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Four Essays on the Impact of Institutions, Technological Change, and Globalization on Labor Market Outcomes

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Chapter 1

Introduction

A great part of humanity participates about half of its lifetime in the labor market. The reasons are manifold: first, it may be argued from a social and psychological perspective that individuals achieve one's full potential through the participation in the labor market and that the feeling to be needed strengthens the intrinsic motivation, self-satisfaction, and self-esteem.[1] Further, there is a bulk of literature showing that a spell of unemployment will lead to a systematically lower life satisfaction even after several years (for an overview, see Clark, 2006; Clark et al., 2008; Clark & Georgellis, 2013; J. M. Bauer et al., 2015; Neve & Ward, 2017).[2] Second, the participation in the labor market and especially the performance therein constitutes individuals' wealth, mainly due to wage payments, and enables a certain degree of freedom. It decides which type of goods and services individuals can afford to consume, if they can rent a flat or a house, or wether or not they are able to possess a house on their own, if they are able to go on vacation and where they are able to

[1]It is meanwhile acknowledged by economists that psychological factors play a role in the incentivisation of workers. Many workers do not only care about their own wage payment, but also on how much their peers receive. Further, reciprocity, responding to a perceived positive action with another one to reward kind actions, shapes individuals' utility (for an overview, see e.g., Fehr & Falk, 2002; Sobel, 2005; Falk & Fischbacher, 2006). Lastly, altruism, implying that the well being of an individual depends positively on the well being of others, is used to explain charitable donations and volunteering (see Becker, 1974).

[2]The paper of J. M. Bauer et al. (2015) evolved out of a seminar paper I wrote together with a colleague during my studies.

go an vacation, which schools their children attend, and so forth (see Borjas, 2013). Thus, it becomes evident that the labor market outcomes of individuals, such as the employment prospect and wage payments, determine their well-being and their life to a great amount. On top of that, it can be argued that a well-functioning labor market, where as many people as possible participate in and where a more or less fair income distribution may be realized, is also of interest for politicians and societies as a whole, since economic growth and social harmony crucially depend on these things. This makes it clear, why not only labor economists, but also non-labor economists and the general public should be interested in the functioning of labor markets. Especially recent years have shown that the traditional configuration and functioning of labor markets comes under pressure. While this thesis can certainly not address all of the issues that are playing a role in shaping labor markets, several important phenomena are studied to analyze how these affect the labor market outcomes of individuals. These are:[3]

- How does the coordination of unions at the firm level depend on the degree of product differentiation and how does it affect the wage rate of workers?
- How does a deregulation of temporary agency employment affect the employment structure in an economy?
- Will low-skilled workers lose their job due to automation?
- What are the effects of low-skilled immigration?

While the first two questions reveal how a change that is brought up by institutions affects several labor market outcomes, the third topic deals with an issue of technological change and the fourth one with an important aspect of globalization.

To be more precise, the impact of institutions and in particular collective bargaining has been on the agenda of labor economists for decades. However, the feature of multi-unionism is less considered. Multi-unionism describes the presence of two or more labor

[3]Next to the examined issues in this thesis, there are a lot of other interesting policy issues labor economics are dealing with, such as the effects of offshoring, the impact of introducing a minimum wage on the unemployment rate of low-skilled workers or the optimal design of the unemployment benefit system in order to reduce the duration of unemployment.

unions at the firm level. In Germany, June 23, 2010 served as and important day for labor union policy, since the principle of tariff unity was abolished.[4] From this day forward it has been allowed that various tariff agreements for different occupational groups can coexist within a firm, even if they only apply to a minority of workers within that firm. As a consequence, the incentive for occupational groups to form craft unions and to achieve independent tariff agreements raised rapidly, which resulted in a couple of strikes in the aviation industry and the rail transport. Subsequently, in 2015 the government passed the Federal Act on Tariff Unity (*Gesetz zur Tarifeinheit*, BGBl. I, 1130), which amended § 4a of the Collective Bargaining Agreement Act (*Tarifvertragsgesetz*) and regulates that only one contract is valid within a firm, when unions are representing the same occupational group, namely the tariff agreement of the union that represents more members of the particular occupation group. In view of this new law, the rail transport was marked by a wave of strikes and by the longest strike in the history, as the smaller craft union continuously tried to defect members from the larger industry union.

A second institutional change was conducted by governments in the last couple of decades in the European Union due to the deregulation of temporary agency employment. Temporary agency employment is one form of an atypical employment relationship and involves three parties: a worker that is employed at a temporary employment agency that acts as an intermediary and lends the worker to a client firm, where the worker is used for production. Both sides, employers and employees have an incentive to engage in temporary agency employment. From the employers' side it can be argued that the use of temporary agency employment leads to saving costs and increasing profits, e.g. since the employment protection of temporary agency workers is rather week (see, e.g., Jahn & Weber, 2016). Further, the use of temporary agency workers allows firms to adjust their work force very easily in production peaks or in a period with a lack of orders (see Houseman, 2001; Ono & Sullivan, 2013; Baumgarten & Kvasnicka, 2017). From the perspective of the worker, it may be argued that especially young workers and students hire at a temporary employment agency in order to obtain diversified labor market experience in a short time, and thereby raise their attractiveness for future employers (see Crimmann et

[4]See, Federal Labour Court (*Bundesarbeitsgericht*), decision from June 23, 2010 – 10 AS 3/10.

al., 2009).[5] A more important argument, however, is that temporary agency employment serves as a stepping stone to regular employment (see Nunez & Livanos, 2015).[6]

The third part of this thesis deals with the issue of technological change. More than 80 years ago, John Maynard Keynes anticipated the rapid technological progress that occurred since then, but he also supposed that "we are being afflicted with a new disease of which some readers may not have heard the name, but of which they will hear a great deal in the years to come – namely, technological unemployment" (Keynes, 1930). Wassily Leontief shared a similar opinion and stated that "Labor will become less and less important (...) More and more workers will be replaced by machines. I do not see that the new industries can employ everybody who wants a job."[7] Even if the predictions of these two influential economists haven been proven to be wrong in the past, the concern that the automation of tasks that were previously performed by humans will make them redundant is rising again due to the enormous progress of automation, robotics and artificial intelligence in recent years (see Akst, 2013; Brynjolfsson & McAfee, 2014; Ford, 2016; Davison, 2017).

The last part of this thesis picks up the issue of immigration, which is an important characteristic in today's globalized world. Globalization facilitates immigration as international trade and outsourcing activities lead to more competition and specialization and, therefore, also reduced prices for long-distance transport. Further, the freedom of movement for workers in the European Union and progressing digitalization, which makes it much easier to collect information about potential destination countries, both increase the migration flows. Germany, for example, is the second largest destination country in recent years (OECD, 2014) and has to deal with a net migration of 1.1 million people in the peak of 2015 (Brücker et al., 2017). These large migration flows may be one reason

[5]This incentive prevails even if studies reveal that temporary agency workers receive a 25% lower wage rate than regular workers (see Jahn & Pozzoli, 2013) and that labor turnover is about five times higher (see Haller & Jahn, 2014).

[6]There are of course more reasons than those mentioned here for engaging in temporary agency employment both for workers and firms.

[7]See the interview by Charlotte Curtis, "Machines vs. Workers", The New York Times, February 8, 1983.

for the rise of nationalist parties in many countries, since a lot of Germans and Europeans are afraid of feeling overwhelmed by immigrants and refugees and actively protest against open borders.

By taking state-of-the-art models in labor economics and enriching them with the specific issue at hand, this thesis sheds some light to answer the aforementioned questions in a novel framework and reveals some potential channels that should not be overlooked when policy makers address these issues in modern societies. The contribution can be split in four parts. Chapter 2 picks up a rather special feature of labor union organization and analyzes how the decision of labor unions to merge or to bargain as separate entities depends on the degree of product differentiation. Chapters 3 examines how deregulation efforts of a government, in form of temporary agency employment, affect the employment structure and the position of labor unions in the economy. Chapter 4 analyzes if progressing automation may lead to skill-specific technological unemployment in the long run. Finally, Chapter 5 studies how the technological orientation of an economy may change due to an exogenous inflow of immigrants.

Chapter 2 (single authored) seizes on the issue of multi-unionism and studies diverse firm-union negotiations. To do so, it uses a partial equilibrium model as in Horn & Wolinsky (1988a) to examine the effects of multi-unionism on labor market outcomes, such as the wage rates of workers and the merger incentives of the labor unions. There are two labor unions that supply labor to a single firm, which produces two final goods. While the first good is produced with workers of one labor union, the second good requires labor input from the other union. Using a linear demand function with differentiated products (see Dixit, 1979; Singh & Vives, 1984) makes it possible to distinguish two cases: substitutable products in consumption (tariff competition) and complementary products in consumption (tariff plurality). Three forms of negotiations are examined and compared to each other: joint, simultaneous and sequential bargaining. Under joint bargaining, the unions decide ex-ante (before negotiations take place) to merge and to bargain as a single entity, while they bargain separately and at the same time under simultaneous bargaining, and lastly separately, but lagged under sequential bargaining. The scope of bargaining is about wages, while firms set the optimal employment level.

All of the results are calculated for the asymmetric Nash bargaining solution. Using this type of model, it can be shown that labor unions have strict incentives to merge if the products are substitutable in consumption, while they want to stay separated and bargain sequentially with the firm for complementary products. As a second result, the model reveals that the decisions of unions to merge or to bargain as single entities are beneficial for workers in terms of their wage rate. Only for complementary products, the workers of the union that bargains in a second stage under sequential bargaining would be better off in case of simultaneous bargaining.

Chapter 3 (joint work with Philipp Baudy) investigates the deregulation of temporary agency employment, which has been an important instrument for politicians in the last few decades to break up the rather rigid labor markets in the European Union, especially in Germany through the so-called "Agenda 2010", and to make them more flexible. It uses a general equilibrium matching model à la Mortensen & Pissarides (1994) and Pissarides (2000) to analyze how a deregulation of temporary agency employment affects the rate of unemployment and the employment structure in a unionized economy. To be more specific, it builds up on the work of Delacroix (2006), Ebell & Haefke (2006), C. Bauer & Lingens (2013), and Krusell & Rudanko (2016), who make first attempts to incorporate labor unions in the search and matching framework, and Neugart & Storrie (2006) and Baumann et al. (2011), who are the first that introduce temporary agency employment in the search and matching model. In doing so, it is the first theoretical model that combines labor unions and temporary agency employment in the matching framework and makes it possible to address the question whether or not regularly employed workers get substituted by temporary agency workers due to continuous deregulation efforts. In the model, multiple-worker firms produce differentiated goods using regularly employed workers that are represented by firm-level labor unions or they may use temporary agency workers for some parts of the production. Temporary agency workers are perfect substitutes for regular workers. To reflect one of the central advantages of temporary agency employment, which is that temporary agency employment serves as a stepping-stone for regular employment, temporary agency workers are allowed to search on-the-job for regular employment. The model predicts that the deregulation of temporary agency work reduces overall unemployment and increases the rate of regular employment. Since temporary agency employment is more attractive due to its deregulation, labor unions have to reduce their wage claims for regular workers leading to lower wages and, therefore, a higher employment rate. It can be further shown that labor unions come under pressure due to the deregulation, since the negative wage effect outweighs the positive employment effect on labor unions' utility. The last, and probably most interesting result, is that there exists a hump-shaped relationship between the degree of legal deregulation of temporary agency employment and its rate of employment. The main driver behind this finding are voluntary, non-institutional regulations that arise due to agreements between firms and employee representations. These agreements become more important, the cheaper and thereby less regulated temporary agency employment is. This negative effect counteracts the direct effect of reduced costs that arise due to the deregulation and outweighs the latter effect if legal regulation is sufficiently low. The last finding reveals that the fear of opponents of temporary agency employment, that a deregulation of temporary agency employment creates more precarious employment, may not be supported at least in this type of model. It shows that a steady deregulation of temporary agency employment does not necessarily lead to an increase in precarious employment. In addition, this finding fits very well to the data, since the rate of temporary agency employment is rather non-volatile and relatively stable at a level around 2% in most industrialized countries.

While Chapter 3 is more backward looking and focuses on an aspect of deregulation that changed the flexibility of labor markets in the last couple of decades, Chapter 4 (joint work with Klaus Prettner) is more forward looking and deals with the issue of automation that may fundamentally alter the international division of labor and the functioning of labor markets itself in the not too distant future. While the previous and most influential contributions of Hémous & Olsen (2016) and Acemoglu & Restrepo (2018) concentrate on the effects of automation on economic growth and inequality using the R&D-based growth literature, the model in Chapter 4 takes a different perspective and addresses the question if automation has the potential to create technological unemployment. To address this question, and similar to Chapter 3, the model in Chapter 4 uses the search and matching framework of Mortensen & Pissarides (1994) and Pissarides (2000). Further, the model features two types of workers, high- and low-skilled workers, with an exogenous skill distribution and two types of one-worker firms that operate in the intermediate goods sector and require high- or low-skilled workers for production, respectively. Both intermediate goods are then used for the production of a final good. Next to low- and high-skilled labor, traditional capital in the form of assembly lines, factory buildings etc. and automation capital in form of industrial robots, self-driving cars, 3D printers etc. are used for the production of the final good. The final good is produced according to a CES production structure, where automation capital serves as a perfect substitute for low-skilled labor and an imperfect substitute for high-skilled labor. Using this framework, it can be shown that the accumulation of automation capital decreases the labor market tightness in the low-skilled labor market and increases the labor-market tightness in the high-skilled labor market. This in turn decreases the job finding probability of low-skilled workers and increases that of high-skilled workers, which in turn leads to a higher unemployment rate of low-skilled workers and a lower unemployment rate of high-skilled workers. It can be further concluded that the worse outside option of low-skilled workers, due to a lower job finding probability, is responsible for a drop in low-skilled workers' wage rate, while exactly the opposite holds true for high-skilled workers. These findings are also of interest for politicians, since the current setting suggests that progressing automation leads to a rise in inequality and, therefore, may even foster the division of societies in countries that are already shaped by a non-negligible social inequality.

Chapter 5 (single authored) picks up another aspect and phenomena that takes on an important role in today's globalized world by taking a closer look at the effects of immigration. While there already exist contributions that study the effects of immigration on the wage level of natives and the employment structure of the host country in a search and matching framework à la Mortensen & Pissarides (1994) and Pissarides (2000) (see, e.g., Chassamboulli & Palivos, 2013, 2014; Battisti et al., 2017; Liu et al., 2017), no attention has been paid to the question whether or not an increase in immigration changes the technology choices of firms in the host country. Therefore, Chapter 5 addresses this issue and answers the question if an increase in low-skilled immigration changes the technological orientation of the host country. As the previous two chapters, Chapter 5 uses the search and matching framework of Mortensen & Pissarides (1994) and Pissarides (2000) and, in addition, builds on the influential work of Albrecht & Vroman (2002).[8] The model incorporates three types of workers: low-skilled immigrants and low- and high-skilled natives. Further, there are two types of firms: low- and high-tech firms. While low-skilled workers can only be hired in low-tech firms, the model also allows for educational mismatch as high-skilled workers can be hired in both type of firms. The skill distribution of workers is considered to be exogenous, whereas firms may endogenously adjust their technology by deciding ex ante if they want to use the basic or the advanced technology for production. Workers randomly match with these vacancies. While firms differ in the technology they use for production, productivity is higher in high-tech firms, and in the costs of maintaining a vacancy, workers differ in their flow income of unemployment and the costs of searching for a job. These costs are higher for immigrants due to existing language barriers, non-existence of a social network, social stigma against immigrants, and so forth. The developed model suggests that an influx of low-skilled immigrants deteriorates the technology level used in the host country and leads to a more intensive use of the basic technology. High-skilled natives gain in terms of employment, but lose in terms of their wage rate due to low-skilled immigration. Surprisingly, low-skilled natives benefit in both terms due to the shift towards the basic technology. This result is also of interest for politicians, since it shows that there might also be positive aspects of immigration for substitutable production factors if there are firms in the economy that adjust there production pattern to the changed skill-mix of labor supply. Lastly, the model analyzes the effects of policies that improve the access of immigrants to the labor market. The effects are exactly the opposite: firms shift their production towards the advanced technology, while low-skilled natives are hurt and high-skilled natives receive a higher wage rate, but suffer from additional unemployment.

Finally, after the four models have been developed and analyzed in detail, Chapter 6 discusses and concludes the thesis.

[8] Dolado et al. (2009) extend their model by introducing on-the-job search, while Baudy (2017) incorporates temporary agency employment.

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Chapter 2

Multi-unionism at the Firm Level: The Impact of Asymmetric Nash Bargaining Solutions on Labor Unions' Merger Incentives

2.1 Introduction

Multi-unionism describes a situation where at least two or more labor unions represent union members at the firm or industry level for collective bargaining purposes. For the last couple of decades, this trend has been rising and takes on an important role in labor relations in most European countries. At the national level, multi-unionism prevails due to the existence of two or more labor union federations. Including Germany, 85% of the European Union member states have more than one labor union federation, who are organizing several labor unions and its members. Even in member states, where only one labor union federation exists (Austria, Ireland, Latvia and United Kingdom), a couple of labor unions are unionized within this federation. However, the industrial relation environment in Europe differs from the one in North America. In the United States of America, multi-unionism disappeared after the National Labor Relations Act (Wagner Act) was passed in 1935. Therefore, there is only one specific labor union that has the exclusive right to represent and negotiate for employees in a firm (see Akkerman, 2008).

Considering the high presence of multi-unionism that firms are facing nowadays in Europe, there has been a growing amount of empirical and theoretical research being done in labor economics. Reasons for this could be due to not only the high relevance, but also the political need for politicians and economic policy. This chapter tries to fill a gap in the theoretical literature on multi-unionism at the firm level and contributes to the literature in the following ways. First, different bargaining types, such as, joint, simultaneous, and sequential bargaining between one firm and two labor unions are analyzed in a right-to-manage model.[1] Second, all of the results are calculated for the asymmetric Nash bargaining solution.

The choice of the appropriate bargaining scope is an ongoing discussion in the labor union literature. Regardless of whether establishments or labor unions are asked if employment is part of the negotiations or not, the answer seems to support the right-to-manage model (see Oswald, 1993; Booth, 1995). However, it is sometimes argued that labor unions and firms implicitly bargain over employment due to so called "manning" levels, which represent capital-to-labor or labor-to-output ratios. Nevertheless, there is no reason why such contracts determine the employment level, since firms may, for example, adjust both capital and employment (see Beissinger & Baudy, 2015).

From an empirical perspective, the findings are rather mixed. While some studies find evidence for equilibria lying on the labor demand curve, other papers find evidence in favor of equilibria on the Pareto curve or aside of both. Lawson (2011) provides a beneficial and detailed survey of this literature. Although there are several studies that find evidence in favor of the efficient bargaining model, it should be considered that empirical tests that try to differentiate between the right-to-manage model and the efficient bargaining model have pointed out a number of problems. For example, they have to make joint assumptions about labor unions' preferences, the market structure, technologies, etc. (for an detailed overview of these econometric issues, see Booth, 1995).

[1] This analysis builds on the right-to-manage model of collective bargaining introduced by Nickell & Andrews (1983). This framework differs from the efficient bargaining model, where firms and labor unions bargain over wages and employment levels.

From a theoretical point of view, it can be argued that the outcome of efficient bargaining may not be realized. The reason is that firms, for any degree of union influence over employment, will always have an incentive to deviate from the outcome of efficient bargaining that normally lies on the Pareto curve and to choose its profit maximizing employment level on the labor demand curve (see Naylor, 2003). Nevertheless, it should be taken into account that the results may be different if a "game-theoretic approach" is used in union-oligopoly negotiations (see, e.g., Schroeder & Tremblay, 2014; Fanti, 2015; Fanti & Buccella, 2017). However, in a recent contribution Buccella & Fanti (2017) point out that the timing of the bargaining agenda is assumed to be exogenous in most of the literature. Considering that the timing of the game is endogenous and a decisional variable of the firm, they show that efficient bargaining does not emerge as a unique equilibrium. Regarding these reasons and complementing existing literature, such as, Upmann & Müller (2014) and Aghadadashli & Wey (2015), a right-to-manage model is assumed.

So far, most studies have used alternative bargaining models or a different methodological outline. The theoretical methodology used in this chapter is guided by the model from Horn & Wolinsky (1988a). Their study contemplates negotiations between a firm and two labor unions, where each unions' work force produces a differentiated (either complementary or substitutable) good, over the wage rate, whereas the employment levels are determined by the employer. In comparison to the right-to-manage model, it is assumed that the employment levels are exogenously fixed. They cannot be adjusted by the firm after successful wage negotiations. Horn & Wolinsky (1988b) use the right-to-manage model to study bargaining between a duopoly of firms that acquire labor inputs through bilateral monopoly relations with the unions. Thus, they analyze merger incentives of the unions in the upstream industry if bargaining takes place with two firms. Closely related to this chapter is Aghadadashli & Wey (2015), who apply a similar theoretical outline. However, they mainly use an efficient bargaining model and do not consider asymmetric Nash bargaining solutions.

There are very few empirical studies that analyze the effect of multi-unionism on wages and the incidence of industrial action. Machin et al. (1993) use data from the 1984 Workplace Industrial Relations Survey in the United Kingdom to study the relationship between multi-unionism and a couple of outcome variables. They find that plants with multi-unionism and separate bargaining agreements pay ceteris paribus higher wages than those plants that bargain with a joint union under multi-unionism or with a single labor union.[2] Further, the same industrial plants have a lower financial performance and a higher probability of facing a strike that lasts at least one day. Thus, they conclude that it is not the presence of multi-unionism that leads to negative bargaining outcomes, but whether or not the labor unions bargain individually or as a single entity under multi-unionism. Metcalf et al. (1993) use data of firms in the British manufacturing industry from the years 1981-1989. They find that the probability of a strike is higher if the unions bargain separately than if they bargain as a single entity. Further, the strike probability increases in the number of bargaining groups. Akkerman (2008) uses data of four industrial sectors for seven European countries from 1990-2006. Her findings indicate a positive relationship between strike frequency and the number of unions. In addition, her empirical analysis shows that this positive effect is present in sectors with a heterogenous work force, but not in those sectors where the work force is rather homogenous. Last but not least, Jansen (2014) uses data for more than 5,000 firms for 27 European Union members states in 2009. Similar to the aforementioned authors, his findings confirm the positive relationship between strike incidence and the number of unions at the workplace. Further, he shows that the effect of multi-unionism on strike incidence differs substantially across countries.

Supported by literature, one result is that the already existing merger incentives of the unions, when joint bargaining is compared to sequential and simultaneous bargaining, can be confirmed in a right-to-manage model. Unions have strict incentives to merge if the two products are substitutes in consumption, while they bargain independently and sequentially if the products are complements in consumption. Further, it is demonstrated that the decision of unions to merge or to bargain independently favor workers in terms of their wage rate. Only for complementary products, the workers of the union that bargains in a second stage under sequential bargaining would prefer to bargain simultaneously.

The remainder of this chapter is organized as follows. Section 2.2 surveys the existing

[2] Naylor (1995) provides a theoretical interpretation for this empirical finding.

theoretical literature on multi-unionism. Section 2.3 contains the outline of the theoretical framework and explains the components of the model. In Section 2.4, the model is analyzed for different bargaining regimes in order to identify the merger incentives of the unions. Finally, Section 2.5 summarizes the results and concludes.

2.2 Literature Review

Taking into account that multi-unionism is rather the rule than the exception in European countries, the question for potential reasons of the development of craft unions arise. Theoretically, there exist few explanations for the development and the rise of craft unions. The first theory stems from Olson (1965), which focuses on a politico-economic perspective. He argues that small and homogenous worker groups have problems to assert their interests properly in industry wide unions. Thus, these groups have incentives to represent their interests separately in smaller craft unions. Further, individuals have high incentives to free-ride in larger groups. The free-rider problem occurs when individuals benefit from goods or services without bearing any costs (e.g. membership fees). According to the neoclassical theory of labor demand, labor unions that only organize a small group of workers are more successful in increasing wages (see, e.g. Borjas, 2010, pp. 114-115). The reason is that it is more likely that the labor costs of a small group make up only a minor part of total production costs. Thus, the relatively inelastic labor demand curve makes it possible to increase wages without losing many jobs. The last theory stems from Horn & Wolinsky (1988a) and is considered to be a part of the domain of industrial economics. The development of craft unions can be seen as an instrument to achieve an economic rent for those occupational groups that are complementary in their labor skills compared to other worker groups used in production. This is due to the fact that these groups can force a firm to shut down production in the event of a strike, which then results in a higher bargaining power of the workers. Thus, the workers are better off to organize themselves separately in a craft union in order to achieve higher wages.

The theoretical literature on multi-unionism dates back to the end of the eighties and consists of several papers, such as Horn & Wolinsky (1988a, 1988b), Dowrick (1993) and

Gürtzgen (2003). In Horn & Wolinsky (1988a), a firm and two unions debate over the wage rate, whereas the employment levels are set by the employer. Wages are determined in three stages. In the first stage, the firm sets the employment levels. In comparison to the right-to-manage model, it is assumed that the employment levels are exogenously fixed. Therefore, they cannot be altered by the firm after the negotiations about wages were finalized. Thus, it is considered that the firm looks through the next two stages and considers how the employment decision will affect the outcomes of the following stages. In the second stage, the unions decide if they want to bargain jointly or simultaneously with the firm, while the negotiations about wages take place in the third stage. In order to solve this bargaining problem, the authors use an extended version of the strategic bargaining model by Rubinstein (1982). Their main findings are the following: if the worker groups are substitutable, the unions are better off if they form a joint union. The rationale is that the bargaining power of each union is weaker in the case that the worker groups are substitutable. If there is a disagreement between the firm and the workers (e.g. a strike), the firm can easily replace workers of a union with members from the other union and continue production. In contrast, if the worker groups are complementary then the utility of the unions is maximized if they bargain separately. The is due to the relatively high bargaining power of the unions, as it is not possible for the firm to proceed production with only one worker group. Thus, the decision of the form of unionization depends on the degree of differentiation of the worker groups.

In Horn & Wolinsky (1988b), a right-to-manage model is used to study the bargaining problem between a duopoly of firms that receives labor through bilateral monopoly relations with the labor unions. Hence, the authors analyze merger incentives in the upstream industry if bargaining takes place with two firms. It is shown that the merger incentives of the unions are identical to those in Horn & Wolinsky (1988a), where bargaining takes place with a single firm. Further, the incentives of the firms to merge in a downstream market are analyzed if negotiations take place with a single labor union. It is highlighted that the sum of the profits of a duopoly of firms is larger than the profits of a downstream monopoly if the products are substitutable. Thus, the gains from monopolizing a downstream industry are smaller than the losses obtained due to having a worse bargaining position. In contrast, the profits of a downstream monopoly are larger than the profits of the total downstream industry (duopoly of firms) if the goods are complementary.

Similar to Horn & Wolinsky (1988b), Dowrick (1993) takes product market competition into account. He uses the right-to-manage model to analyze wage negotiations in the case of a duopoly of firms and labor unions. However, the author extends the model of Horn & Wolinsky (1988b) in two ways. First, he analyzes eight different bargaining and organizational structures. Second, strike payoffs are considered and are assumed to be endogenous. His main finding is that the impact of the level of bargaining on wage outcomes are not clear. The effects are only conclusive if the level of organization (specifically the level of the labor unions) is changed in a similar way.

In contrast, Gürtzgen (2003) does not only allow for horizontally mergers, she also takes into account vertical mergers. These are characterized by cooperation across firms or industries. In addition, she extends the 2×2 duopoly of Dowrick (1993) to the more general case of multiple labor unions and firms. In comparison to the aforementioned papers, she assumes a monopoly-union model.[3] Her essential finding is that wages cannot be ranked according to the degree of centralization. The reason being is that wages are not solely dependent on the cooperation dimension, but also on the specific technical relationship between different worker groups.

Certainly, the previously discussed papers are not the only ones that cover multi-unionism. Next to these seminal papers, there are several other papers that deal with different elements of labor union centralization (see Davidson, 1988; Dowrick, 1989; Hoel, 1989; Jun, 1989; Cheung & Davidson, 1991; Buccella, 2013; Upmann & Müller, 2014; Han & Mukherjee, 2017).

The paper closely related to this chapter is Aghadadashli & Wey (2015). In their main analysis, it is assumed that a single firm uses labor inputs from two unions in order to produce a single product. Whereas, in an extension it is supposed that a firm negotiates with two unions, where the workers of each union produce a differentiated good. According to Aghadadashli & Wey (2015), a prominent example for the latter

[3] In the monopoly-union model the unions unilaterally determine the wages, while the firm sets the optimal employment levels.

setting is the framework of the dominant German railway company (*Deutsche Bahn*; DB). The DB offers rail journeys as well as intercity bus services. Most of the train drivers are represented by the the German Train Drivers Union (*Gewerkschaft Deutscher Lokomotivführer*), while on the other hand bus drivers of the DB are organized in the Railway and Transport Union (*Eisenbahn- und Verkehrsgewerkschaft*). Thus, the two services can be substitutable or complementary in consumption. In comparison to the main analysis, it is not necessary for the relationships to be perfect. In both models, an efficient bargaining model is used to analyze the bargaining problem between a single firm and two unions. Despite joint and simultaneous bargaining, the authors study sequential bargaining. Their findings support the existing merger results in related literature: labor unions have strict incentives to merge if the workers are substitutable, while the unions stay separated if the worker groups are complementary. Furthermore, the main analysis shows that under sequential bargaining that labor union, who bargains first with the firm has a first-mover advantage if the workers are substitutable. For complementary workers, a second-mover advantage exists. Regarding the analysis of the extension (two differentiated products), sequential bargaining leads to over-employment (under-employment) if the products are substitutable (complementary).

2.3 Outline of the Theoretical Framework

2.3.1 Basic Assumptions

A model is considered in which a single firm bargains with two labor unions. The framework of this type of model is borrowed from Horn & Wolinsky (1988a). The downstream market consists of one firm (employer). The firm negotiates with two unions in the upstream market: union X and union Y.

Three different forms of firm-union negotiations are studied: joint, simultaneous, and sequential bargaining. The firm can only start production if the negotiations with at least one union are successful. Before the negotiations take place, unions X and Y can decide whether they want to merge or to stay separated. If the unions decide to merge, the firm has to negotiate with a joint union Z. If the unions do not merge, there is the possibility to study simultaneous and sequential bargaining. Under simultaneous bargaining, the firm bargains at the same time with unions X and Y. Whereas, under sequential bargaining it is assumed that the firm bargains first with union X and afterwards with union Y.

The model used in this chapter to describe the scope of bargaining is the right-to-manage model. In contrast to the efficient bargaining model, the firm only bargains with the unions over the wage rates, while the optimal employment levels are set unilaterally by the firm. With that, another difference between the two bargaining models is that for the right-to-manage model the equilibrium lies on the labor demand curve. However, in the case of efficient bargaining, the Pareto efficient equilibrium lies on the contract curve. These two curves are normally different from each other (see Booth, 1995, p. 135). In order to see if the implications and merger incentives of the labor unions depend on the model being used, diverse bargaining problems are studied in a right-to-manage model.

2.3.2 Production and Firms

The firm produces two final goods. The production of good 1 requires only labor input from union X, while the production of good 2 uses labor input from union Y. Variables q_1 and q_2 denote the output of good 1 and 2, respectively. For simplification, constant returns to scale are assumed in production. The production function of good 1 and 2 are the following: $q_1 = x$ and $q_2 = y$, where x and y are the corresponding employment levels of unions X and Y. Concerning the demand for good i, a linear demand function with differentiated products is assumed (see Dixit, 1979; Singh & Vives, 1984). Thus, the inverse demand for good i can be written as

$$p_i(q_i, q_j) = 1 - q_i - \gamma q_j, \text{ with } i, j = 1, 2 \text{ and } i \neq j. \tag{2.1}$$

The variable p_i denotes the price of good i, while the parameter γ indicates the degree of product differentiation and shows how the two products are related to each other. It is assumed that $\gamma \in (-1, 1]$.[4] Thus, it is possible to distinguish between three different

[4]The two goods are perfect substitutes at the upper bound $\gamma = 1$, while they would be perfect complements at $\gamma = -1$. However, the lower bound does not contain $\gamma = -1$, since some solutions are not defined for this case.

cases. These cases can be illustrated with the help of the following proof: in a first step, the inverse demand function from eq. (2.1) is solved for q_i. Analogously, the respective inverse demand function of good j is solved for q_j. Inserting the latter result in q_i gives

$$q_i = \frac{1 - p_i - \gamma + \gamma p_j}{1 - \gamma^2}.$$

Thus, the cross derivative of q_i with respect to p_j is given by

$$\frac{\partial q_i}{\partial p_j} = \frac{\gamma}{1 - \gamma^2},$$

where the fraction is positive for $\gamma > 0$, implying that the products are substitutes in consumption. When $\gamma < 0$, the fraction is negative. Hence, the products are complements in consumption. For $\gamma = 0$, the derivative is also equal to zero. Thus, the last case reflects independence between the products. A positive γ induces tariff competition between the two unions, while a negative γ gives rise to tariff plurality.

With the help of the inverse goods demand and the production functions the profit of the firm, given that it reaches an agreement with both unions, can be stated as

$$\pi(x, w, y, r) = (1 - x - \gamma y)x + (1 - y - \gamma x)y - xw - yr, \tag{2.2}$$

with w and r denoting the wage rate of workers of unions X and Y, respectively. In the case that the firm does not reach an agreement with union X or union Y, the profits of the firm are given by

$$\pi^{DX} = (1 - y)y - yr \quad \text{and} \quad \pi^{DY} = (1 - x)x - xw, \tag{2.3}$$

where π^{DX} (π^{DY}) is the disagreement point of the firm if it does not reach an agreement with union X (Y). Hence, these two terms are the corresponding outside options of the firm that are used in the bargaining problems. Furthermore, it is assumed that the joint surplus is

$$\Pi := \pi + u_x + u_y, \tag{2.4}$$

where u_x and u_y are the corresponding utility levels of unions X and Y.

2.3.3 Labor Unions

It is assumed that all employed workers of the firm are either a member of union X or Y. The utility functions of the unions follow the specification suggested by Dunlop (1944):

$$u_x = xw \quad \text{and} \quad u_y = yr. \tag{2.5}$$

The two unions want to maximize their corresponding wage bill. Furthermore, it is assumed that unions X and Y are symmetric. Inspection of eq. (2.5) shows that the utility the unions obtain if no agreement is achieved with the firm is equal to zero, since the firm hires no workers from the respective union.

In case that the two unions merge, the utility of the joint union Z is the sum of the individual wage bills and is given by

$$u_z = xw + yr. \tag{2.6}$$

2.4 Solution of the Model

The solution depends on the bargaining model that is analyzed. Under joint and simultaneous bargaining, the agents' decision are taken in two stages. In the first stage, the firm negotiates either simultaneously with unions X and Y, or with a joint union Z over the corresponding wage levels. In the second stage, the firm unilaterally determines the employment levels for the two worker groups. It takes into account that the optimal employment levels depend on the wage rates negotiated in stage 1. Under sequential bargaining, the agents' decision are taken in three stages. In the first stage, the firm bargains with union X over the wage w. In the second stage, the firm negotiates with union Y over the corresponding wage level r. It is taken into account that the optimal wage level r depends on the wage rate w negotiated between the firm and union X in stage 1. In the third stage, the firm determines the corresponding employment levels for the two worker groups. It is considered by the firm that the optimal employment levels depend on the wage levels bargained over in stage 1 and 2. In order to obtain a subgame perfect Nash equilibrium for the three types of bargaining models, both two-stage games and the three-stage game must be solved by backward induction.

Since the profit-maximization problem of the firm is the same across the three bargaining regimes, it is introduced only once. The firm chooses the number of workers of unions X and Y in stage 2 among joint and simultaneous bargaining and in stage 3 among sequential bargaining. The maximization problem of the firm is given by

$$\max_{x,y} \pi = (1 - x - \gamma y)x + (1 - y - \gamma x)y - xw - yr. \tag{2.7}$$

Maximization yields the following labor demand functions

$$x = \frac{1 - w - \gamma + \gamma r}{2(1 - \gamma^2)} \quad \text{and} \quad y = \frac{1 - r - \gamma + \gamma w}{2(1 - \gamma^2)}. \tag{2.8}$$

2.4.1 Joint Bargaining

If the unions X and Y decide to merge in a first act, the firm bargains with the joint union Z. Thus, union Z bargains with the firm over both wage rates w and r.

Stage 2

In order to simplify the maximization problem in stage 2 and particularly the bargaining problem in stage 1, the property of symmetry of the worker groups is used. This symmetry ensures that the bargaining outcomes will also be symmetric. Thus, it holds that: $x = y$ and $w = r$.[5] Using this information, eq. (2.8) can be rewritten to obtain

$$x = y = \frac{1 - w}{2(1 + \gamma)}. \tag{2.9}$$

Stage 1

In stage 1, the firm bargains with union Z over the wage rate w and r. As the workers are symmetric, eq. (2.6) can be rewritten to obtain $u_z = 2xw$. The generalized Nash-bargaining problem between the firm and union Z can then be stated as

$$\begin{aligned} &\max_{w} [\pi(x, w, y, r)]^{1-\beta}[u_z]^{\beta} \\ &= [2x(1 - x - \gamma x - w)]^{1-\beta}[2xw]^{\beta}, \end{aligned} \tag{2.10}$$

[5]The original bargaining problem that does not use the property of symmetry is provided in Appendix 2.A.1.

where $\beta \in [0,1]$ denotes the bargaining power of the union. Neither the joint union Z nor the firm has an outside option available as the union represents all workers. Using in addition the employment level x obtained in the second stage from eq. (2.9), the generalized Nash-bargaining problem between the firm and union Z is given by

$$\max_{w} \left[\frac{(1-w)^2}{2(1+\gamma)}\right]^{1-\beta} \left[w\frac{1-w}{1+\gamma}\right]^{\beta}. \tag{2.11}$$

The equilibrium wage rate that solves this bargaining problem is[6]

$$\hat{w} = \hat{r} = \frac{\beta}{2}. \tag{2.12}$$

Substitution of the equilibrium wage from eq. (2.12) in the the solution of the employment level determined by eq. (2.9) gives

$$\hat{x} = \hat{y} = \frac{2-\beta}{4(1+\gamma)}. \tag{2.13}$$

Inserting the equilibrium wage rates and employment levels into the profit function (2.2) and the utility function of the joint union (2.6) yields

$$\hat{\pi} = \frac{(2-\beta)^2}{8(1+\gamma)}, \tag{2.14}$$

while the utility of union Z is

$$\hat{u}_z = \beta\frac{2-\beta}{4(1+\gamma)}. \tag{2.15}$$

The joint surplus from eq. (2.4) is given by

$$\hat{\Pi} = \frac{(2+\beta)(2-\beta)}{8(1+\gamma)}. \tag{2.16}$$

Lemma 1. *Consider joint bargaining between the firm and an encompassing union. The bargaining outcomes depend in the following way on the union's bargaining power β and the degree of product differentiation γ:*

(*i*) $\dfrac{\partial \hat{w}}{\partial \beta} = \dfrac{1}{2} > 0,$

(*ii*) $\dfrac{\partial \hat{w}}{\partial \gamma} = 0,$

[6] Hats indicate equilibrium values in the joint bargaining model.

$$(iii)\ \frac{\partial \hat{x}}{\partial \beta} = -\frac{1}{4(1+\gamma)} < 0,$$

$$(iv)\ \frac{\partial \hat{x}}{\partial \gamma} = -\frac{2-\beta}{4(1+\gamma)^2} < 0,$$

$$(v)\ \frac{\partial \hat{u}_z}{\partial \beta} = \frac{1-\beta}{2(1+\gamma)} \gtreqqless 0 \text{ if } \begin{cases} 0 \leq \beta < 1 \wedge -1 < \gamma \leq 1, \\ \beta = 1, \end{cases}$$

$$(vi)\ \frac{\partial \hat{u}_z}{\partial \gamma} = -\beta\frac{2-\beta}{4(1+\gamma)^2} \lesseqqgtr 0 \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge -1 < \gamma \leq 1, \\ \beta = 0, \end{cases}$$

$$(vii)\ \frac{\partial \hat{\pi}/\hat{\Pi}}{\partial \beta} = -\frac{4}{(2+\beta)^2} < 0,$$

$$(viii)\ \frac{\partial \hat{\pi}/\hat{\Pi}}{\partial \gamma} = 0.$$

Proof. It can be easily seen from the partial derivatives of the respective equations that parts (i) - (iv), (vii) and (viii) hold for the whole range of parameter values. Further, parts (vii) and (viii) follow from dividing eq. (2.14) by eq. (2.16), which gives $\frac{\hat{\pi}}{\hat{\Pi}} = \frac{2-\beta}{2+\beta}$. The partial derivatives yield the respective result. □

2.4.2 Simultaneous Bargaining

If the unions X and Y decide not to merge in the beginning of the game, the first possibility to study is simultaneous bargaining. Hence, the firm bargains at the same time with union X over the wage rate w and with union Y over the wage rate r. Employment is solely determined by the firm in stage 2. The labor demand functions are given by eq. (2.8).

Stage 1

In stage 1, the firm bargains with union X over the wage rate w, and with union Y over wage rate r. The generalized Nash-bargaining problem between the firm and union X

can be stated as[7]

$$\max_w [\pi(x,w,y,r) - \pi^{DX}]^{1-\beta}[u_x]^\beta$$
$$= [x(1-x-2\gamma y - w)]^{1-\beta}[xw]^\beta. \tag{2.17}$$

Taking into account that the employment levels are given by eq. (2.8), maximization yields[8]

$$\tilde{w} = \tilde{r} = \beta \frac{1-\gamma}{2-\gamma\beta}. \tag{2.18}$$

The equilibrium employment levels are determined by inserting the equilibrium wages from eq. (2.18) in the solution of the employment levels in the second stage given by eq. (2.8):

$$\tilde{x} = \tilde{y} = \frac{2-\beta}{2(1+\gamma)(2-\gamma\beta)}. \tag{2.19}$$

Substitution of the equilibrium values from eqs. (2.18) and (2.19) into the profit function (2.2) and the utility functions (2.5) yields

$$\tilde{\pi} = \frac{(2-\beta)^2}{2(1+\gamma)(2-\gamma\beta)^2}, \tag{2.20}$$

while the wage bills of unions X and Y are

$$\tilde{u}_x = \tilde{u}_y = \beta(2-\beta)\frac{1-\gamma}{2(1+\gamma)(2-\gamma\beta)^2}. \tag{2.21}$$

Thus, if both unions bargain simultaneously with the firm, the wage rates, the employment levels, and the utility of the unions are identical. The joint surplus is given by

$$\tilde{\Pi} = (2-\beta)\frac{2+\beta(1-2\gamma)}{2(1+\gamma)(2-\gamma\beta)^2}. \tag{2.22}$$

Lemma 2. *Consider separate bargaining between the firm and two unions. Under simultaneous bargaining the outcomes depend in the following way on the unions' bargaining power β and the degree of product differentiation γ:*

$$(i)\ \frac{\partial \tilde{w}}{\partial \beta} = \frac{2(1-\gamma)}{(2-\gamma\beta)^2} \geqq 0 \text{ if } \begin{cases} 0 \le \beta \le 1 \wedge -1 < \gamma < 1, \\ \gamma = 1, \end{cases}$$

[7] The generalized Nash-bargaining problem between the firm and union Y can be stated analogously. The maximization problem is not stated here due to similarity.

[8] Tildes indicate equilibrium values in the simultaneous bargaining model.

$$(ii)\quad \frac{\partial \tilde{w}}{\partial \gamma} = -\beta \frac{2-\beta}{(2-\gamma\beta)^2} \leqq 0 \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge -1 < \gamma \leq 1, \\ \beta = 0, \end{cases}$$

$$(iii)\quad \frac{\partial \tilde{x}}{\partial \beta} = -\frac{1-\gamma}{(1+\gamma)(2-\gamma\beta)^2} \leqq 0 \text{ if } \begin{cases} 0 \leq \beta \leq 1 \wedge -1 < \gamma < 1, \\ \gamma = 1, \end{cases}$$

$$(iv)\quad \frac{\partial \tilde{x}}{\partial \gamma} = -\frac{(2-\beta)[2-\beta(1-2\gamma)]}{2(1+\gamma)^2(2-\gamma\beta)^2} \gtreqless 0 \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge 0,5 < \gamma \leq 1 \text{ and } 2 < \beta(1+2\gamma), \\ 0 < \beta \leq 1 \wedge 0,5 \leq \gamma \leq 1 \text{ and } 2 = \beta(1+2\gamma), \\ 0 \leq \beta \leq 1 \wedge -1 < \gamma \leq 1 \text{ and } 2 > \beta(1+2\gamma), \end{cases}$$

$$(v)\quad \frac{\partial \tilde{u}_x}{\partial \beta} = \frac{(1-\gamma)[2-\beta(2-\gamma)]}{(1+\gamma)(2-\gamma\beta)^3} \gtreqless 0 \text{ if } \begin{cases} 0 \leq \beta \leq 1 \wedge -1 < \gamma < 1 \text{ and } 2 > \beta(2-\gamma), \\ \gamma = 1 \vee 0 < \beta \leq 1 \wedge -1 < \gamma \leq 0 \text{ and } 2 = \beta(2-\gamma), \\ 0 < \beta \leq 1 \wedge -1 < \gamma < 0 \text{ and } 2 < \beta(2-\gamma), \end{cases}$$

$$(vi)\quad \frac{\partial \tilde{u}_x}{\partial \gamma} = -\beta(2-\beta)\frac{2+\beta-\gamma\beta(1-\gamma)}{(1+\gamma)^2(2-\gamma\beta)^3} \leqq 0 \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge -1 < \gamma \leq 1, \\ \beta = 0, \end{cases}$$

$$(vii)\quad \frac{\partial \tilde{\pi}/\tilde{\Pi}}{\partial \beta} = -\frac{4(1-\gamma)}{[2+\beta(1-2\gamma)]^2} \leqq 0 \text{ if } \begin{cases} 0 \leq \beta \leq 1 \wedge -1 < \gamma < 1, \\ \gamma = 1, \end{cases}$$

$$(viii)\quad \frac{\partial \tilde{\pi}/\tilde{\Pi}}{\partial \gamma} = 2\beta\frac{2-\beta}{[2+\beta(1-2\gamma)]^2} \geqq 0 \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge -1 < \gamma \leq 1, \\ \beta = 0. \end{cases}$$

Proof. Parts (i) - (vi) follow from the partial derivatives of the respective equations. The partial derivative of part (iv) shows that the employment levels decrease in γ as long as $2 > \beta(1+2\gamma)$. This condition is fulfilled for $\gamma \in (-1, 0.5)$. For values of γ that indicate a higher degree of substitutability among the products, it depends on the size of β if the partial derivative will be positive, negative or zero. Part (v) follows a similar logic and shows that the sign of the derivative is ambiguous. Parts (vii) and (viii) follow from dividing eq. (2.20) by eq. (2.22), which gives $\frac{\tilde{\pi}}{\tilde{\Pi}} = \frac{2-\beta}{2+\beta(1-2\gamma)}$. The partial derivatives yield the respective results. □

2.4.3 Sequential Bargaining

If unions X and Y decide not to merge in a first act, the second possibility to study is sequential bargaining. It is assumed that the firm bargains first with union X over the wage w and afterwards with union Y over the wage r. Employment is solely determined by the firm in stage 3. The employment levels are given by eq. (2.8).

Stage 2

In stage 2, the firm negotiates with union Y over the wage rate r. Taking into account that the employment levels are determined in the third stage, the generalized Nash-bargaining problem between the firm and union Y can be written as

$$\begin{aligned} &\max_r [\pi(x,w,y,r) - \pi^{DY}]^{1-\beta}[u_y]^{\beta} \\ &= \left[\frac{1-r-\gamma+\gamma w}{2(1-\gamma^2)}\right]^{2(1-\beta)} \left[r\frac{1-r-\gamma+\gamma w}{2(1-\gamma^2)}\right]^{\beta}. \end{aligned} \tag{2.23}$$

Maximization gives

$$r = \beta\frac{1-\gamma+\gamma w}{2}. \tag{2.24}$$

Eq. (2.24) shows that the wage rate w, which will be negotiated in the first stage, exerts a positive externality on the wage rate r if the products are substitutable and a negative one if the workers are complementary. This is quite intuitive, since a larger negotiated wage rate w improves also the bargaining position of union Y if the products are substitutable. The reason is that the firm employs only workers from the union with the lower negotiated wage. Thus, union Y has a certain scope to increase its wage rate.

Stage 1

Considering the employment levels determined in the third stage and the wage rate r given by eq. (2.24), the generalized Nash-bargaining problem between the firm and union X can be stated as

$$\begin{aligned} &\max_w [\pi(x,w,y,r) - \pi^{DX}]^{1-\beta}[u_x]^{\beta} \\ &= \left[\frac{(1-w)(2-\gamma^2\beta)-\gamma(2-\beta)}{4(1-\gamma^2)}\right]^{2(1-\beta)} \left[w\frac{(1-w)(2-\gamma^2\beta)-\gamma(2-\beta)}{4(1-\gamma^2)}\right]^{\beta}. \end{aligned} \tag{2.25}$$

Maximization gives[9]

$$w^* = \beta(1-\gamma)\frac{2+\gamma\beta}{2(2-\gamma^2\beta)}. \tag{2.26}$$

Inserting w^* in eq. (2.24) yields the wage rate workers of union Y receive:

$$r^* = \beta(1-\gamma)\frac{4+\gamma\beta(2-2\gamma+\gamma\beta)}{4(2-\gamma^2\beta)}. \tag{2.27}$$

In order to obtain the equilibrium employment levels, w^* and r^* have to be inserted in the solution of the employment levels determined in the third stage. This gives

$$x^* = (2-\beta)\frac{2+\gamma\beta}{8(1+\gamma)}, \tag{2.28}$$

while the employment level of union Y becomes

$$y^* = (2-\beta)\frac{4+\gamma\beta(2-2\gamma+\gamma\beta)}{8(1+\gamma)(2-\gamma^2\beta)}. \tag{2.29}$$

Substituting the equilibrium wage rates and employment levels into the profit function (2.2) and the utility functions (2.5) gives

$$\begin{aligned}\pi^* = &\frac{(2-\beta)^2}{64(1+\gamma)(2-\gamma^2\beta)^2}\Big[32(1+\gamma\beta) - 16\gamma^2\beta(2-\beta) \\ &- 4\gamma^3\beta^2(6-\beta) + 8\gamma^4\beta^2(1-\beta) + \gamma^4\beta^4(1-\gamma) + 4\gamma^5\beta^3\Big],\end{aligned} \tag{2.30}$$

while the wage bill of union X is

$$u_x^* = \beta(1-\gamma)(2-\beta)\frac{(2+\gamma\beta)^2}{16(1+\gamma)(2-\gamma^2\beta)}, \tag{2.31}$$

and the utility of union Y becomes

$$u_y^* = \beta(1-\gamma)(2-\beta)\frac{[4+\gamma\beta(2-2\gamma+\gamma\beta)]^2}{32(1+\gamma)(2-\gamma^2\beta)^2}. \tag{2.32}$$

The joint surplus is given by

$$\begin{aligned}\Pi^* = &\frac{(2-\beta)}{64(1+\gamma)(2-\gamma^2\beta)^2}\Big[32(2+\beta) + 16\gamma\beta^2(1-3\gamma) - 16\gamma^2\beta(4-\beta^2) \\ &- 4\gamma^3\beta^3(8-\beta) + 16\gamma^4\beta^2(1+\beta) + \gamma^4\beta^4(6\gamma-10+\beta-\gamma\beta)\Big].\end{aligned} \tag{2.33}$$

[9] Asterisks indicate equilibrium values in the sequential bargaining model.

Lemma 3. *Consider separate bargaining between the firm and two unions. If the firm bargains first with union X and afterwards with union Y, the following orderings prevail:*

$$(i)\ \ w^* \gtreqqless r^* \ \text{ if } \begin{cases} (0<\beta\leq 1 \wedge 0<\gamma<1) \vee (0<\beta\leq 1 \wedge -1\leq\gamma<0), \\ \beta=0 \vee \gamma=0 \vee \gamma=1, \end{cases}$$

$$(ii)\ \ x^* \lesseqqgtr y^* \ \text{ if } \begin{cases} (0<\beta\leq 1 \wedge 0<\gamma\leq 1) \vee (0<\beta\leq 1 \wedge -1<\gamma<0), \\ \beta=0 \vee \gamma=0, \end{cases}$$

$$(iii)\ \ u_x^* \gtreqqless u_y^* \ \text{ if } \begin{cases} (0<\beta\leq 1 \wedge -1<\gamma<0) \vee \\ (0<\beta<1 \wedge 0<\gamma<1 \text{ and } \frac{8}{\beta} > 2\gamma\beta(2-\gamma)+\gamma^2(4+\beta^2)+8), \\ (\beta=0 \vee \gamma=0 \vee \gamma=1) \vee \\ (0<\beta<1 \wedge 0<\gamma<1 \text{ and } \frac{8}{\beta} = 2\gamma\beta(2-\gamma)+\gamma^2(4+\beta^2)+8), \\ 0<\beta\leq 1 \wedge 0<\gamma<1 \text{ and } \frac{8}{\beta} < 2\gamma\beta(2-\gamma)+\gamma^2(4+\beta^2)+8. \end{cases}$$

Proof. Part (i) follows by comparing eqs. (2.26) and (2.27) with one another, while eqs. (2.28) and (2.29) have to be compared to prove part (ii). Part (iii) follows by comparing eqs. (2.31) and (2.32) in the text. It is not possible to make a general statement for substitutable products, since $u_x^* < u_y^*$ only holds if $\frac{8}{\beta} < 8 + 2\gamma\beta(2-\gamma) + \gamma^2(4+\beta^2)$. Even if this is true for a range of parameter values, there exist combinations for which this condition does not hold. □

If the unions bargain sequentially with the firm, the wage rates, the employment levels, and the utility of the unions will be different. Thus, sequential bargaining between the firm and both unions creates externalities. The direction of the externalities depend on the order of bargaining. Part (i) states that workers always inherit a first-mover advantage in terms of their wage rate. Wages are only identical in cases of perfectly substitutable and independent products or in the case of a zero bargaining power of the union. For $\gamma = 1$ the wage levels are equal to zero. The reason is that the firm employs workers only from the union which pays the lower negotiated wage. Thus, the unions undercut each other driving wages down to zero in equilibrium. Part (ii) is a consequence of part (i) and shows that the higher wage rate w goes along with a lower employment level x, in comparison to the employment level y. Part (iii) reveals that the right-to-manage model implies a first-mover advantage for negative values of γ under sequential bargaining. In the case of substitutable products, no clear statement can be made. This result is different to the findings obtained in the literature if the efficient bargaining model is used (see Aghadadashli & Wey, 2015). In their setting, a second-mover advantage exists for complementary products. There are two motives: first, under efficient bargaining the disagreement point of the firm is better when bargaining with the first union. Thus, the first union creates a positive externality on the second union, which raises the second unions' utility level above the utility level of the first union. Second, since the firm retains the right to set the optimal employment level in a right-to-manage model in the third stage, the disagreement point in the second stage cannot be negative as the firm would not employ workers from the first union and, as a consequence, shut down production.

2.4.4 Merger Incentives of the Labor Unions

This section compares the results of the three analyzed bargaining regimes in order to identify the merger incentives of the labor unions. Before doing so, the equilibrium wage rates, employment rates, and the firms' profit across the three bargaining models are compared to one another.

Proposition 2.1. *Consider joint, simultaneous and sequential bargaining. A comparison of the respective wage rates across regimes yields the following orderings:*

$$(i)\;\; \hat{w} \gtreqless \tilde{w},\, \hat{w} \gtreqless w^*,\, \hat{r} \gtreqless \tilde{r},\, \hat{r} \gtreqless r^* \;\text{ if } \begin{cases} 0 < \beta \leq 1 \,\wedge\, 0 < \gamma \leq 1, \\ \beta = 0 \,\vee\, \gamma = 0, \\ 0 < \beta \leq 1 \,\wedge\, -1 < \gamma < 0, \end{cases}$$

$$(ii)\;\; w^* \geqq \tilde{w} \;\text{ if } \begin{cases} (0 < \beta \leq 1 \,\wedge\, 0 < \gamma < 1) \,\vee\, (0 < \beta \leq 1 \,\wedge\, -1 < \gamma < 0), \\ \beta = 0 \,\vee\, \gamma = 0 \,\vee\, \gamma = 1, \end{cases}$$

$$(iii)\;\; r^* \gtreqless \tilde{r} \;\text{ if } \begin{cases} 0 < \beta \leq 1 \,\wedge\, 0 < \gamma < 1, \\ \beta = 0 \,\vee\, \gamma = 0 \,\vee\, \gamma = 1, \\ 0 < \beta \leq 1 \,\wedge\, -1 < \gamma < 0. \end{cases}$$

Proof. Parts (i) - (iii) can be easily proved by comparing the respective wage rates that have been previously derived. □

Part (i) - (iii) show that bargained wages are identical if the products are independent of each other or if the unions have no bargaining power at all, while the wages under sequential and simultaneous bargaining are in addition identical for perfectly substitutable products. Further, part (i) demonstrates that for substitutable products the equilibrium wage rates are the highest under joint bargaining, while they are the lowest for complementary products under joint bargaining. Part (ii) shows that union X negotiates a higher wage rate under sequential bargaining, while part (iii) states that union Y, which bargains in a second step under sequential bargaining, achieves negotiating a higher wage for substitutable products. Despite that, its negotiated wage rate is lower for complementary products compared to simultaneous bargaining.

Proposition 2.2. *Consider joint, simultaneous and sequential bargaining. A comparison of the respective employment rates across regimes yields the following orderings:*

$$(i)\ \ \hat{x} \gtreqqless \tilde{x},\ \hat{x} \gtreqqless x^*,\ \hat{y} \gtreqqless \tilde{y},\ \hat{y} \gtreqqless y^* \ \text{ if } \begin{cases} 0 < \beta \leq 1 \ \wedge \ -1 < \gamma < 0, \\ \beta = 0 \ \vee \ \gamma = 0, \\ 0 < \beta \leq 1 \ \wedge \ 0 < \gamma \leq 1, \end{cases}$$

$$(ii)\ \ x^* \leqq \tilde{x} \ \text{ if } \begin{cases} (0 < \beta \leq 1 \ \wedge \ 0 < \gamma \leq 1) \ \vee \ (0 < \beta \leq 1 \ \wedge \ -1 < \gamma < 0), \\ \beta = 0 \ \vee \ \gamma = 0, \end{cases}$$

$$(iii)\ \ y^* \gtreqqless \tilde{y} \ \text{ if } \begin{cases} 0 < \beta \leq 1 \ \wedge \ 0 < \gamma \leq 1, \\ \beta = 0 \ \vee \ \gamma = 0, \\ 0 < \beta \leq 1 \ \wedge \ -1 < \gamma < 0. \end{cases}$$

Proof. Parts (i) - (iii) follow from comparing the respective employment rates that have been previously derived. □

Parts (i) and (ii) directly follow from Proposition 2.1 as the higher bargained wage rates go in line with lower employment rates. Surprisingly, part (iii) shows that not only the bargained wage rate under sequential bargaining, but also the employment level of union Y is higher for substitutable products and lower for complementary products. The reason is the strong externality union X exerts due to its first-mover advantage in terms of its wage rate.

Proposition 2.3. *Consider joint, simultaneous and sequential bargaining. A comparison of the respective profit of the firm across regimes yields the following orderings:*

$$(i)\ \hat{\pi} \gtreqqless \tilde{\pi},\ \hat{\pi} \gtreqqless \pi^* \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge -1 < \gamma < 0, \\ \beta = 0 \vee \gamma = 0, \\ 0 < \beta \leq 1 \wedge 0 < \gamma \leq 1, \end{cases}$$

$$(ii)\ \pi^* \leqq \tilde{\pi} \text{ if } \begin{cases} (0 < \beta \leq 1 \wedge 0 < \gamma < 1) \vee (0 < \beta \leq 1 \wedge -1 \leq \gamma < 0), \\ \beta = 0 \vee \gamma = 0 \vee \gamma = 1. \end{cases}$$

Proof. Parts (i) - (iii) can be proved by comparing the respective profit levels of the firm that have been previously derived. □

As expected, part (i) shows that the higher wage rate unions are able to negotiate under joint bargaining leads to higher wage costs and, therefore, lower profits for substitutable products, while the profits are higher for complementary products. Part (ii) reveals that despite completely independent or perfectly substitutable products and a zero bargaining power of unions, the profit of the firm is always larger under simultaneous bargaining compared to sequential bargaining.

Next, the equilibrium utility levels of unions X and Y are compared with the respective utility levels the unions receive under joint bargaining in order to identify the merger incentives in the initial stage.[10] The incentives of a merger are studied separately for each union, since it cannot be taken as given that a utility transfer between both unions takes place.[11] For simultaneous bargaining, a merger exists if it holds that $\hat{u}_x > \tilde{u}_x \wedge \hat{u}_y > \tilde{u}_y$, where $\hat{u}_x = \hat{u}_y = \frac{\hat{u}_z}{2}$.

[10] It can be shown analytically that the merger results are robust if a rent maximizing utility function of a union or Stone-Geary type utility function is used.

[11] Horn & Wolinsky (1988a), Jun (1989), Cheung & Davidson (1991) and Upmann & Müller (2014) share a similar opinion.

Proposition 2.4. *Consider joint, simultaneous and sequential bargaining. A comparison of the respective utility levels of the unions across regimes yields the following orderings:*

$$(i)\ \ \hat{u}_x \gtreqqless \tilde{u}_x,\ \hat{u}_y \gtreqqless \tilde{u}_y \ \text{ if } \begin{cases} (0<\beta\le 1 \wedge 0<\gamma\le 1)\vee \\ (0<\beta\le 1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) < -\gamma\beta^2), \\ (\beta=0 \vee \gamma=0)\vee \\ (0<\beta<1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) = -\gamma\beta^2), \\ 0<\beta<1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) > -\gamma\beta^2, \end{cases}$$

$$(ii)\ \ \hat{u}_x \gtreqqless u_x^* \ \text{ if } \begin{cases} (0<\beta\le 1 \wedge 0<\gamma\le 1)\vee \\ (0<\beta\le 1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) < \gamma\beta^2(1-\gamma)-2\gamma\beta), \\ (\beta=0 \vee \gamma=0)\vee \\ (0<\beta<1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) = \gamma\beta^2(1-\gamma)-2\gamma\beta), \\ (0<\beta<1 \wedge -1<\gamma<0 \text{ and } 4(1-\beta) > \gamma\beta^2(1-\gamma)-2\gamma\beta), \end{cases}$$

$$(iii)\ \ \hat{u}_y \gtreqqless u_y^* \ \text{ if } \begin{cases} (0<\beta\le 1 \wedge 0<\gamma\le 1)\vee \\ 0<\beta\le 1 \wedge -1<\gamma<0 \text{ and } 2(2-\gamma^2\beta) > \sqrt[2]{1-\gamma}[4+\gamma\beta(2-2\gamma+\gamma\beta)], \\ (\beta=0 \vee \gamma=0)\vee \\ 0<\beta<1 \wedge -1<\gamma<0 \text{ and } 2(2-\gamma^2\beta) = \sqrt[2]{1-\gamma}[4+\gamma\beta(2-2\gamma+\gamma\beta)], \\ 0<\beta<1 \wedge -1<\gamma<0 \text{ and } 2(2-\gamma^2\beta) < \sqrt[2]{1-\gamma}[4+\gamma\beta(2-2\gamma+\gamma\beta)], \end{cases}$$

$$(iv)\ \ \tilde{u}_x \leqq u_x^* \ \text{ if } \begin{cases} (0<\beta\le 1 \wedge 0<\gamma<1) \vee (0<\beta\le 1 \wedge -1<\gamma<0), \\ \beta=0 \vee \gamma=0 \vee \gamma=1, \end{cases}$$

$$(v)\ \ \tilde{u}_y \gtreqqless u_y^* \ \text{ if } \begin{cases} 0<\beta\le 1 \wedge -1<\gamma<0, \\ \beta=0 \vee \gamma=0 \vee \gamma=1, \\ 0<\beta\le 1 \wedge 0<\gamma<1. \end{cases}$$

Proof. Parts (iv) and (v) can be easily proved by comparing the respective utility functions of the unions that have been previously derived. Part (i) requires more attention. It can be shown that $\hat{u}_x < \tilde{u}_x \wedge \hat{u}_y < \tilde{u}_y$ for complementary products if $4(1-\beta) > -\gamma\beta^2$. Assuming that $\gamma \to -1$ makes it least likely that the inequality holds, since the right-hand side gets larger. In this case, $\beta > 0.83$ in order for the inequality not to hold. Further, it becomes obvious that parts (ii) and (iii) deliver no clear results for complementary products. □

Parts (i) - (iii) show that unions X and Y are indifferent between merging and staying separated if the worker groups are independent of each other or if the union has no bargaining power at all. Further, parts (i) - (iii) show that the unions are indifferent for very specific combinations of parameter values. However, the unions have strict incentives to merge if the products are substitutes in consumption ($0 < \gamma \leq 1$). On the other hand, parts (i) - (iii) do not reveal clear results for complementary products ($-1 < \gamma < 0$). As already mentioned, it has to hold that $\beta > 0.83$ in order that the unions want to merge for complementary workers if they bargain simultaneously. Under sequential bargaining, union X only has an incentive to merge for complementary workers if $\beta > 0.92$.[12] In a recent study, Hirsch & Schnabel (2014) try to infer the union power in a right-to-manage model of collective bargaining with the help of annual data for Germany from 1992-2009. Using a utilitarian objective function, their analysis shows that the union power is in the range of 15-25% in Germany.[13] Thus, the empirical evidence predicts parameter values that support simultaneous bargaining and sequential bargaining for complementary workers. These findings are used to summarize unions' merger decisions and the subgame-perfect equilibrium outcomes.

Proposition 2.5. *The following contracts are established in equilibrium when joint bargaining is compared to simultaneous bargaining and sequential bargaining:*
(i) if $0 < \gamma \leq 1$, wages and employment levels are given by $\hat{w}, \hat{r}, \hat{x}, \hat{y}$,
(ii) if $-1 < \gamma \leq 0$, wages and employment levels are given by w^*, r^*, x^*, y^*.

Proof. Proposition 2.4 can be used to establish a ranking in unions' utilities. For $0 < \gamma \leq 1$

[12]In comparison to part (i), this cannot be seen directly from the condition of part (ii) as the RHS does not continuously in- or decrease in γ. Therefore, the condition is plotted in a three-dimensional space. Appendix 2.A.2 provides the corresponding figure. The three-dimensional plot of the condition of part (iii) is not provided in the Appendix, since it is enough to show that a merger does not materialize if one union has an incentive to bargain separately. However, it has to hold that $\beta > 0.59$ in order that union Y has an incentive to merge for complementary products.

[13]They also conduct several robustness checks with Stone-Geary preferences and different weights on employment and wages. None of their results yield a higher bargaining power than 83%. Capuano & Schmerer (2015) confirm this result. They use data from the linked employer-employee data based on the IAB establishment panel over the years 1996-2008 and estimate a collective bargaining power of 15%.

it holds that $\hat{u}_x > u_x^* > \tilde{u}_x$ and $\hat{u}_y > u_y^* > \tilde{u}_y$. Thus, unions X and Y have strict incentives to merge and the equilibrium contract can only be given by joint bargaining. It is further assumed that the unions do not merge if they are indifferent between merging and staying separated. This proves part (i). To prove part (ii), it is not possible to establish an unambiguous ranking for unions' utility as for substitutable products. However, it is considered that empirical evidence predicts values for the unions' bargaining power β that are only in line with separate bargaining for complementary products. Thus, both unions will bargaining separately with the firm. However, the question remains open if the equilibrium contract is given by simultaneous or sequential bargaining. In order to identify which contract should be implemented in equilibrium, the joint surplus under simultaneous bargaining, given by eq. (2.22), is compared with the surplus obtained under sequential bargaining, see eq. (2.33). A comparison yields the following result:

$$\tilde{\Pi} \gtreqless \Pi^* \text{ if } \begin{cases} 0 < \beta \leq 1 \wedge 0 < \gamma \leq 1, \\ \beta = 0 \vee \gamma = 0, \\ 0 < \beta \leq 1 \wedge -1 < \gamma < 0. \end{cases}$$

Since the joint surplus is always larger under sequential bargaining for $-1 < \gamma < 0$, the equilibrium contract is given by sequential bargaining. It is further assumed that in the case of indifference the sequential bargaining contract is implemented. □

Using the just established equilibrium contracts, it becomes obvious from Proposition 2.1 that the unions' decision to merge or to bargain individually benefit workers in terms of their wage rate. Only for complementary products, workers of union Y, which bargains in a second stage under sequential bargaining, would receive a higher wage rate under simultaneous bargaining.

2.5 Summary and Conclusion

This chapter develops a theoretical model that analyzes the impact of multi-unionism on equilibrium outcomes, such as, wage rates and the merger incentives of the labor unions. Studying the effects of multi-unionism is an important issue, especially since in European countries multi-unionism is on the rise for the last couple of decades. A model variant is considered, where a single firm has to bargain with two labor unions. It is assumed that the firm produces two final goods, whereas the production of each good requires only the labor input from the corresponding labor union. In order to model the negotiations between the firm and the unions, a right-to-manage model is used.

The comparison of joint bargaining with sequential and simultaneous bargaining predicts that the existing merger results of the unions can be supported in a right-to-manage model for the asymmetric Nash bargaining solution: labor unions have strict incentives to merge if the products are substitutable in consumption, while they bargain independently and sequentially if the products are complementary. The model further demonstrates that workers benefit in terms of their wage rate from the decision of unions to merge or to stay separated. Only for complementary products, the workers of the union that bargains in a second stage under sequential bargaining would receive a higher wage rate under simultaneous bargaining.

There are still some open questions regarding the theoretical literature on multi-unionism. For example, it would be interesting to see how the equilibrium outcomes and the merger incentives of the unions are affected in a framework, which takes the competition between unions for members into account. It is commonly known that craft unions try to persuade members from the larger industry unions to switch unions in order to increase their power. Furthermore, the question about the stability of the equilibrium contracts under sequential bargaining remains open. Due to the first-mover advantage, workers are strictly better off if they are a member of the union that is bargaining in a first stage with the firm. Thus, the members of the other union have strict incentives to switch to the union that bargains first. As a consequence, the contract of the other union would not be enforceable in equilibrium. All in all, the analyzed model is missing a mechanism that prevents members to defect to the union that bargains in a first step with the firm.

2.A Appendix

2.A.1 Joint Bargaining without the Symmetry Assumption

Stage 2

In stage 2, the firm chooses the number of workers of unions X and Y. The maximization problem of the firm is given by

$$\max_{x,y} \pi = (1 - x - \gamma y)x + (1 - y - \gamma x)y - xw - yr. \tag{2.34}$$

The first-order conditions that solve the maximization problem of eq. (2.34) are

$$x = \frac{1 - 2\gamma y - w}{2} \quad \text{and} \quad y = \frac{1 - 2\gamma x - r}{2}. \tag{2.35}$$

Inserting the solutions from eq. (2.35) in each other, the corresponding employment levels are given by eq. (2.8):

$$x = \frac{1 - w - \gamma + \gamma r}{2(1 - \gamma^2)} \quad \text{and} \quad y = \frac{1 - r - \gamma + \gamma w}{2(1 - \gamma^2)}.$$

Stage 1

The generalized Nash-bargaining problem between the firm and union Z can be stated as

$$\begin{aligned} &\max_{w,r} [\pi(x, w, y, r)]^{1-\beta} [u_z]^\beta \\ &= [(1 - x - \gamma y)x + (1 - y - \gamma x)y - xw - yr]^{1-\beta} [xw + yr]^\beta. \end{aligned} \tag{2.36}$$

Using the employment levels determined in the second stage, the bargaining problem between the firm and union Z from eq. (2.36) can be written as

$$\begin{aligned} \max_{w,r} &\left[(1 - w)\frac{1 - w - \gamma + \gamma r}{4(1 - \gamma^2)} + (1 - r)\frac{1 - r - \gamma + \gamma w}{4(1 - \gamma^2)}\right]^{1-\beta} \\ &\times \left[w\frac{1 - w - \gamma + \gamma r}{2(1 - \gamma^2)} + r\frac{1 - r - \gamma + \gamma w}{2(1 - \gamma^2)}\right]^\beta. \end{aligned} \tag{2.37}$$

The wage rates that solve the first-order conditions are given by

$$\hat{w} = \hat{r} = \frac{\beta}{2}. \tag{2.38}$$

Substituting the equilibrium wages from eq. (2.38) in the solution of the employment levels in the second stage, the equilibrium employment levels read

$$\hat{x} = \hat{y} = \frac{2-\beta}{4(1+\gamma)}.$$

The just calculated equilibrium wage rates and employment levels are used to solve the rest of the model. This proceeds analogously to the simple model that is presented in the main body of the chapter.

2.A.2 Incentive of Union X to Merge for Complementary Workers under Sequential Bargaining

Figure 2.1 plots the condition of Proposition 2.4 part (ii) in a three-dimensional space. The condition regulates if union X is indifferent between merging and bargaining sequentially, prefers a merger or wants to stay separated for complementary products. While the orange plot represents the LHS, $4(1-\beta)$, the red plot depicts the RHS as given by $\gamma\beta^2(1-\gamma) - 2\gamma\beta$. It can be clearly seen that $4(1-\beta) < \gamma\beta^2(1-\gamma) - 2\gamma\beta$ and, therefore, $\hat{u}_x > u_x^*$ only holds if $\beta > 0.92$.

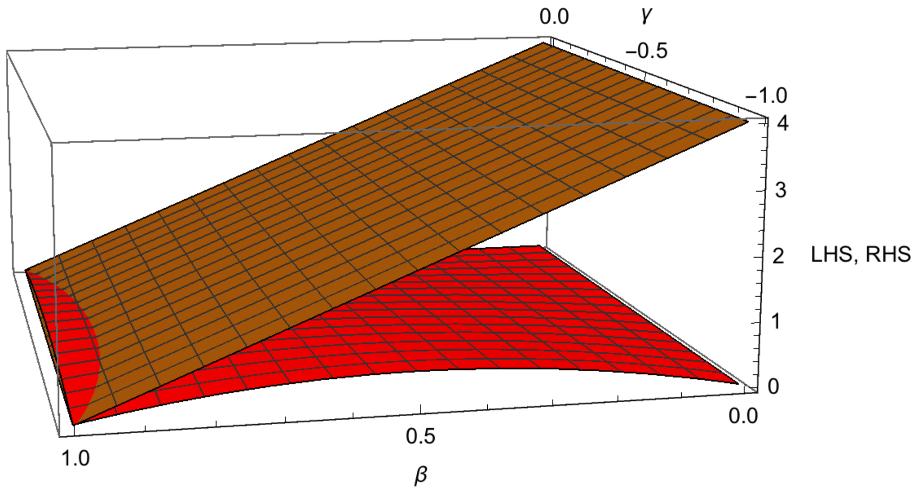

Figure 2.1: Condition of Proposition 2.4 Part (ii) for Complementary Products

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Chapter 3

Deregulation of Temporary Agency Employment in a Unionized Economy: Does This Really Lead to a Substitution of Regular Employment?*

3.1 Introduction

During the last two decades, the use of temporary agency work increased tremendously in almost all OECD countries. In Germany, for example, the number of temporary agency workers increased sevenfold (Jahn & Weber, 2016). With a share of temporary agency employment on overall employment of just about 2% in most industrialized countries, temporary agency employment may seem to be rather small and, therefore, to be a minor labor market issue at first sight. However, the deregulation of temporary agency employment is an important, frequently used and highly discussed labor market policy

*This chapter is the result of joint work with Philipp Baudy and has appeared in an earlier version as Baudy & Cords (2016).

instrument in Europe. There has been ongoing institutional deregulation of temporary agency employment aiming at increasing flexibility of the countries' labor markets. For instance, in Germany the deregulation of temporary agency employment was part of the labor market reform "Agenda 2010" of the former social-democratic chancellor Gerhard Schröder in 2003. The aim of increasing the attractiveness of temporary agency employment was, next to other labor market instruments, to reduce unemployment and to increase the international competitiveness of the German economy. The political idea behind the deregulation of temporary agency employment is to bring more people to work that are not able to find a job in the regular labor market, e.g. long-term unemployed. By using temporary workers in the production, firms may "test" the workers and, afterwards, convert their employment relationship to regular employment. From the firm's perspective, there are various motives for using temporary agency workers in the production process (see, e.g., Holst et al., 2010). One of them is that using temporary agency workers in the production allows to easily adjust the workforce to uncertainty about future output levels, workforce fluctuations, worker absence etc., since temporary agency workers are not covered by employment protection (see Houseman, 2001; Ono & Sullivan, 2013). Another argument for replacing regular by temporary workers is that the use of the latter may lead to cost savings and increasing profits (see, e.g., Jahn & Weber, 2016).

In most European countries, wages are determined by collective bargaining agreements between firms and labor unions. The use of temporary agency employment may lead to a substitution of part of the regular workforce that is represented by the unions. Thus, labor unions have to take the behavior of the employment agencies into account in the negotiation process. Otherwise, the increasing attractiveness for firms to use temporary agency work may induce a substantial replacement of regular employment and, hence, deteriorate the labor unions' position in the economy.

Despite the important role of labor unions in almost all European economies, up to now there has been limited attention on the investigation of temporary agency employment on labor union's behavior. Beissinger & Baudy (2015) give a first theoretical contribution analyzing the firm's strategic use of potential temporary agency employment in the wage-setting process to dampen labor union's wage claims. However, the model neglects the general equilibrium effects of increasing temporary agency employment. Therefore, it is not able to cope with the main argument of opponents of temporary agency work that the ongoing transition to more flexible labor markets leads to a change in the employment structure towards more precarious employment and a decrease in union coverage. Thus, it is left to analyze the effects of temporary agency work on overall employment and the employment structure in the economy in a dynamic setup.

To close this gap, the present chapter analyzes the general equilibrium effects of temporary agency employment in a frictional labor market à la Mortensen & Pissarides (1994) and Pissarides (2000). It is assumed that there are large firms producing differentiated goods with labor being the only production factor. Workers can either be hired directly by the firms or, alternatively, the firm may borrow workers from temporary employment agencies. Both types of work are modeled as perfect substitutes. Regular workers are organized in firm-level labor unions. Agencies are small (one worker) and bargain individually with the firm over the fee a firm has to pay for using temporary workers in its production. This model framework enables to reveal the employment structure in the economy and its adjustment to shocks like institutional changes in the regulation of temporary employment agencies. Furthermore, it is possible to analyze how union coverage evolves in the economy and to examine the flows in the different labor market states. Legal (de)regulation is modeled by regulatory costs arising from institutional barriers like limitations regarding the maximum period of assignment of temporary workers, re-employment bans, synchronization bans or equal pay obligations for regular and temporary agency workers. Higher legal regulation leads to increasing regulatory costs.

The main result of the model is that there is a hump-shaped relationship between temporary agency employment used in the production and its degree of legal deregulation. At first sight, this may be counterintuitive as it means that progressive legal deregulation does not inevitably lead to an increase in temporary agency employment but it may even decline. Furthermore, regular employment monotonically increases in the deregulation of temporary employment. Thus, there is no reduction in the degree of union coverage but, on the contrary, it even increases. Unions and single workers both suffer from temporary agency employment due to declining wage rates and labor unions utility. The findings reject the main argument of opponents of temporary agency employment and support the policy makers' idea that legal deregulation of temporary agency employment increases the flexibility of the European labor markets and brings people to work who may not find regular employment. The model supports the deregulation efforts of temporary agency employment in order to increase the employment level.

The structure of the chapter is as follows. Section 3.2 gives a brief discussion of related literature on labor unions and temporary agency employment. Section 3.3 describes the outline of the model and its components in more detail before the model is solved in Section 3.4. Section 3.5 defines the equilibrium. In Section 3.6, the model is calibrated and its predictions considering the employment structure in the economy are presented. Section 3.7 examines the key insights of the model, i.e. the changes in the wage setting and the employment structure triggered by legal deregulation of the temporary employment sector. Finally, Section 3.8 summarizes the results and concludes.

3.2 Related Literature

The behavior of labor unions has already been widely discussed in the literature (for an overview see Booth, 1995; Boeri et al., 2001; Addison & Schnabel, 2003). However, little attention was paid on modeling unionized labor markets in the framework of search and matching for a long time. A first contribution to labor unions in the matching framework is given by Delacroix (2006). He introduces a multisectorial model with a varying degree of union coverage and monopolistic competition in the goods market and investigates the union's reaction to changes in the unemployment insurance. Based on this framework, Ebell & Haefke (2006) study the effects of a product market deregulation on the formation of labor unions by endogenizing the choice of the bargaining institution. Bauer & Lingens (2013) investigate the efficiency in search models with large firms and collectively bargained wages, while Krusell & Rudanko (2016) analyze the intertemporal effect of unions' commitment to future wages. In another recent contribution, Ranjan (2013) examines the general equilibrium effects of decreasing offshoring costs in a unionized economy. He identifies a non-monotonic relationship of unemployment and offshoring costs in the domestic, offshoring country. Decreasing costs of offshoring increase unemployment first, but a further reduction leads to a decrease in unemployment afterwards.

Theoretical work on temporary agency employment is rather limited. The very first theoretical contributions are given by Autor (2001, 2003). While his first paper investigates the role of employment agencies in the screening for regular jobs, the latter describes that firms relinquish to substitute the whole workforce by temporary agency employment due to distinct capital investments related to specific workers. The first contribution to temporary agency employment in the framework of search and matching is provided by Neugart & Storrie (2006). The authors analyze the increase of temporary agency employment based on an improved matching efficiency that is induced by temporary work agencies acting as intermediaries in the matching process of workers and firms. Baumann et al. (2011) use the same framework and enrich the model setup by endogenous job destruction. However, the majority of research on temporary agency employment is based on its empirical investigation and focuses on its strategic use in the production (see, e.g., Vidal & Tigges, 2009; Holst et al., 2010), its effect on the employment structure (Jahn & Bentzen, 2012; Haller & Jahn, 2014), the wage differential of temporary agency work (Garz, 2013), and the question if temporary agency employment may be used as a stepping stone to regular employment (see, e.g., Amuedo-Dorantes et al., 2008; Kvasnicka, 2009; Autor & Houseman, 2005, 2010; Jahn & Rosholm, 2013, 2014).

3.3 Outline of the Model

3.3.1 Labor Market Flows

All workers are assumed to be identical. Following Neugart & Storrie (2006), the workforce is segmented into four different groups. As in the standard matching literature, workers are either unemployed (U) or directly employed at a firm (regular employment, R). Furthermore, workers can be employed at temporary employment agencies. Temporary employment agencies hire workers and have them in their pool (unassigned temporary work, T) with the aim to lend the workers to firms that use the workers in their production (assigned temporary work, A). Unemployed workers may either find a regular job or become unassigned temporary workers. Once in the pool of the temporary employment agency, the job in state T may either be destroyed to unemployment with an exogenous rate δ or the temporary agency worker becomes assigned to a firm. Moreover, temporary agency workers (assigned and unassigned) search on-the-job for regular employment. It is assumed that the effectiveness of search is higher for temporary workers compared to that of unemployed workers. This is reflected by parameters γ_T and γ_A for unassigned and assigned temporary workers, respectively. Assigned temporary workers may find regular jobs or their current position is destroyed with the exogenous rate χ, meaning that they fall back to state T just being in the pool of the temporary employment agency. Employment of regular workers is destroyed to unemployment with the exogenous rate δ, which coincides with the job destruction rate of unassigned temporary jobs. It is assumed that $\chi > \delta$. The reason is that due to its flexibility and a lack of employment protection instruments, temporary agency employment is more affected by exogenous shocks than regular jobs.

Workers accept the first suitable job offer they get whatever type it is and matching of firms and workers/agencies is formally described by the matching function

$$M_i = M(V_i, S_i). \tag{3.1}$$

The matching function exhibits constant returns to scale, is increasing in both arguments, at least twice differentiable, and satisfies the Inada conditions. M_i denotes the instantaneous flow of hires for the different employment states $i = T, A, R$. The number of vacancies posted in state i is denoted by V_i. The number of job-searchers in the respective state is given by S_i. Firms post vacancies for regular and assigned temporary jobs, while temporary employment agencies only post vacancies for unassigned temporary workers. Vacancies posted in state i are filled with the rate $M(V_i, S_i)/V_i \equiv m(\theta_i)$, while the workers' finding rate for a job in state i is $M(V_i, S_i)/S_i \equiv \theta_i m(\theta_i)$. Variable $\theta_i \equiv V_i/S_i$ reflects the labor market tightness in state i. The number of job-searchers differs across the states and, thus, labor market tightness θ_i has to be stated for each "submarket" separately. Unemployed workers search for both, regular and temporary employment, while temporary workers are allowed to search for regular employment on-the-job. Thus, there is an overlap in the groups searching for different types of jobs. The total number of job-searchers

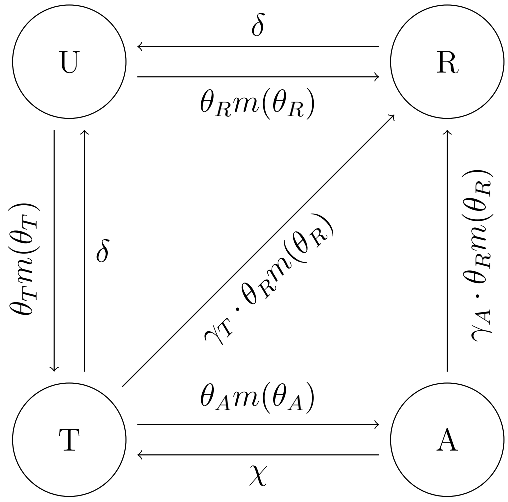


Figure 3.1: Labor Market Flows

for unassigned temporary agency employment equals the number of unemployed workers, $S_T = U$. Unassigned temporary workers look for assignments, $S_A = L_T$. L_i denotes the amount of employed workers in the respective state. Moreover, all workers in states U, T, and A search for regular jobs, i.e. $S_R = U + \gamma_T \cdot L_T + \gamma_A \cdot L_A$. As temporary workers' search effectiveness differs from the search effectiveness of unemployed workers, $\gamma_T \cdot L_T$ and $\gamma_A \cdot L_A$ describe the *effective* number of unassigned and assigned temporary workers looking for regular employment, respectively.[1] Using the information about vacancies and job-searchers in each submarket, it can be concluded that unemployed workers find jobs in regular employment with rate $\theta_R m(\theta_R)$, while unassigned and assigned temporary workers find regular jobs with probabilities $\gamma_T \theta_R m(\theta_R)$ and $\gamma_A \theta_R m(\theta_R)$, respectively. Unemployed workers find unassigned temporary jobs with probability $\theta_T m(\theta_T)$ and, once in the pool of the agency, become assigned with probability $\theta_A m(\theta_A)$. Figure 3.1 depicts the labor market flows.

Using the information about the flows into and out of the different labor market states, the instantaneous flows are represented by

$$\dot{L_T} = m(\theta_T) \cdot V_T + \chi \cdot L_A - \theta_A m(\theta_A) \cdot L_T - \gamma_T \theta_R m(\theta_R) \cdot L_T - \delta \cdot L_T \qquad (3.2)$$

$$\dot{L_A} = m(\theta_A) \cdot V_A - \chi \cdot L_A - \gamma_A \theta_R m(\theta_R) \cdot L_A \qquad (3.3)$$

[1] Total labor force N is normalized to unity. Hence, $U + L_T + L_A + L_R = 1$, with U, L_T, L_A, and L_R denoting the unemployment and employment rates, respectively.

$$\dot{L_R} = m(\theta_R) \cdot V_R - \delta \cdot L_R. \tag{3.4}$$

In the steady state, the in- and outflows for the different states coincide, i.e. $\dot{L_T} = \dot{L_A} = \dot{L_R} = 0$. Thus, eqs. (3.2) - (3.4) can be rewritten to[2]

$$[\delta + \theta_A m(\theta_A) + \gamma_T \theta_R m(\theta_R)] \cdot L_T = m(\theta_T) \cdot V_T + \chi \cdot L_A \tag{3.5}$$

$$[\chi + \gamma_A \theta_R m(\theta_R)] \cdot L_A = m(\theta_A) \cdot V_A \tag{3.6}$$

$$\delta \cdot L_R = m(\theta_R) \cdot V_R. \tag{3.7}$$

Similar to the employment flows, the flows into and out of unemployment are

$$\dot{U} = \delta \cdot L_R + \delta \cdot L_T - \theta_T m(\theta_T) \cdot U - \theta_R m(\theta_R) \cdot U. \tag{3.8}$$

As the change in unemployment is zero in steady state, i.e. $\dot{U} = 0$, the equilibrium unemployment rate is formally represented by

$$U = \frac{\delta(L_R + L_T)}{\theta_T m(\theta_T) + \theta_R m(\theta_R)}. \tag{3.9}$$

Note that equilibrium unemployment does not directly depend on the labor market tightness in state A. The amount of assigned temporary workers only influences the structure of employment, but not its rate. There is no direct channel from assigned temporary work to unemployment or vice versa.

3.3.2 Goods Market

Households act as consumers in the goods market and, at the same time, as workers in the labor market. Consumers are risk neutral in the aggregate consumption good and have Dixit & Stiglitz (1977) preferences over a continuum of differentiated goods. The goods demand function can be derived from the following optimization problem that the households are facing:

$$\max_{c_{j,k}} \left(\int_0^n c_{j,k}^{\frac{\eta-1}{\eta}} \, dj \right)^{\frac{\eta}{\eta-1}} \quad \text{with} \quad \eta > 1, \tag{3.10}$$

[2]The flow equations given here represent the firm's perspective. They can easily be converted to the respective flow equations from the workers side of view. To do so, the respective job-searchers of each state and the condition that the total labor force equals the sum of the workers of each state have to be used. Appendix 3.A.1 provides the respective equations.

subject to the resource constraint

$$I_k = \int_0^n c_{j,k} \cdot \left(\frac{P_j}{P}\right) \cdot dj, \tag{3.11}$$

where j denotes the differentiated good, k the household and n the number of firms. Further, $c_{j,k}$ denotes household k's consumption of good j, while I_k is the real income of household k. Parameter η gives the elasticity of substitution across the differentiated goods, while $p_j = P_j/P$ is the firm's price relative to the aggregate price level. The solution to the aforementioned maximization problem and, thus, aggregate demand for good j is given by

$$Y_j \equiv \int_0^m c_{j,k} \cdot dk = p_j^{-\eta} \cdot I, \tag{3.12}$$

with m being the number of households, $I \equiv \int_0^m I_k \cdot dk$ being aggregate real income and $P \equiv (\int_0^n P_j^{1-\eta} dj)^{\frac{1}{1-\eta}}$ denoting the price index.

3.3.3 Firms

In contrast to the basic matching model of Mortensen & Pissarides (1994) and Pissarides (2000), the model in this chapter is dealing with large firms that employ multiple workers. Each firm j produces a single, differentiated final good. There are two reasons for using large firms instead of one-worker firms. First, in models of monopolistic competition the optimal firm size and its output level are determined endogenously. Hence, restricting the firm size to one worker conflicts with monopolistic goods market competition (for more details, see Ebell & Haefke, 2006). Second, assuming firm-level labor unions representing more than one worker, it is natural to assume bargaining with large firms. Considering the production technology of the firm, final goods are produced by using labor as the only input factor. Workers can either be employed directly at the respective firm (regular workers), or they are borrowed from temporary work agencies (assigned temporary workers). The amount of regular workers employed at firm j is denoted by $L_{j,R}$, while $L_{j,A}$ gives the amount of temporary agency workers used in the production. The firm's production technology is described by

$$Y_j = \tau \cdot [L_{j,R} + L_{j,A}]^{\rho}, \tag{3.13}$$

where τ denotes an efficiency parameter and $\rho \in (0,1)$ captures decreasing returns to scale in the production. Using this type of production technology reflects the idea that regular workers and temporary agency workers are perfect substitutes. This is a reasonable assumption because temporary agency employment is used in almost all branches and in particular in blue-collar, low-skilled jobs, to replace regular workers doing simple tasks. The reason to replace regular workers doing simple tasks is all about lowering costs.

The instantaneous profit of a firm is given by[3]

$$\pi_j = p_j(Y_j)\, Y_j - w_R\, L_{j,R} - \varepsilon x\, L_{j,A}^{\sigma} - h\,(V_{j,A} + V_{j,R}), \tag{3.14}$$

with $p_j(Y_j)$ representing the firm's inverse goods demand function that can be derived from eq. (3.12). Variable w_R denotes the wage rate of regular workers. The fee the firm has to pay to the temporary work agency is depicted by x, while h denotes the costs of posting a vacancy in state A and R. Parameter ε describes regulatory costs or rather institutional barriers associated with firm's use of temporary employment, e.g. employment protection, the maximum period of assignment, synchronization ban and re-employment ban. Next to institutional regulations, there are often voluntary firm-level agreements between employers and employee representations regulating the use of temporary agency employment. For instance, such agreements limit the share of temporary agency workers on all employees within a firm or specify a maximum duration of assignment undercutting the legal time limit. Furthermore, they may include commitments for transferring temporary workers to regular contracts after a specific assignment period or expand the rights of the employees representative committee with increasing temporary agency employment used within the firm.[4] Such non-institutional firm-level costs of temporary agency work are convexly increasing in the number of employed temporary workers, as many of these regulations apply only if the amount of temporary agency workers in the firm exceeds specific levels. In principle, it holds that the stronger the employee representation in a

[3] Appendix 3.A.2 shows that this profit function is strictly concave and, hence, a profit maximum exists.

[4] An overview of such voluntary firm-level agreements used in Germany are provided by R. Krause (2012).

firm, the more agreements apply with an increasing amount of temporary agency workers. The convexity of the costs is reflected by parameter $\sigma > 1$.[5] $V_{j,R}$ and $V_{j,A}$ denote the number of vacancies firm j posts for regular and temporary workers, respectively.

3.3.4 Workers

The expected value of regular employment is given by

$$r\Psi_R = w_R + \delta \cdot (\Psi_U - \Psi_R). \tag{3.15}$$

Wage rate w_R reflects the instantaneous utility of being regularly employed, while the second term depicts the loss from becoming unemployed weighted by its probability of occurrence δ. The expected value of being unemployed is given by

$$r\Psi_U = z + \theta_T m(\theta_T) \cdot (\Psi_T - \Psi_U) + \theta_R m(\theta_R) \cdot (\Psi_R - \Psi_U). \tag{3.16}$$

Parameter z denotes the net income of being unemployed. The last two terms at the right-hand-side (RHS) describe the expected gains from possible changes in the labor market state. Similarly, the present discounted value of being in the pool of the temporary work agency is

$$r\Psi_T = w_T + \delta \cdot (\Psi_U - \Psi_T) + \theta_A m(\theta_A) \cdot (\Psi_A - \Psi_T) + \gamma_T \cdot \theta_R m(\theta_R) \cdot (\Psi_R - \Psi_T). \tag{3.17}$$

Variable w_T denotes the payment that temporary agency workers receive for being in the pool of the temporary work agency.[6] By searching on-the-job they may improve their position in the labor market and find regular employment with probability $\gamma_T \theta_R m(\theta_R)$. The worker's expected value of assigned temporary agency employment is

$$r\Psi_A = w_A + \chi \cdot (\Psi_T - \Psi_A) + \gamma_A \cdot \theta_R m(\theta_R) \cdot (\Psi_R - \Psi_A), \tag{3.18}$$

[5] This type of convex costs are also used by Koskela & Schöb (2010) and Ranjan (2013). They argue that the costs of offshoring are convex. Such costs are similar to the costs of temporary agency employment as offshoring is also used as a potential cost-saving production alternative for firms.

[6] This labor market setup fits well to Central European countries such as France, Germany, the Netherlands, and Sweden (Arrowsmith, 2006). In those countries temporary workers even receive a wage when they are just on the books of the temporary work agency.

with w_A denoting the wage that temporary workers receive being assigned to a firm. For simplicity reasons it is assumed that the agency sets w_T and w_A in a way that makes the worker at the margin indifferent between being unemployed, being in the pool of temporary employment agencies, or being assigned to a client firm, such that

$$\Psi_U = \Psi_T = \Psi_A. \tag{3.19}$$

Even if this assumption seems quite strong at first sight, it is reasonable. It reflects the fact that temporary agency workers usually have a rather weak bargaining position as they are not organized in labor unions (see, e.g., Storrie, 2002; Dolado et al., 2000; Neugart & Storrie, 2006). Furthermore, workers may accept a rather low utility out of being employed at a temporary employment agency. They use temporary agency employment as a stepping stone to regular employment. The probability of finding a regular job while being employed at a temporary employment agency is higher compared to finding a regular job out of being unemployed. Moreover, eq. (3.19) simplifies the model significantly. Applying this assumption, the value functions (3.15) - (3.18) simplify to

$$r\Psi_R = w_R + \delta \cdot (\Psi_U - \Psi_R), \tag{3.20}$$

$$r\Psi_T = w_T + \gamma_T \, \theta_R m(\theta_R) \, (\Psi_R - \Psi_T), \tag{3.21}$$

$$r\Psi_A = w_A + \gamma_A \, \theta_R m(\theta_R) \, (\Psi_R - \Psi_A), \tag{3.22}$$

$$r\Psi_U = z + \theta_R m(\theta_R) \, (\Psi_R - \Psi_U). \tag{3.23}$$

3.3.5 Labor Unions

It is assumed that all regularly employed workers are members of a labor union. Firm specific, symmetric labor unions determine the wage rate for regular workers by maximizing the rent of its members. The rent of a union member equals the difference between the expected value of regular employment and the outside option, which is the value of being unemployed. Thus, the rent of a union member is given by $\Psi_R - \Psi_U$. As the union bargains for all regular workers that are employed at firm j, the utility of the respective labor union is formally represented by

$$\Lambda_j = [\Psi_R - \Psi_U] \cdot L_{j,R}. \tag{3.24}$$

3.3.6 Temporary Employment Agencies

Temporary employment agencies pay a wage rate w_A to temporary agency workers that are assigned to a client firm and a wage rate w_T to unassigned temporary agency workers that are only in the pool of the agency. For each assigned temporary agency worker, the agency receives a fee x from the firm the worker is lend to.

In contrast to firms, it is considered to have one-worker agencies. Each agency offers a single vacancy that can be filled by an unemployed worker. In case of a successful match, the unemployed worker switches to the worker pool of the agency and waits for assignment at a client firm. The agency's expected profit of posting a vacancy is

$$r\Omega_V = -\tilde{h} + m(\theta_T)[\Omega_T - \Omega_V], \tag{3.25}$$

where $\tilde{h}$ denotes the cost of a vacancy.[7] The expected profit of having a worker on hold, Ω_T, is

$$r\Omega_T = -w_T + \theta_A m(\theta_A)[\Omega_A - \Omega_T] + \gamma_T \theta_R m(\theta_R)[\Omega_V - \Omega_T] + \delta[\Omega_V - \Omega_T]. \tag{3.26}$$

Even in case of a filled vacancy, eq. (3.26), there is no positive flow income but, on the contrary, the agency has to pay w_T. Having a vacancy filled is only worthwhile for the agency due to the potential assignment of the worker to a client firm. This is reflected by the second term at the right-hand-side. In general, the last three terms denote the expected gains/losses due to changes in the different labor market states. Finally, the agency's expected profit of assigning a worker to a client firm is given by

$$r\Omega_A = x - w_A + \gamma_A \theta_R m(\theta_R)[\Omega_V - \Omega_A] + \chi[\Omega_T - \Omega_A], \tag{3.27}$$

[7] Agency's vacancy costs $\tilde{h}$ differ from the firm's vacancy costs h with $h > \tilde{h}$. This reflects the fact that the firms' screening process of potential employees is more intensive, since they are more interested in long-term employment relationships and stronger rules of employment protection apply, while agencies are able to quit the employment relationship easier.

where $x - w_A$ denotes the flow profit in this state. Using eqs. (3.25) - (3.27), the agency's job creation can formally be described as

$$\frac{\tilde{h}}{m(\theta_T)} = \frac{\theta_A m(\theta_A)(x - w_A) - w_T[r + \chi + \gamma_A \theta_R m(\theta_R)]}{[r + \theta_A m(\theta_A) + \gamma_T \theta_R m(\theta_R) + \delta] \cdot [r + \chi + \gamma_A \theta_R m(\theta_R)] - \chi \theta_A m(\theta_A)}. \quad (3.28)$$

3.4 Solution of the Model

Recalling the assumption that the values of being unemployed, being in the pool of the temporary employment agency, and being assigned to a client firm coincide, the wage rates of assigned and unassigned temporary workers can be derived using the workers' asset functions. The bargaining problems between firms and unions and firms and agencies are interrelated due to the substitutability of regular and temporary agency employment in the firms' production technology. Hence, the whole bargaining game consists of two stages involving three bargaining parties: Firms, unions, and temporary employment agencies.

(i) In the first stage, there are two simultaneous bargaining games. On the one hand, the firm bargains with the agency over the fee the firm has to pay to the agency to use temporary agency workers in the production process. As we are dealing with one-worker agencies, the bargaining problem is of the type individual bargaining. On the other hand, the labor union determines the wage rate of regular workers. As the union is responsible for all regular workers in a firm, the bargaining problem is a collective one. For both bargaining games the model uses the so-called right-to-manage model. The negotiation games are further specified in the respective subsections.

(ii) In the second stage, the firm uses its "right to manage" to set the respective employment levels for regular and temporary agency workers.

In order to obtain a subgame perfect Nash equilibrium for the whole bargaining game, the two stages have to be solved by backward induction.

3.4.1 Firm's Labor Demand

The firm's intertemporal profit maximization problem is given by

$$\max_{\substack{V_{j,R}(s)\\ V_{j,A}(s)\\ L_{j,R}(s)\\ L_{j,A}(s)}} \int_t^{\infty} e^{-r(s-t)} \Big\{ p[Y_j(s)]\, Y_j(s) - w_R(s)\, L_{j,R}(s) - \varepsilon x(s)\, L_{j,A}^{\sigma}(s) - h\,[V_{j,A}(s) + V_{j,R}(s)] \Big\} ds, \tag{3.29}$$

subject to the laws of motion for assigned temporary and regular workers, eqs. (3.3) and (3.4), and the goods demand and production function, given by eqs. (3.12) and (3.13), respectively. Thus, the current-value Hamiltonian that solves this intertemporal maximization problem can formally be stated as

$$\begin{aligned} H =& \tau^{\kappa}(L_{j,R} + L_{j,A})^{\rho\kappa} I^{1-\kappa} - w_R\, L_{j,R} - \varepsilon x\, L_{j,A}^{\sigma} - h\,(V_{j,A} + V_{j,R}) \\ &+ \lambda_1[m(\theta_R)V_{j,R} - \delta L_{j,R}] + \lambda_2[m(\theta_A)V_{j,A} - \chi L_{j,A} - \gamma_A\theta_R m(\theta_R)L_{j,A}], \end{aligned} \tag{3.30}$$

with eqs. (3.3) and (3.4) denoting the equations of motion for the state variables $L_{j,R}$ and $L_{j,A}$, and $\lambda_1 \equiv \mu_1 e^{-r(s-t)}$ and $\lambda_2 \equiv \mu_2 e^{-r(s-t)}$ being the current-value Lagrange multipliers. Variables $V_{j,A}$ and $V_{j,R}$ are the control variables of the intertemporal maximization problem. Parameter $\kappa \equiv (\eta - 1)/\eta$, with $\kappa \in (0, 1)$, reflects the firm's monopoly power in the goods market. The lower κ, the higher the firm's monopoly power. The relevant first-order conditions of the intertemporal maximization problem are

$$\frac{\partial H}{\partial V_{j,R}} = -h + \lambda_1 m(\theta_R) = 0, \tag{3.31}$$

$$\frac{\partial H}{\partial V_{j,A}} = -h + \lambda_2 m(\theta_A) = 0, \tag{3.32}$$

$$\frac{\partial H}{\partial L_{j,R}} = \rho\kappa\tau^{\kappa}(L_{j,R} + L_{j,A})^{\rho\kappa-1} I^{1-\kappa} - w_R - \delta\lambda_1 = r\lambda_1 - \dot{\lambda}_1, \tag{3.33}$$

$$\frac{\partial H}{\partial L_{j,A}} = \rho\kappa\tau^{\kappa}(L_{j,R} + L_{j,A})^{\rho\kappa-1} I^{1-\kappa} - \sigma\varepsilon x L_{j,A}^{\sigma-1} - \lambda_2[\chi + \gamma_A\theta_R m(\theta_R)] = r\lambda_2 - \dot{\lambda}_2. \tag{3.34}$$

In the steady state it has to hold that $\dot{\lambda}_1 = \dot{\lambda}_2 = 0$ and $\dot{L}_{j,R} = \dot{L}_{j,A} = 0$. By substituting eqs. (3.31) and (3.32) in eqs. (3.33) and (3.34), respectively, the first-order conditions turn out to be

$$\rho\kappa\tau^{\kappa}(L_{j,R} + L_{j,A})^{\rho\kappa-1} I^{1-\kappa} - w_R = (r + \delta)\frac{h}{m(\theta_R)}, \tag{3.35}$$

$$\rho\kappa\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-1}I^{1-\kappa}-\sigma\varepsilon xL_{j,A}^{\sigma-1}=[r+\chi+\gamma_A\theta_R m(\theta_R)]\frac{h}{m(\theta_A)}. \tag{3.36}$$

Eqs. (3.35) and (3.36) determine the firm's labor demand for regular and assigned temporary workers. Theoretically, it may be possible that firms only produce with one type of labor. Appendix 3.A.3 discusses the conditions for such corner solutions to appear. However, in the following it is assumed that parameters are such that regular and temporary employment are both positive, i.e. there is an interior solution.[8]

It can be easily shown that[9]

$$\frac{dL_{j,R}}{dw_R}<0,\ \frac{dL_{j,R}}{dx}>0,\ \frac{dL_{j,A}}{dx}<0,\ \text{and}\ \frac{dL_{j,A}}{dw_R}>0.$$

3.4.2 Wage Determination for Regular Workers

The wage rate for regular workers is determined by collective bargaining. Since the union represents all regular employed workers in a firm, it has a very strong bargaining position. Thus, it is assumed that wages are determined by a special variant of the right-to-manage model, namely the monopoly union model. This simplifies the formal analysis of the model. Having monopoly power, the union has the exclusive right to set the wage rate of regular workers. In response, the firm sets the corresponding employment level. Thus, the union has to take account of the firm's labor demand for regular workers that decreases in the wage of regular workers as well as the labor demand for assigned temporary workers that increases in the wage of regular workers.

The monopoly union maximizes its objective function, eq. (3.24), subject to the total labor demand of the firm, given by eqs. (3.35) and (3.36). Using eqs. (3.20) and (3.23), the rent of a single worker is given by

$$\Psi_R-\Psi_U=\frac{w_R-z}{r+\delta+\theta_R m(\theta_R)}. \tag{3.37}$$

[8]This rather restrictive assumption is based on Ranjan (2013, p. 176), who uses a similar assumption concerning the two production factors domestic labor and a foreign produced input, which are perfect substitutes in production.

[9]Appendix 3.A.4 provides the detailed calculations.

The union's maximization problem can formally be stated by the following Lagrangian function:

$$\begin{aligned}\mathscr{L} = &\frac{w_R - z}{r+\delta+\theta_R m(\theta_R)} \cdot L_{j,R} + \xi_1 \left[\frac{r+\delta}{m(\theta_R)} h - \rho\kappa\tau^{\kappa} (L_{j,R} + L_{j,A})^{\rho\kappa-1} I^{1-\kappa} + w_R \right] \\ &+ \xi_2 \left[\frac{r+\chi+\gamma_A \theta_R m(\theta_R)}{m(\theta_A)} h - w_R - \frac{r+\delta}{m(\theta_R)} h + \sigma\varepsilon x L_{j,A}^{\sigma-1} \right].\end{aligned} \tag{3.38}$$

The first-order conditions are

$$\frac{\partial \mathscr{L}}{\partial L_{j,R}} = \frac{w_R - z}{r+\delta+\theta_R m(\theta_R)} - \xi_1 \cdot \rho\kappa(\rho\kappa - 1)\tau^{\kappa} (L_{j,R} + L_{j,A})^{\rho\kappa-2} I^{1-\kappa} = 0, \tag{3.39}$$

$$\frac{\partial \mathscr{L}}{\partial L_{j,A}} = -\xi_1 \cdot \rho\kappa(\rho\kappa - 1)\tau^{\kappa} (L_{j,R} + L_{j,A})^{\rho\kappa-2} I^{1-\kappa} + \xi_2 \cdot (\sigma - 1)\sigma\varepsilon x L_{j,A}^{\sigma-2} = 0, \tag{3.40}$$

$$\frac{\partial \mathscr{L}}{\partial w_R} = \frac{L_{j,R}}{r+\delta+\theta_R m(\theta_R)} + \xi_1 - \xi_2 = 0. \tag{3.41}$$

Combining eqs. (3.39) - (3.41), the wage rate for regular workers is given by

$$w_R = z + L_{j,R} \left[\frac{(\rho\kappa - 1)\rho\kappa\tau^{\kappa} (L_{j,R} + L_{j,A})^{\rho\kappa-2} I^{1-\kappa} \cdot (\sigma - 1)\sigma\varepsilon x L_{j,A}^{\sigma-2}}{(\rho\kappa - 1)\rho\kappa\tau^{\kappa} (L_{j,R} + L_{j,A})^{\rho\kappa-2} I^{1-\kappa} - (\sigma - 1)\sigma\varepsilon x L_{j,A}^{\sigma-2}} \right]. \tag{3.42}$$

Evaluation of the RHS of eqs. (3.42) reveals that the term in brackets is positive. Thus, the union sets the wage rate for regular workers as a mark-up over the net income of being unemployed.

3.4.3 Determination of the Fee for Firm's Use of Temporary Employment

The fee for using a temporary agency worker in the production is determined by bargaining between firms and temporary work agencies. As each agency employs only one worker, the bargaining problem is similar to individual bargaining. In contrast to the monopoly union model, which is used for the determination of the union's wage claims, firms and agencies bargain directly over the fee. This reflects the fact that a single agency is less powerful in the negotiation process than a labor union. Furthermore, firms that hire more than one agency worker have to bargain with several temporary employment agencies separately.

The firm treats each additional assigned temporary worker as a marginal worker. Thus, the rent of the firm in the Nash product equals the contribution of an additional assigned temporary worker, which is formally represented by the partial derivative of the firms profit with respect to $L_{j,A}$. As it has to be taken into account that the labor demand of regular and assigned temporary workers are mutually best responses, the firm's profit is evaluated at the optimal labor demand for regular workers, $L^*_{j,R}$. Thus, the generalized Nash-bargaining problem between the firm and the agency can be stated as

$$\max_x \Big[\Omega_A - \Omega_T\Big]^\beta \cdot \Big[\frac{\partial \pi(L^*_{j,R})}{\partial L_{j,A}}\Big]^{1-\beta}, \tag{3.43}$$

where $\beta \in (0,1)$ denotes the agency's bargaining power. The agency's rent, $\Omega_A - \Omega_T$, can be computed using eqs. (3.25) - (3.27) and the free entry condition, $\Omega_V = 0$. It is formally given by

$$\Omega_A - \Omega_T = \frac{x - w_A + w_T + \frac{\tilde{h}}{m(\theta_T)} \cdot [\gamma_T \theta_R m(\theta_R) + \delta - \gamma_A \theta_R m(\theta_R)]}{r + \chi + \theta_A m(\theta_A) + \gamma_A \theta_R m(\theta_R)}. \tag{3.44}$$

Taking into account that the number of regular workers is chosen to maximize the firm's profit, the marginal contribution of an additional assigned temporary agency worker for the firm is given by

$$\frac{\partial \pi(L^*_{j,R})}{\partial L_{j,A}} = w_R - \sigma \varepsilon x L^{\sigma-1}_{j,A}. \tag{3.45}$$

Thus, the first-order condition of the bargaining problem in eq. (3.43) is

$$\beta \cdot \big(w_R - \sigma \varepsilon x L^{\sigma-1}_{j,A}\big) = (1-\beta) \cdot \Big[x - w_A + w_T + \frac{\tilde{h}}{m(\theta_T)} \cdot \big[\gamma_T \theta_R m(\theta_R) + \delta - \gamma_A \theta_R m(\theta_R)\big]\Big] \cdot \sigma \varepsilon L^{\sigma-1}_{j,A}. \tag{3.46}$$

After some rearrangement, the optimal fee for temporary workers can be obtained as

$$x = \beta \frac{w_R}{\sigma \varepsilon L^{\sigma-1}_{j,A}} + (1-\beta)\Bigg[\bigg(w_A + \frac{\tilde{h}}{m(\theta_T)} \gamma_A \theta_R m(\theta_R)\bigg) - \bigg(w_T + \frac{\tilde{h}}{m(\theta_T)}[\gamma_T \theta_R m(\theta_R) + \delta]\bigg)\Bigg]. \tag{3.47}$$

In the hypothetical case that the whole bargaining power is on the side of the agency (i.e. $\beta = 1$), the fee would equal the first term on the RHS. Thus, the agency would set the fee in order to equate the unit costs of regular and assigned temporary employment. In the other hypothetical case that the whole bargaining power is on the firm's side (i.e. $\beta = 0$), the fee would equal the term in brackets. It would therefore hold, that the firm's fee is exactly the difference between the agency's total costs of an assigned temporary job and the agency's total costs of an unassigned temporary worker. As the bargaining power is shared between the firm and the agency, the optimal fee is the weighted sum of the aforementioned described terms.

3.4.4 Wage Determination for Agency Workers

Workers are indifferent between being unemployed or in either state of temporary agency employment, see eq. (3.19). Thus, the wage rates that temporary agency workers receive can easily be computed by combining the respective asset functions. Using eqs. (3.20), (3.21), and (3.23), the wage for unassigned temporary workers turns out to be

$$w_T = z + (w_R - z) \cdot \Gamma_T(\theta_R), \quad \text{where} \quad \Gamma_T(\theta_R) = \left[\frac{(1-\gamma_T)\theta_R m(\theta_R)}{r + \delta + \theta_R m(\theta_R)}\right]. \tag{3.48}$$

Similarly, using eqs. (3.20), (3.22), and (3.23), the wage for assigned temporary workers can be computed as

$$w_A = z + (w_R - z) \cdot \Gamma_A(\theta_R), \quad \text{where} \quad \Gamma_A(\theta_R) = \left[\frac{(1-\gamma_A)\theta_R m(\theta_R)}{r + \delta + \theta_R m(\theta_R)}\right]. \tag{3.49}$$

Wages are set as a mark-up over net unemployment income. The mark-up is denoted by $\Gamma_l(\theta_R)$, with $l = A, T$. As the wage rate for regular workers is larger than the net income of being unemployed, it is easy to see that the mark-up is only positive if the search effectiveness parameters γ_T and γ_A are smaller than unity. Parameters γ_T and γ_A being equal to unity means that the search effectiveness of temporary workers coincides with that of unemployed workers. In this case, the wage rates of both types of temporary workers simplify to the net unemployment income, i.e. $w_T = w_A = z$. It seems plausible to assume that the search effectiveness of unassigned and assigned temporary workers is larger than the search effectiveness of an unemployed worker. In this case, the resulting wage rates are smaller than the net income of being unemployed. At first sight, this sounds counterintuitive. However, it reveals the idea that unassigned and assigned temporary agency workers temporarily accept a lower wage, since they hope to find a regular job with larger probability compared to looking for regular employment while being unemployed. This is in line with the idea that temporary agency work is a stepping stone into regular employment.

3.5 Steady-State Equilibrium

The key endogenous variables θ_i, w_i, x, L_i and U for $i = T, A, R$ are determined by the flow equations (3.5) - (3.7) and (3.9), the labor demand equations (3.28), (3.35) and (3.36), the equations for workers wage rates (3.48), (3.49) and (3.42), and the fee that firms have to pay for using temporary agency employment in the production, eq. (3.47). Furthermore, in equilibrium the resource constraint, that aggregate demand and aggregate production coincide, has to hold. Hence,

$$Y \equiv \int_0^n Y_j \left(\frac{P_j}{P} \right) dj \tag{3.50}$$

is fulfilled. Due to symmetry of the firms in equilibrium, the firm's price coincides with the aggregate price level, hence, $p_j = 1$ and eq. (3.50) simplifies to $Y = n\,Y_j$. This automatically implies that $I = Y_j$.

3.6 Calibration

To describe the equilibrium of the model and to show the effects of the legal deregulation, the model is calibrated using values that result in an overall unemployment rate that is similar to what is observed for industrialized countries. The matching function that is used in the following is of Cobb-Douglas type and formally represented by

$$M = \zeta \cdot V_i^{1-\alpha} \cdot S_i^{\alpha}. \tag{3.51}$$

Parameter α indexes the matching elasticity and ζ is a scale parameter denoting the efficiency of the matching process. Following Petrongolo & Pissarides (2001), the matching elasticity is set to $\alpha = 0.5$. The scale parameter of the matching function is $\zeta = 0.3$ (M. U. Krause & Uhlig, 2012).

As described in the outline of the model, unions are modeled to embody the full wage-setting power in the determination of regular workers' wages. In contrast to that, it is assumed that in firm-agency bargaining over the firm's fee for using temporary agency employment, agencies have a rather low bargaining power, set to $\beta = 0.2$. This is mainly based on two reasons. First, contrary to unions who embody specific human capital and clearly differ from each other, firms may be rather indifferent between the agencies to bargain with since the workers that are represented by temporary work agencies perform more or less simple tasks. Second, the agencies' relatively low bargaining power reflects the existing imbalance in the size of firms using temporary agency employment and its supplier. Even if limiting the size of the agency in the present model to one worker is rather restrictive, empirical studies support this imbalance in the size of the bargaining parties. For instance, while the workforce of almost all German firms using temporary agency employment comprises more than 50 employees (Crimmann et al., 2009), 82% of the temporary employment agencies have less than 20 employees (Bundesagentur für Arbeit, 2016a).

Reflecting the idea of temporary agency work being a stepping stone to regular employment, it is assumed that the search effectiveness of temporary agency workers is larger compared to that of unemployed workers. Furthermore, the search effectiveness of assigned temporary agency workers even exceeds that of unassigned temporary agency workers. Even if assigned temporary agency workers are not under contract of a firm, they already work for regular firms and therefore have a higher chance to find regular employment compared to unassigned temporary workers. This idea is captured by the parameterization of $\gamma_A = 1.2$ and $\gamma_T = 1.15$.

For simplicity reasons it is assumed that any type of job is destroyed with exogenous rate $\delta = \chi = 0.02$ (M. U. Krause & Uhlig, 2012).[10] The net income of being unemployed is assumed to be related to the wage rate of regular workers with a standard value of the replacement ratio of 60%. The interest rate is $r = 0.05$, goods demand elasticity is given by $\eta = 2.5$, resulting in $\kappa = 0.6$, and the production function parameter is $\rho = 0.9$. Parameter σ, assuring convexity of the cost function of assigned temporary agency employment and reflecting firm-level costs of voluntary restrictions of temporary agency employment, is chosen to be $\sigma = 1.2$. This ensures that the cost function is not too convex.[11] The

[10]Haller & Jahn (2014) show that labor turnover is five times higher in temporary agency jobs than in regular employment. In the present model, this labor turnover is described by the combination of a higher rate of exogenous job destruction and successful on-the-job search of agency workers. However, as a higher value for the rate of job destruction does not qualitatively change the results of Sections 3.6 and 3.7, it is for simplicity reasons assumed that δ and χ coincide.

[11]If the costs are too convex, there is no interior solution and the firms only use regular employment in

size of the labor force, N, and the scale parameter of the production function, τ, are normalized to unity. For simplicity reasons it is assumed that the costs of posting a job at a regular firm and a temporary employment agency coincide and are equal to $h = \tilde{h} = 0.058$. Parameter ε can be considered as regulatory costs of temporary agency employment compared to regulatory costs of regular employment, which are normalized to unity. For the calibration in this section, regulatory costs of temporary agency employment are assumed to be slightly higher than for regular workers, i.e. $\varepsilon = 1.1$. This reflects still existing legal regulations, such as the maximum period of assignment or the equal pay obligation for regular and temporary workers. In Section 3.7, ε varies, taking values in the domain 0.5 to 1.4. The reason for ε varying in a rather wide range is as follows: regulatory costs of temporary agency employment may be smaller than for regular employment ($\varepsilon < 1$), because there is either no or rather a weak employment protection. On the other hand, they may be higher ($\varepsilon > 1$), e.g. due to the synchronization ban and re-employment ban. Table 3.1 provides the full list of parameter values used in the calibration.

Table 3.1: Parameter Values for Germany

Parameter	Description	Value
α	Matching elasticity	0.5
β	Bargaining power of the agency	0.2
γ_A	Search effectiveness of assigned temporary workers	1.2
γ_T	Search effectiveness of unassigned temporary workers	1.15
δ, χ	Job destruction rate	0.02
ε	Regulatory costs of temporary workers	0.5-1.4
ζ	Matching efficiency	0.3
η	Goods demand elasticity	2.5
ρ	Production function parameter	0.9
σ	Non-institutional, firm-level costs of using temporary workers	1.2
τ	Efficiency of the production technology	1
$h, \tilde{h}$	Costs of posting a vacancy	0.058
N	Size of the labor force	1
r	Interest rate	0.05
z	Net income of being unemployed	$0.6 \cdot w_R$

The parameter values chosen fit well with the employment structure observable in Germany. Temporary employment in almost all OECD countries is around 2% (CIETT,

the production. This is theoretically possible, but not realistic as the average rate of temporary agency employment in industrialized countries is about 2%.

2013). The observed overall unemployment rate in Germany is about 6.5% in 2016 (Bundesagentur für Arbeit, 2016b). The model predicts an unemployment rate of 6.7%, almost coinciding with the value observed for Germany. Temporary employment (assigned and unassigned temporary work) equals 2.7%, while the rate of regular employment is 90.6%.

3.7 Decrease in Regulatory Costs For Using Temporary Agency Workers

As indicated in Section 3.1, in recent decades there have been continuous deregulation efforts regarding temporary agency employment aiming at more flexible European labor markets. This section takes a closer look at the effects of such a deregulation, which is modeled as a reduction in regulatory costs ε. Calibrating the model using the values stated in Section 3.6 and a varying degree of $\varepsilon \in [0.5, 1.4]$, the effects of a legal deregulation on the workers' wage rates and the firm's fee for using temporary agency employment, depicted in Figure 3.2, can be summarized in the following conjectures:

Conjecture 1. *Workers' wage rates decrease in increasing deregulation, while the firm's fee for using temporary agency employment increases in the degree of deregulation.*

Furthermore, Figure 3.3 depicts the steady-state employment rates for the different values of ε and can be summarized as follows:

Conjecture 2. *The legal deregulation of temporary agency employment leads to a monotonic reduction in unemployment as it lowers firm's production costs and, thus, induces a higher overall labor demand. At the same time, it increases regular employment and, hence, the degree of employment covered by labor union bargaining. Unassigned temporary employment also increases monotonically. However, there is a hump-shaped relationship between regulatory costs and temporary agency employment used in the firm's production.*

The firm's decision of using regular or temporary agency employment in the production is based on the marginal costs of the respective worker. Due to the substitutability of both types of workers, marginal costs of regular and temporary workers have to coincide in equilibrium and, furthermore, have to be balanced with marginal revenue. The optimality conditions of the firm's intertemporal optimization problem, eq. (3.35) for regular workers and eq. (3.36) for temporary agency workers, can be rearranged such that the left-hand-sides (LHS) equal the firm's marginal revenue. The RHS denotes the marginal costs of the respective type of worker:

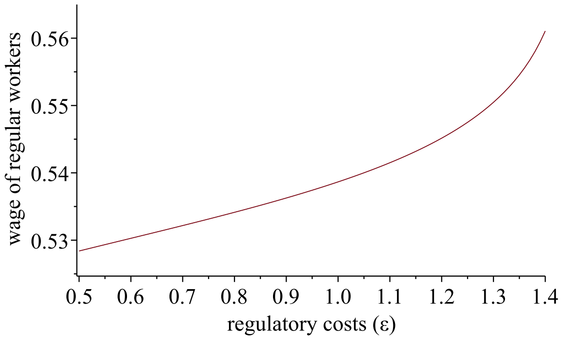
$$\rho\kappa\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-1}I^{1-\kappa}=w_R+(r+\delta)\frac{h}{m(\theta_R)}, \tag{3.52}$$

$$\rho\kappa\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-1}I^{1-\kappa}=\sigma\varepsilon x L_{j,A}^{\sigma-1}+[r+\chi+\gamma_A\theta_R m(\theta_R)]\frac{h}{m(\theta_A)}. \tag{3.53}$$

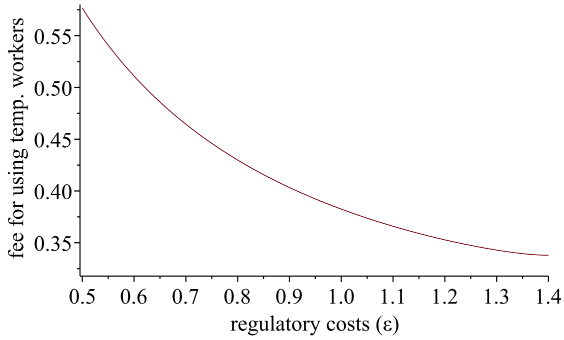
The marginal costs of both groups of workers consist of two parts each. The first term of the respective marginal cost function reflects the unit costs of an additional worker, while the second term represents the costs of posting a vacancy that are taken into account in the intertemporal maximization problem.

Recall that the wage rate for regular workers, the fee, and the employment rates are determined in two stages. In the first stage, labor unions set the wage rate w_R and, at the same time, agencies and firms bargain over the fee x. In the second stage, firms respond by choosing the optimal employment levels of the respective type of worker based on the determined wage rate and the fee. While unions take the employment responses for regular and temporary agency employment into account, the one-worker agency neglects the effects of its own behavior on the employment level of assigned temporary workers.

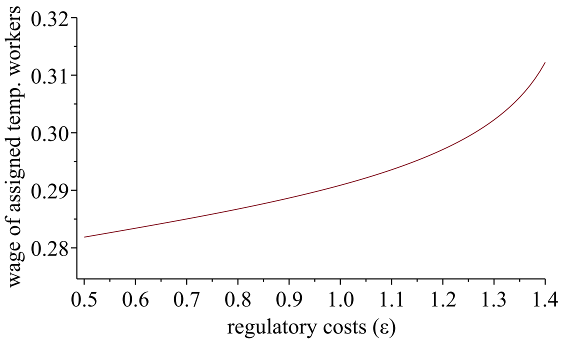
A reduction in regulatory costs leads ceteris paribus to a decrease in the unit costs of temporary agency workers which, in principle, increases the firm's demand for this type of workers. The resulting increase in assigned temporary agency employment L_A decreases the firm's marginal revenue. Due to the substitutability of regular and temporary agency workers unions have to reduce their wage claims, as a reaction to the legal deregulation, to prevent a substitution of regular employment by temporary agency workers. This can also be seen from eq. (3.42). The resulting reduction in labor union's wage claims maintains the attractiveness of using regular employment compared to temporary agency employment. Furthermore, the decrease in unit costs increases the firm's labor demand for regular workers. The increase in regular employment cushions the firm's increasing demand for temporary agency employment initialized by the shock in ε. To state it differently, legal deregulation leads to an overall increase in firms' labor demand, which is not fully served by temporary agency employment, but (partly) substituted by an increase in regular employment. Figure 3.2a shows that w_R decreases monotonically, but with decreasing rate. Furthermore, Figure 3.3a shows that L_R increases monotonically, but



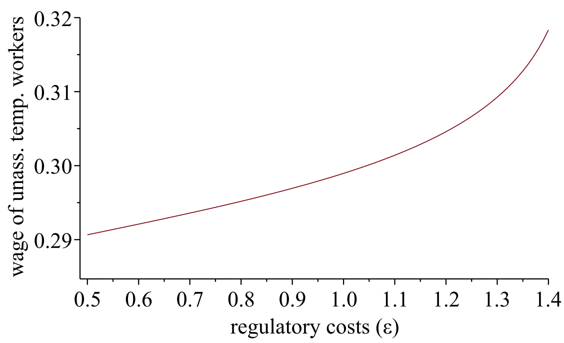
(a) wage rate of regular workers



(b) fee for using temp. workers



(c) wage rate of assigned temp. workers



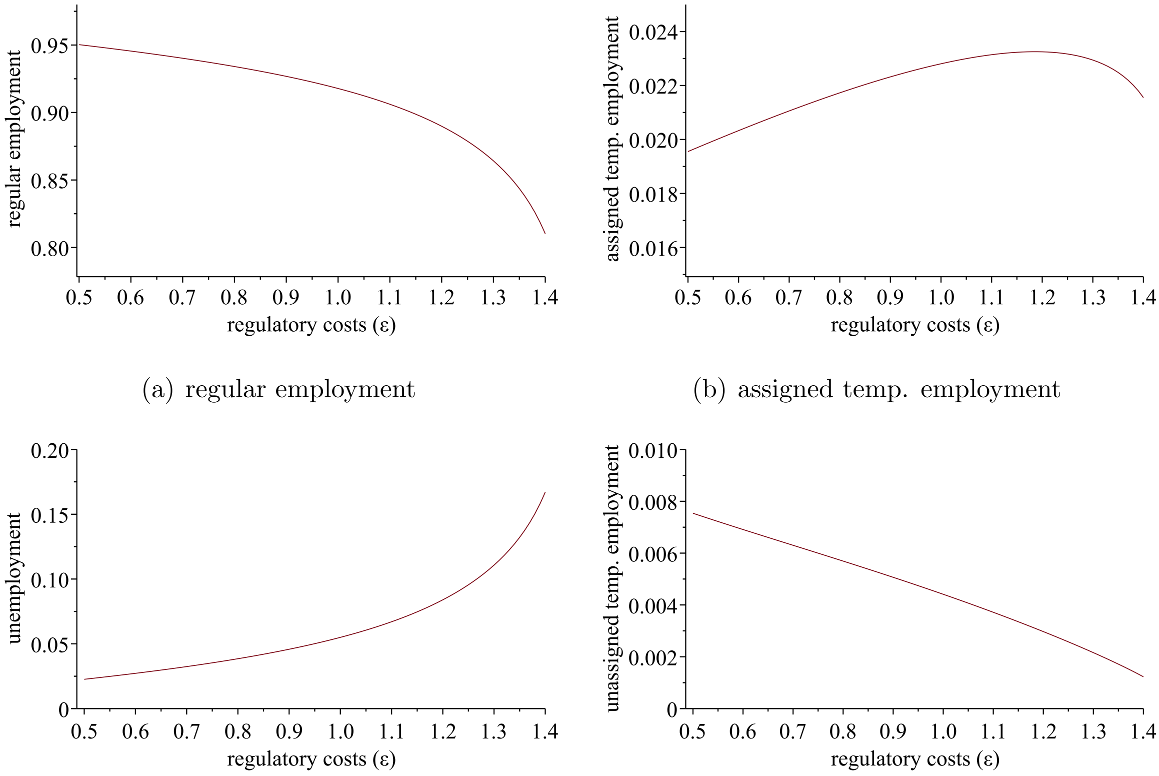
(d) wage rate of unassigned temp. workers

Figure 3.2: Reaction of Fee and Wages to a Change in Regulatory Costs of Temporary Agency Employment

with decreasing rate. The concavity of regular employment stems from the convex costs of temporary agency employment. The higher the rate of assigned temporary agency employment, the larger its impact on the marginal costs of temporary agency workers. As the union considers the employment effects for both types of labor input in the wage determination, it anticipates that the less regulated and, ceteris paribus, the higher assigned temporary agency employment, the higher its impact on the marginal costs of assigned temporary agency workers. Thus, the substitution of regular employment by temporary agency workers declines in L_A as its impact on the marginal costs of temporary agency employment increases. The resulting changes in the wage claims and the employment rate of regular workers are, therefore, weaker.

As stated above, the reduction in regulatory costs directly affects the marginal costs of temporary agency workers, LHS of eq. (3.53), and ceteris paribus increases the labor demand for this production factor. Although, as can be seen directly from eq. (3.47), the decrease in regulatory costs encourages the agencies to increase the fee x and, by this, the agencies' profit. This increase cushions the reduction in marginal costs as it opposes the effect initialized by the shock in regulatory costs. As agencies and firms bargain individually and agencies are small (one worker), the agency does not take into account that the firm responses by adjusting the amount of temporary agency work due to changes in the fee x. Even if the employment response of temporary agency employment may still be positive overall, the increase in the fee x dampens the firm's increasing labor demand for this employment type induced by legal deregulation.

Furthermore, as the agency considers the firm's demand for regular employment in the determination of the fee x, it anticipates that the lower the legal regulation, the lower the firm's adjustment of regular employment to changes in regulatory costs. The agency assumes that with decreasing ε its scope to adjust x upwards increases. Thus, the fee x increases convexly in decreasing legal regulation of temporary agency work. This is depicted in Figure 3.2b. However, the agency does not take into account that the less regulated temporary agency work and, ceteris paribus, the higher the demand for temporary agency workers, the higher its impact on the convex unit costs of this production factor, see RHS of eq. (3.53). These two reasons, the increase in x and L_A's increasing impact on marginal costs, finally lead to the marginal costs of temporary agency employment being higher than the firm's marginal revenue and, furthermore, the marginal costs of regular employment. Thus, firms react to the agencies behavior with a reduction in temporary agency employment in order to balance marginal revenue and marginal costs, eq. (3.53). Overall, the aforementioned mechanisms lead to the hump-shaped relationship



(a) regular employment (b) assigned temp. employment

(c) unemployment (d) unassigned temp. employment

Figure 3.3: Employment Reaction to a Change in Regulatory Costs of Temporary Agency Employment

of temporary agency employment and regulatory costs, as shown in Figure 3.3b.[12]

Using the argumentation above, the steady-state changes of the wage rates of temporary agency workers can be explained. The wage rates of temporary workers, given in eqs. (3.48) and (3.49), positively depend on the wage rate of regular workers. The higher the wage rate of regular workers, the higher the mark-up on unemployment income and, thus, the higher the wage rate of temporary agency workers. Hence, the behavior of the wages qualitatively coincide with that of regular workers' wages. This is depicted in

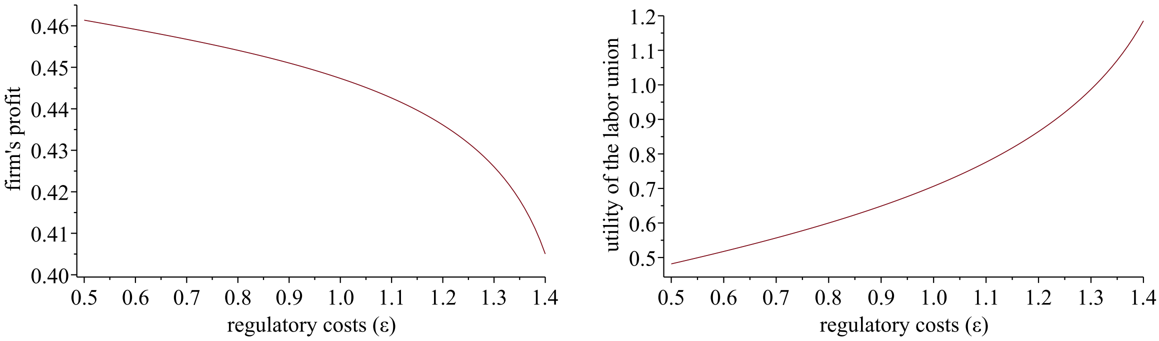
[12]Next to the effects on unit costs, the agency's and union's behavior also affects the second part of the marginal costs, the vacancy costs that are taken into account in the intertemporal maximization problem. For simplicity reasons, these effects are not considered in more detail in the argumentation provided above.

Figures 3.2c and 3.2d.

Figure 3.3c gives the steady-state unemployment rate for varying values of ε. Even if the composition of the firm's increased labor demand is a priori unclear, it is obvious that legal deregulation leads to an overall increase in total employment as it decreases the costs of regular and temporary workers. Thus, based on the depicted development of the employment rates of regular and assigned temporary workers, legal deregulation of temporary employment leads to a monotonic decrease in overall unemployment.

Figure 3.3d shows that unassigned temporary agency employment monotonically increases in legal deregulation. Having in mind that there is a hump-shaped relationship of assigned temporary employment and regulatory costs, this may be counterintuitive at first sight. The reason is that legal deregulation leads to an increase in the fee x, which increases the expected profit of the agency, eq. (3.27). More agencies enter the market leading to an increase in employment of unassigned temporary workers. Thus, legal deregulation of temporary agency employment drives agencies to hoard idle labor waiting for an assignment in a client firm.

Finally, Figure 3.4 takes a closer look at the firm's profit and the union's utility due to changing regulatory costs. Legal deregulation of temporary agency employment leads



(a) firm's profit (b) utility of the labor union

Figure 3.4: Evolution of Firm's Profit and Union's Utility due to a Change in Regulatory Costs of Temporary Agency Employment

to a more profitable production alternative for firms and dampens union's wage claims. Furthermore, it decreases the costs of using temporary agency employment in the production. Thus, it is intuitive that the firm's profit monotonically increases in the degree of legal deregulation, as depicted in Figure 3.4a. Even if regular employment increases monotonically in legal deregulation, the wage rate for regular workers and, hence, the rent of a single worker, decreases. The increase in regular employment does not balance the loss in individual workers' rent. Thus, the utility of the labor union decreases in legal deregulation, see Figure 3.4b. Even if the rate of regular employment and, as a consequence, the degree of union coverage in the economy increases, unions suffer by declining wages caused by temporary agency employment.

3.8 Summary and Conclusions

This chapter develops a theoretical model to analyze the general equilibrium effects of the legal deregulation of temporary agency employment on negotiated wages and the employment structure in a unionized economy. Large firms produce differentiated goods using labor as the only production factor. Workers can either be hired directly by the firm (regular workers) or by temporary employment agencies that lend the workers to client firms for the production process. Both types of work are perfect substitutes. Regular workers are represented by firm-level labor unions, which are assumed to be monopoly unions. Temporary employment agencies are small (one worker) and bargain individually with the firm over the fee that the agency receives from the firm for borrowing a worker. In response to the determined fee and the claimed wage, the firm chooses the respective employment levels used in its production.

While there already exist contributions on labor unions and temporary employment agencies in the literature, this model is the first that combines temporary agency employment and the wage-setting behavior of labor unions in a frictional labor market to discuss the agency's impact on regular employment and the overall employment structure.

The most striking result is that the model predicts that legal deregulation of temporary agency employment does not lead to a steady increase in this employment type implying that there is no substitution of regular employment. Instead, there exists a hump-shaped relationship between temporary agency employment and its degree of legal deregulation.

Whereas deregulation out of a high degree of regulation leads to an increase in temporary agency employment, its rate decreases the more extensive legal deregulation is. Thus, deregulation efforts of the temporary agency employment sector that occurred in most European countries in recent decades, do not inevitable lead to a strengthening of this sector, but may even lead to a declining rate of temporary agency employment in the economy. At the same time, the rate of regular employment increases monotonically and overall employment benefits from the deregulation.

The reason for the hump-shaped pattern of temporary agency employment and the steady increase in regular employment is the cost structure of temporary agency employment. There are often voluntary, non-institutional firm-level agreements restricting the degree of temporary agency employment used in the production. Thus, the costs of temporary agency employment increase convexly. The higher the rate of temporary agency employment induced by legal deregulation, the higher the impact of the non-institutional firm-level agreements on marginal costs. Because agencies are rather small compared to the large firms they bargain with, they do not consider the consequences of the convex cost structure in their negotiations. Combined with the fact that a more attractive temporary agency employment forces the labor unions to reduce their wage claims for regular employed workers to prevent employment losses and maintain the competitiveness with temporary agency employment, temporary agency employment may even decrease in the degree of legal deregulation, while regular employment increases monotonically. Nevertheless, even if legal deregulation does not lead to a decline in the coverage of collectively bargained wages in the economy, it leads to a reduction in workers' wage rates and a reduction in labor union's utility.

These findings reject the main argument of opponents of temporary agency employment that its legal deregulation leads to a substitution of regular employment and to a higher share of precarious employment. Hence, the policy makers' idea that legal deregulation of temporary agency employment increases the flexibility of the European labor markets and brings people to work who may not find regular employment, seems to be verified. Thus, legal deregulation of temporary agency employment aiming at an increasing employment level may be continued.

3.A Appendix

3.A.1 Steady State Employment

Using the steady-state conditions for each labor market state, the respective job-searchers and the condition that $U+L_T+L_A+L_R = 1$, the respective equations from the perspective of the firm can be rewritten to obtain the different employment rates across states

$$L_T = \frac{\theta_T m(\theta_T) \cdot (1 - L_R) + [\chi - \theta_T m(\theta_T)] \cdot L_A}{\delta + \theta_T m(\theta_T) + \theta_A m(\theta_A) + \gamma_T \theta_R m(\theta_R)}, \tag{3.54}$$

$$L_A = \frac{\theta_A m(\theta_A) L_T}{\chi + \gamma_A \theta_R m(\theta_R)}, \tag{3.55}$$

$$L_R = \frac{[1 - L_T(1-\gamma_T) - L_A(1-\gamma_A)] \cdot \theta_R m(\theta_R)}{\delta + \theta_R m(\theta_R)}. \tag{3.56}$$

The numerators denote the flows into and out of the respective labor market states. Division by the respective denominator weights the employment rates by the average retention period of a job in the respective state.

3.A.2 Concavity of the Firm's Instantaneous Profit Function

Using eqs. (3.12) and (3.13), the instantaneous profit of the firm, eq. (3.14), can be written as

$$\pi_j = \tau^\kappa (L_{j,R} + L_{j,A})^{\rho\kappa} I^{1-\kappa} - w_{j,R}\, L_{j,R} - \varepsilon x\, L_{j,A}^\sigma - h\,(V_{j,A} + V_{j,R}), \tag{3.57}$$

with $\kappa = (\eta - 1)/\eta$. The lower κ, the higher the firm's monopoly power in the goods market. The second order conditions are

$$\frac{\partial^2 \pi}{\partial L_{j,R}^2} = \rho\kappa(\rho\kappa - 1)\tau^\kappa (L_{j,R} + L_{j,A})^{\rho\kappa - 2} I^{1-\kappa} < 0, \tag{3.58}$$

$$\frac{\partial^2 \pi}{\partial L_{j,A}^2} = \rho\kappa(\rho\kappa - 1)\tau^\kappa (L_{j,R} + L_{j,A})^{\rho\kappa - 2} I^{1-\kappa} - \sigma(\sigma-1)\varepsilon x L_{j,A}^{\sigma-2} < 0, \tag{3.59}$$

$$\frac{\partial^2 \pi}{\partial L_{j,R} \partial L_{j,A}} = \rho\kappa(\rho\kappa - 1)\tau^\kappa (L_{j,R} + L_{j,A})^{\rho\kappa - 2} I^{1-\kappa} < 0. \tag{3.60}$$

While the necessary condition for a profit maximum is that the first-order conditions are equal to zero, the sufficient condition for a profit maximum is

$$\frac{\partial^2 \pi}{\partial L_{j,R}^2} \frac{\partial^2 \pi}{\partial L_{j,A}^2} - \left(\frac{\partial^2 \pi}{\partial L_{j,R} \partial L_{j,A}} \right)^2 > 0. \tag{3.61}$$

This can be seen to hold for $\kappa \in (0,1)$ and $\sigma > 1$:

$$\rho\kappa(\rho\kappa - 1)\tau^{\kappa}(L_{j,R} + L_{j,A})^{\rho\kappa-2} I^{1-\kappa} \cdot [-\sigma(\sigma-1)\varepsilon x L_{j,A}^{\sigma-2}] > 0. \tag{3.62}$$

3.A.3 Corner Solutions in Firm's Production

The decision of the firm, which type of labor input to use in the production, directly depends on the marginal costs of each labor input. If the costs of an additional temporary worker undercut (exceed) the marginal costs of a regular worker, the firm will only produce with temporary workers (regular workers). Evaluating eqs. (3.35) and (3.36) at $L_A > 0$ and $L_R = 0$, it turns out that the firm will produce by solely using temporary workers in the entire production, if

$$\tau^{\kappa} L_{j,R}^{\rho\kappa} I^{1-\kappa} = \sigma x \varepsilon L_A^{\sigma-1} + [r + \chi + \gamma_A \theta_R m(\theta_R)] \frac{h}{m(\theta_A)} < w_R + (r + \delta) \frac{h}{m(\theta_R)}.$$

On the contrary, evaluating eqs. (3.35) and (3.36) at $L_R > 0$ and $L_A = 0$, it follows that the final good will be produced by solely using regular employment, if

$$\tau^{\kappa} L_{j,R}^{\rho\kappa} I^{1-\kappa} = w_R + (r + \delta) \frac{h}{m(\theta_R)} < [r + \chi + \gamma_A \theta_R m(\theta_R)] \frac{h}{m(\theta_A)}.$$

Choosing the cost function of temporary employment to be convex (but not too convex) ensures to rule out the first case, since temporary employment becomes too expensive at a certain level of production. On the other hand, a convex cost function implies that temporary workers are relatively cheap at a low level of production, making the second case less likely. Thus, the probability to obtain an interior solution crucially depends on the convexity of the cost function of temporary agency employment.

3.A.4 Derivatives of Firm's Labor Demand

Using eqs. (3.35) and (3.36), respectively, it turns out that the labor demand decreases with respect to its own costs, i.e. formally

$$\frac{dL_{j,R}}{dw_R} = \frac{1}{\rho\kappa(\rho\kappa-1)\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-2}I^{1-\kappa}} < 0, \tag{3.63}$$

and

$$\frac{dL_{j,A}}{dx} = \frac{\sigma L_{j,A}^{\sigma-1}}{\rho\kappa(\rho\kappa-1)\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-2}I^{1-\kappa} - \sigma(\sigma-1)\varepsilon x L_{j,A}^{\sigma-2}} < 0. \tag{3.64}$$

Taking eqs. (3.63) and (3.64) into account, it can be shown that the labor demand of regular (temporary) workers increases in the fee x (wage of regular workers)

$$\frac{dL_{j,R}}{dx} = -\frac{dL_{j,A}}{dx} > 0, \tag{3.65}$$

$$\frac{dL_{j,A}}{dw_R} = \frac{\rho\kappa(\rho\kappa-1)\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-2}I^{1-\kappa}\cdot\frac{dL_{j,R}}{dw_R}}{\sigma(\sigma-1)\varepsilon x L_{j,A}^{\sigma-2} - \rho\kappa(\rho\kappa-1)\tau^{\kappa}(L_{j,R}+L_{j,A})^{\rho\kappa-2}I^{1-\kappa}} > 0. \tag{3.66}$$

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Chapter 4

Technological Unemployment Revisited: Automation in a Search and Matching Framework*

4.1 Introduction

Reports in the news show on a daily basis that robots are outcompeting humans on more and more tasks (see, for example, The Economist, 2014, 2017; Davison, 2017). This holds true even for tasks that were seen as unautomatable just a few years ago. While industrial robots are substituting for assembly line workers in the automotive industry since decades, recent years are characterized by advances in driverless cars and trucks, diagnosing diseases, producing customized parts and medical implants, writing novels, and even doing science (National Science Foundation, 2009; Schmidt & Lipson, 2009; Barrie, 2014; Abeliansky et al., 2015; Ford, 2015).

Ever since the publication of the working paper version of Frey & Osborne (2013, 2017), who claim that 47% of the jobs in the United States are highly susceptible to computerization over the coming two decades, policymakers, economists, and the general public have been concerned about mass unemployment in the age of automation. However, these

*This chapter is the result of joint work with Klaus Prettner and has appeared as Cords & Prettner (2018).

high numbers are criticized for various reasons. For example, Arntz et al. (2016) argue that specific tasks get automated but not whole jobs. They incorporate this insight into the method used by Frey & Osborne (2013, 2017) and calculate that only 9% of all jobs in the United States can be automated in the near future when assuming such a task-based perspective. In addition, there are compensating mechanisms in actually existing economies such as i) decreasing prices of the goods that are produced in an automated manner such that spending on goods and services that are produced by humans might increase, or ii) an increase in the production of robots and 3D printers that might require additional human labor. On top of these arguments, Bloom et al. (2018) take into account that building robots is costly and takes time. Thus, not all jobs that could be substituted by robots from a technical perspective will indeed vanish soon. Instead, economic considerations need to be taken into account because often it will not pay off for firms to substitute cheap labor by expensive robots. Bloom et al. (2018) calculate that the predicted evolution of the stock of industrial robots according to the International Federation of Robotics (2017) together with the estimates of Acemoglu & Restrepo (2017) that one industrial robot substitutes for around six workers, implies the loss of approximately 60 million jobs worldwide until 2030.[1] While these numbers are nowhere near the 47% of all jobs mentioned by Frey & Osborne (2013, 2017), they are nevertheless large and give rise to some concern. Thus, it is important to analyze the pathways by which robots have the potential to lead to technological unemployment within the modern literature on the determinants of endogenous unemployment levels.

Most recently, Hémous & Olsen (2016) and Acemoglu & Restrepo (2018) pioneered the analysis of the effects of automation on economic growth and inequality within the R&D-based growth literature. In Hémous & Olsen (2016), final goods are produced using

[1]Dauth et al. (2017) apply the analysis of Acemoglu & Restrepo (2017) to Germany and find that there, one robot only substitutes for two manufacturing workers. Dauth et al. (2017) trace this difference between the United States and Germany back to the flexibility of German labor unions in setting the bargained wage. If we use the numbers of Dauth et al. (2017) as a baseline for the calculations, we would get a lower number of jobs that will be lost due to automation until 2030 (approximately 20 million worldwide). In addition, these calculations do not take into account that jobs will be created in the manufacturing sector in general equilibrium.

a variety of intermediate goods, while in Acemoglu & Restrepo (2018), final goods are produced using a variety of tasks. In both papers the intermediate varieties/tasks are either produced by labor or by labor-replacing machines. R&D-driven innovation leads to new varieties/tasks that always come into existence as un-automated and, thus, have to be produced by human labor. Firms then decide whether to make investments to automate the production of their intermediate variety/task. Along the balanced growth path, there is always a constant range of goods/tasks that are produced by low-skilled workers. As a consequence, technological unemployment is less of a concern in the long run. The wages of low-skilled workers rise due to innovation because a higher rate of creation of intermediate goods/tasks raises the range of these goods/tasks that are produced by low-skilled labor. Even more productive automation could lead to higher wages for low-skilled workers because it encourages more innovation. In both contributions, technological unemployment is not at the focus.

As far as the theoretical underpinnings of changing unemployment in the age of automation are concerned, Prettner & Strulik (2017) explore some potential channels. They propose an R&D driven growth model in which new technologies are labor-replacing robots that substitute for low-skilled workers. High-skilled workers are either engineers in the final goods sector or scientists in the R&D sector. Low-skilled workers are employed at assembly lines in the final goods sector. As a consequence, the wages of low-skilled workers stagnate in the face of automation, whereas the wages of high-skilled workers rise. In their model, voluntary equilibrium unemployment will result if there exists a social safety net that is financed out of a wage tax on low-skilled and high-skilled workers. The reason is that the outside option for low-skilled workers becomes more attractive over time because the wages of low-skilled workers stagnate, while the social security benefits rise due to the contributions of high-skilled workers.

In an extension of the model, Prettner & Strulik (2017) show that even involuntary equilibrium unemployment is possible in such a setting. The argument is rooted in the fair wage theory based on Akerlof & Jellen (1990): individuals compare their own wages with those of their peers and perceive their wage as unfair if it lies below a weighted average of their own market clearing wage and the wage of their reference group on the labor market. If workers perceive their wage as unfair, they do not entail full effort at work. The wages of high-skilled workers, which constitute the reference group for low-skilled workers, are higher than the wages of low-skilled workers. Thus, the wages of low-skilled workers that are perceived as fair have to be higher than their market clearing wages to induce full effort of low-skilled workers. At this wage rate, more low-skilled workers seek jobs than firms are willing to provide. Thus, there is involuntary unemployment of low-skilled workers in equilibrium.

The discussions so far show that equilibrium unemployment in the age of automation can take the form of voluntary unemployment and involuntary unemployment based on fair wage considerations. This chapter contributes to this debate by introducing automation into the modern search and matching theory of frictional unemployment based on Mortensen & Pissarides (1994) and Pissarides (2000). Assuming that low-skilled workers are easier to substitute than high-skilled workers, which is the empirically relevant case up to now, the model predicts that automation leads to higher equilibrium wages of high-skilled workers and to a tighter high-skilled labor market. The reverse holds true for low-skilled workers. As a consequence, unemployment of low-skilled workers rises, while unemployment of high-skilled workers falls.

This chapter is organized as follows. Section 4.2 discusses the related literature on automation and search and matching models. Section 4.3 contains the description of the model. Section 4.4 derives the analytical results, while Section 4.5 concludes, draws potential lessons for policy makers, and discusses promising future research avenues.

4.2 Related Literature

This chapter builds upon the literature on automation and the search and matching theory of the labor market. As far as automation is concerned, Steigum (2011) and Prettner (2018) augment the standard neoclassical growth models of Solow (1956), Cass (1965), and Koopmans (1965) by a production factor that is a perfect substitute for labor, while it is accumulated similar to physical capital. They show that this automation capital has the potential to lift an economy out of the traditional stagnation steady state even in the absence of technological progress. The reason is that automation capital makes the production factor labor accumulable such that the Cobb-Douglas production technology is transformed endogenously into an AK production technology. Thus, the possibility for long-run economic growth emerges in the neoclassical growth model, which has considerable consequences for welfare in the long run.

While the long-run implications of capital accumulation for economic growth are strikingly similar in the models of Solow (1956), Cass (1965), and Koopmans (1965) on the one hand, and in the overlapping generations model of Diamond (1965) on the other hand, their implications on the growth effects of automation are the opposite of each other. Sachs & Kotlikoff (2012), Benzell et al. (2015), and Sachs et al. (2015) show numerically that long-run stagnation emerges in an overlapping generations model with automation. Gasteiger & Prettner (2017) provide an analytical explanation for this finding. Since individuals save exclusively out of wage income in the overlapping generations model and automation reduces wages, there is a vicious circle that prevents the economy from taking off. In the standard neoclassical growth framework of Solow (1956), Cass (1965), and Koopmans (1965), by contrast, individuals save out of wage income *and* out of capital income. Thus, a similar vicious circle is not present in these types of models with automation such that long-run growth is feasible.

Irrespective of whether automation is analyzed in the neoclassical growth models of Solow (1956), Cass (1965), and Koopmans (1965) or in the overlapping generations model of Diamond (1965), the distributional effects of automation are similar. Since automation substitutes for workers but the income of robots flows to capital owners, the capital income share of the economy rises, which is consistent with the stylized facts over the last decades (Elsby et al., 2013; Karabarbounis & Neiman, 2014). The fact that wealth is more concentrated than income implies that the automation-induced rise in the capital income share contributes to a rise in overall income inequality (cf. Piketty, 2014; Krusell & Smith, 2015). At the same time, low-skilled workers are still more susceptible to automation than high-skilled workers such that automation leads to a rising skill premium and thereby raises wage inequality (Hémous & Olsen, 2016; Acemoglu & Restrepo, 2018; Prettner & Strulik, 2017; Lankisch et al., 2017).

While there seems to be a consensus that automation will lead to higher inequality, the effects on unemployment are still subject to considerable debates. To gain deeper insights from a theoretical perspective on the endogenous evolution of involuntary unemployment, it is necessary to consider the search and matching model à la Mortensen & Pissarides (1994) and Pissarides (2000). In this type of models, unemployment emerges due to search frictions in the labor market. Assuming such a search and matching based perspective allows to derive the effects of an increase in the stock of robots on the employment structure via its impact on job creation and the job search behavior of workers that responds endogenously. This chapter is the first that studies the effects of automation on skill-specific involuntary frictional unemployment.

The contributions of Chassamboulli & Palivos (2013, 2014), Fadinger & Mayr (2014), and Battisti et al. (2017) are related to this chapter because they use a similar methodological framework. While Fadinger & Mayr (2014) endogenize the state of technology and study the effects of a change in skill endowments, the other articles analyze the impact of skill-specific immigration. All of these articles share important elements with this chapter, such as the existence of two separate labor markets, one for high-skilled workers and one for low-skilled workers, and a similar production structure according to which the final good is produced based on a CES production function, while the intermediate goods are produced by high-skilled and low-skilled labor based on a linear technology. The decisive difference to these contributions lies at the level where the exogenous shock takes place. While low-skilled immigration substitutes for low-skilled natives in the production of the low-skilled intensive intermediate good in Chassamboulli & Palivos (2013, 2014) and Battisti et al. (2017), automation capital appears in the production function of the final good and substitutes for the low-skilled intensive intermediate good in this chapter. Taking taxi drivers as an example, low-skilled immigrants may substitute for low-skilled natives as drivers. However, self-driving cars (automation capital) will be able to replace the occupation group of taxi drivers altogether in the not too distant future. This aspect cannot be analyzed without the presence of the new production factor of automation capital.

4.3 The Model

Consider an economy in which workers have two different skill levels $i = \{L, H\}$, where L denotes low-skilled individuals and H denotes high-skilled individuals. The skills are distributed exogenously on a two-point distribution: the fraction λ of the population is low skilled, while the remaining fraction $1 - \lambda$ is high skilled. Normalizing the population size to unity implies that the population shares of a particular skill level are equal to the numbers of low-skilled and high-skilled workers, respectively. Time evolves continuously and workers can be in either of two states: employed or unemployed. Workers live indefinitely, are risk neutral, discount the future at the constant rate $r > 0$, and cannot choose to switch their skill level, i.e., education is exogenous and fixed.

4.3.1 Production Technology

Three goods are produced in the economy. A final consumption good Y and two intermediate goods Y_H and Y_L that are used in the production of the final good. Each high-skilled worker produces one unit of the intermediate good Y_H and each low-skilled worker produces one unit of the intermediate good Y_L. Due to this structure, there is no need to distinguish between the employment level of a given skill type i and the output of the corresponding intermediate good i, thus, $Y_H \equiv H$ and $Y_L \equiv L$. From now on, the intermediate goods that are produced by low-skilled workers are referred to as low-skilled intensive, while the intermediate goods produced by high-skilled workers are high-skilled intensive.

Apart from high-skilled and low-skilled labor, there are two other production factors: traditional physical capital in the form of machines, assembly lines, and factory buildings, which is denoted by K, and automation capital in the form of industrial robots, self-driving cars, 3D printers, etc. which is denoted by P for "programmable labor." Automation capital is a perfect substitute for low-skilled workers and an imperfect substitute for high-skilled workers (cf. Lankisch et al., 2017). The CES production function of the final good is given by

$$Y = AK^{\alpha}[\gamma(L + P)^{\sigma} + (1 - \gamma)H^{\sigma}]^{\frac{1-\alpha}{\sigma}}, \tag{4.1}$$

where α denotes the elasticity of output with respect to traditional capital, $\gamma \in (0, 1)$ refers to the production weight of low-skilled intermediates and of programmable labor, $\sigma \in (-\infty, 1]$ determines the substitutability between both types of workers, and A is an efficiency parameter. From now on, the focus of this chapter is on the empirically relevant case $\sigma \in (0, 1)$, in which low-skilled and high-skilled workers are gross substitutes (Autor, 2002; Acemoglu, 2009).

All of the three goods are sold in competitive markets and the price of the final good is used as the numéraire, implying that the prices of the two intermediate goods p_H and p_L are equal to their marginal products. Hence, it holds that $p_H = \partial Y/\partial H$ and $p_L = \partial Y/\partial L$. Furthermore, firms can buy and sell traditional capital on a competitive capital market without delay. Thus, it holds that $p_K = \partial Y/\partial K = r+\delta$, where δ denotes the depreciation rate of traditional capital. Differentiating eq. (4.1) and using $p_K = \partial Y/\partial K = r + \delta$, the prices of the two intermediate goods are given by[2]

$$p_L = (1-\alpha)\gamma A^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}} \left[(1-\gamma)\left(\frac{H}{L+P}\right)^{\sigma} + \gamma\right]^{\frac{1-\sigma}{\sigma}}, \tag{4.2}$$

$$p_H = (1-\alpha)(1-\gamma) A^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}} \left[(1-\gamma) + \gamma\left(\frac{L+P}{H}\right)^{\sigma}\right]^{\frac{1-\sigma}{\sigma}}. \tag{4.3}$$

If the rate of return on automation capital would be lower than the rate of return on traditional capital, rational investors would only invest in traditional capital, and vice versa. For an interior equilibrium to exist, it needs to be the case that both types of investments deliver the same rate of return. Thus, it holds that $p_K = p_P = r + \delta$, with p_P being the price of automation capital.

It can be seen immediately that – for the empirically relevant range of σ – an increase in the number of high-skilled workers increases the price of the goods produced by low-skilled workers and reduces the price of the goods produced by high-skilled workers. In case of an increase in the number of low-skilled workers, the reverse is true. It is shown later how an increase in P affects the prices of the high-skilled and low-skilled intensive good.

[2] Appendix 4.A.1 provides detailed calculations.

4.3.2 Labor Market

There are two separate labor markets, one for high-skilled labor and one for low-skilled labor. High-skilled workers direct their job search only to the high-skill intensive sector, while low-skilled workers direct their search only to the low-skill intensive sector (see, for example, Belan et al., 2010; Chassamboulli & Palivos, 2013, 2014; Hagedorn et al., 2016; Battisti et al., 2017; Liu et al., 2017). The matching function of firm i can be formally described by

$$M_i = M(V_i, U_i), \tag{4.4}$$

where M_i denotes the instantaneous flow of hires, V_i refers to the number of vacancies that are posted, U_i is the number of job-searchers, which equals the number of unemployed workers, and the function $M(\cdot, \cdot)$ exhibits constant returns to scale, is increasing in both arguments, at least twice differentiable, and satisfies the Inada conditions. The arrival rate of any worker per vacancy is $M(V_i, U_i)/V_i \equiv m(\theta_i)$, where $\theta_i \equiv V_i/U_i$ measures the labor market tightness in terms of the number of vacancies per unemployed person in the economy. From these expressions it follows immediately that the arrival rate of any vacancy per unemployed worker is $M(V_i, U_i)/U_i \equiv \theta_i m(\theta_i)$. As a consequence, the arrival rate for firms decreases in θ_i, whereas the arrival rate for workers increases in θ_i.

4.3.3 Firms

In line with the literature, the firms that produce in the intermediate goods sector are small and each firm offers only one job (see, for example, Mortensen & Pissarides, 1994; Albrecht & Vroman, 2002; Dolado et al., 2009; Gautier et al., 2010).[3] The number of firms is determined endogenously in equilibrium. Firms $i = \{H, L\}$ can either post a high-skill intensive vacancy, which is only suited for high-skilled workers, or a low-skill intensive vacancy, which is only suited for low-skilled workers. The value functions of the firms differ according to whether the firm has filled the vacancy or not. If the firm has filled the vacancy, it produces the corresponding good $i = \{H, L\}$ and sells it on the

[3]Pissarides (2000) shows that the outcome of the single-worker model is equivalent to a model with large firms that face adjustment costs of employment.

market for the price p_i. The firm pays the wage w_i to its workers and with a probability $(1 - s_i)$ the vacancy is still filled in the next period, such that s_i is the exogenous rate of job destruction. With this structure it is obvious that the value function of a firm with a filled vacancy is given by

$$r\Pi_i^F = p_i - w_i + s_i(\Pi_i^V - \Pi_i^F). \tag{4.5}$$

By contrast, a firm that does not fill the vacancy has no labor costs and no revenues but has to pay costs for a vacancy (e.g., job advertisement cost), which are denoted by h_i. With the probability $m(\theta_i)$ the firm manages to fill the vacancy such that its value function is given by

$$r\Pi_i^V = -h_i + m(\theta_i)(\Pi_i^F - \Pi_i^V). \tag{4.6}$$

4.3.4 Workers

The behavior of workers can be analyzed in a similar vein as the behavior of firms. Workers who are employed receive the wage w_i and become unemployed in the next instant with the probability s_i. Thus, the value function of an employed worker is given by

$$r\Psi_i^E = w_i + s_i(\Psi_i^U - \Psi_i^E). \tag{4.7}$$

An unemployed person receives a flow benefit z_i while being unemployed. This flow benefit includes the opportunity costs of employment such as unemployment benefits, leisure, and the potential income generated by home production. With the probability of finding a job being equal to $\theta_i m(\theta_i)$, the value function of an unemployed person is given by

$$r\Psi_i^U = z_i + \theta_i m(\theta_i)(\Psi_i^E - \Psi_i^U). \tag{4.8}$$

4.4 Solution of the Model

This section solves the model, describes the steady-state solution, and provides the comparative statics analysis with respect to the effects of the accumulation of automation capital on unemployment and wages of high-skilled and low-skilled workers, respectively.

4.4.1 Wage Determination

Since the workers strictly prefer being employed to being unemployed and the firms strictly prefer a filled vacancy to the situation of an unfilled vacancy, there is a surplus to be gained from a successful match. This chapter follows the literature and assumes that the firm and the worker bargain over the distribution of the surplus from the match in a cooperative bargaining process (see, for example, Mortensen & Pissarides, 1994, 1999; Pissarides, 2000; Gautier, 2002). Once a worker of type i and a firm with the same skill requirements meet each other, they solve a generalized Nash bargaining problem given by

$$\max_{w_i} \left\{ \Psi_i^E - \Psi_i^U \right\}^{\beta} \cdot \left\{ \Pi_i^F - \Pi_i^V \right\}^{1-\beta}, \tag{4.9}$$

where $\beta \in (0,1)$ represents the bargaining power of the worker. Maximizing the Nash product yields the equilibrium expression for the wage rate as given by

$$w_i = z_i + (p_i - z_i) \cdot \Gamma(\theta_i), \tag{4.10}$$

with

$$\Gamma(\theta_i) = \beta \frac{r + s_i + \theta_i m(\theta_i)}{r + s_i + \theta_i m(\theta_i)\beta}.$$

Thus, the wage is set as a mark-up over the income enjoyed while being unemployed. The mark-up itself consists of two parts. The first part is the profit that a firm earns if it fills a vacancy with an employee who only earns the outside option z_i. This is the largest possible overall profit a firm could make. Second, the term $\Gamma(\theta_i)$ provides the effective bargaining power of the workers as described by Cahuc et al. (2014). This term refers to those part of the largest possible overall profit that a firm can make by filling a vacancy that the workers are able to appropriate by negotiation. As is intuitive, this bargaining power rises with the bargaining weight of the workers (β) and with the labor market tightness (θ_i), whereas it decreases with the job destruction rate (s_i). Appendix 4.A.2 provides the detailed calculations regarding the derivation of the wage rate.

4.4.2 Labor Demand and Employment

Firms enter the market and open their vacancies as long as the expected profit of posting a vacancy is positive. Free market entry drives the expected profit of a vacancy down to zero such that

$$\Pi_i^V = 0 \tag{4.11}$$

holds at the long-run equilibrium. Further, the present value function of a filled job, eq. (4.5), is used and combined with the equilibrium wage level w_i to obtain the following labor demand:

$$\frac{h_i}{m(\theta_i)} = (1-\beta)\frac{(p_i - z_i)}{r + s_i + \theta_i m(\theta_i)\beta}. \tag{4.12}$$

Thus, the average costs of a vacancy equal the expected profit of a filled job.

At a steady-state equilibrium, the flows in and out of unemployment have to be equal, i.e., $\dot{U}_i = 0$. Using that the number of low-skilled workers in the economy is given by $\lambda = U_L + L$, with U_L being the number of unemployed low-skilled workers, while the number of high-skilled workers is given by $1 - \lambda = U_H + H$, with U_H being the number of unemployed high-skilled workers, the steady-state unemployment rates u_i are given by

$$\frac{U_L}{\lambda} = u_L = \frac{s_L}{s_L + \theta_L m(\theta_L)} \tag{4.13}$$

and

$$\frac{U_H}{1-\lambda} = u_H = \frac{s_H}{s_H + \theta_H m(\theta_H)}. \tag{4.14}$$

Analogously, the employment levels are

$$L = \lambda \frac{\theta_L m(\theta_L)}{s_L + \theta_L m(\theta_L)} \tag{4.15}$$

and

$$H = (1-\lambda)\frac{\theta_H m(\theta_H)}{s_H + \theta_H m(\theta_H)}. \tag{4.16}$$

4.4.3 Effects of the Accumulation of Automation Capital

Before the central results are derived and discussed, the steady-state equilibrium of the economy will be defined.

Definition 1. *A steady-state equilibrium of the developed search and matching model with automation and skill heterogeneity is characterized by a stationary economy in which the key endogenous variables* $\left\{\theta_i, p_i, p_k, w_i, H, L, K, u_i\right\}$ *are determined by the following equations:*

(i) the flow eqs. (4.13) - (4.16)*,*

(ii) the prices of the two intermediates as given by eqs. (4.2) *and* (4.3) *and of capital as given by* $p_k = r + \delta = \alpha Y/K$*,*

(iii) the wage rates as given by eq. (4.10)*,*

(iv) labor demand for each skill level as given by eq. (4.12)*.*

Next, the central results of the developed model will be stated in the following three propositions. Proposition 4.1 describes the effects of automation capital on labor market tightness in the low-skilled labor market and in the high-skilled labor market, respectively.

Proposition 4.1. *The accumulation of automation capital P decreases the labor market tightness in the low-skilled labor market and increases the labor-market tightness in the high-skilled labor market.*

Proof. See Appendix 4.A.3 for the formal proof. □

To provide an intuition for this result, it is considered that an increase in the stock of robots P reduces the price of goods produced by low-skilled workers and raises the price of the goods produced by high-skilled workers. This gives rise to the following lemma.

Lemma 4. *An increase in the stock of robots P reduces the price of goods produced by low-skilled workers and raises the price of the goods produced by high-skilled workers.*

Proof. See Appendix 4.A.4 for the formal proof. □

An increase in the number of robots leads to a substitution of the goods that are produced with low-skilled labor by robots in final goods production. Thus, the price of the goods produced by low-skilled workers decreases, which leads to lower profits of the firms that produce low-skilled intensive goods. This in turn reduces the number of firms that produce low-skilled intensive goods at the steady-state equilibrium and therefore reduces the overall flow of low-skilled vacancies for a given number of low-skilled workers. Thus, labor market tightness decreases for low-skilled workers. By contrast, the demand of the final goods sector for intermediate goods produced by high-skilled workers increases, which raises the price of high-skilled intensive goods and hence the profits of firms producing these goods. The reason is that H and P are imperfect substitutes, implying that the price of the high-skilled intermediate good depends positively on the amount of automation and negatively on the amount of high-skilled labor. At the steady-state equilibrium, there will then be firm entry into the high-skilled intensive goods production such that the flow of vacancies for a given number of high-skilled workers increases. This, in turn, raises the tightness of the high-skilled labor market.

Proposition 4.2 describes the effects of automation capital on the unemployment rates of both types of skills.

Proposition 4.2. *The accumulation of automation capital P increases the unemployment rate of low-skilled workers and decreases the unemployment rate of high-skilled workers.*

Proof. See Appendix 4.A.5 for the formal proof. □

This result is a consequence of the results obtained in Proposition 4.1. Labor market tightness increases for high-skilled workers as automation progresses, while labor market tightness decreases for low-skilled workers. As a consequence, the job finding probability of high-skilled workers increases, while that of low-skilled workers decreases, which, in turn, lowers the unemployment rate of low-skilled workers and increases the unemployment rate of high-skilled workers.

Proposition 4.3 describes the effects of automation capital on the wage rates of both types of workers.

Proposition 4.3. *The accumulation of automation capital P decreases the wage rate of low-skilled workers and increases the wage rate of high-skilled workers.*

Proof. See Appendix 4.A.6 for the formal proof. □

This finding is a consequence of the previously obtained results. It has been shown already that the marginal product of the low-skilled intensive good in final goods production decreases once that automation is accounted for, while the marginal product of the high-skilled intensive good in final goods production increases. The increase in the price of the goods produced by high-skilled workers leads to a higher match surplus for firms in the high-skilled intensive sector, which induces vacancy posting and raises labor market tightness in that sector. The so induced increase in the job-finding probability of high-skilled workers improves their outside option and strengthens their bargaining position, which in turn raises their wage rate. For low-skilled workers, the opposite results emerge. This channel is known from the immigration literature, where a similar production function of the final good implies that low-skilled immigrants are perfect substitutes for low-skilled natives and imperfect substitutes for high-skilled native workers (see, for example, Chassamboulli & Palivos, 2013, 2014; Chassamboulli & Peri, 2015; Liu et al., 2017).

4.5 Conclusions

This chapter uses automation capital as an additional production factor and embeds it in the standard search and matching model augmented by skill heterogeneity, imperfect substitutability between high-skilled workers and low-skilled workers, different search costs and job destruction rates across skill levels. Automation capital is considered to be a perfect substitute for low-skilled labor and an imperfect substitute for high-skilled labor. Using this structure, it is possible to analyze how an increase in the stock of robots effects wage inequality and involuntary unemployment across skill levels. The model predicts that the accumulation of automation capital decreases the labor market tightness in the low-skilled labor market and increases the labor-market tightness in the high-skilled labor market. This leads to a rising unemployment rate of low-skilled workers and a falling unemployment rate of high-skilled workers. In addition, automation leads to falling wages of low-skilled workers and rising wages of high-skilled workers.

Previous contributions have clarified that higher unemployment due to automation could come in the form of i) higher voluntary unemployment if the wages of low-skilled workers stagnate in the wake of automation, while welfare benefits rise with the average wage, and ii) in the form of higher involuntary unemployment if low-skilled workers perceive their wage as unfair and react by exerting less effort. Then firms would need to raise the wages for low-skilled workers above their marginal productivity to induce low-skilled workers to exert full effort. In this situation, equilibrium unemployment would result. The contribution of this chapter clarifies that also higher frictional unemployment might be a result of automation.

From a policy perspective, the issue of higher frictional unemployment could be addressed by i) raising the efficiency of the search process, ii) making sure to raise the fraction of individuals who are skilled by investing in higher education and retraining programs, and iii) potentially one could think about public employment programs for low-skilled workers who are negatively affected by automation and for whom retraining programs do not work appropriately. Such a program might put long-term unemployed into publicly paid jobs at the community level that would not be profitable for private firms like cleaning parks, spending time with the elderly, etc. These programs might be a good alternative for the long-term unemployed who are cut off of the labor market, because the net costs are just the top-up on the unemployment benefits and there might be positive side effects apart from the benefit of the work done for the community. These positive side effects might come in the form of higher levels of self-esteem of the persons enrolled in such schemes, staying better integrated in the society via the connections in the community and at the workplace, and of not losing certain basic skills.

The model that is developed in this chapter abstracts from endogenous education decisions such that individuals cannot switch from being low skilled to being high skilled subject to investment costs as in Prettner & Strulik (2017). Introducing such an endogenous education decision could yield additional insights into the long-run adjustment dynamics to rising technological unemployment. In addition, it might be interesting to introduce a service sector in which low-skilled workers could also find work and might not yet be threatened to get replaced by automation capital to a similar extent as in manufacturing (Autor & Dorn, 2013). Another promising avenue for further research would be to augment the search and matching model by fair wage considerations to analyze two distinct sources of involuntary unemployment within the model (cf. Prettner & Strulik, 2017; Kuang & Wang, 2017).

4.A Appendix

4.A.1 Prices of the Intermediate Goods

Differentiating the production function, eq. (4.1), with respect to the number of high-skilled workers, with respect to the number of low-skilled workers, and with respect to traditional capital yields

$$\frac{\partial Y}{\partial H} = p_H = Y(1-\alpha)(1-\gamma)H^{\sigma-1}\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{-1}, \tag{4.17}$$

$$\frac{\partial Y}{\partial L} = p_L = Y(1-\alpha)\gamma(L+P)^{\sigma-1}\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{-1}, \tag{4.18}$$

$$\frac{\partial Y}{\partial K} = p_K = \alpha A K^{\alpha-1}\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{\frac{1-\alpha}{\sigma}}. \tag{4.19}$$

Solving eq. (4.19) for K and using $p_K = r+\delta$ provides us with

$$K = \left(\frac{\alpha A}{r+\delta}\right)^{\frac{1}{1-\alpha}}\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{\frac{1}{\sigma}}. \tag{4.20}$$

Next, eqs. (4.17) and (4.18) are divided by $p_K = \alpha Y/K$, which can be derived by collecting terms in eq. (4.19). This yields

$$\frac{p_H}{p_K} = \frac{1-\alpha}{\alpha}(1-\gamma)H^{\sigma-1}K\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{-1}, \tag{4.21}$$

$$\frac{p_L}{p_K} = \frac{1-\alpha}{\alpha}\gamma(L+P)^{\sigma-1}K\Big[(1-\gamma)H^\sigma + \gamma(L+P)^\sigma\Big]^{-1}. \tag{4.22}$$

Substituting eq. (4.20) in eqs. (4.21) and (4.22), using $p_K = r+\delta$, and rearranging leads to the prices of the two intermediate goods as given by eqs. (4.2) and (4.3):

$$p_L = (1-\alpha)\gamma A^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}}\left[(1-\gamma)\left(\frac{H}{L+P}\right)^\sigma + \gamma\right]^{\frac{1-\sigma}{\sigma}},$$

$$p_H = (1-\alpha)(1-\gamma)A^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}}\left[(1-\gamma) + \gamma\left(\frac{L+P}{H}\right)^\sigma\right]^{\frac{1-\sigma}{\sigma}}.$$

4.A.2 Wage Determination

Once a worker and a firm with the same skill requirements meet, they bargain over the wage rate. They solve the generalized Nash-bargaining problem given by

$$\max_{w_i}\left\{\Psi_i^E - \Psi_i^U\right\}^\beta \cdot \left\{\Pi_i^F - \Pi_i^V\right\}^{1-\beta}. \tag{4.23}$$

Maximization of the Nash product delivers the sharing rule

$$\beta[\Pi_i^F - \Pi_i^V] = (1-\beta)[\Psi_i^E - \Psi_i^U]. \tag{4.24}$$

Using the present value functions, eqs. (4.5) and (4.7), together with the free entry condition $\Pi_i^V = 0$, the rents of firms and workers can be derived as

$$\Psi_i^E - \Psi_i^U = \frac{w_i - r\Psi_i^U}{r+s_i} \quad \text{and} \quad \Pi_i^F - \Pi_i^V = \frac{p_i - w_i}{r+s_i}. \tag{4.25}$$

Substituting eq. (4.25) in eq. (4.24) and rearranging leads to

$$w_i = \beta p_i + (1-\beta) r\Psi_i^U. \tag{4.26}$$

The wages are the weighted sum of the worker's productivity and the value of unemployment. The weights are given by the bargaining power of the respective participant in the negotiations. Next, $\Psi_i^E - \Psi_i^U$ has to be substituted in the present value function for unemployed workers, eq. (4.8). For the substitution, the sharing rule (4.24) is used. This yields

$$\Psi_i^E - \Psi_i^U = \beta \cdot S, \tag{4.27}$$

with $S = (\Psi_i^E - \Psi_i^U) + (\Pi_i^F - \Pi_i^V)$ being the surplus of a match of the respective bargaining parties. Using eq. (4.25), it turns out that

$$\Psi_i^E - \Psi_i^U = \beta\Big(\frac{p_i - r\Psi_i^U}{r+s_i}\Big). \tag{4.28}$$

Substituting eq. (4.28) in eq. (4.8), the expected value of being unemployed is

$$r\Psi_i^U = \frac{z_i(r+s_i) + p_i\theta_i m(\theta_i)\beta}{r+s_i+\theta_i m(\theta_i)\beta}. \tag{4.29}$$

Finally, inserting eq. (4.29) into eq. (4.26) and rearranging leads to the wage rate given in eq. (4.10):

$$w_i = z_i + (p_i - z_i)\cdot\Gamma(\theta_i),$$

with

$$\Gamma(\theta_i) = \beta\frac{r+s_i+\theta_i m(\theta_i)}{r+s_i+\theta_i m(\theta_i)\beta}.$$

4.A.3 Proof of Proposition 4.1

To see how the wages, employment levels, etc. of workers change due to the accumulation of automation capital, it is necessary to derive how the labor market tightness in each labor market is affected by an increase in P. To do so, the total differential of eq. (4.12) is calculated for each labor market, which thereby proves Proposition 4.1. Afterwards, Propositions 4.2 and 4.3 are proved. However, before the change in wages in Section 4.A.6 can be derived, it is first necessary to derive the change in p_L and p_H as given by eqs. (4.2) and (4.3) and as stated in Lemma 4. Section 4.A.4 contains the corresponding proof.

Proof of Proposition 4.1. In the low-skilled labor market total differentiation delivers

$$\underbrace{h_L \frac{m(\theta_L)\beta\frac{\partial\theta_L m(\theta_L)}{\partial\theta_L} - [r + s_L + \beta\theta_L m(\theta_L)]m'(\theta_L)}{m(\theta_L)^2}}_{C>0} \frac{d\theta_L}{dP} =$$

$$\left[\frac{dH}{d\theta_H}\frac{d\theta_H}{dP} - \frac{H}{L+P}\left(\frac{dL}{d\theta_L}\frac{d\theta_L}{dP} + 1\right)\right] \times$$

$$\underbrace{(1-\beta)(1-\alpha)\gamma A^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}}(1-\sigma)(1-\gamma)\left[(1-\gamma)\left(\frac{H}{L+P}\right)^{\sigma} + \gamma\right]^{\frac{1-2\sigma}{\sigma}} \frac{H^{\sigma-1}}{(L+P)^{\sigma}}}_{B>0}. \tag{4.30}$$

Rearranging yields

$$\left[C + B\frac{H}{L+P}\frac{dL}{d\theta_L}\right]\frac{d\theta_L}{dP} = B\left[\frac{dH}{d\theta_H}\frac{d\theta_H}{dP} - \frac{H}{L+P}\right]. \tag{4.31}$$

Analogously, the total differential in the high-skilled labor market is given by

$$\underbrace{h_H \frac{m(\theta_H)\beta\frac{\partial\theta_H m(\theta_H)}{\partial\theta_H} - [r + s_H + \beta\theta_H m(\theta_H)]m'(\theta_H)}{m(\theta_H)^2}}_{D>0} \frac{d\theta_H}{dP} =$$

$$\left[-\frac{L+P}{H}\frac{dH}{d\theta_H}\frac{d\theta_H}{dP} + \left(\frac{dL}{d\theta_L}\frac{d\theta_L}{dP} + 1\right)\right] \times$$

$$\underbrace{(1-\beta)(1-\alpha)\gamma A^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}}(1-\sigma)(1-\gamma)\left[(1-\gamma) + \gamma\left(\frac{L+P}{H}\right)^{\sigma}\right]^{\frac{1-2\sigma}{\sigma}} \frac{(L+P)^{\sigma-1}}{H^{\sigma}}}_{B_1>0}. \tag{4.32}$$

Rearranging yields

$$\frac{d\theta_H}{dP} = \frac{B_1}{D + B_1 \frac{L+P}{H} \frac{dH}{d\theta_H}} \left[\frac{dL}{d\theta_L} \frac{d\theta_L}{dP} + 1 \right]. \tag{4.33}$$

Substituting eq. (4.33) in eq. (4.31) and simplifying yields

$$\frac{d\theta_L}{dP} = -\frac{BD}{C\left(D + B_1 \frac{L+P}{H} \frac{dH}{d\theta_H}\right) + BD \frac{H}{L+P} \frac{dL}{d\theta_L}} \frac{H}{L+P} < 0. \tag{4.34}$$

In the next step, eq. (4.34) is substituted in eq. (4.33) to obtain

$$\frac{d\theta_H}{dP} = \frac{B_1 C}{C\left(D + B_1 \frac{L+P}{H} \frac{dH}{d\theta_H}\right) + BD \frac{H}{L+P} \frac{dL}{d\theta_L}} > 0. \tag{4.35}$$

Eqs. (4.34) and (4.35) prove Proposition 4.1. □

4.A.4 Proof of Lemma 4

Proof of Lemma 4. Total differentiation of the price of the low-skill intensive intermediate good delivers

$$\frac{dp_L}{dP} = \left[\frac{dH}{d\theta_H} \frac{d\theta_H}{dP} - \frac{H}{L+P} \left(\frac{dL}{d\theta_L} \frac{d\theta_L}{dP} + 1 \right) \right] \times \underbrace{(1-\alpha)\gamma A^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r+\delta} \right)^{\frac{\alpha}{1-\alpha}} (1-\sigma)(1-\gamma) \left[(1-\gamma) \left(\frac{H}{L+P} \right)^{\sigma} + \gamma \right]^{\frac{1-2\sigma}{\sigma}} \frac{H^{\sigma-1}}{(L+P)^{\sigma}}}_{B_2 > 0}. \tag{4.36}$$

Inserting eqs. (4.34) and (4.35) and simplifying yields

$$\frac{dp_L}{dP} = -\frac{B_2 CD}{C\left(D + B_1 \frac{L+P}{H} \frac{dH}{d\theta_H}\right) + BD \frac{H}{L+P} \frac{dL}{d\theta_L}} \frac{H}{L+P} < 0. \tag{4.37}$$

The procedure for the price of the high-skill intensive intermediate good is similar. Total differentiation yields

$$\frac{dp_H}{dP} = \left[-\frac{L+P}{H} \frac{dH}{d\theta_H} \frac{d\theta_H}{dP} + \left(\frac{dL}{d\theta_L} \frac{d\theta_L}{dP} + 1 \right) \right] \times \underbrace{(1-\alpha)\gamma A^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r+\delta} \right)^{\frac{\alpha}{1-\alpha}} (1-\sigma)(1-\gamma) \left[(1-\gamma) + \gamma \left(\frac{L+P}{H} \right)^{\sigma} \right]^{\frac{1-2\sigma}{\sigma}} \frac{(L+P)^{\sigma-1}}{H^{\sigma}}}_{B_3 > 0}. \tag{4.38}$$

Substituting in eqs. (4.34) and (4.35) and simplifying provides

$$\frac{dp_H}{dP} = \frac{B_3 CD}{C\left(D + B_1 \frac{L+P}{H}\frac{dH}{d\theta_H}\right) + BD\frac{H}{L+P}\frac{dL}{d\theta_L}} > 0. \tag{4.39}$$

Eqs. (4.37) and (4.39) prove Lemma 4. □

4.A.5 Proof of Proposition 4.2

Proof of Proposition 4.2. Using the change in labor-market tightness in each labor market, the change in the respective employment levels and unemployment rates, as given by eqs. (4.13) - (4.16), can be easily derived as follows:

$$\frac{dL}{dP} = \lambda \frac{s_L}{[s_L + \theta_L m(\theta_L)]^2} \frac{\partial \theta_L m(\theta_L)}{\partial \theta_L} \underbrace{\frac{d\theta_L}{dP}}_{<0} < 0 \tag{4.40}$$

$$\frac{du_L}{dP} = -\frac{s_L}{[s_L + \theta_L m(\theta_L)]^2} \frac{\partial \theta_L m(\theta_L)}{\partial \theta_L} \frac{d\theta_L}{dP} > 0 \tag{4.41}$$

$$\frac{dH}{dP} = (1-\lambda) \frac{s_H}{[s_H + \theta_H m(\theta_H)]^2} \frac{\partial \theta_H m(\theta_H)}{\partial \theta_H} \underbrace{\frac{d\theta_H}{dP}}_{>0} > 0 \tag{4.42}$$

$$\frac{du_H}{dP} = -\frac{s_H}{[s_H + \theta_H m(\theta_H)]^2} \frac{\partial \theta_H m(\theta_H)}{\partial \theta_H} \frac{d\theta_H}{dP} < 0. \tag{4.43}$$

Eqs. (4.41) and (4.43) prove Proposition 4.2. □

4.A.6 Proof of Proposition 4.3

Proof of Proposition 4.3. Finally, it is possible to derive the change in the wage rates. The total differential of the wage rate, as given by eq. (4.10), in each labor market is

$$\frac{dw_L}{dP} = \Gamma(\theta_L) \underbrace{\frac{dp_L}{dP}}_{<0} + (p_L - z_L) \frac{(1-\beta)(r+s_L)}{[r + s_L + \beta\theta_L m(\theta_L)]^2} \frac{\partial \theta_L m(\theta_L)}{\partial \theta_L} \underbrace{\frac{d\theta_L}{dP}}_{<0} < 0, \tag{4.44}$$

$$\frac{dw_H}{dP} = \Gamma(\theta_H) \underbrace{\frac{dp_H}{dP}}_{>0} + (p_H - z_H) \frac{(1-\beta)(r+s_H)}{[r + s_H + \beta\theta_H m(\theta_H)]^2} \frac{\partial \theta_H m(\theta_H)}{\partial \theta_H} \underbrace{\frac{d\theta_H}{dP}}_{>0} > 0. \tag{4.45}$$

This proves Proposition 4.3. □

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Chapter 5

Endogenous Technology, Matching, and Overqualification: Does Low-Skilled Immigration Affect the Technological Alignment of the Host Country?*

5.1 Introduction

In recent years, the number of refugees has severely increased in Germany and other European countries. Especially countries, such as Iraq and Syria, where human rights are violated and war is omnipresent, face a huge outflux of refugees. For example, in Germany the number of asylum applications increased about 267% from 2014 to 2016 (Bundesagentur für Arbeit, 2017). Facing this enormous increase, there is an ongoing public and political debate within and across European countries about how this situation changes the European Union and its member states, and how it should be dealt with. Politicians and scientists agree that the key factor for a successful integration of these

*A previous version of this chapter has appeared as Cords (2017).

refugees is their participation in the labor market. However, such a substantial shock in labor supply may strongly change the respective countries' labor markets.

This chapter analyzes the effects of low-skilled immigration on the host country in a theoretical model. In particular, the model investigates how the technological alignment of the economy is altered. It is assumed that immigration is low skilled, since it is known that most refugees from the aforementioned countries are indeed low skilled (Brücker et al., 2015a, 2015b).[1] Even if there are, up to now, no completely reliable numbers concerning the qualification of refugee immigrants, it can be concluded that about two out of three refugees have visited at maximum secondary school. Further, about two-thirds have not completed vocational training (compared to 14% of German citizens with no immigration background). Even if refugee immigrants are high skilled, it remains open if their skills are comparable to those of high-skilled natives in Europe. The reason is that the educational system is very different between countries, such as Germany and countries from the middle east. Hanushek & Woessmann (2015) compare the educational performance of pupils across 81 countries. They find that the average performance of 15 year old pupils from Syria is 140 PISA-points worse than that of German pupils of the same age. This amounts in about the knowledge pupils acquire in four to five school years.

To analyze the effects of immigration, a search and matching model à la Mortensen & Pissarides (1994) and Pissarides (2000) is applied. Thus, unemployment is present due to the existence of frictions in the labor market. In comparison to the standard matching model, there is more than one type of worker. Since it is distinguished between high and low skills, natives and immigrants, and it is allowed for low-skilled immigration, the model incorporates three groups of workers. The distribution of skills across workers is assumed to be exogenous. Firms post either high- or low-tech vacancies, however, they cannot distinguish ex ante whether they meet a native or an immigrant. While the skill distribu-

[1]Keep in mind that refugees differ from economic immigrants in several aspects, such that refugees have on average less education and proficiency in foreign language, are initially less healthy, face initially worse labor market expectations, etc. (see Chin & Cortes, 2015). Throughout this chapter, the notions refugee immigration and low-skilled immigration are used interchangeably.

tion of workers is exogenously given, the skill requirements of firms adjust endogenously. Thus, the chapter is able to address the question how low-skilled immigration affects the firms' technology choice and, hence, the technological orientation of the host country as a whole. Furthermore, it analyzes if policies that improve the access of immigrants to the labor market counteract or even strengthen the effects that are induced by an increase in immigration. To do so, the model builds on Albrecht & Vroman (2002), who investigate the technology choice of firms under worker heterogeneity in the absence of immigration.

The main result of the model is that firms react to the increase in low-skilled immigration by using the basic technology more intensively. Thus, the composition of jobs in the economy changes. Many firms shift their production to the less-advanced technology and produce simple, less-advanced goods. It is further shown that low-skilled immigration is beneficial for low-skilled natives, while high-skilled workers are hurt in terms of wages, but gain in terms of employment. At first sight, this may seem implausible, since low-skilled immigrants are competing with low-skilled natives for jobs. However, firms react to the increase in low-skilled immigration by producing with the less-advanced technology more intensively. Hence, the pervasive fear of low-skilled workers to get displaced by immigrants is unfounded at least in this type of model. As a second result, it can be shown that policies that target at a reduction in immigrants' costs of searching for a job, to improve immigrants' access to the labor market, work in the opposite direction. Firms have an incentive to produce with the more advanced technology. Thus, the host country is shaped by a high-tech production industry. Hence, it may be a favorable economic policy to improve the access of immigrants to the labor market. However, such policies hurt low-skilled natives both in terms of wages and employment, while high-skilled natives gain in terms of wages, but lose in terms of employment. A drawback of such policies is that the wage inequality among native skill groups increases.

The structure of this chapter is as follows. Section 5.2 gives a brief discussion of related literature. Section 5.3 describes the outline of the model and its components in more detail, before the equilibrium is derived in Section 5.4. Section 5.5 provides analytical results, i.e. analyzes the changes in the technology choices of firms, the wage-setting and employment structure triggered by an increase in low-skilled immigration and by a decrease in search costs of immigrants. Section 5.6 calibrates the model to German data and measures quantitatively the effects of these two scenarios. Finally, Section 5.7 summarizes the results and concludes.

5.2 Related Literature

The model, that will be developed in the following, combines several strands of literature. Most of the theoretical literature in labor economics studies the effects of immigration within a standard neoclassical growth model (for an overview, see Ben-Gad, 2004, 2008; Moy & Yip, 2006; Palivos & Yip, 2010). However, a basic assumption of this type of model is that there is perfect competition in the labor market and, thus, there is no involuntary unemployment. Up to now, there exist only a few studies that analyze the impact of immigration in a search and matching model à la Mortensen & Pissarides (1994) and Pissarides (2000). Ortega (2000), Liu (2010), Chassamboulli & Palivos (2013, 2014) and Battisti et al. (2017) provide first contributions to analyze the labor market effects of immigration. Their focus is on the effects of skill specific immigration on the wage level, employment and its structure in the host country. However, it is not taken into account that firms may adjust their production technology. The implementation of such an endogenous technology choice is necessary, since skill-specific immigration leads to a change in the relative supply of labor. As a consequence, the incentives of firms to invest in specific technologies may change. This results in an endogenous, skill-biased technical change. Further, it is not considered that there is a skill mismatch in the labor market.

Theoretical work on endogenous technology choices is rather limited. Acemoglu (1999) studies the effects of skill-biased technical change. In his model, the job-filling and job-finding rate are exogenously given, which yields to the conclusion that all jobs are identical in the economy if the productivity difference between low- and high-skilled workers is small and/or if the proportion of high-skilled workers in the economy is low enough. Mortensen & Pissarides (1999) also use a model with an exogenous skill distribution of workers and heterogeneity on both sides of the market to show that the effects of a skill-biased technical change depend on the different systems of unemployment insurance and employment protection in Europe and the US. However, they assume that workers are able to direct their search, which leads to perfect matching of workers and jobs with the appropriate skill requirement.[2] This chapter uses and extends the framework developed by Albrecht & Vroman (2002), who investigate how a change in the productivity of a high-skilled job changes the technology choices of firms in a closed economy. In their model, there are two type of workers, low- and high-skilled, that are searching for a job. Jobs differ in their skill requirement. Jobs that use the basic technology can either be performed by low- or high-skilled workers, while a job that uses the more advanced technology can only be occupied by a high-skilled worker.[3] Davidson et al. (2008) extend this framework to two countries that differ in the technologies firms produce with. In comparison to this chapter, they look at the effects of offshoring and distinguish between short- and long-run effects of offshoring. While low- and high-skilled workers are hurt in the short run, the long-run effects of offshoring high-tech jobs in a specific industry improves the position of low-skilled workers in the same industry. Dolado et al. (2009) use the model of Albrecht & Vroman (2002) and enrich it by on-the-job search. Baudy (2017) goes beyond Albrecht & Vroman (2002) and introduces temporary agency employment by assuming that the output a regular worker produces is higher than the output a temporary worker produces using a less advanced technology. He shows that a deregulation of temporary agency employment affects the technological orientation of the economy through a more intensive use of the less advanced technology.

Liu et al. (2017) are the first that study immigration in a search and matching model that takes the labor market sorting of Albrecht & Vroman (2002) into account. However, they focus on the imperfect transferability of foreign human capital and neglect the endogenous technology choice of firms. This chapter is the first theoretical work that combines immigration, educational mismatch among natives and endogenous, skill spe-

[2]Another contribution is provided by McKenna (1996). In comparison to the other papers, he endogenizes the educational decision of workers in a two-sector matching model.

[3]For example, Gautier (2002) justifies this labor market sorting by using the example of a hamburger-flipping job, which can be performed by everyone, while only very few skilled workers can be occupied at NASA as an engineer.

cific technology choices all together in a search and matching framework. Thus, it is possible to reveal how immigration and a reduction in the barriers for integration and participation in the labor market of immigrants affects the technological orientation of the host country.

5.3 Outline of the Model

5.3.1 Basic Assumptions

All workers are assumed to live forever, to be risk neutral and to discount the future at a constant rate $r > 0$. Further, the model is in continuous time. As in the standard matching literature, workers can be in either of two states: employed or unemployed. Workers differ in their country of origin, with $i = \{N, I\}$, where N stands for native and I for immigrant. The measure of natives is normalized to 1. Immigrants are low skilled, implying that their measure is $I_L = I$. Furthermore, natives have different skill levels, with $j = \{L, H\}$, where L denotes low-skilled individuals and H denotes high-skilled individuals. The skills are distributed exogenously on a two-point distribution: fraction p is low-skilled, while the remaining fraction $1 - p$ is high-skilled.

Considering the jobs that firms offer, they can either be filled or vacant. There are two type of jobs, which differ in their skill requirement. If any job is filled, it gets destroyed with the exogenous job destruction rate δ.[4] Before a firm enters the market and posts a vacancy, it has to make a decision concerning its technology choice. The firms' production technology is described as follows: each firm that decides to adopt the basic technology produces y_L units of output if a job is filled, independent of the type of worker the job is filled with.[5] Thus, low- and high-skilled workers are perfect substitutes for low-tech firms.

[4]Assuming the job destruction rate to be equal across jobs does not change the qualitative results and, further, simplifies the analytical derivations. Albrecht & Vroman (2002), Davidson et al. (2008) and Dolado et al. (2009) apply the same assumption.

[5]It is also possible to assume that high-skilled workers produce μy_L units of output. However, Gautier (2002) points out that there is no reason to assume μ to be unequal than unity. Further, Blázquez & Jansen (2008) and Dolado et al. (2009) also assume μ to be equal to unity.

Firms that use the advanced technology can only produce with high-skilled workers.[6] If a job is filled, high-skilled workers produce y_H units of output, with $y_H > y_L$.[7] Adopting the labor market sorting of Albrecht & Vroman (2002), there are two types of equilibria: ex-post segmentation (EPS) and cross-skill matching (CSM). In EPS, low-skilled workers work in low-tech jobs and high-skilled workers only work in high-tech jobs, since these workers refuse to be occupied in a low-tech job. On the other hand, in CSM, high-skilled workers sort themselves also into low-tech jobs. The type of segmentation that emerges depends mainly on the labor market expectations of high-skilled workers and the wage they could earn in a low-tech job. If the wage paid for them in a low-tech job is quite low and they expect to find a high-tech job relatively fast, they will sort themselves only in high-tech jobs. Thus, the resulting equilibrium is an EPS. On the other hand, if the wage that could be earned in a low-tech job is high enough and they do not expect to find a high-tech job very fast, the resulting equilibrium is an CSM. Further, the probability that a CSM exists is higher, the smaller the gap between the productivity in a high-tech and low-tech job, and the smaller the share of high-skilled natives. In this chapter, the focus is on a CSM, meaning that high-skilled workers take any job that is offered to them.[8] Thus, high-skilled workers prefer to be employed in a low-tech job rather than staying unemployed. There are mainly two reasons: first, in a richer model with more than two skill groups, overqualification is a more prominent issue. Second, using data from the

[6]This chapter abstracts from studying the case where low-skilled workers can be employed in a high-tech job. Underqualification does not seem to play a big role in a country such as Germany, for which the model is calibrated below. McGowan & Andrews (2015) calculate the skill and qualification mismatch based on the OECD Survey of Adult Skills (PIAAC). They find that under-skilling only amounts to less than 4 % in Germany in the year 2012, while over-skilling is around 23 %.

[7]Using this simple production structure keeps the model tractable and makes it possible to derive clear analytical results. This would not be the case if a production structure like in Chapter 4 would be considered, where a final good is produced using two intermediates, which are imperfectly substitutable. In this case, the larger supply of low-skilled labor, due to an exogenous increase in immigration, would decrease the price of the low-tech good and increase the price of the high-tech good. This channel, which is investigated in Chassamboulli & Palivos (2013, 2014), would counteract the effect that arises due to the technology adaption of firms.

[8]It will be shown later that the conditions for a CSM are fulfilled.

EU-LFS for high-skilled German natives that are aged 15-64, it can be shown that 9.8 % are overqualified.[9]

Unemployed workers and vacancies meet each other randomly, so that the matching function can formally be described by

$$M = M(v, u). \tag{5.1}$$

Search is undirected, meaning that vacancies can not direct their search to a specific type of worker. Thus, there is a single labor market featuring low- and high-skilled workers and low-tech and high-tech firms. The matching function exhibits constant returns to scale, is increasing in both arguments, at least twice differentiable, and satisfies the Inada conditions. M denotes the instantaneous flow of hires. The number of vacancies posted are denoted by v, while the number of job-searchers equals the unemployment rate u. Further, the fraction of vacancies that require a low-skill level is given by ϕ, while γ denotes the fraction of unemployed workers that are low skilled.[10] The arrival rate of any worker per vacancy is $M(v, u)/v \equiv m(\theta)$, while the arrival rate of any vacancy per unemployed worker is $M(v, u)/u \equiv \theta m(\theta)$. The arrival rate for firms decreases in θ, while the latter one increases in θ. Variable $\theta \equiv v/u$ reflects the overall labor market tightness. As not all combinations of firms and workers fulfill their mutual requirements, the arrival rates can be further specified. For instance, the effective arrival rate of vacancies for unemployed low-skilled workers is $\phi\theta m(\theta)$. Further, the effective arrival rate of workers for a high-tech vacancy is $(1 - \gamma)m(\theta)$.

The assumption of undirected search is often used in economic literature if workers differ in their skills (see, e.g., Albrecht & Vroman, 2002; Wong, 2003; Dolado et al., 2009; Chassamboulli, 2011; Agnese & Hromcová, 2016). The reasons are manifold. First, it is often observed that the difficulty of firms is not to trace potential applicants, but rather the process of screening applications for the ideal candidate. For example, van Ours & Ridder (1993) confirm this, since they find that the duration of vacancies mainly consist of

[9]As already mentioned above, McGowan & Andrews (2015) show that over-skilling even amounts to approximately 23 %.

[10]This type of modelling follows Albrecht & Vroman (2002).

a selection period, while attracting potential candidates takes only a relatively small time. Another argument in favor of undirected search in models with heterogeneity on both sides of the market is provided by Acemoglu (1999). He states that the skill level is imperfectly correlated with observable characteristics, such as age and years of education. It will be seen later in the description of the model that workers in this chapter do not only differ in terms of skill and productivity, but also in terms of their outside option (for example, due to a different entitlement towards unemployment benefits or higher search costs of immigrants). This even reinforces Acemoglu's argument. Lastly, Pries (2008) adds that even if the firm should be able to reveal the productivity or the opportunity costs of a worker once they meet, what is important for an argument in favor of directed search is whether the productivity or the opportunity costs of a worker can be precisely identified prior to an interview, which is indeed doubtful. For the second degree of heterogeneity, namely if the worker is a native or an immigrant, the model follows Chassamboulli & Palivos (2014) and Battisti et al. (2017), where firms cannot distinguish immigrants and natives ex ante (when posting vacancies), but ex post (when bargaining about wages). This feature explains the wage gap between immigrants and natives of the same skill group that arises due to a weaker bargaining position of immigrants.

From the workers point of view it can be argued that a high-tech firm can not prevent to receive applications from low-skilled immigrants. Even if the skills of immigrants may not be comparable to the skills of high-skilled natives, and foreign professional qualifications are often not recognized by authorities, immigrants with a self-perceived high-skill level will also apply for a high-tech job.[11] In a similar vein, it can be argued that also natives often apply for job offers that do not really fit their specific experience and skill level as many job advertisements are rather difficult to understand, or it may be difficult for the workers to identify which types of skills are required in particular. This behavior is acknowledged by firms, who know that there is seldom a job applicant that fulfills every criteria of the job advertisement.[12]

[11] A refugee that worked as a doctor in his home country, for example, wants to get hired as a doctor as well in Germany and will not directly apply for a position as a nurse.

[12] This argument is even more vigorous in reality, where workers are not classified into two skill levels,

The way of representing the meeting technology is decisively different between the frameworks of Albrecht & Vroman (2002) on the one hand, and Neugart & Storrie (2006) as well as Chassamboulli & Palivos (2013, 2014) on the other hand. Albrecht & Vroman (2002) define an overall labor market tightness and distinguish, e.g., the effective arrival rate of vacancies for workers by multiplying the overall labor market tightness with the fraction of high- or low-tech vacancies. Neugart & Storrie (2006) as well as Chassamboulli & Palivos (2013, 2014) construct a specific labor market tightness for each submarket, the former for temporary agency and regular vacancies while the latter do it for high- and low-skill intensive jobs.[13]

5.3.2 Firms

Firms are small and offer only one job. Before entering the market, they ex-ante decide which type of technology to use in their production. Once a low-tech job is filled, the firm's expected profit is

$$r\Pi^F_{NL} = y_L - w_{NL} + \delta(\Pi^V_L - \Pi^F_{NL}), \tag{5.2}$$

$$r\Pi^F_{IL} = y_L - w_{IL} + \delta(\Pi^V_L - \Pi^F_{IL}), \tag{5.3}$$

$$r\Pi^F_{OH} = y_L - w_{OH} + \delta(\Pi^V_L - \Pi^F_{OH}). \tag{5.4}$$

Low-tech vacancies can either be filled with a low-skilled native (NL), with an immigrant (IL) or with a high-skilled worker (OH). The expected profits of a low-tech job that is filled by a low-skilled worker (native or immigrant, respectively), are given in eq. (5.2) and (5.3). The worker produces y_L units of output, which is the same for low-skilled natives and low-skilled immigrants, while the firm has to pay a wage rate w_{NL} or w_{IL},

but feature a continuum of skills. It may be useful to consider the case of an potential applicant that perfectly fulfills every requirement of a certain job advertisement. The only thing that is demanded in the job advertisement and that the applicant does not exhibit is, for example, foreign experience. However, this does not keep the potential applicant away from submitting the application.

[13] While this chapter uses the approach of Albrecht & Vroman (2002), Chapter 3 uses the approach of Neugart & Storrie (2006), and Chapter 4 follows Chassamboulli & Palivos (2013, 2014).

respectively.[14] Further, the last term on the right-hand-side (RHS) denotes the loss the firm experiences if the job is destroyed, weighted by its probability of occurrence δ. Equation (5.4) represents the case where a low-tech vacancy is filled with a high-skilled worker. Even if the high-skilled worker is overqualified for this type of job, the output produced is the same as for a low-skilled worker, y_L. However, the firm pays a different wage w_{OH}, which represents the wage a high-skilled, overqualified worker obtains. Again, the last term on the RHS denotes the loss that occurs for the firm if the job is hit by a shock and gets destroyed. The present value of a filled high-tech job is given by

$$r\Pi_H^F = y_H - w_H + \delta(\Pi_H^V - \Pi_H^F). \quad (5.5)$$

Since high-tech jobs can only be performed by high-skilled individuals, the output produced is y_H and the wage the worker receives is w_H. Again, the last term denotes the loss if the position gets vacant.[15]

The firm's expected profit of posting a low-tech vacancy is

$$r\Pi_L^V = -c_L + m(\theta)\Big[\gamma\big[\varepsilon(\Pi_{IL}^F - \Pi_L^V) + (1-\varepsilon)(\Pi_{NL}^F - \Pi_L^V)\big] + (1-\gamma)(\Pi_{OH}^F - \Pi_L^V)\Big], \quad (5.6)$$

where c_L denotes the costs of a low-tech vacancy and ε is the fraction of low-skilled unemployed that are immigrants. Considering the present value for a low-tech vacant job, it is known that low-tech jobs can be occupied by low-skilled natives, low-skilled immigrants or high-skilled workers. Thus, the gain a firm obtains if a job gets filled is a weighted sum of the potential gains multiplied by the effective arrival rates and, thus, depends on the type of worker the vacancy is filled with. In case that a low-tech vacancy gets filled with an immigrant, the firm gains $\Pi_{IL}^F - \Pi_L^V$, while the effective arrival rate is the product of the overall vacancy arrival rate $m(\theta)$ and the probability to meet an immigrant $\gamma\varepsilon$. If the vacancy gets filled with a low-skilled native, the effective arrival rate is $m(\theta)\gamma(1-\varepsilon)$ and the related gain of the firm is $\Pi_{NL}^F - \Pi_L^V$. Lastly, if the firm meets a high-skilled worker, the vacancy is filled with rate $m(\theta)(1-\gamma)$, while the related gain of the firm is given by $\Pi_{OH}^F - \Pi_L^V$.

[14] Even if immigrants and low-skilled natives produce the same output, their wages are different. Section 5.4.1 shows that the reason is the difference in the costs of searching for a job.

[15] Since high-skilled individuals are necessarily natives by assumption, the index N is omitted.

The firm's expected profit of posting a high-tech vacancy is

$$r\Pi_H^V = -c_H + m(\theta)(1-\gamma)(\Pi_H^F - \Pi_H^V), \tag{5.7}$$

with c_H denoting the costs of a high-tech vacancy. The last term on the RHS denotes the gain $\Pi_H^F - \Pi_H^V$ a high-tech firm obtains if a vacant job gets filled. The gain is only weighted by the effective arrival rate of workers for a high-tech vacancy $m(\theta)(1-\gamma)$. The reason is that only high-skilled workers can perform a job with high-skill requirements.

5.3.3 Workers

The behavior of workers can be stated similar to the firms' value functions. The expected value of employment for low-skilled workers is given by

$$r\Psi_{NL}^E = w_{NL} + \delta(\Psi_{NL}^U - \Psi_{NL}^E), \tag{5.8}$$

$$r\Psi_{IL}^E = w_{IL} + \delta(\Psi_{IL}^U - \Psi_{IL}^E). \tag{5.9}$$

The wage rates w_{NL} and w_{IL}, respectively, denote the instantaneous wage income in a low-tech job. The second term on the RHS reflects the loss from becoming unemployed, weighted by its probability of occurrence δ.

The expected value of employment for high-skilled workers is given by

$$r\Psi_{OH}^E = w_{OH} + \delta(\Psi_H^U - \Psi_{OH}^E), \tag{5.10}$$

$$r\Psi_H^E = w_H + \delta(\Psi_H^U - \Psi_H^E). \tag{5.11}$$

Per instantaneous time interval, a high-skilled worker that is employed in a low-tech firm receives wage rate w_{OH}. A high-skilled worker that is employed in a high-tech firm obtains wage rate w_H per instantaneous time interval. Again, the second term on the RHS reflects the loss from becoming unemployed, weighted by its probability of occurrence δ, respectively.

Finally, the present value functions of being unemployed are

$$r\Psi_{NL}^U = z_L + \theta m(\theta)\phi(\Psi_{NL}^E - \Psi_{NL}^U), \tag{5.12}$$

$$r\Psi_{IL}^{U} = z_L - h_I + \theta m(\theta)\phi(\Psi_{IL}^{E} - \Psi_{IL}^{U}), \tag{5.13}$$

$$r\Psi_{H}^{U} = z_H + \theta m(\theta)\Big[(1-\phi)(\Psi_{H}^{E} - \Psi_{H}^{U}) + \phi(\Psi_{OH}^{E} - \Psi_{H}^{U})\Big], \tag{5.14}$$

for low-skilled natives, immigrants and high-skilled natives, respectively. While being unemployed workers receive a flow income z_j, which includes the opportunity costs of employment such as unemployment benefits, leisure and the payoff from home production. Further, the search costs of immigrants are denoted by h_I. It is more difficult for immigrants to find a job, compared to natives, due to existing language barriers, the lack or non-existence of a social network, non-recognition of foreign professional qualifications, social stigma against immigrants and so forth. As natives do not face these problems, there are no search costs for native job seekers (the same assumption is also applied in Ortega, 2000; Battisti et al., 2017; Chassamboulli & Palivos, 2014; Liu et al., 2017). The last term on the RHS describes the expected gain from possible changes in the labor market state. For low-skilled workers of either origin the gain is weighted by the effective arrival rate of low-tech vacancies $\theta m(\theta)\phi$. Considering eq. (5.14), the potential gain of changing the labor market state is a weighted sum, since high-skilled workers can either be hired by a low-tech, or a high-tech firm. The weights are depicted by the effective arrival rate of low-tech vacancies $\theta m(\theta)\phi$, and the effective arrival rate of high-tech vacancies $\theta m(\theta)(1-\phi)$, respectively.

5.4 Solution of the Model

5.4.1 Wage Determination

Once a low-skilled native and a low-tech firm meet each other, they solve a generalized Nash bargaining problem given by

$$\max_{w_{NL}} \Big\{\Psi_{NL}^{E} - \Psi_{NL}^{U}\Big\}^{\beta} \cdot \Big\{\Pi_{NL}^{F} - \Pi_{L}^{V}\Big\}^{1-\beta}, \tag{5.15}$$

where $\beta \in (0,1)$ represents the bargaining power of the worker. Maximizing the Nash product gives

$$w_{NL} = z_L + (y_L - z_L) \cdot \Gamma_L(\theta), \tag{5.16}$$

with $\Gamma_L(\theta) = \beta\frac{r+\delta+\theta m(\theta)\phi}{r+\delta+\theta m(\theta)\beta\phi}$. Thus, the wage for low-skilled natives is set as a mark-up over the income enjoyed while being unemployed. The mark-up $\Gamma_L(\theta)$ gives the effective bargaining power of low-skilled natives, see Cahuc et al. (2014).

The wage rate for high-skilled workers that are employed in a high-tech firm is determined in a similar way. The wage is given by

$$w_H = z_H + (y_H - z_H) \cdot \Gamma_H(\theta) - (1-\beta)\frac{\theta m(\theta)\beta\phi(y_H - y_L)}{r+\delta+\theta m(\theta)\beta}, \tag{5.17}$$

with $\Gamma_H(\theta) = \beta\frac{r+\delta+\theta m(\theta)}{r+\delta+\theta m(\theta)\beta}$ denoting the effective bargaining power of all high-skilled natives. In comparison to the wage rate for low-skilled natives, the effective bargaining power does not depend on the fraction of vacancies that require a particular skill type as high-skilled workers are able to work in both type of jobs. Further, the wage rate is lowered by the last term on the RHS due to the possibility of a mismatch.

The wage rate for immigrants can be stated as follows

$$w_{IL} = z_L - h_I + [y_L - (z_L - h_I)] \cdot \Gamma_L(\theta). \tag{5.18}$$

Again, the wage for low-skilled immigrants is set as a mark-up over net unemployment income $z_L - h_I$. As low-skilled natives have a better outside option than immigrants, due to immigrants' positive search costs, low-tech firms have to pay low-skilled natives higher wages. Thus, low-tech firms prefer to hire immigrants.

The wage rate for high-skilled workers that work in low-tech firms is also determined by individual bargaining. Finally, the wage turns out to be

$$w_{OH} = z_H + (y_L - z_H) \cdot \Gamma_H(\theta) + (1-\beta)\frac{\theta m(\theta)\beta(1-\phi)(y_H - y_L)}{r+\delta+\theta m(\theta)\beta}. \tag{5.19}$$

The wage is set as a mark-up over the income a high-skilled worker enjoys while being unemployed. It should be further noted $w_{OH} > w_{NL}$ as high-skilled workers have a better outside option than low-skilled natives. Thus, low-tech firms prefer to hire low-skilled workers rather than high-skilled workers. Appendix 5.A.1 provides detailed calculations about the derivation of the wage rates.

5.4.2 Labor Demand and Equilibrium

Firms that use the basic technology and the more advanced technology enter the market and open their vacancies as long as the expected profit of posting a vacancy is positive. Free market entry drives the expected profit of a vacancy down to zero, i.e.

$$\Pi_H^V = \Pi_L^V = 0. \tag{5.20}$$

Further, the present value functions of a filled job, eqs. (5.2) - (5.5), are used and combined with the equilibrium wage levels w_{NL}, w_{IL}, w_{OH}, and w_H. Thus, the labor demand for high-skill employment is

$$\frac{c_H(r+\delta)}{m(\theta)} = (1-\beta)(1-\gamma)\frac{(y_H - z_H)(r+\delta) + \phi\theta m(\theta)\beta(y_H - y_L)}{r+\delta+\theta m(\theta)\beta}, \tag{5.21}$$

while the labor demand for low-skill employment is given by

$$\begin{aligned}\frac{c_L(r+\delta)}{m(\theta)} =& \frac{\gamma(r+\delta)(1-\beta)}{r+\delta+\phi\theta m(\theta)\beta}\Big[\varepsilon[y_L-(z_L-h_I)]+(1-\varepsilon)(y_L-z_L)\Big] \\ &+(1-\beta)\frac{(1-\gamma)(r+\delta)}{r+\delta+\theta m(\theta)\beta}\Big[(y_L-z_H)-\theta m(\theta)\beta(1-\phi)(y_H-y_L)\Big].\end{aligned} \tag{5.22}$$

Appendix 5.A.2 provides detailed calculations, of how the two labor demand conditions can be derived.

In equilibrium, the flows in and out of unemployment have to be equal, i.e. $\dot{u} = 0$. Thus, the steady-state flow for low-skilled immigrants is given by

$$\phi\theta m(\theta)\gamma\varepsilon u = \delta\left[\frac{I}{1+I} - \gamma u\varepsilon\right]. \tag{5.23}$$

Immigrants meet low-tech vacancies at rate $\phi\theta m(\theta)$ per instantaneous time interval. Multiplying this rate with the rate of unemployed immigrants $\gamma\varepsilon u$ represents the instantaneous inflow of immigrants into jobs that demand low skills. At the same time, employment of immigrants $\frac{I}{1+I} - \gamma u\varepsilon$ is destroyed at rate δ.[16] The equilibrium in- and outflow of low-skilled natives can be summarized as

$$\phi\theta m(\theta)\gamma(1-\varepsilon)u = \delta\left[\frac{p}{1+I} - \gamma u(1-\varepsilon)\right]. \tag{5.24}$$

[16]Recall, that the number of immigrants has to be normalized by the total number of workers, which is given by $1+I$.

Unemployed low-skilled natives $\gamma(1-\varepsilon)u$ find employment at a low-tech firm with rate $\phi\theta m(\theta)$. At the same time, employment of low-skilled natives $\frac{p}{1+I} - \gamma u(1-\varepsilon)$ is destroyed with rate δ.

Similar to low-skilled workers, the flow into and out of unemployment for high-skilled workers at a low-tech firm is given by

$$\phi\theta m(\theta)(1-\gamma)u = \delta\left[\frac{1-p}{1+I} - (1-\gamma)u)\right]\sigma, \tag{5.25}$$

with σ being the fraction of high-skilled workers that are overqualified, i.e. the fraction of high-skilled workers that are employed in low-tech jobs. Unemployed, high-skilled natives $(1-\gamma)u$ find employment at a low-tech firm with rate $\phi\theta m(\theta)$. At the same time, employment of high-skilled natives that are employed at a low-tech firm $[\frac{1-p}{1+I} - (1-\gamma)u)]\sigma$ is destroyed with rate δ. The equilibrium in- and outflow of high-skilled natives at a high-tech firm can be summarized as

$$(1-\phi)\theta m(\theta)(1-\gamma)u = \delta\left[\frac{1-p}{1+I} - (1-\gamma)u)\right](1-\sigma). \tag{5.26}$$

Unemployed, high-skilled natives $(1-\gamma)u$ find employment at a high-tech firm with rate $(1-\phi)\theta m(\theta)$. At the same time, employment of high-skilled natives that are employed at a high-tech firm $[\frac{1-p}{1+I} - (1-\gamma)u)](1-\sigma)$ is destroyed with rate δ.

The flow eqs. (5.23) - (5.26) can be used to solve for the two endogenous variables u and ϕ, which yields[17]

$$u = \frac{\delta(1-p)}{(1-\gamma)(1+I)[\delta + \theta m(\theta)]}, \tag{5.27}$$

$$\phi = \frac{(p+I)(1-\gamma)(\theta m(\theta) + \delta) - \gamma(1-p)\delta}{\theta m(\theta)\gamma(1-p)}. \tag{5.28}$$

It can easily be shown that the ceteris paribus changes of ϕ are[18]

$$\frac{\partial\phi}{\partial\theta} > 0 \quad \text{and} \quad \frac{\partial\phi}{\partial\gamma} < 0.$$

[17]Appendix 5.A.3 shows that the fraction of high-skilled workers that are employed in low-tech jobs (σ) and the fraction of vacancies that require low-skill levels (ϕ) coincide.

[18]$\frac{\partial\phi}{\partial\theta} > 0$ for $\gamma > \frac{p+I}{1+I}$. This is fulfilled in CSM, as low-skilled workers compete with high-skilled workers for low-tech jobs. Hence, the job finding rate of high-skilled workers is greater than the one of low-skilled workers.

In order to derive the unemployment rates for each group of workers, it is taken into account that $u_{IL} \equiv \frac{\gamma\varepsilon u}{I}(1+I)$, $u_{NL} \equiv \frac{\gamma(1-\varepsilon)u}{p}(1+I)$, and $u_H \equiv \frac{(1-\gamma)u}{1-p}(1+I)$. Solving the respective worker flows, the unemployment rates are given by[19]

$$u_{IL} = \frac{U_{IL}}{I} = u_{NL} = \frac{U_{NL}}{p} = \frac{\delta}{\delta + \phi\theta m(\theta)} \quad \text{and} \quad u_H = \frac{U_H}{1-p} = \frac{\delta}{\delta + \theta m(\theta)}. \tag{5.29}$$

Using the unemployment rates for low-skilled natives and immigrants, it can be easily verified that $\varepsilon \equiv \frac{U_{IL}}{U_{IL}+U_{NL}}$ reduces to $\varepsilon = \frac{I}{p+I}$.

The interest of this chapter is on an equilibrium where all types of workers are employed and cross-skill matching is present, i.e. high-skilled natives work in both type of jobs. In order that such an equilibrium exist the following conditions have to hold: $y_L > z_L$, which automatically implies that $y_L > z_L - h_I$. Further, it has to hold that $y_h > z_H$ and for the existence of CSM

$$(y_L - z_H)(r+\delta) > \theta m(\theta)\beta(1-\phi)(y_H - y_L). \tag{5.30}$$

Appendix 5.A.4 provides detailed explanations.

Finally, the four endogenous variables u, θ, γ and ϕ can be determined using the labor demand conditions, eqs. (5.21) and (5.22), and the expressions for the unemployment rate and the fraction of vacancies that require a low-skill level, eqs. (5.27) and (5.28).

5.5 General Equilibrium Analysis

5.5.1 The Effects of Low-skilled Immigration

The model presented above is rather sophisticated and incorporates different mechanisms through which native workers are affected by an influx of immigration. In order to derive some analytical results, before the model will be calibrated, a few assumptions are made. To analyze the effects of an inflow of immigration, modeled by an increase in I, it is considered that the costs of a vacancy are identical across jobs ($c_H = c_L$). It is further assumed that the costs of searching for a job for natives and low-skilled immigrants are

[19]The unemployment rates of low-skilled natives and immigrants coincide, as they have the same effective arrival rate and the same job destruction rate. The levels of employment (E_H, E_{NL} and E_{IL}) can be derived in a similar manner.

identical, i.e. $h_I = 0$. This implies that the wages of low-skilled natives and immigrants are identical, meaning that the only difference between those two types of workers lies in their country of origin.[20] Considering job creation of low-skilled jobs, eq. (5.22), it is evident that the fraction of unemployed low-skilled workers that are immigrants (ε) drops out. Thus, immigration does not directly affect natives through the job creation channel anymore, since the expected profit of a low-tech job does not depend on the composition of low-skilled workers.

Proposition 1 *Assuming that the costs of a vacancy are identical across jobs ($c_H = c_L$), and that the costs of searching for a job are the same for all low-skilled workers ($h_I = 0$), it can be shown that an influx of low-skilled immigrants I*

(i) Encourages firms to invest in the basic technology ϕ;

(ii) Increases the wage rate w_{NL} and decreases the unemployment rate u_{NL} of low-skilled natives;

(iii) Decreases the wage rates w_H and w_{OH}, and the unemployment rate u_H of high-skilled natives.

Proof. See Appendix 5.A.5 for the formal proof. □

The mechanisms behind the result in *(i)* are the following. An increase in immigration raises the relative supply of the low-skilled production factor. Thus, the effective arrival rate of those workers increases, which in turn raises the expected profit out of a low-tech job. Hence, firms decide ex-ante to invest more in the basic technology.

The findings in *(ii)* follow from the result in *(i)*. On the one hand, the increase in the fraction of low-tech vacancies increases the effective arrival rate for low-skilled natives, since the entry of low-skill firms also raises labor market tightness. This relative demand effect is known from Albrecht & Vroman (2002), who exogenously increase the proportion of low-skilled workers, and Dolado et al. (2009), who analyze the case of skill upgrading.

[20] This case is, thus, slightly different from the case of an exogenous increase of low-skilled natives, since this shock would increase the proportion of low-skilled natives in an economy. This is not the case for an exogenous increase of low-skilled immigrants.

On the other hand, there is a countervailing effect since low-skilled natives face a higher competition due to the new arrivals. However, this effect is weaker than the corresponding effects in Albrecht & Vroman (2002) and Dolado et al. (2009), since the relative supply of low-skilled natives does not increase, but even decreases due to immigration. As the first effect dominates the latter one, the unemployment rate of low-skilled natives decreases. A smaller unemployment rate raises the scope of bargaining for low-skilled natives. Thus, their wage rate increases.

The intuition for *(iii)* is as follows. Due to the increase in the fraction of low-tech vacancies, the value of unemployment for high-skilled workers decreases. The reason is that the gain for high-skilled workers is larger if they are employed in a high-tech firm, compared to a low-tech firm, see eq. (5.14). On the other hand, the availability of more low-tech vacancies increases the overall job offer arrival rate. As the former effect dominates, all high-skilled workers reduce their wage claims. This leads to a concomitant decrease in high-skilled natives' unemployment rate.

These findings support the results of the directed technological change literature, see Acemoglu (1998, 2002).[21] An increase in the supply of the low-skilled production factor triggers entry in the sector that uses this factor intensive in production, which in turn increases the relative efficiency of that factor via a market-size effect and decreases the relative price of that factor. When the supply of low-skilled workers increases, the market for the basic technology expands. Thus, more effort will be devoted to invest in the basic technology (market-size effect). In contrast, when the relative price of the simple good decreases, the technology used in its production demands a lower price, which decreases the incentive to upgrade the basic technology (price effect). If the goods are gross or perfect substitutes in consumption, the market-size effect dominates the price effect.

5.5.2 The Effects of a Change in Search Costs of Immigrants

In order to improve the integration of immigrants in the society, an easier access to the labor market serves as a precondition. Therefore, it is often an aim of politicians to reduce

[21] Fadinger & Mayr (2014) extend this result to matching frictions in skill-specific labor markets.

the costs of searching for a job of immigrants, e.g. through language courses, a more improved advice in a job center and so on. Further, the longer immigrants live in the host country, the better they learn the language and the more they assimilate into the society. Hence, both the specific targeted policies of politicians and the willingness of immigrants to become part of the society reduce the barriers for integration and participation in the labor market, i.e. immigrants' search costs h_I decline.

Proposition 2 *Assuming that the costs of a vacancy are identical across jobs ($c_H = c_L$), a decrease in the search costs of immigrants h_I*

(i) Discourages firms to invest in the basic technology ϕ;

(ii) Decreases the wage rate w_{NL} and increases the unemployment rate u_{NL} of low-skilled natives;

(iii) Increases the wage rates w_H and w_{OH}, and the unemployment rate u_H of high-skilled natives.

Proof. Appendix 5.A.6 provides the formal proof. □

The mechanisms behind the result in *(i)* are described below. The difference in search costs among low-skilled natives and immigrants ensures that the expected profit of a low-tech job depends on the composition of low-skilled workers. A decrease in search costs of immigrants leads to an increase in the flow income of unemployment for immigrants $z_L - h_I$. This increase in turn decreases the expected profit of a low-tech firm. The reason is that the higher outside option of low-skilled immigrants translates into a smaller surplus the firm obtains from matching with an immigrant, as immigrants claim higher wages. Since the expected profit of a low-tech job declines, less firms will decide to use the basic technology and, thus, ϕ declines.

The findings in *(ii)* follow from *(i)*. The decline in the fraction of low-tech vacancies directly decreases the effective arrival rate for low-skilled natives. Thus, less low-skilled natives exit the unemployment pool. A higher unemployment rate reduces the scope of bargaining for low-skilled natives. Thus, the wage rate of low-skilled natives decreases.

The result in *(iii)* can be explained in the following way. The decrease in the fraction of low-tech vacancies translates into a higher value of unemployment for high-skilled natives. Therefore, all high-skilled workers increase their wage claims, since it is less painful for high-skilled natives to be unemployed. The rise in their wage rates also increases their unemployment rate, as the firms' wage costs for high-skilled workers are higher.

5.6 Quantitative Results

This section calibrates the model to German data, to show how immigration quantitatively affects the technological alignment of the economy and the labor market outcomes of different types of workers. Further, the calibration is used to assess how it changes the total steady-state surplus of the economy. For the welfare analysis it is assumed that all firms are owned by natives who obtain all the profits. Thus, overall welfare of natives is

$$W = Y + z_H U_H + z_L U_{NL} - v\phi c_L - v(1-\phi)c_H - w_{IL}\big[I - U_{IL}\big], \qquad (5.31)$$

where $Y = (1-\sigma)E_H y_H + \big[E_{NL} + E_{IL} + \sigma E_H\big] y_L$ denotes the aggregate level of output. In spirit of Chassamboulli & Palivos (2013, 2014), an alternative measure of net income to natives that does not include the income enjoyed by unemployed natives is provided

$$W_1 = W - z_H U_H - z_L U_{NL}. \qquad (5.32)$$

The calibration uses the following Cobb-Douglas matching function

$$M = \xi \cdot u^{\alpha} v^{1-\alpha}, \qquad (5.33)$$

where ξ denotes the efficiency of the matching process and $\alpha \in (0,1)$ denotes the matching elasticity. The model is fully characterized by 14 parameters. Table 5.1 lists eight parameters that are taken from available empirical literature. First, the elasticity of the matching function α is set to 0.5, which is in the range of estimates reported in Petrongolo & Pissarides (2001). Second, following most of the literature, including Petrongolo & Pissarides (2001), the bargaining power β is set to 0.5, so that the Hosios condition ($\alpha = \beta$) is fulfilled (Hosios, 1990). Next, the matching efficiency parameter ξ and the productivity in a low-tech job y_L are normalized to unity. Following Hobijn & Şahin (2009),

Table 5.1: Baseline Parameter Values

Parameter	Description	Value	Source
α	Matching elasticity	0.5	Petrongolo & Pissarides (2001)
β	Bargaining power	0.5	Petrongolo & Pissarides (2001)
ξ	Matching efficiency parameter	1	Normalized
y_L	Production in a low-tech job	1	Normalized
r	Quarterly real interest rate	0.012	Chassamboulli & Palivos (2014)
δ	Quarterly job destruction rate	0.0318	Hobijn & Şahin (2009)
p	Share of low-skilled natives	0.74	Battisti et al. (2017)
I	Ratio of low-skilled immigrants	0.1215	Battisti et al. (2017)

the quarterly job destruction rate δ for Germany is calculated to be 0.0318, while the quarterly real interest rate r is estimated to be 0.012 (Chassamboulli & Palivos, 2014). Finally, Battisti et al. (2017) estimate the share of low-skilled natives p to be 0.74, while the normalized number of low-skilled immigrants I can then be calculated to be 0.1215.[22] The remaining six parameters of the model are chosen such that the model reflects seven calibration targets obtained from German data, see Table 5.2.

Table 5.2: Matched Targets

Target	Source	Value
Return to skill for native workers	EU-SILC	1.45
Native-immigrant wage premium	EU-SILC	1.10
Replacement ratios, both skill groups	Battisti et al. (2017)	0.44
Vacancy to unemployment ratio	EU-LFS, Eurostat	0.35
Fraction of vacancies that require low skills	IAB Job Vacancy Survey	0.81
Fraction of unemployed that are low skilled	EU-LFS	0.56

Notes: All targets are constructed for Germany. All values that are obtained by the EU-LFS and EU-SILC databases refer to working age population, aged 15-64 or 18-64 (depending on the availability of the data). Further, they are averaged over the period 2005-2015. The vacancy data from the IAB Job Vacancy Survey ranges between years 2010-2015. The skill groups are calculated using educational attainments of the ISCED-11 classification system. Individuals are low skilled up to secondary school certificate, i.e. up to level 4 of the ISCED scale. Those individuals between levels 5 and 8 of the ISCED scale are high skilled.

[22]The ratio of low-skilled immigrants is obtained by dividing their raw number by the native labor force.

Table 5.3 shows the six parameters that are obtained by exactly reproducing the number of moments with the model for Germany.[23]

Table 5.3: Calibrated Parameter Values

Parameter	Description	Value
c_H	Costs of a high-tech vacancy	2.88
c_L	Costs of a low-tech vacancy	1.30
y_H	Production in a high-tech job	1.67
h_I	Search costs of low-skilled, unemployed immigrants	0.61
z_L	Flow income of low-skilled, unemployed workers	0.40
z_H	Flow income of high-skilled, unemployed workers	0.59

Notes: Calibrated from moments of the data for Germany.

5.6.1 Increase in Low-skilled Immigration

This section analyzes the effects of low-skilled immigration by increasing the share of immigrants in the labor force by one percentage point, i.e. it increase from 12.15% to 13.15%. Table 5.4 provides the results for the full version of the model, with $h_I > 0$ and $c_H > c_L$. In comparison to the simplified version that was investigated analytically, immigration also has a direct effect via job creation, see eq. (5.22), since it is cheaper for firms to hire immigrants due to their higher search costs. An increase in immigration leads to an increase in the expected profit of a low-tech firm, which results in an enhanced vacancy posting of low-tech jobs. Thus, in the full model, the relative demand effect is even strengthened by the effect that is active through job creation.[24] This leads to a decreasing unemployment rate of low-skilled natives, while their scope of bargaining increases.

Considering high-skilled natives, the availability of more low-tech vacancies increases their overall job offer arrival rate. On the other hand, there is a negative effect on the

[23]In both simulation exercises that are conducted below, the conditions for CSM are fulfilled.

[24]Dolado et al. (2009) show that there are opposing effects in the case of skill-upgrading and that it is a priori unclear how the unemployment rate of high-skilled workers reacts. They use a similar argument and explain that it is more likely that the demand effect outweighs the supply effect in case of on-the-job search.

Table 5.4: The Effects of an Increase in Low-skilled Immigration (Changes in Percentage Points)

Variable	(1) $h_I > 0$ $c_H > c_L$
Overall	
θ	0.96
γ	-0.02
ϕ	1.34
u	-0.10
Low-skilled Natives	
w_{NL}	0.08
u_{NL}	-0.11
Low-skilled Immigrants	
w_{IL}	0.16
u_{IL}	-0.11
High-skilled Natives	
w_H	-0.37
w_{OH}	-0.37
u_H	-0.05
Welfare and Output	
W	-0.08
W_1	-0.04
Y	0.84

outside option of high-skilled workers since their expected labor income decreases due to the increase in the fraction of low-tech jobs. As the latter effect is dominant, their value of unemployment decreases. Thus, high-skilled natives reduce their wage claims, while their unemployment rate decreases. In contrast to Liu et al. (2017), the mismatch ratio among high-skilled natives increases due to the shift towards the basic technology.

Further, the analysis of the basic model in Section 5.5.1 together with Table 5.4 reveal that almost all effects coincide for both specifications of the model, whereas the only qualitative difference is that γ decreases. The driving force for the decrease in the fraction of unemployed that are low skilled is the larger decrease in the unemployment rate of low-skilled workers due to enhanced low-tech vacancy posting.

Finally, it is worth noting that these effects are exactly the opposite one expects in a model with perfect competition and no search frictions. In the present model, low-skilled natives gain due to higher search costs (implying lower net unemployment benefits) of low-skilled immigrants, while high-skilled natives lose due to the possibility of cross skill matching and the endogenous response of firms. Low-skilled immigration encourage firms to invest more in the basic technology. Thus, the technological orientation of the economy shifts away from more advanced, innovative products to less advanced, simpler products.[25] The shift in the production towards cheaper, simpler products goes along with a decrease in welfare. Aggregate production increases despite the adoption of the basic technology.

5.6.2 Decrease in Search Costs of Immigrants

This section quantifies the effects of a decrease in the search costs of low-skilled immigrants. It is assumed that they decrease by one percentage point. Table 5.5 illustrates the results for the full model. The qualitative results are exactly the same as for the

Table 5.5: The Effects of a Decrease in Search Costs of Low-skilled Immigrants (Changes in Percentage Points)

Variable	Change
Overall	
θ	-1.19
γ	0.16
ϕ	-0.96
u	0.10
Low-skilled Natives	
w_{NL}	-0.08
u_{NL}	0.11
Low-skilled Immigrants	
w_{IL}	0.45
u_{IL}	0.11
High-skilled Natives	
w_H	0.25
w_{OH}	0.25
u_H	0.06
Welfare and Output	
W	0.04
W_1	0.00
Y	0.05

simplified version of the model analyzed in Section 5.5.2. A decrease in the search costs of low-skilled immigrants raises their expected utility of being unemployed. Since immigrants are better off while being unemployed, wage pressure increases and, thereby,

[25]This result is in line with the findings reported in empirical studies suggesting that the production technology responds endogenously to immigration induced changes in the relative supply of labor. A few recent studies are Lewis (2003) and Doms & Lewis (2006) for the US, González & Ortega (2011) for Spain, and Dustmann & Glitz (2015) for Germany.

unemployment goes up. Both, the decrease in the search costs and the increase in the wage rate lower the expected profit from a filled low-tech job. Hence, firms invest ex-ante less in the basic technology, implying a decrease in overall labor market tightness and the fraction of low-tech vacancies. As a consequence, the effective arrival rate for low-skilled natives declines. Hence, their unemployment rate goes up, forcing low-skilled natives to dampen their wage claims. Considering high-skilled natives, their value of unemployment increases due to the decline in the fraction of low-tech vacancies. Thus, high-skilled natives increase their wage claims leading to higher unemployment. In addition, their mismatch ratio goes down due to the adoption of the more advanced technology.

Overall, it is evident that policies, which simplify the participation of immigrants in the labor market, are suitable to cushion or even reverse the unfavorable shift towards a low-tech economy. However, they lead to an increase in the wage gap among natives. As expected, the shift towards the production of high-tech goods increases aggregate production and benefits the overall welfare of natives.

5.7 Summary and Conclusion

This chapter develops a theoretical model to study the effects of low-skilled immigration on wages, the employment structure and especially the technology choice of firms in a host country with labor market frictions. Firms have to decide ex ante which technology to use for production. They can either choose a basic or a more advanced technology. Native workers are either low or high skilled, whereas immigrants are assumed to be low skilled. While the skill distribution of workers is exogenous, the technology choice of the firms are determined endogenously. It is also taken into account that overqualification exists among high-skilled natives. Thus, a high-tech firm only hires high-skilled workers, while a low-tech firm employs either a low- or a high-skilled worker.

While there already exist contributions that study one or more issues of immigration, overqualification and endogenous technology choices, this chapter is the first that combines all of those issues in a frictional labor market to analyze the impact of immigration on wages, the employment structure and especially the technology choices of firms.

The main result of the model is that firms react to an increase in low-skilled immigration and shift their production towards the basic technology and produce simple, less-advanced goods. Thus, the composition of jobs in the host country changes. A further, remarkable result is that low-skilled immigration is beneficial for low-skilled natives, while high-skilled workers are hurt in terms of wages, but gain in terms of employment. At first sight, this may seem implausible, since low-skilled immigrants are competing with low-skilled natives for jobs. However, firms react to the increase in low-skilled immigration by producing with the less-advanced technology more intensively. Hence, the omnipresent fear of low-skilled workers to get substituted by immigrants is unfounded at least in this model setting.

As a second result, it can be shown that policies that improve immigrants' access to the labor market, work in the opposite direction. Firms use the advanced technology more intensively, which leads to the creation of a high-tech production industry in the host country. From this point of view it may be a suitable economic policy to pursue a better integration of immigrants to the labor market. On the contrary, such policies hurt low-skilled natives both in terms of wages and employment, while high-skilled natives gain in terms of wages, but lose in terms of employment. Thus, a disadvantage of such policies is that the change towards high-tech production goes along with an increase in the wage inequality among native skill groups.

The focus of this chapter is on the effects of low-skilled immigration on the technological alignment of the host country. Therefore, a few simplifying assumptions are made, while other interesting questions arising from the model are left for further research. For example, it would be interesting not only to allow for an endogenous skill response of firms, but also to endogenize the educational decision of workers. The effect on the technological alignment of the economy would crucially depend on the degree of mismatch, since more individuals may decide to stick to a basic education level if the mismatch of high-skilled workers is quite pronounced in the economy. It would be interesting to examine how the short-run effects (fixed education level) differ from the long-run effects (endogenous education choice) as a lot of workers may decide to pursue the basic education due to the unfavorable shift towards a low-tech economy and the drop in high-skilled workers' wages and employment that is induced by an increase in low-skilled immigration.

5.A Appendix

5.A.1 Wage Determination

Once a high-skilled worker and a high-tech firm meet, they bargain over the wage rate.[26] They solve the generalized Nash-bargaining problem given by

$$\max_{w_H} \left\{ \Psi_H^E - \Psi_H^U \right\}^{\beta} \cdot \left\{ \Pi_H^F - \Pi_H^V \right\}^{1-\beta}. \tag{5.34}$$

Maximization of the Nash product delivers the sharing rule

$$\beta[\Pi_H^F - \Pi_H^V] = (1-\beta)[\Psi_H^E - \Psi_H^U]. \tag{5.35}$$

Using the present value functions, eqs. (5.5) and (5.11), together with the free entry condition $\Pi_H^V = 0$, the rents of firms and workers can be substituted by

$$\Psi_H^E - \Psi_H^U = \frac{w_H - r\Psi_H^U}{r+\delta} \qquad \text{and} \qquad \Pi_H^F - \Pi_H^V = \frac{y_H - w_H}{r+\delta}. \tag{5.36}$$

Rearrangement leads to

$$w_H = \beta y_H + (1-\beta) r \Psi_H^U. \tag{5.37}$$

The wage for high-skilled workers is the weighted sum of the worker's productivity and the value of unemployment. The weights are given by the bargaining power of the respective participant in the negotiations. In a next step, $r\Psi_H^U$ has to be replaced. Thus, $\Psi_H^E - \Psi_H^U$ as well as $\Psi_{OH}^E - \Psi_H^U$ have to be substituted in the present value function for unemployed high-skilled workers, eq. (5.14). To substitute for the rent of a high-skilled worker that is employed in a high-tech firm, the sharing rule, eq. (5.35), gives

$$\Psi_H^E - \Psi_H^U = \beta \cdot S, \tag{5.38}$$

with $S = (\Psi_H^E - \Psi_H^U) + (\Pi_H^F - \Pi_H^V)$ being the surplus of a match of the respective bargaining parties. Using eq. (5.36), it turns out that

$$\Psi_H^E - \Psi_H^U = \beta \Big(\frac{y_H - r\Psi_H^U}{r+\delta} \Big). \tag{5.39}$$

[26]The formal derivations of the wage rates for low-skilled natives, overqualified natives and immigrants are similar to that of high-skilled natives. Thus, their derivations are not provided in more detail.

Considering the rent of a high-skilled worker that is employed in a low-tech job $\Psi^E_{OH} - \Psi^U_H$, the respective sharing rule suggests that the rent of an overqualified worker is

$$\Psi^E_{OH} - \Psi^U_H = \beta\Big(\frac{y_L - r\Psi^U_H}{r+\delta}\Big). \tag{5.40}$$

Substituting eqs. (5.39) and (5.40) in eq. (5.14), the expected value of being unemployed for a high-skilled worker is

$$r\Psi^U_H = \frac{z_H(r+\delta) + \theta m(\theta)\beta\Big[(1-\phi)y_H + \phi y_L\Big]}{r+\delta+\theta m(\theta)\beta}. \tag{5.41}$$

Finally, insertion of eq. (5.41) in eq. (5.37) and some rearrangement leads to the wage rate given in eq. (5.17):

$$w_H = z_H + (y_H - z_H)\cdot\Gamma_H(\theta) - (1-\beta)\frac{\theta m(\theta)\beta\phi(y_H - y_L)}{r+\delta+\theta m(\theta)\beta},$$

with $\Gamma_H(\theta) = \beta\frac{r+\delta+\theta m(\theta)}{r+\delta+\theta m(\theta)\beta}$.

5.A.2 Derivation of Equilibrium Labor Demand

Using the firm's value functions (5.5) and (5.7) and the free-entry condition $\Pi^V_H = 0$, job creation of high-tech jobs can be stated as

$$\frac{c_H}{m(\theta)(1-\gamma)} = \frac{y_H - w_H}{r+\delta}. \tag{5.42}$$

Thus, it has to hold that the expected costs of creating a high-tech vacancy equals the expected profit of a filled high-tech job, discounted by the effective discount rate $r+\delta$. Substituting w_H by its expression as given by eq. (5.17), equilibrium labor demand for high-tech jobs is

$$\frac{c_H(r+\delta)}{m(\theta)} = (1-\beta)(1-\gamma)\frac{(y_H - z_H)(r+\delta) + \phi\theta m(\theta)\beta(y_H - y_L)}{r+\delta+\theta m(\theta)\beta}.$$

Using the firm's value functions (5.2) - (5.4), (5.6) and the free-entry condition $\Pi^V_L = 0$, job creation of low-tech jobs can be stated as

$$\frac{c_L}{m(\theta)} = \gamma\Big[\varepsilon\frac{y_L - w_{IL}}{r+\delta} + (1-\varepsilon)\frac{y_L - w_{NL}}{r+\delta}\Big] + (1-\gamma)\frac{y_L - w_{OH}}{r+\delta}. \tag{5.43}$$

Hence, the expected costs of creating a low-tech vacancy equals the expected profit of a filled, discounted low-tech job. The expected profit of a filled low-tech job is a weighted sum and depends on the type of worker the vacancy is filled with. The weights are represented by the probability of meeting the respective type of worker. Inserting w_{IL}, w_{NL} and w_{OH} as given by eqs. (5.16), (5.18) and (5.19), equilibrium labor demand for low-tech jobs is

$$\begin{aligned}\frac{c_L(r+\delta)}{m(\theta)} =& \frac{\gamma(r+\delta)(1-\beta)}{r+\delta+\phi\theta m(\theta)\beta}\Big[\varepsilon[y_L-(z_L-h_I)]+(1-\varepsilon)(y_L-z_L)\Big] \\ &+(1-\beta)\frac{(1-\gamma)(r+\delta)}{r+\delta+\theta m(\theta)\beta}\Big[(y_L-z_H)-\theta m(\theta)\beta(1-\phi)(y_H-y_L)\Big].\end{aligned}$$

5.A.3 Derivation of σ

Solving the flow for overqualified high-skilled workers that end up in low-tech jobs, eq. (5.25), for σ gives

$$\sigma = \frac{\phi\theta m(\theta)(1-\gamma)u}{\delta\big[1-p-(1-\gamma)u\big]}. \tag{5.44}$$

The unemployment rate u can be replaced by using eq. (5.27). After some rearrangement, it turns out that the fraction of high-skilled workers that are employed in low-tech jobs equals the fraction of low-tech vacancies, i.e. $\sigma = \phi$. The intuition for this result is as follows: every worker, independent of the respective skill level, accepts the first low-tech job offer. Further, a firm that uses the basic technology hires the very first applicant that arrives. Thus, the fraction of high-skilled workers that are overqualified and work in low-tech jobs is determined by the probability that the vacancy they are facing is a low-tech one.

5.A.4 Conditions for the Existence of CSM

A match between a firm and a worker of either skill type is formed if the respective surplus of the match is positive. In order that each type of worker is hired, it is enough to show that the respective profit of the firm is positive.[27] Using eq. (5.5), the profit of a high-tech

[27] The sharing rule for high-skilled workers, for example, can be rewritten to obtain

$$\Pi_H^F = \frac{1-\beta}{\beta}[\Psi_H^E - \Psi_H^U].$$

firm that hires a high-skilled native is

$$\Pi_H^F = \frac{y_H - w_H}{r + \delta}. \tag{5.45}$$

Insertion of eq. (5.17) to substitute w_H and simplification gives

$$\Pi_H^F = \frac{1 - \beta}{r + \delta + \theta m(\theta)\beta}(y_H - z_H), \tag{5.46}$$

which is positive if $y_H > z_H$. Similarly, $\Pi_{NL}^F > 0$ if $y_L > z_L$ and $\Pi_{IL}^F > 0$ if $y_L > z_L - h_I$. Thus, a match between a low-tech firm and a low-skilled native will be successful, since its profit is positive. Even if an immigrant will accept a lower wage, implying that the firms' profit will be higher, the firm does not to wait for an immigrant. Finally, cross-skill matching exists if $\Pi_{OH}^F > 0$. This is the case if

$$(y_L - z_H)(r + \delta) > \theta m(\theta)\beta(1 - \phi)(y_H - y_L).$$

This assumption guarantees that

$$\Pi_{OH}^F = \frac{1 - \beta}{\beta}[\Psi_{OH}^E - \Psi_H^U] > 0 = \Pi_L^V. \tag{5.47}$$

Thus, a low-tech firm as well as a high-skilled native prefer to form a match rather than stay vacant or unemployed, respectively.

5.A.5 Comparative Statics for a Change in I

As discussed in Section 5.5.1, it is assumed that $c_H = c_L = c$ and $h_I = 0$. This leads the LHS of eqs. (5.21) and (5.22) to be identical. Equalizing eqs. (5.21) and (5.22) and some rearrangement gives

$$\frac{\gamma(r + \delta)}{r + \delta + \phi\theta m(\theta)\beta}(y_L - z_L) = (1 - \gamma)(y_H - y_L). \tag{5.48}$$

To derive the changes in ϕ, γ, θ and u, eqs. (5.21), (5.27), (5.28) and (5.48) are used. Taking the total derivative of eq. (5.28) and solving for $d\phi/dI$ gives

$$\frac{d\phi}{dI} = \frac{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}D_2 - \frac{d\gamma}{dI}C_1 + D_1}{\theta m(\theta)\gamma(1 - p)}, \tag{5.49}$$

Thus, a positive profit of a firm automatically implies that the workers' rent is positive as well, since $\beta \in (0, 1)$.

where $C_1 \equiv (1-p)\big[\phi\theta m(\theta)+\delta\big]+(p+I)\big[\delta+\theta m(\theta)\big]$, $D_1 \equiv (1-\gamma)\big[\delta+\theta m(\theta)\big]$ and $D_2 \equiv (p+I)(1-\gamma)-\phi\gamma(1-p)$.[28] Next, take the total derivative of eq. (5.21), rearrange and collect terms to obtain

$$\begin{aligned} A_1\frac{d\gamma}{dI} =&(1-\gamma)\theta m(\theta)\beta(y_H-y_L)\frac{d\phi}{dI}+\frac{d\theta}{dI}\frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)} \\ &-\frac{d\theta}{dI}\frac{\frac{\partial\theta m(\theta)}{\partial\theta}m(\theta)\beta\Big[c(r+\delta)-(1-\beta)m(\theta)(1-\gamma)\phi(y_H-y_L)\Big]}{m(\theta)^2(1-\beta)}, \end{aligned} \tag{5.50}$$

with $A_1 \equiv (y_H-z_H)(r+\delta)+\phi\theta m(\theta)\beta(y_H-y_L)$. The total derivative of eq. (5.48) is given by

$$\frac{d\gamma}{dI}\Bigg[D_3+(y_H-y_L)\big[r+\delta+\phi\theta m(\theta)\beta\big]\Bigg]=(1-\gamma)(y_H-y_L)\beta\Bigg[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}+\theta m(\theta)\frac{d\phi}{dI}\Bigg], \tag{5.51}$$

where $D_3 \equiv (r+\delta)(y_L-z_L)$. Substitution of $d\phi/dI$ by eq. (5.49) and some rearrangement leads to

$$\frac{d\gamma}{dI}=\frac{C_3\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}+C_4}{A_2}, \tag{5.52}$$

with $C_3 \equiv (y_H-y_L)\beta\frac{(1-\gamma)^2(p+I)}{\gamma(1-p)}$, $C_4 \equiv (y_H-y_L)\beta\frac{(1-\gamma)^2[\delta+\theta m(\theta)]}{\gamma(1-p)}$, and $A_2 \equiv D_3+(y_H-y_L)\big[r+\delta+\phi\theta m(\theta)\beta\big]+(1-\gamma)(y_H-y_L)\beta\frac{C_1}{\gamma(1-p)}$. Using eq. (5.52), $d\gamma/dI$ can be substituted in eq. (5.49) and, thus,

$$\frac{d\phi}{dI}=\frac{1}{\theta m(\theta)\gamma(1-p)}\Bigg\{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}\Bigg[D_2-\frac{C_1C_3}{A_2}\Bigg]+D_1-\frac{C_1C_4}{A_2}\Bigg\}. \tag{5.53}$$

Finally, eqs. (5.52) and (5.53) are inserted into eq. (5.50) to derive a single equation that only depends on the change in overall labor market tightness θ. After some computational steps it turns out that

$$\frac{d\theta}{dI}=-\frac{C_4(r+\delta)(z_H-z_L)}{A_2B}, \tag{5.54}$$

with

$$\begin{aligned} B \equiv&\frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)}-\frac{C_3}{A_2}\frac{\partial\theta m(\theta)}{\partial\theta}\Bigg[A_1+(1-\gamma)\beta(y_H-y_L)\frac{C_1}{\gamma(1-p)}\Bigg] \\ &-\frac{\partial\theta m(\theta)}{\partial\theta}\beta\Bigg[\frac{c(r+\delta)}{m(\theta)(1-\beta)}-\frac{(1-\gamma)^2(p+I)(y_H-y_L)}{\gamma(1-p)}\Bigg]. \end{aligned}$$

[28]It will be shown later that D_2 is positive.

It can be easily seen that the numerator in eq. (5.54) is positive. Thus, the change in overall labor market tightness depends on the sign of B in the denominator, since A_2 is positive as well. It is easy to verify that the first two terms in B are negative. Hence, if the last term in corner brackets is positive, B is clearly negative. Thus, the whole denominator of eq. (5.54) would be negative implying a positive relationship between overall labor market tightness and low-skilled immigration. The term is positive if it holds that

$$\frac{c(r+\delta)}{m(\theta)(1-\beta)} - \frac{(1-\gamma)^2(p+I)(y_H - y_L)}{\gamma(1-p)} > 0. \tag{5.55}$$

Replacing the first fraction by eq. (5.21) gives

$$\frac{(y_H - z_H)(r+\delta)}{r+\delta+\theta m(\theta)\beta} + (y_H - y_L)\left[\frac{\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)}\right] > 0. \tag{5.56}$$

It is a reasonable assumption to assume that the unemployment benefits of high-skilled workers are smaller than the value of production in a low-skilled job. This assumption can be used to simplify eq. (5.56). Thus, if this condition is fulfilled for $z_H = y_L$, it has to hold for $z_H < y_L$ as well. Since $y_H - y_L$ is positive, it is enough to show that

$$\frac{r+\delta+\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)} > 0. \tag{5.57}$$

Now, two cases can be distinguished in order to show that eq. (5.57) is positive: in the first extreme case that $\phi = 1$, the first fraction equals unity. Thus, it is enough to show that the second fraction is smaller than unity. This is the case if $\gamma > \frac{p+I}{1+I}$. This condition is fulfilled, since low-skilled workers compete with high-skilled workers for low-tech jobs. Thus, the job finding rate of high-skilled workers is greater than the one of low-skilled workers, since high-skilled workers can be employed in both types of jobs. In the second extreme case, it is assumed that $\phi = 0$. This implies that the first term reduces to $\frac{r+\delta}{r+\delta+\theta m(\theta)\beta} > 0$. As there is a negative relationship between ϕ and γ, the latter is very large. Thus, $\frac{(1-\gamma)(p+I)}{\gamma(1-p)} \to 0$. Since eq. (5.57) is fulfilled for both extreme cases, it is also valid for all possible combinations in between. Therefore, B is indeed negative and it follows that

$$\frac{d\theta}{dI} > 0. \tag{5.58}$$

In order to derive the change in γ, $d\theta/dI$ has to be inserted in eq. (5.52). Expanding the second fraction to the same denominator and some rearrangement leads to

$$\frac{d\gamma}{dI} = \frac{C_4}{A_2 B}\left[B - \frac{C_3}{A_2}\frac{\partial \theta m(\theta)}{\partial \theta}(r+\delta)(z_H - z_L)\right] > 0. \tag{5.59}$$

To examine how the fraction of low-tech vacancies changes due to an increase in immigration, eq. (5.59) has to be inserted in eq. (5.49). Simplification yields

$$\frac{d\phi}{dI} = \frac{\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dI}D_2 + \frac{D_1}{A_2}(y_H - y_L)[r+\delta+\phi\theta m(\theta)\beta] + \frac{D_1 D_3 B_1}{A_2 B} - \frac{C_1 C_3 C_4}{A_2^2 B}(r+\delta)(y_L - z_H)}{\theta m(\theta)\gamma(1-p)}, \tag{5.60}$$

with

$$B_1 \equiv \frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right]\frac{\partial m(\theta)}{\partial \theta}}{m(\theta)^2(1-\beta)} - \frac{C_3}{A_2}\frac{\partial \theta m(\theta)}{\partial \theta}A_1 - \frac{\partial \theta m(\theta)}{\partial \theta}\left[\beta\frac{c(r+\delta)}{m(\theta)(1-\beta)} - C_3\right].$$

It is easy to verify that B_1 is negative as it is just a component of B. Thus, $\frac{d\phi}{dI}$ is only positive if $D_2 \equiv (1-\gamma)(p+I) - \phi\gamma(1-p)$ is positive. Inserting the equilibrium value for ϕ, it turns out that $D_2 \equiv \delta\frac{\gamma(1-p)-(p+I)(1-\gamma)}{\theta m(\theta)}$. It can easily be shown that D_2 is positive for $\gamma > \frac{p+I}{1+I}$, which is fulfilled. This implies that

$$\frac{d\phi}{dI} > 0. \tag{5.61}$$

The changes in the unemployment rates of the different types of workers can be analyzed forming the total differential of eq. (5.29)

$$\frac{du_{NL}}{dI} = -\frac{u_{NL}}{\delta + \phi\theta m(\theta)}\left[\phi\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] < 0, \tag{5.62}$$

$$\frac{du_{IL}}{dI} = -\frac{u_{IL}}{\delta + \phi\theta m(\theta)}\left[\phi\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] < 0, \tag{5.63}$$

$$\frac{du_H}{dI} = -\frac{u_H}{\delta + \theta m(\theta)}\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dI} < 0. \tag{5.64}$$

It is easy to see that the unemployment rates of the three type of workers decrease due to an increase in immigration since overall labor market tightness and the fraction of low-tech vacancies both increase in immigration. Total differentiation of the overall unemployment rate u does not deliver a clear sign. However, it holds that $\frac{du}{dI} = \frac{du_{NL}}{dI} + \frac{du_{IL}}{dI} + \frac{du_H}{dI}$. Since the unemployment rate of each type of worker on the RHS decreases, it has to hold that

$$\frac{du}{dI} < 0. \tag{5.65}$$

Finally, the changes in the four wage rates have to be determined. Taking the total differential of eqs. (5.17) and (5.19), the wage rates of high-skilled workers are identical and given by

$$\frac{dw_H}{dI} = \beta \frac{(1-\beta)\left[\frac{r+\delta}{r+\delta+\theta m(\theta)\beta} \frac{\partial \theta m(\theta)}{\partial \theta} \frac{d\theta}{dI}\left[y_H - z_H - \phi(y_H - y_L)\right] - \theta m(\theta)(y_H - y_L)\frac{d\phi}{dI}\right]}{r+\delta+\theta m(\theta)\beta}. \tag{5.66}$$

Since the sign is not clear, the change in labor market tightness, eq. (5.54), and the change in the fraction of vacancies that are opened for low-skilled workers, eq. (5.60), have to be inserted. Rearrangement yields to

$$\begin{aligned}\frac{dw_H}{dI} = \beta \frac{1-\beta}{r+\delta+\theta m(\theta)\beta}\Bigg[& -\frac{y_H - y_L}{\gamma(1-p)}\frac{D_1 D_3}{A_2 B}B_3 - \frac{r+\delta}{r+\delta+\theta m(\theta)\beta}\frac{\partial \theta m(\theta)}{\partial \theta}\phi(y_H - y_L)\frac{d\theta}{dI} \\ & - \frac{y_H - y_L}{\gamma(1-p)}\left(\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dI}D_2 + \frac{D_1}{A_2}(y_H - y_L)[r+\delta+\phi\theta m(\theta)\beta] - \frac{C_1 C_3 C_4}{A_2^2 B}(r+\delta)(y_L - z_H)\right) \\ & + \frac{\partial \theta m(\theta)}{\partial \theta}\frac{C_4}{A_2 B}(r+\delta)\Bigg\{\frac{r+\delta}{r+\delta+\theta m(\theta)\beta}(y_H - z_H)(y_L - z_H) \\ & + (y_L - z_L)(y_H - y_L)\left(\frac{\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)}\right)\Bigg\}\Bigg],\end{aligned} \tag{5.67}$$

with

$$B_3 \equiv \frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right]\frac{\partial m(\theta)}{\partial \theta}}{m(\theta)^2(1-\beta)} - \frac{C_3 A_1}{A_2}\frac{\partial \theta m(\theta)}{\partial \theta} < 0.$$

In eq. (5.67), all terms are negative despite the one in curly brackets. If the term in curly brackets is positive, the whole expression gets negative, which implies that the wage of high-skilled and overqualified workers decreases due to immigration. Considering the term in curly brackets, it has been verified before that $\frac{r+\delta+\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)} > 0$. Hence, the term in curly brackets is positive if $(y_H - z_H)(y_L - z_H) \geq (y_H - y_L)(y_L - z_L)$, which can be shown to be true for plausible parameter values and, thus,

$$\frac{dw_H}{dI} < 0 \quad \text{and} \quad \frac{dw_{OH}}{dI} < 0. \tag{5.68}$$

What is left is to analyze how the wage rates of low-skilled workers change in immigration. Taking the total derivative of eqs. (5.16) and (5.18), the change in the wage rates for low-skilled natives and immigrants can be expressed as follows:

$$\frac{dw_{NL}}{dI} = \beta \frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2}(y_L - z_L)\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\underbrace{\frac{d\theta}{dI}}_{>0} + \theta m(\theta)\underbrace{\frac{d\phi}{dI}}_{>0}\right] > 0, \tag{5.69}$$

$$\frac{dw_{IL}}{dI} = \beta \frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2}(y_L - z_{IL})\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] > 0. \tag{5.70}$$

5.A.6 Comparative Statics for a Change in h_I

As discussed in Section 5.5.2, it is taken into account that $c_H = c_L = c$. This leads the LHS of eqs. (5.21) and (5.22) to be identical. Equalizing eqs. (5.21) and (5.22) and some rearrangement gives

$$\frac{\gamma(r+\delta)}{r+\delta+\phi\theta m(\theta)\beta}\Big[\varepsilon[y_L - (z_L - h_I)] + (1-\varepsilon)(y_L - z_L)\Big] = (1-\gamma)(y_H - y_L). \tag{5.71}$$

To derive the changes in ϕ, γ and θ, eqs. (5.21), (5.28) and (5.71) are used. Total differentiation of eq. (5.28) and some rearrangement gives

$$\frac{d\phi}{dh_I} = \frac{1}{\theta m(\theta)\gamma(1-p)}\left[\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}D_2 - \frac{d\gamma}{dh_I}C_1\right]. \tag{5.72}$$

The total derivative of eq. (5.21) is similar to the previous case and given by

$$\begin{aligned} A_1\frac{d\gamma}{dh_I} =& (1-\gamma)\theta m(\theta)\beta(y_H - y_L)\frac{d\phi}{dh_I} + \frac{d\theta}{dh_I}\frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)} \\ &- \frac{d\theta}{dh_I}\frac{\frac{\partial\theta m(\theta)}{\partial\theta}m(\theta)\beta\left[c(r+\delta) - (1-\beta)m(\theta)(1-\gamma)\phi(y_H - y_L)\right]}{m(\theta)^2(1-\beta)}. \end{aligned} \tag{5.73}$$

In a next step, the total differential of eq. (5.71) is computed, which gives

$$\begin{aligned} \varepsilon\gamma(r+\delta) =& (1-\gamma)(y_H - y_L)\beta\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I} + \theta m(\theta)\frac{d\phi}{dh_I}\right] \\ &- \frac{d\gamma}{dh_I}\left[D_4 + (y_H - y_L)\left[r+\delta+\phi\theta m(\theta)\beta\right]\right], \end{aligned} \tag{5.74}$$

with $D_4 \equiv (r+\delta)\big[\varepsilon[y_L-(z_L-h_I)]+(1-\varepsilon)(y_L-z_L)\big]$. Substituting $d\phi/dh_I$ by eq. (5.72) and rearrangement gives

$$\frac{d\gamma}{dh_I}=\frac{C_3\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}-\varepsilon\gamma(r+\delta)}{A_3}, \tag{5.75}$$

with $A_3 \equiv D_4+(y_H-y_L)\big[r+\delta+\phi\theta m(\theta)\beta\big]+(1-\gamma)(y_H-y_L)\beta\frac{C_1}{\gamma(1-p)}$. Furthermore, replacement of $d\gamma/dh_I$, eq. (5.75), in eq. (5.72) leads to

$$\frac{d\phi}{dh_I}=\frac{1}{\theta m(\theta)\gamma(1-p)}\left\{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}\left[D_2-\frac{C_1C_3}{A_3}\right]+\frac{C_1}{A_3}\varepsilon\gamma(r+\delta)\right\}. \tag{5.76}$$

Using eqs. (5.75) and (5.76) in eq. (5.73) it is possible to derive a single equation that only depends on the change in overall labor market tightness:

$$\frac{d\theta}{dh_I}=-\frac{\varepsilon\gamma(r+\delta)}{A_3B_4}\left[A_1+(1-\gamma)(y_H-y_L)\beta\frac{C_1}{\gamma(1-p)}\right]>0, \tag{5.77}$$

with

$$B_4 \equiv \frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)}-\frac{C_3}{A_3}\frac{\partial\theta m(\theta)}{\partial\theta}\left[A_1+(1-\gamma)\beta(y_H-y_L)\frac{C_1}{\gamma(1-p)}\right]$$
$$-\frac{\partial\theta m(\theta)}{\partial\theta}\beta\left[\frac{c(r+\delta)}{m(\theta)(1-\beta)}-\frac{(1-\gamma)^2(p+I)(y_H-y_L)}{\gamma(1-p)}\right]<0.$$

In order to see how the fraction of unemployed that are low skilled change in search costs of low-skilled immigrants, eq. (5.77) has to be inserted in eq. (5.75). This gives

$$\frac{d\gamma}{dh_I}=-\frac{B_5}{A_3B_4}\varepsilon\gamma(r+\delta)<0, \tag{5.78}$$

with

$$B_5 \equiv \frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)}-\frac{\partial\theta m(\theta)}{\partial\theta}\left[\beta\frac{c(r+\delta)}{m(\theta)(1-\beta)}-C_3\right]<0.$$

As $\frac{d\theta}{dh_I}>0$ and $\frac{d\gamma}{dh_I}<0$, using eq. (5.72) it is easy to verify that

$$\frac{d\phi}{dh_I}>0. \tag{5.79}$$

Total differentiation of the overall unemployment rate and the unemployment rates of each type of worker gives their changes as

$$\frac{du}{dh_I}=\frac{u}{(1-\gamma)(1+I)\big[\delta+\theta m(\theta)\big]}\left[\big[\delta+\theta m(\theta)\big]\frac{d\gamma}{dh_I}-(1-\gamma)\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}\right]<0, \tag{5.80}$$

$$\frac{du_{NL}}{dh_I} = -\frac{u_{NL}}{\delta + \phi\theta m(\theta)} \left[\phi \frac{\partial \theta m(\theta)}{\partial \theta} \frac{d\theta}{dh_I} + \theta m(\theta) \frac{d\phi}{dh_I} \right] < 0, \tag{5.81}$$

$$\frac{du_H}{dh_I} = -\frac{u_H}{\delta + \theta m(\theta)} \frac{\partial \theta m(\theta)}{\partial \theta} \frac{d\theta}{dh_I} < 0, \tag{5.82}$$

$$\frac{du_{IL}}{dh_I} = -\frac{u_{IL}}{\delta + \phi\theta m(\theta)} \left[\phi \frac{\partial \theta m(\theta)}{\partial \theta} \frac{d\theta}{dh_I} + \theta m(\theta) \frac{d\phi}{dh_I} \right] < 0. \tag{5.83}$$

Next, to analyze the change in the wage rates of high-skilled workers, the total differentials are build. These are identical and are, thus, given by

$$\frac{dw_H}{dh_I} = \beta \frac{(1-\beta) \left[\frac{r+\delta}{r+\delta+\theta m(\theta)\beta} \frac{\partial \theta m(\theta)}{\partial \theta} \frac{d\theta}{dh_I} \left[y_H - z_H - \phi(y_H - y_L) \right] - \theta m(\theta)(y_H - y_L) \frac{d\phi}{dh_I} \right]}{r + \delta + \theta m(\theta)\beta}. \tag{5.84}$$

Substitution of eq. (5.76) and eq. (5.77) leads to

$$\begin{aligned} \frac{dw_H}{dh_I} = -\beta \frac{1-\beta}{r+\delta+\theta m(\theta)\beta} \frac{\varepsilon\gamma(r+\delta)}{A_3 B_4} \Bigg[& \frac{\partial \theta m(\theta)}{\partial \theta} \frac{D_5 D_6}{1-\gamma} \\ & + \frac{y_H - y_L}{\gamma(1-p)} C_1 \left(\frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right] \frac{\partial m(\theta)}{\partial \theta}}{m(\theta)^2(1-\beta)} - \frac{\partial \theta m(\theta)}{\partial \theta} \beta D_6 \right) \Bigg], \end{aligned} \tag{5.85}$$

with $D_5 \equiv A_1 + (1-\gamma)\beta(y_H - y_L)\frac{C_1}{\gamma(1-p)}$ and $D_6 \equiv \frac{c(r+\delta)}{m(\theta)(1-\beta)} - \frac{(1-\gamma)^2(p+I)(y_H-y_L)}{\gamma(1-p)}$. Thus, the wage rates for high-skilled workers decrease as long as the term in big corner brackets is negative. This condition holds, so that

$$\frac{dw_H}{dh_I} < 0 \quad \text{and} \quad \frac{dw_{OH}}{dh_I} < 0. \tag{5.86}$$

Finally, the change in the wage rate for low-skilled natives is given by

$$\frac{dw_{NL}}{dh_I} = \beta \frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2} (y_L - z_L) \left[\phi \frac{\partial \theta m(\theta)}{\partial \theta} \underbrace{\frac{d\theta}{dh_I}}_{>0} + \theta m(\theta) \underbrace{\frac{d\phi}{dh_I}}_{>0} \right] > 0. \tag{5.87}$$

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Chapter 6

Conclusions

Well-functioning labor markets are undoubtedly a prerequisite not only for individuals, who mostly spend a large time of there life on the labor market and whose well being depend on there performance and thereby there wage payments, but also for governments and societies as economic growth and social harmony among citizens vitally build upon a strong participation of individuals in the labor market and a rather fair income distribution. Especially previous years have shown that labor markets come under pressure, since several modern phenomena may change their functioning. This thesis picks up some of these phenomena and contributes to the literature by developing four theoretical models to consider the effects on several labor market outcomes. To be more precise, it analyzes how the coordination of labor unions depends on the degree of product differentiation and how the unions' decision to merge or to stay separated affect the wage and employment rates of workers. Further, it examines how the ongoing deregulation of temporary agency employment affects labor market outcomes such as the rate of regularly employed workers and the employment structure of the economy. In addition, the question is addressed if low-skilled workers will be substituted by automation. Finally, the thesis discusses how the technological alignment of an economy changes due to an exogenous inflow of low-skilled immigrants.

Chapter 2 studies the issue of multi-unionism, which is a special feature of labor union representation and reflects a situation where two or more labor unions represent union members at the firm level. To do so, it uses a partial equilibrium model and examines how the decision of labor unions to merge or to stay independent depends on the degree of product differentiation. The model features two labor unions and a single firm that produces two final goods. Each good requires labor input only from one corresponding union. The two products are either substitutable in consumption (tariff competition) or they are complementary in consumption (tariff plurality). To identify the merger incentives of the labor unions, the outcomes of joint bargaining are compared to those under separate bargaining. Separate bargaining can either take place simultaneously or sequentially. Labor unions have to decide ex-ante whether they want to merge or not. The scope of bargaining is about wages, while the firms decide about the level of employment. The model predicts that labor unions have strict incentives to merge if the products are substitutable in consumption, while they want to bargain individually with the firm for complementary products. Further, it can be shown that workers benefit from the unions' decision in terms of their wage rate. Only for complementary products, workers of the union that bargains lastly under sequential bargaining would be better of under simultaneous bargaining.

Chapter 3 analyzes the continuous deregulation efforts concerning temporary agency employment that took place in almost all European countries in recent decades. It uses a general equilibrium matching model to investigate the effects of a deregulation of temporary agency employment on wage setting and the employment structure in a unionized economy. The models main advantage, compared to a partial equilibrium model, is that it goes beyond studying the optimal behavior of individual market participants, such as temporary work agencies, and makes it possible to reveal how such a policy changes the employment structure and the magnitude of precarious employment. Chapter 3 develops a search and matching model with large firms that produce differentiated goods using regularly employed workers and, in addition, temporary agency workers that may search on-the-job for regular employment. The model further comprises firm-level labor unions in order to see how the position of labor unions in the economy is affected through a legal deregulation. It can be shown that the legal deregulation of temporary agency employment increases overall employment, deteriorates labor unions' position in the economy, as it becomes cheaper to use temporary agency employment, and decreases the wage regular workers receive. In addition, the model identifies that even if the rate of regular employment increases in legal deregulation, labor unions suffer from declining wages since this negative effect outweighs the positive one, through an increase in the rate of regular employment, in labor unions' utility. A last and surprising result of the model is, that it predicts a hump-shaped relationship between the degree of legal deregulation of temporary agency employment and its employment rate used in production. An important driver behind this finding are voluntary, non-institutional firm-level agreements that restrict the use of temporary agency employment in the production. Due to the convex cost structure, the impact of such agreements is higher, the more deregulated and, therefore, the more attractive it is ceteris paribus for firms to use temporary agency workers in their production. These non-institutional agreements are normally on the agenda of employee representations of firms, especially of those firms that operate in the manufacturing sector. Hence, the model delivers a theoretical foundation for the real world phenomena that in almost all industrialized countries the rate of temporary agency employment stays relatively stable at a low level. As a consequence thereof, it contradicts the main argument of opponents of temporary agency work, that the deregulation of it necessarily creates more precarious employment in an economy.

Chapter 4 examines a relatively new research field by analyzing the effects of automation. While the rather small amount of previous studies mainly focused on the effects of economic growth and wage inequality within the R&D growth literature, less attention has been paid to potential changes of the unemployment structure in the era of automation. Therefore, Chapter 4 connects automation with the search and matching theory to reveal if the accumulation of automation capital creates technological unemployment. The model comprises one-worker firms that either operate in a low-skill intensive or high-skill intensive intermediate sector and employ low- or high-skilled workers, with a fixed skill distribution, respectively. Next to the two intermediate goods, traditional capital in the form of machines, assembly lines etc., and automation capital in the form of industrial robots, 3D printer etc. are used in the production of a final good. Automation capital serves as a perfect substitute for low-skilled labor and an imperfect substitute for high-skilled labor in the production of the final good. Using this framework, it can be shown that the accumulation of automation capital leads to the creation of technological unemployment. While high-skilled workers benefit from a rising employment rate, low-skilled workers suffer and get replaced by automation capital. As a second result, the model predicts that automation decreases the wage of low-skilled workers and increases the wage of high-skilled workers. The results are also of interest from the policy point of view, since progressive automation even widens the wage inequality across skill groups, which is already present and rising in the last couple of decades in many OECD countries. Proper investments in higher education and retraining programs may even be more important than ever in the era of automation, to prevent that more and more low-skilled workers will be cut off the labor market.

Chapter 5 deals with the international movement of people into a destination country, since immigration is undoubtedly an essential aspect in today's globalized world. In particular, it focuses on the technological orientation of the host country and studies the effects of low-skilled immigration on the technology choices of firms. To do so, it uses a search and matching model that incorporates two type of firms that either use a basic technology to produce with or a more advanced technology. Firms have to decide ex-ante with which technology they want to produce. Workers match with these vacancies randomly and consist out of three groups: low- and high-skilled natives and low-skilled immigrants. While the skill distribution of workers is exogenous, firms may endogenously adjust their skill requirements. Another feature of the model is that it captures educational mismatch, since high-skilled natives may be overqualified and find employment at a low-tech firm. The model suggests that an increase in low-skilled immigration causes firms to change their behavior and to shift their production towards the basic technology. In addition, another surprising result is that low-skilled natives benefit from the influx of low-skilled immigrants due to the change in the technological orientation of the economy, while the wage rate of high-skilled natives decreases, whereas their employment rate goes up. Next to the effects of low-skilled immigration, the model analyzes how policies that improve immigrants' access to the labor market function. The model suggest exactly the opposite: firms use the advanced technology more intensively, whereas low-skilled natives are hurt and high-skilled natives gain in terms of wages, but lose in terms of employment.