namely to $b = 0.734$. The combined cost reduction leads to an increase in w by 0.35 percent. The other variable changes are quantitatively greater than in the benchmark model. Hence, by introducing FDI and an according cost component, we have increased the explanatory power of the model in terms of changes in the wage and skill structure: the fraction explained is now 6.7 instead of 4.9 percent. This is not a large fraction either, but still more than before. In relative terms, this is equal to an increase of 38 percent in terms of explanatory power.

The rise in α from 0.15 to 0.23 might seem a little steep, therefore we also ran a simulation for the employment approach, implying an increase in α from 0.05 to 0.06. Naturally, the change in the relative wage is smaller then. Calibrating the model accordingly (not in the table), it turns out that the combined reduction of τ and b so as to attain a value of $\alpha = 0.06$ (as in the last column of Table 5.5) yields an increase in w of 0.27 percent. This is less than the 0.35 percent from the sales approach, but still more than the 0.25 percent from the model without horizontal FDI. Therefore, although the gains are very small, the model's explanatory power can be enhanced a little even for the alternative empirical equivalent of α.

Chapter 6

Challenging the Trade-Inequality Link: the Role of Non-Tradables

Our models assume constant goods prices, therefore real expenditure is just nominal expenditure divided by a constant, namely λ. There is, however, a continuous improvement of goods quality, thus consumers benefit from this process: they pay the same price for their goods bundle but receive goods of higher quality with each new instant in time, which makes their instantaneous utility grow at rate g. This process can also be interpreted the other way round: it is equivalent to a situation where consumers face the same quality level but see goods prices decline, which makes their income more valuable in terms of goods they can purchase. Hence, the endogenous-growth mechanism described by the model can by viewed as a continuous increase in real income. For "real" values to increase it does not matter whether the numerator increases while the denominator stays constant or the numerator stays constant while the denominator declines.

Our concept of the relative wage employed so far assumes that both skilled and unskilled workers[1] face the same price index: they consume the same symmetrically-weighted basket of an infinitely large number of tradable goods. It is therefore not necessary to calculate a price-index-adjusted (i.e., real) relative wage. In reality, however, consumption expenditure consists not only of internationally tradable goods but also of locally supplied non-tradable services. We will refer to them in the following as "non-tradables." By construction of the model, all goods consumed are tradable and the increase in real income therefore stems from quality improvements (or, put differently,

[1] As mentioned before, there is a distinction between (given) "ability" and (acquired) "skill." When referring to a "skilled" worker, we mean one whose ability is at least θ_0, which has induced him to undergo training. After the training period, he is a worker both of high ability and of high skill.

price reductions) in the tradable sector alone. If we add non-tradables to the basket of goods consumed, the concept of the relative wage used so far is only appropriate in terms of describing inequality if all households consume tradables and non-tradables in the same proportion; otherwise the relative wage has to be adjusted by a household-specific price index in order to arrive at a measure for the real relative wage. Given different rates of inflation of tradables and non-tradables, households with different consumption patterns benefit from the trade-induced increase in real income to a different extent, depending on their tradables consumption as a fraction of total expenditure.

There is evidence that consumers from different income groups have different consumption patterns. Among others, Gregorio et al. (1994) argue that households with a higher income devote a larger share of their expenditure to services. For the time being we use "higher income" and "higher skill level" synonymously, although we will check for the correlation between income and skill later on. Unfortunately, the fact alone that our nominal measure of the relative wage may be inappropriate to fully capture inequality does not permit us to state that the explanatory power of the model increases when using data on real instead of nominal relative wages. The reason is that the model is by construction only able to explain nominal wage outcomes. We can, however, incorporate the different consumption patterns into the model and see how households behave and how the model performs. This is of particular interest when it comes to welfare outcomes as different consumption bundles lead to different ability-specific welfare changes.

The purpose of this chapter is twofold. First, in Section 6.1 we derive a measure for the real relative wage that fits our model context. We then apply this measure to actual data and evaluate the discrepancy between the real and nominal relative wages. Second, we extend the benchmark model accordingly in Section 6.2. Two new features are incorporated: the dependence of consumption expenditure on household ability as well as the presence of a non-tradables sector. Section 6.3 presents the model calibration and the simulation results. Furthermore, we derive the equivalent variation for this model extension.

6.1 Real Relative Wages

After deriving a measure for the (change in) the real relative wage in Section 6.1.1, we feed our equation with data in Section 6.1.2. The issue of different household types facing different rates of inflation has been addressed before, most notably by Michael (1979), Garner et al. (1996), and more recently by Hobijn and Lagakos (2005). Differentiation with respect to ability or skill, however, has not been done so far.

6.1.1 Formal Derivation of the Real Relative Wage

This subsection derives a measure for the real relative wage. We assume that the expenditure shares of tradables for skilled and unskilled households are ν_H and ν_L, respectively. For the time being, we assume that $\nu_H < \nu_L$. If households gain utility from consumption of tradables and non-tradables in a Cobb-Douglas manner, as we will model it in Section 6.2.1.1, the price indices faced by both household types are

$$P_H = (P^T)^{\nu_H}(P^N)^{1-\nu_H} \tag{6.1}$$

and

$$P_L = (P^T)^{\nu_L}(P^N)^{1-\nu_L}, \tag{6.2}$$

where P^T and P^N are the price indices of tradables and non-tradables, respectively. Denoting relative changes as hats, we get

$$\widehat{P}_H = \nu_H \widehat{P}^T + (1-\nu_H)\widehat{P}^N \tag{6.3}$$

and

$$\widehat{P}_L = \nu_L \widehat{P}^T + (1-\nu_L)\widehat{P}^N. \tag{6.4}$$

We define the real relative wage w_r as the relative wage adjusted by the corresponding price indices:

$$w_r = \frac{w_H/P_H}{w_L/P_L} = w \cdot \frac{P_L}{P_H}. \tag{6.5}$$

Therefore,

$$\widehat{w}_r = \widehat{w} + \widehat{P}_L - \widehat{P}_H. \tag{6.6}$$

Plugging (6.3) and (6.4) into (6.6) yields

$$\widehat{w}_r = \widehat{w} - (\nu_L - \nu_H)\big(\widehat{P}^N - \widehat{P}^T\big). \tag{6.7}$$

(6.7) can be interpreted as follows. According to our assumption, $(\nu_L - \nu_H) > 0$. Moreover, in terms of our endogenous-growth model, the second bracket must be greater than zero: we already explained why growth in our model is equivalent to price reductions (i.e., deflation) of tradables, and since non-tradables prices are constant (there are no non-tradables in our model) the difference of $\widehat{P}^N$ and $\widehat{P}^T$ must be positive. In fact, the model equivalent of $\big(\widehat{P}^N - \widehat{P}^T\big)$ is the growth rate of real GDP, which we have always referred to as g.

We will, however, check for two empirical specifications: the actual difference of $\widehat{P}^N$ and $\widehat{P}^T$ found in the data as well as data on g. If unskilled households devoted a higher share of their expenditure to tradables *and* the inflation rate of tradables was lower than that of non-tradables, unskilled households would benefit more from trade-induced price changes than skilled households. The change in the real relative wage would therefore be smaller than the change in the nominal relative wage. In other words: our measure of w employed so far would exaggerate the development of inequality. Whether this is actually the case is the topic of the next section.

6.1.2 Data on Real Relative Wages

Based merely on economic intuition, it is not clear which of the two goods types—tradables or non-tradables—are consumed to a greater extent when income increases and hence how expenditure shares react to changes in income. On the one hand, one could argue that tradables include items such as food and energy-related consumption (depending strongly on world commodity prices), and those items are essential, but consumption grows less than proportional (there is a natural limit to human food consumption and taking hot showers). This would imply a negative relationship between income (or skill) and the expenditure share spent on tradables.[2] On the other hand, one could produce the same argument for some non-tradables (such as housing), although the case based on anecdotal evidence is certainly much stronger for non-tradables. Therefore, although it seems plausible to assume a negative relationship between income and relative tradables expenditure, the nature of this relationship is not trivial and cannot be inferred on a purely theoretical basis.

We therefore have to take a look at actual data in order to find out about both the quality of the relationship as well as the magnitude we are talking about. Since we have dealt with European data so far it would be desirable to have European figures for the difference of interest, $(\nu_L - \nu_H)$. A database containing figures of household characteristics as well as some expenditure data for many OECD countries including the four countries we have been observing so far is the Luxembourg Income Study (LIS). The major caveat

[2] We abstract from the possibility of household saving and borrowing here, aimed at delaying or bringing forward consumption, respectively. Total household expenditure is treated as equal to household income. Note that saving and borrowing leads to a serious problem when taking either income or expenditure as a measure for the standard of living: in expenditure terms, the standard of living of two otherwise identical households is higher for the household that is borrowing money at the time of observation. In contrast, the income approach would state that both households enjoy the same standard of living. We just look at total consumption expenditure and do not care whether the money is borrowed or not (i.e., we do not care about future amortization and interest payments). Cp. Goodman and Webb (1996) for further investigation of the issue.

of the LIS data is, however, that expenditure figures classified by goods categories are of hardly any use for our purposes. For instance, the German data, taken from the German Socio-Economic Panel, contain expenditure figures only for food expenditure, rent, and ancillary costs related to housing, which account for only 40 percent of total income on average (there are no data on total expenditure). It is true that there are much more detailed expenditure data available for Germany by means of the sample survey of income and expenditure ("Einkommens- und Verbrauchsstichprobe"), but the shortcoming of that survey is less extensive data on household characteristics as we would require them. To make a long story short: instead of European data we apply data from the Consumer Expenditure Survey (CEX), gathered annually in the United States. It seems reasonable to assume that household preferences are very similar across industrialized countries—and preferences are the basis of the expenditure share differential. Hence, the CEX data are as good as any European data for our purposes. They have a major advantage: very detailed expenditure figures as well as many household characteristics collected.

In order to calculate $(\nu_L - \nu_H)$, two points have to be addressed in advance. First, how to differentiate between "unskilled" and "skilled" workers and second, how to distinguish "tradables" from "non-tradables." The degree of skill can be determined using the skill level of the household reference person.[3] The threshold we apply is the following: a household is "skilled" if the reference person is at least a high school graduate and unskilled otherwise; this comes close to our ISCED-based threshold applied to European data before. Using data from the first quarter of 2006, this means that 84.5 percent of all households are skilled.

Differentiating tradables from non-tradables is more challenging. There are hundreds of goods and services listed in the CEX data, ranging from expenditures on "nightware and loungeware" over "boat maintenance" to "private school bus transport." We only consider the figures for the top-level groups and in some cases use a finer grid. One method to check whether a good is tradable comes from Gregorio et al. (1994), defining a good as "tradable" if the export share of total production exceeds a certain threshold (10 percent in their case). They come to the conclusion that all goods considered are tradable, but none of the services. Since we have a much finer classification of services at hand than Gregorio et al. (1994), we take a somewhat different approach. Our tradables and non-tradables groups as well as their respective share in total expenditure are presented in Table 6.1.

[3] According to www.bls.gov/cex/faq.htm, "[t]he reference person of the consumer unit is the first member mentioned by the respondent when asked to 'Start with the name of the person or one of the persons who owns or rents the home.' "

Category	Tradable	Exp. Share (Skilled)	Exp. Share (Unskilled)	Exp. Share (Total)
Food				
Food at home	yes	0.123	0.180	0.132
Food away from home	no	0.039	0.026	0.037
Alcoholic beverages	no	0.009	0.005	0.009
Tobacco prod. and smoking supplies	no	0.009	0.016	0.010
Apparel	yes	0.021	0.018	0.020
Housing				
Shelter	no	0.225	0.237	0.227
Utilities				
Natural gas	yes	0.022	0.029	0.023
Electricity	yes	0.037	0.053	0.040
Fuel oils and other fuels	yes	0.005	0.007	0.005
Telephone services	no	0.031	0.040	0.033
Water	no	0.011	0.015	0.011
Household operations	no	0.017	0.009	0.016
House furnishings and equipment	yes	0.023	0.019	0.022
Education	no	0.020	0.003	0.017
Entertainment				
Fees and admissions	no	0.011	0.003	0.010
Televisions, radios, sound equipm.	yes	0.023	0.024	0.023
Other equipment and services	unclear	0.012	0.007	0.011
Reading	no	0.004	0.002	0.003
Transportation	yes	0.129	0.117	0.127
Health care	no	0.067	0.078	0.068
Personal care products and services	no	0.008	0.005	0.007
Personal insurance and pensions	no	0.116	0.078	0.110
Cash contributions	no	0.030	0.023	0.029
Miscellaneous expenditures	unclear	0.011	0.009	0.011
Sum		1.000	1.000	1.000
Tradables		0.394	0.454	0.403
Non-tradables		0.606	0.546	0.597

Table 6.1: Classification of Tradables and Non-Tradables. Source: own calculations based on CEX (2006).

In order to fully capture which part of a good's or service's price is influenced by trade and which is not, one would have to perform a very fine classification as well as an analysis of the cost of each industry. Apparel prices, for instance, stem partly from material cost, partly from labor cost, rent of the store etc. These different price components are tradable to a different extent in reality. For apparel as well as food consumed at home, however, we just assume that they are perfectly tradable—the idea here is rather to get a reasonable estimate of the expenditure shares than to perform a thorough industry analysis. Food consumed away from home (presumably in a restaurant, which is a service) is considered non-tradable. Alcoholic beverages and tobacco are subject to "sin taxes" that make up a large portion of the price, therefore they are considered non-tradables, too. Moreover, it is hardly possible to transport large amounts of these legal drugs across international borders. Shelter is non-tradable as well, but the picture for utilities is more differentiated: while water and telephone services are mainly local or national goods, the energy-related utilities are heavily influenced by international commodity prices. Household operations include services such as childcare and babysitting while house furnishing and equipments include tradable items such as furniture and appliances. Education is arguably a local good; entertainment is split between locally purchased fees and admissions and tradable electronic devices. Reading is probably mostly local due to language barriers. Transportation depends heavily on energy prices, thus we regard this as a tradable. Health care, insurance, and cash contributions can hardly be traded. Two groups are marked "unclear," so we attribute one half of those expenditures to tradables and the other half to non-tradables.

The differences in expenditure shares between skilled and unskilled households are quite remarkable for some goods. As expected, less skilled households spend relatively more on basic needs such as food at home, shelter, and utilities, but go less often to a restaurant, read less, go less often to a cinema or theater, have fewer babysitters, and are not as well insured against personal risks and poverty when old. The fact that skilled households spend a fraction about seven times as large as that of unskilled households on becoming more skilled (education) gives cause for serious concern. The problem is that since unskilled households do not make a serious effort to escape from poverty by investing in their own human capital, they will have a hard time escaping at all.

As one can see from the last two lines of Table 6.1, $(\nu_L - \nu_H) = 0.06$. This result is not only economically meaningful but also statistically significant: a t-test of difference in means reveals significance at the 1-percent level. For lack of alternatives, we assume that this difference does apply to European countries as well. In order to check for the magnitude of the price index effect according to (6.7), we need some data on the inflation differential, $\left(\widehat{P}^N - \widehat{P}^T\right)$. Different authors reach different conclusions: Gregorio et al. (1994) find values between zero (Canada) and 3.3 percentage points (Japan), with the United States and European countries between these two extremes; the period under consideration is 1970–85. By contrast, Hobijn and Lagakos (2005) find that between 1987 and 2002 poor households faced a slightly higher rate of inflation (about 0.1 percentage points on average) then non-poor households, which the authors mainly attribute to oil price fluctuations. A household qualifies as "poor" if its income is below the official Census Bureau poverty threshold. However, the authors do not explicitly state the expenditure share of the different household types with respect to the tradability of goods. The major difference between papers studying inflation differentials such as Hobijn and Lagakos (2005) and our approach summarized by (6.7) is that those papers make use of industry-specific (not tradability-specific) inflation data while we explicitly focus on the impact of trade on household-specific price indices.

The question remains: what is the best empirical equivalent of $\left(\widehat{P}^N - \widehat{P}^T\right)$ for our purposes? Recalling the commodity price explosion of the last few years, one could argue that tradables inflation is now higher than non-tradables inflation. The underlying idea of our endogenous-growth model—faster productivity growth in the tradables than in the non-tradables sector and hence a decline in the relative price of tradables—precludes the notion that $\widehat{P}^T$ might be greater than $\widehat{P}^N$, and the recently observed steep rise in commodity prices will certainly not last in perpetuity. Assuming a rather modest inflation differential of 1 percentage point yields the following result. The nominal wage rose by $1.44/1.37 - 1 \approx 5.1\%$ in six years (1992–98) while the price index effect amounts to $(\nu_L - \nu_H) \cdot (1.01^6 - 1) = 0.06 \cdot (1.01^6 - 1) \approx 0.37\%$. In order to arrive at the real relative wage, we have to subtract 0.37% from 5.1% from which we can conclude that the relative change in the real relative wage is about 93 percent of the relative change in the nominal relative wage. With a greater inflation differential of 2 percentage points, which is equal to our long-term growth rate g, we find that the relative change in the real relative wage is about 85 percent of the relative change in the nominal real wage. This is not a huge discrepancy but still confirms that it is worth distinguishing between real and nominal relative wages. Note, however, that the relative change in the real relative wage can easily become greater than the relative change in the nominal relative wage when tradable prices (mostly commodity prices) rise as steeply as between 2003 and 2008. Moreover, our calculations are based on the assumption that $(\nu_L - \nu_H)$ remains roughly constant over time.

6.2 A Simple Model Extension with Non-Tradables

The aim here is a set up a model that incorporates both households' ability-dependent consumption basket as well as non-tradables production and the respective changes in full-employment conditions. A common way to make the expenditure *share* of one good depend on the *level* of income are Stone-Geary preferences. Section 6.2.1 shows, however, that a Stone-Geary specification is not appropriate in the presence of economic growth in the tradables sector. Instead, we offer an alternative specification that suits our model context, namely expenditure shares depending on individual ability levels. Moreover, we present empirical evidence justifying our specific type of utility function. Section 6.2.2 discusses the entire model as well as its CGE formulation.

6.2.1 Household Preferences

6.2.1.1 Model Specification

The most straightforward approach to generate a negative relationship between income and the share of tradables consumed are non-homothetic preferences of the Stone-Geary type. One could simply assume that consumer utility stems from tradables consumption C^T and non-tradables consumption C^N:

$$U(C^T, C^N) = \nu \log(C^T - \bar{C}^T) + (1 - \nu) \log(C^N - \bar{C}^N), \tag{6.8}$$

where superscripts T and N denote tradables and non-tradables consumption while the bars represent subsistence levels of consumption; $0 < \nu < 1$. Maximizing (6.8) with respect to C^N and C^T subject to the budget constraint yields the expenditure spent on tradables as a share of total income M (which is assumed to be equal to total expenditure in this simple static view):

$$\frac{p^T C^T}{M} = \nu + (1 - \nu) \cdot \frac{p^T \bar{C}^T}{M} - \nu \cdot \frac{p^N \bar{C}^N}{M}. \tag{6.9}$$

Given that $(1-\nu)p^T \bar{C}^T > \nu p^N \bar{C}^N$, i.e., the (reversely weighted) subsistence consumption of tradables is greater than the subsistence consumption of non-tradables, the entire expression given by (6.9) depends negatively on M. Alternatively one could assume that there is no subsistence level of C^N. The result is the same: households with higher income devote a smaller fraction of consumption expenditure to tradables. From this one can infer that skilled households consume relatively more non-tradables, as we have seen in Section 6.1.2. The problem with Stone-Geary preferences is that expenditure shares depend on (real) income levels, which is a problem as income is constantly growing over time. As we require expenditure shares that are constant over time, we have to employ preferences of a different type.

The idea is to make expenditure shares depend on ability levels instead of consumption expenditure (or income). As we will demonstrate in Section 6.2.1.2, income and skill are closely related—which is of course the relationship key to any endogenous skill decision. To the best of our knowledge, this type of preferences does not occur in the literature yet. Using our old notation of q/N as the amount of tradable manufacturing goods consumed per capita (we dispense with time, quality, and goods indices here) and introducing Y/N as the amount of non-tradables consumed per capita, we can formulate household utility maximization as a trade-off between tradables and non-tradables consumption. Recall that according to (3.1)–(3.4), utility maximization takes place in three steps: allocating lifetime wealth across time, allocating expenditure at each instant across products, and allocating expenditure at each instant for each tradable product across available quality levels. We just add another step, namely allocation between tradables and non-tradables. The function to be maximized is again

$$U_\theta \equiv \int_0^\infty N_0 e^{-(\rho-n)s} \log u_\theta(s)\,\mathrm{d}s, \tag{6.10}$$

but we change instantaneous utility into

$$\log u_\theta(s) = \int_0^1 \log\Big[\sum_j \lambda^j q_\theta(j,\omega,s)\Big]\,\mathrm{d}\omega + \zeta\mu^\theta \log Y_\theta(s). \tag{6.11}$$

The term $\zeta\mu^\theta$ in (6.11) deserves some explanation. As demonstrated above, we have data on different combinations of θ and ν, thus we roughly know how a curve in the θ-ν-space looks like. When calibrating the model, two aspects of the data can be captured by our functional form, namely the level of ν for a given θ as well as the slope of the curve in the θ-ν-space, both of which can be roughly observed. $\zeta > 0$ governs the level while $\mu > 0$ governs the slope; $\zeta\mu^\theta$ is the elasticity of instantaneous utility with respect to Y. Formulating the dependence of utility on θ in this manner guarantees that expenditure shares do not reach extreme values for the extreme cases of $\theta = 0$ and $\theta = 1$, as we will see in a moment. Meanwhile, (6.11) implies two things. First, the higher a household's ability level θ the higher the utility gained from non-tradables consumption. People with a high θ value services higher: this preference specification may seem odd at first glance but we will try to justify it in Section 6.2.1.2. Second, services are a homogenous good, i.e., there is no continuum of services as it is the case for manufacturing goods.

The equation for expenditure spent on manufacturing goods remains unchanged:

$$c_\theta(s) = \int_0^1 \Big[\sum_j p(j,\omega,s) q_\theta(j,\omega,s) \Big] \, \mathrm{d}\omega, \tag{6.12}$$

but we have to change the budget constraint since expenditure is spent on both manufactures and services:

$$W_\theta(t) + Z_\theta(t) = \int_t^\infty N_0[c_\theta(s) + p_Y Y_\theta(s)] e^{ns} e^{-[R(s)-R(t)]} \, \mathrm{d}s, \tag{6.13}$$

where p_Y is the price of services and remains constant. Solving the optimization problem given by (6.10)–(6.13) yields $\dot{c}/c = \dot{Y}/Y = r(t) - \rho$ since $\zeta\mu^\theta$ cancels out when the equating the derivative of the Hamiltonian with zero. As we have considered the steady-state case of $\dot{c}/c = 0$ so far, $\dot{Y}/Y$ is zero as well, and the result of $r(t) = \rho$ remains unchanged. This result also becomes obvious from the simple reasoning that tradables and non-tradables are always consumed in the same proportion, thus their growth rates must be the same as well.

We assume that tradables and non-tradables are produced with a common skill intensity. The reason is straightforward: in the original model without non-tradables, tradables constitute the entire "production economy" (there simply is nothing else in the model). With tradables and non-tradables present, both of them now constitute the entire production economy; whether we let the skill intensities of goods and services production differ does not alter the fact that R&D remains the skilled-labor-intensive activity. Hence, introducing another parameter of service production yields no additional insight. Moreover, assuming that goods and services are produced with the same technology entails that the unit cost of service production is also one (recall that $A(w_L, w_H)$ is our numéraire). Together with the assumption of perfect competition in the service sector we find that the price of services p_Y is one, which is very convenient. Thus the trade-off between tradables and non-tradables can be expressed as maximizing

$$\log q + \zeta\mu^\theta \log Y \tag{6.14}$$

subject to total expenditure $M = \lambda q + Y$. The Marshallian demands are

$$q = \frac{M}{\lambda(1+\zeta\mu^\theta)} \quad \text{and} \quad Y = \frac{\zeta\mu^\theta M}{1+\zeta\mu^\theta}, \tag{6.15}$$

which yields expenditure shares ν and $1-\nu$ of tradables and non-tradables, respectively:

$$\nu = \frac{\lambda q}{M} = \frac{1}{1+\zeta\mu^{\theta}} \quad \text{and} \quad 1-\nu = \frac{Y}{M} = \frac{\zeta\mu^{\theta}}{1+\zeta\mu^{\theta}}. \tag{6.16}$$

(6.16) has the advantage that expenditure shares are independent of income levels. Instead, ν depends negatively on θ. Both tradables and non-tradables will therefore be produced in the long run. Moreover, since θ is bound to $[0,1]$, the tradable share ν is bound to $[1/(1+\zeta\mu), 1/(1+\zeta)]$, which avoids extreme values of ν, as would be the case if θ entered in a multiplicative rather than exponential fashion into the utility function.

6.2.1.2 Empirical Justification

Our goal here is to justify an expenditure share of tradables that is decreasing in the household ability level but independent of household income, as modelled in Section 6.2.1.1. If the model were correct, a regression using both skill and income as explanatory variables for the expenditure share of tradables would deliver the result that income becomes insignificant while skill remains highly significant. Unfortunately, this is not the case, but we can nevertheless perform some regressions pointing out that our preferences may be justified.

We use five different regressors; the dependent variable is always the expenditure share spent on tradables (cp. Table 6.2 for our regression results). The first regressor is the log of household income as reported in the Interview Survey of CEX (2006). Only complete income reporters are part of our sample. Second, we include the degree the reference person has attained, serving as a proxy for the ability level of the household. There are nine levels of educational attainment: "never attended school," "first through eighth grade," "ninth through twelfth grade (no high school diploma)," "high school graduate," "some college, less than college graduate," "associate's degree (occupational/vocational or academic)," "bachelor's degree," "master's degree," and "professional/doctorate degree." Not surprisingly, a skilled/unskilled dummy performs worse than the degree itself. Third, we examine the interaction effect of income and skill.

	I	II	III	IV	V	VI	VII
log(income)	-0.0240*		-0.0166*	-0.0053	-0.0217*	-0.0148*	-0.0199*
	(-11.93)		(-8.14)	(-0.34)	(-10.40)	(-7.20)	(-9.47)
degree		-0.0231*	-0.0197*	-0.0107	-0.0269*	-0.0191*	-0.0163*
		(-15.77)	(-13.06)	(-0.84)	(-11.14)	(-12.68)	(-10.74)
log(income)×degree				-0.0009			
				(-0.72)			
household members					0.0152*		0.0154*
					(9.69)		(9.84)
population size						-0.0099*	-0.0102*
						(-5.73)	(-5.97)
R^2	0.0385	0.0657	0.0825	0.0826	0.1061	0.0908	0.1149
Standard error	0.1502	0.1481	0.1467	0.1467	0.1448	0.1461	0.1441

Table 6.2: Determinants of Tradables Expenditure Shares. Source: own calculations based on CEX (2006). Dependent variable: expenditure share spent on tradables. Number of observations in all regressions: 3558. t-values are in parentheses. '*' indicates significance at the 1-percent level. Intercept coefficients are suppressed.

Fourth, we include the number of household members as an explanatory variable to account for an equivalence-scale-like effect: economic needs change with household size, based on the fact that there are substantial economies of scale when sharing a common house, car, refrigerator etc. We also checked for alternative specifications incorporating this effect, namely the number of children or the marital status of the reference person, but those indicators are outperformed by the number of household members. Fifth, we include population size as an indicator for a household's location: life in a big city is likely to generate other consumption patterns than life in a small village. Population size is stated as being in one of five categories: "more than 4 million inhabitants," "1.20–4 million," "330,000–1.19 million," ""125,000–329,999," or "less than 125,000." We checked for a rural/urban dummy as well, but that was outperformed by the population size group.

The results presented in Table 6.2 are based on plain OLS regressions. As a preliminary check we ran a regression where income is explained by educational attainment alone (not in the table): with each additional degree attained, income increases by about 20 percent, which is a highly significant result, as expected. It does therefore not come as a surprise that both income and skill explain expenditure shares almost equally well (regressions I and II): for each percent more income earned the expenditure share decreases by about 0.024 percentage points on average (not 2.4 percentage points) while each additional degree attained decreases the share by about 2.3 percentage points. R^2 is a little higher for the skill specification, although R^2 values in general are quite small. Using both regressors as explanatory variables does hardly change this result (regression III) since both of them remain significant, although skill performs slightly better in terms of its t-value. Thus, regression III shows that there must be some other variable that governs expenditure shares apart from income—this other variable is what we assume to be skill, proxied by educational attainment, although the degree attained is certainly not truely exogenous and likely to depend on household income, parents' income, and other factors.

The interaction specification (regression IV) is the only one without any significant results. If the coefficient of the interaction term were significant we would have the following interpretation: a higher income (skill) level makes the negative impact of skill (income) on the expenditure share even greater. In other words: when comparing two households earning the same income (having the same skill level), an increase in skill (income) decreases the expenditure share. However, there is no such interaction effect, thus we have not advanced in terms of our original question, namely whether income or skill is a better predictor for the expenditure share.

Regression V, including the number of household members, shows that more household members lead to relatively more tradables consumption. The reason is that fixed costs such as rent or telephone services can be split between household members while tradable goods such as food or apparel have to be purchased for each single household member. For instance, single-person households spend 10 percent of total expenditure on food at home while four-person households spend 13 percent. The numbers for shelter are just the opposite (25 and 21 percent). Each additional member increases the expenditure share by about 1.5 percentage points on average.

When including population size we find that each additional step on the population size ladder decreases the expenditure share by about 1 percentage point. This is mostly due to the fact that rents are higher in big cities: expenditure spent on shelter amounts to 26 percent in the biggest agglomeration category (more than 4 million inhabitants) while the figure is only 16 percent for the smallest (less than 125,000). The numbers for transport expenditure shares are the mirror image of that: while inhabitants of the biggest cities spend 13 percent on transport, small-towners spend 15 percent since commuting distances are presumably larger. The last specification (regression VII) incorporates both household members and population size, demonstrating that each of the two variables alone has some explanatory power since both coefficients remain significant.

Our seven specifications include three person-specific variables, namely skill, the number of members the person decides to live with (thus often also the number of children a person has), and the size of the agglomeration the person lives in. These are all variables related to an individual's or household's specific characteristics, and all three variables perform well in terms of explaining the expenditure share spent on tradables. In our model all these characteristics are captured by a single variable, namely θ, which can be interpreted as an index of personal (or household) characteristics. For instance, one could argue that more skilled people live in big cities since due to their greater mental capacity, they recognize the benefits of big agglomerations more easily.[4] It is true that income performs similarly well, but never better; if anything, the performance of income is worse than of skill. Most likely it is impossible to find a specification that totally denies the impact of income on expenditure shares. However, given the results obtained here, we consider it justified to model household preferences the way we do, considering θ as an index of household characteristics.

[4] In fact, the impact of skill on the size of the agglomeration where the household is located is positive and highly significant, controlling for household income. This observation might also be due to the fact that specialized skills are more valuable in metropolitan areas where there is a density of other workers with complementary skills, as is the case for technology clusters such as Silicon Valley.

6.2.2 The Model with Non-Tradables

We will now derive the modified full-employment conditions, their impact on the relationship between trade liberalization and the relative wage as well as the modified welfare measures.

6.2.2.1 Production of Non-Tradables

As noted above, services are produced with the same skill intensity as tradables and thus cause a unit cost of $A(w_L, w_H) = 1$. With perfect competition in the service sector, the price of services is one as well. Analogously to manufacturing production per capita, q/N, we consider service production per capita, Y/N. The per capita full-employment conditions (3.29c) and (3.29d) are replaced by

$$\theta_0 = A_L(w_L, w_H)\frac{q}{N} + A_L(w_L, w_H)\frac{Y}{N} \tag{6.17}$$

and

$$\frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) = A_H(w_L, w_H)\frac{q}{N} + A_H(w_L, w_H)\frac{Y}{N} + B_H(w_H)Ik, \tag{6.18}$$

where q/N is determined exactly as in (3.26), namely as $q/N = B(w_H)(\rho + 2I - n)\Psi(\tau)k$. Going back to the optimal consumption decision in (6.15), we can write Y/N as

$$\frac{Y}{N} = \frac{q}{N} \cdot \lambda\zeta\mu^{\bar{\theta}} = c \cdot \zeta\mu^{\bar{\theta}}, \tag{6.19}$$

where $\bar{\theta} = 0.5$ is the average household ability level. (6.19) implies that the expenditure share spent on tradables remains constant.[5] We use $\bar{\theta}$ in (6.19) when determining the aggregate tradables share $\bar{\nu}$. Note that this is an approximation. In order to determine the exact value of Y/q one would have to calculate the non-trivial integral over the expenditure shares of all households. However, since the curve of $\nu(\theta)$ on $[0, 1]$ is almost a straight line with a very slight bend, using $\nu(\bar{\theta})$ as a proxy for $\bar{\nu}$ is an appropriate course of action.

[5] What we neglect here is the fact that a decrease in θ_0 due to trade liberalization has an impact on the proportion of economy-wide spendings that is spent by households with ability below θ_0^0 (the skill threshold before the shock). Once skill upgrading has taken place, households with ability between θ_0^1 (the lower skill threshold after the shock) and θ_0^0 earn a higher wage than before. Since their ability and hence their preferences remain unchanged, relatively more tradables are consumed. Therefore, the average tradable expenditure share $\bar{\nu}$ is decreasing in θ_0. The impact of this reasoning is probably quantitatively negligible as only a small fraction changes its skill level at all, so we do not follow up on this any further.

As economic intuition would suggest, the service sector protects workers from the impact of trade liberalization, which dampens the rise in wage inequality.[6] The higher the relative weight of non-tradables the smaller the impact of trade liberalization on the relative wage. Since non-tradables have a weight greater than zero the impact of trade liberalization must be smaller than in the benchmark model. Furthermore, the mere presence of the non-tradables sector draws away resources from the R&D sector, which implies that the latter is smaller than in the benchmark model. Therefore, starting from a smaller basis, the relative increase in the size of the R&D sector is greater than in the benchmark model once resources are shifted from the tradables and non-tradables sector to the the R&D sector.

6.2.2.2 CGE Formulation

A new variable has been introduced, Y/N, which necessitates a new equation, namely (6.19). The endogenous variables are w_H, w_L, I, and θ_0. The system consists of (3.12), (3.8), (6.17), and (6.18) and looks as follows:

$$A(w_L, w_H) = w_L^a w_H^{1-a} = 1, \tag{6.20a}$$

$$\theta_0 = \varsigma \frac{w_L}{w_H} + \gamma, \tag{6.20b}$$

$$\theta_0 = A_L(w_L, w_H) B(w_H)(\rho + 2I - n)\Psi(\tau)k \cdot \left(1 + \lambda\zeta\mu^{0.5}\right), \tag{6.20c}$$

$$\begin{aligned} \frac{\phi}{2}(\theta_0 + 1 - 2\gamma)(1 - \theta_0) &= A_H(w_L, w_H) B(w_H)(\rho + 2I - n)\Psi(\tau)k \cdot \left(1 + \lambda\zeta\mu^{0.5}\right) \\ &+ B_H(w_H) Ik. \end{aligned} \tag{6.20d}$$

6.2.2.3 Welfare

The welfare measure is different from the one in the benchmark model since there is an additional sector now. Analogously to (3.35) we can derive a closed-form solution for

[6] The idea of protection by means of a non-tradables sector is also pursued by Askenazy (2005), albeit in a North-South model of endogenous growth. He obtains the result that trade liberalization can lead to a decrease in wage inequality; this stems from his assumption of decreasing returns to scale for R&D (our production functions exhibit constant returns to scale for all activities). Moreover, Askenazy (2005) does not deal with endogenous skill supply.

dynastic utility (6.10):

$$U_\theta = \frac{1}{\rho - n}\left(\log c - \log \lambda + \log(1 + \tau/2) + \zeta\mu^\theta \log \frac{Y}{N} + \frac{g}{\rho - n}\right). \tag{6.21}$$

Due to the Cobb-Douglas utility specification, we have constant expenditure shares $Y/N = c \cdot \zeta\mu^\theta$, which can be plugged into (6.21). Again we are looking for the value c^* that generates the same utility under g^0 that c^1 generates under g^1 and we find

$$c^* = c^1 \cdot \exp\left[\frac{g^1 - g^0}{(\rho - n)(1 + \zeta\mu^\theta)}\right] = c^1 \cdot \exp\left[\frac{\nu(\theta)(g^1 - g^0)}{\rho - n}\right], \tag{6.22}$$

which gives us the relative equivalent variation:

$$EV^R \equiv \frac{c^*}{c^0} - 1 = \frac{c^1}{c^0} \cdot \exp\left[\frac{\nu(\theta)(g^1 - g^0)}{\rho - n}\right] - 1. \tag{6.23}$$

It does not matter whether we define EV^R in terms of tradables or non-tradables expenditure since both are proportional. EV^R is ceteris paribus smaller than in the benchmark model since $\nu(\theta) < 1$. The reason is that the economy reaps only part of the benefits from real income growth as only the tradables sector grows.

Deriving the ability-dependent equivalent variations is straightforward now (cp. Section 3.1.8). The budget constraint for skilled households is

$$e^{-(\rho-n)T}(\gamma - \theta)w_H = c + \frac{Y}{N} = c \cdot \left(1 + \zeta\mu^\theta\right), \tag{6.24}$$

where $(1 + \zeta\mu^\theta)$ cancels out when computing the ratio of wage earnings before and after the shock. The three measures amount to

$$EV_H^R = \frac{w_H^1}{w_H^0} \cdot \exp\left[\frac{\nu(\theta)(g^1 - g^0)}{\rho - n}\right] - 1, \tag{6.25}$$

$$EV_L^R = \frac{w_L^1}{w_L^0} \cdot \exp\left[\frac{\nu(\theta)(g^1 - g^0)}{\rho - n}\right] - 1, \tag{6.26}$$

and

$$EV_{LH}^R = \frac{e^{-(\rho-n)T}(\theta - \gamma)w_H^1}{w_L^0} \cdot \exp\left[\frac{\nu(\theta)(g^1 - g^0)}{\rho - n}\right] - 1. \tag{6.27}$$

Note that the θ-values employed to calculate (6.25), (6.26), and (6.27) are different from each other: as opposed to the benchmark model, all three ability-dependent welfare measures depend on θ (whereas this was the case only for EV_{LH} before).

6.3 Model Calibration and Simulation Results

6.3.1 Model Calibration

Compared to the benchmark model, two new parameters are introduced, namely μ and ζ, governing the impact of non-tradables consumption on household utility. What we need for calibration of μ and ζ are different levels of empirical expenditure shares as calculated in Section 6.1.2. We take the following approach: two points on the θ-ν-curve are known at least approximately from Section 6.1.2, namely the θ-ν-combination for the average unskilled household, $(\theta_1, \nu_1) = (\theta_0/2, 0.454) = (0.145, 0.454)$, as well as for the average skilled household with an ability level of $\theta = \theta_0 + (1-\theta_0)/2 = 0.645$ and a corresponding point of $(\theta_2, \nu_2) = (0.645, 0.394)$.[7] We can calculate our two unknown model parameters since we have two points at hand. Rearranging (6.16) yields

$$\zeta = \frac{1/\nu_1 - 1}{\mu^{\theta_1}} = \frac{1/\nu_2 - 1}{\mu^{\theta_2}}. \tag{6.28}$$

Solving (6.28) for μ leads to

$$\mu = \left(\frac{1/\nu_2 - 1}{1/\nu_1 - 1} \right)^{\frac{1}{\theta_2 - \theta_1}}. \tag{6.29}$$

(6.29) can be inserted into (6.28) to obtain

$$\zeta = \left[\frac{(1/\nu_1 - 1)^{\theta_2}}{(1/\nu_2 - 1)^{\theta_1}} \right]^{\frac{1}{\theta_2 - \theta_1}}. \tag{6.30}$$

Plugging ν_1, ν_2, θ_1, and θ_2 into (6.29) and (6.30) gives the slope parameter as $\mu = 1.636$ and the level parameter as $\zeta = 1.120$. The values obtained for μ and ζ imply that the elasticity of non-tradables consumption with respect to utility is $\zeta\mu^{\bar{\theta}} = 1.432$ for the average household. Model parameters differing from the benchmark model are listed in Table 6.3.

The functional form assumed is therefore $\nu(\theta) = 1/(1 + 1.120 \cdot 1.636^{\theta})$, which implies that ν ranges between 0.353 for the most skilled household and 0.472 for the least skilled one, with a slightly convex curvature of $\nu(\theta)$ between these two extremes. Comparing this to actual expenditure shares of very skilled and hardly skilled households yields

[7] Alternatively, we could have taken the start and the end point of the θ-ν-curve, but extremely unskilled and skilled households are very few in number in our sample, therefore the figures for those two extreme points are probably not representative.

Variables			Parameters		
θ_1	0.145	de Grip and Nekkers (2001)	a	0.223	(calibrated)
θ_2	0.645	de Grip and Nekkers (2001)	k	0.636	(calibrated)
ν_1	0.454	CEX (2006)	μ	1.636	(calibrated)
ν_2	0.394	CEX (2006)	ζ	1.120	(calibrated)

Table 6.3: Calibration of the Model with Non-Tradables. Notes: All variables are for the initial year (1992). Variables and parameters not listed have not changed compared to the benchmark model.

that our figures are reasonable; the function performs sufficiently well for a wide range of θ-values.

6.3.2 Simulation Results

Once the model has been calibrated we can run our standard simulation, decreasing trade costs by 2 percentage points; the results are displayed in Table 6.4. As derived in Section 6.2.2, the impact of trade liberalization must be smaller than in the benchmark model due to the presence of a service sector that protects unskilled workers from international competition. The model behavior is qualitatively the same as in the benchmark model. Meanwhile, the growth rate changes by more than in the benchmark model since innovating is less expensive due to a lower relative wage. Note that both production volumes (q/N and Y/N) have decreased, but each one alone by less than q/N decreased in the benchmark model, which is a logical result of the fact that both sectors shoulder the effect of trade liberalization now. As both volumes are proportional, their relative changes must be the same.

EV is calculated with ability $\bar{\theta} = 0.5$, which is a good approximation, as argued above. In order to determine the welfare measures EV_H, EV_L, and EV_{LH}, we use abilities $\theta_0^0 + (1 - \theta_0^0)/2 = 0.645$, $\theta_0^0/2 = 0.145$, and $(\theta_0^0 + \theta_0^1)/2 = (0.29 + 0.2982)/2 = 0.2896$, respectively (again good approximations due to nearly linear behavior of $\nu(\theta)$ on $[0, 1]$). The welfare increases are smaller than in the benchmark model because only a fraction of the benefits from trade liberalization are realized (in the form of an increased growth rate) as not all goods are tradable. As opposed to the benchmark model, however, unskilled households benefit more than skilled households on the long run. This is a quite remarkable finding: despite their declining nominal wage, they gain more in welfare terms than skilled households due to their tradables-prone consumption pattern. Now it becomes obvious why the chapter title is “Challenging the Trade-Inequality Link”: in welfare terms, the relative position of unskilled households is improved ($EV_L^R > EV_H^R$),

Variable	$\tau = 0.145$	$\tau = 0.125$	Relative Change [%]
w_H			0.02
w_L			-0.08
w	1.37	1.3713	0.10
θ_0	0.29	0.2892	-0.29
g	0.02	0.0220	10.05
q/N			-0.37
Y/N			-0.37
EV			3.63
EV_H			3.86
EV_L			4.36
EV_{LH}			11.99
$\bar{w}$			0.01

Table 6.4: Simulation Results for the Model with Non-Tradables. Parameter values: $D = 45$, $T = 4.25$, $n = 0.00378$, $\rho = 0.0248$, $\lambda = 1.2$, $k = 0.636$, $\gamma = -0.567$, $a = 0.223$, $\mu = 1.636$, $\zeta = 1.120$.

which is a result contrary to the benchmark model and contrary to the line of argument of the pertinent literature. Note, however, that this finding depends crucially on interpreting $g = 0.02$ as the *difference* in productivity growth rates in the tradables and non-tradables sector (the non-tradables sector does not contribute to economic growth here). Employing a different value for g might as well reverse our result.

Moreover, one could argue that g should rather be interpreted as the total growth rate of the economy instead of the growth rate of the tradables sector alone. Given that the tradables and non-tradables sector are of roughly the same size, the total growth rate g can roughly be calculated as the mean of both sectoral growth rates. Since the non-tradables sector stagnates by assumption, the tradables sector must grow at about 4 percent per year to yield a total growth rate of 2 percent. With this altered interpretation of g, the ratio EV_L^R/EV_H^R might be affected in either direction. Alternatively we could introduce exogenous growth in the non-tradables sector since non-tradables do experience economic growth in reality, wherever it may stem from. Again the ratio of welfare gains is likely to change, although it is not clear how the outcome will be affected.

This simple model results in a decline of non-tradables production. In the real world, of course, the service sector did not shrink but expanded both in absolute and in relative terms. But even if we had made different assumptions about the production of services (by employing different skill intensities, for instance), both the manufacturing and the service sector would have shrunk in this model, given that we sticked to the crucial assumption that R&D remains the skilled-labor-intensive activity.

Chapter 7

Conclusion

By assumption, relative goods prices are unaffected by trade liberalization in our model, and the relative wage increases only because R&D becomes more profitable. In the presence of unemployment, the relative wage of those who still have a job declines since the increase in unemployment decreases effective labor supply. The unemployment-adjusted relative wage, however, still declines unambiguously. Concerning these two model variants, our contribution was to put them on a common foundation, make them "CGE-ready," apply them to real-world data, and interpret the results. Moreover, in some cases abstract functional forms had to be concretized sensibly, which again yielded parameters that demanded an interpretation. In addition, we have determined the counterfactual changes necessary in order to reflect reality and therefore established ballpark figures of how much trade and how much (trade-independent) technological change as well as organizational or institutional change would have to take place. The qualitative finding that trade liberalization widens the wage gap as well as the quantitative result of the empirical literature that the impact of trade is rather small are confirmed. Integrating the empirical finding that unskilled households consume relatively more tradables into the model shows that the role of international trade in wage determination might be even less prominent.

Apart from these empirical and practical issues, this dissertation has a share in some new theoretical insights. Concerning the model with unemployment, we have introduced a parameter that can be interpreted as representing organizational change when shocked. Moreover, we have identified another parameter that governs institutional change. We therefore have drawn a line between the trade-based and the organizational/institutional-change-based explanation for rising wage inequality. Concerning the model with horizontal FDI, we have isolated a mechanism novel to this type of models. As falling trade costs make horizontal FDI less attractive due to a decreased incentive to avoid them, the impact of falling trade costs on the relative wage is ceteris paribus smaller in the presence of FDI (but qualitatively necessarily the same). In order to account for realistic changes in FDI, a second trade friction parameter had to be introduced, namely the cost of FDI. A combined decrease in both trade friction parameters leads to a stronger increase in the relative wage. Hence, the trade-based explanation of rising wage inequality gains some more weight.

Trade liberalization explains only a small fraction of increasing wage inequality in our model. Simulating technological change or institutional reform, however, reveals that the models are apt to reproduce real-world outcomes. In reality, these phenomena are closely related to trade, therefore the trade explanation is probably much more important than suggested by our simulations. It is difficult, however, to quantify the impact of each channel resulting from repercussions of trade and the various other possible explanations. An important contribution of this dissertation is to isolate at least some possible effects and determine their relative importance.

The reasons for the small fractions explained are manifold. First, there have certainly been many other channels at work than the one described by our Schumpeterian growth model through which trade and skill-biased technological change interact. Those include the impact of market size on technology or the role of defensive innovation and have already been discussed in our literature review. Second, a fact that is often neglected is that even between Northern countries, a large portion of FDI is vertically motivated (cp. Alfaro and Charlton (2007)). This means that a share of the North-North trade volume is due to international outsourcing, which is not part of this model. Fragmentation of production between Northern countries may not seem reasonable at first glance, but given that no two countries in the world are identical, some advantage abroad is very likely to exist, for instance in the form of different skill distributions across countries, as already argued. This can have effects on the wage distribution we have not taken into account. Third, as found by Maurin et al. (2002), the very act of exporting requires skill (product development and marketing in particular). Exported goods are often more skill-intensive than nontradables. Fourth, institutional change may have played an important role. As already mentioned, trade union density declined in Europe, therefore the interaction of institutional change, technological change, and trade liberalization should have led to a considerable rise in the skill premium. Fifth, influences from outside our four-country world have been ignored, in particular the impact of newly industrializing countries such as China and India. Given their enormous growth rates and increasing economic power, they play an important role in global wage determination.

The model with non-tradables has revealed a new channel through which unskilled households benefit from trade liberalization: not only do they gain from trade liberalization in the long run but their gains are even greater than for skilled households since unskilled households consume relatively more tradables. Moreover, the weight of non-tradable services in every economy protects many unskilled workers from the negative effects globalization has on their wages. Trade liberalization does not only induce workers to become skilled by increasing the skill premium but also indirectly supports them in doing so by offering ever cheaper tradables especially to the unskilled, leaving them more resources to invest in their education.

There are some policy implications that follow from this dissertation. Trade liberalization may harm unskilled workers, but only in a level sense, not in terms of income growth. In the long run, all skill groups benefit from trade liberalization as the growth rate of their real income outweighs possible losses from decreased nominal wages. Moreover, anecdotal media reports on the impact of globalization on the wage structure may be exaggerated. Although the model hugely simplifies reality and is highly stylized, it reflects important aspects of the real world, as we have argued. What seems to be much more relevant is the increase in unemployment due to globalization, being an equally favored topic of media coverage. Obviously, technological change, be it induced by trade liberalization or not, destroys jobs, especially those of unskilled workers, but creates new jobs by the same token—this is the very idea of progress through "creative destruction." It is reasonable to assume unskilled workers to suffer more from the fear of becoming unemployed than from the discrepancy between their own wage and the income of skilled workers. Accelerated by the forces of globalization, institutional reform has a great potential to decrease unemployment. From this perspective, trade liberalization has the potential to make both groups better off, given that governments react accordingly—skilled workers in terms of wages, unskilled workers in terms of job security, given sensible labor market policy.

Introducing or increasing minimum wages, making hiring and firing more costly to firms, or hampering temporary employment is very unlikely to be an adequate measure to dampen the impact of globalization on the (unemployment-adjusted) relative wage. Our increasingly technology-oriented world is destined to pay ever higher premia to skill—at least if skill supply reacts as slowly as it has in the past. Any attempt to stop this development by artificial means will prevent an economy from reaping the full benefits of globalization in the form of technology diffusion or increased sales opportunities abroad. Making politics against the market does to seem to be a good idea. Furthermore, like all price changes in a market economy, an increase in the relative wage is the most important indicator for scarcity of skilled labor—without an increase in the relative wage households would hardly know that being skilled is an increasingly demanded quality.

Social unrest due to an increasing wage gap uttered by means of demonstrations or strikes is certainly detrimental to a country, both in terms of living quality and attractiveness as a business location. Economic policy may be able to decelerate the effects of globalization on the surface, accepting more unemployment to avoid higher skill premia. On the long run, however, the social costs of increased unemployment due to lacking labor market flexibility probably outweigh the disutility from envy[1] and the feeling to be treated unjustly. Moreover, the incentives resulting from greater inequality are not clear: either low-income workers are motivated to be more ambitious or they have the feeling that it becomes increasingly tougher to keep up with their high-income colleagues, making them less confident of their own future and therefore less productive. Technological change creates new jobs in the same breath as it destroys them. The only insurance against becoming a loser from globalization is to acquire skill. In this sense, this dissertation underlines a commonplace of economic policy: education is a necessary condition for a developed country to gain from international trade in the long run.

There are different directions for future research. As seen in the counterfactual simulations, relatively small changes in the share of unskilled labor used in production (parameter a) have a considerable impact on the skill premium. It would therefore be interesting to endogenize a. With more skilled labor used in production when trade is liberalized, the effect of globalization would presumably be stronger. The literature review has presented many channels of a possible connection between trade and technological change, apart from the one our models already apply. Moreover, a large portion of total FDI has been neglected as we assumed trade cost savings to be the sole motivation for FDI. Therefore, vertical motives in a North-South model or an extension where firms intentionally reap knowledge spillovers by performing FDI in a country they can learn from will probably give more weight to the trade explanation.

[1]Early attempts to incorporate envy into welfare considerations include Varian (1974) or Feldman and Kirman (1974). The latter define a “fair” (i.e., envy-free) allocation as one without any individual preferring someone else’s situation over his own. They argue that, unlike efficiency, fairness “has no automatic enforcers” (p. 1004).

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Education

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University of Kiel, 10/2003 to 03/2006
Master's studies of economics ("Diplom")
Erich Schneider faculty prize for best master's degree in 2006
Erich Schneider faculty prize for best master's thesis in 2006

Stockholm University, 08/2004 to 12/2004
Master's studies of economics (ERASMUS exchange program)

University of Hamburg, 04/2002 to 09/2003
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AIESEC, largest international student organisation, 10/2003 to 08/2005

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