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

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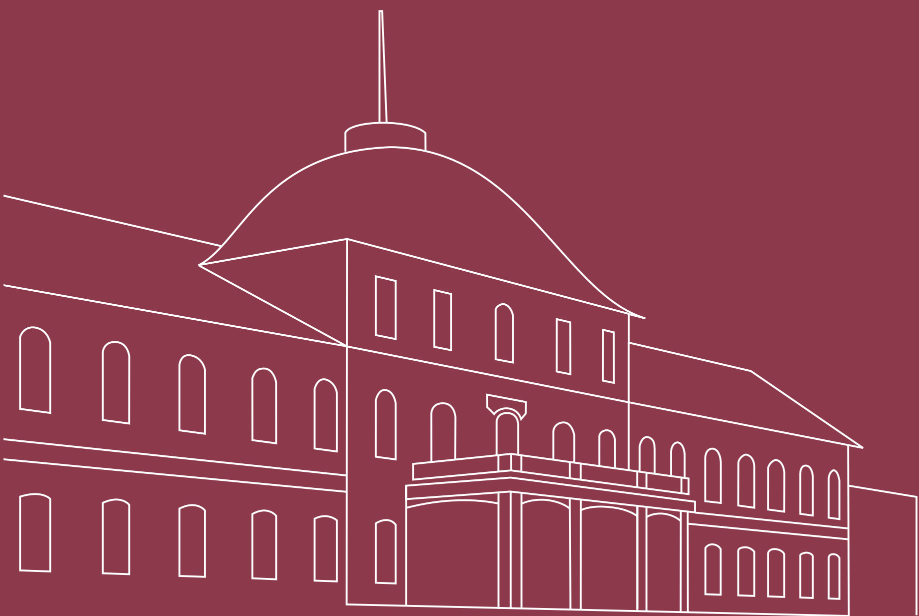

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Endogenous Technology, Matching, and Labor Unions: Does Low-Skilled Immigration Affect the Technological Alignment of the Host Country?*

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Abstract

In recent years, Germany and other European countries face the strongest immigration flow in their history. Experts unanimously agree that one of the core factors of a successful social integration is the labor market participation of the new arrivals. This paper investigates the impact of low-skilled immigration on a unionized economy with labor market frictions. It especially examines how immigration affects the technology choice of firms and, thereby, the technological alignment of the host country. The labor market is characterized by heterogeneity on both sides of the market. Within this framework, it can be shown that low-skilled immigration encourages firms to invest more in a basic technology, which leads to a deterioration of the technology level in the whole economy. It can be further shown that policies, which improve the access of already existing low-skilled immigrants to the labor market counteract the effect that is triggered by an increase in low-skilled immigration.

JEL Classification: F22, J24, J31, J51, J61, J64

Keywords: Immigration, Technology Choice, Search and Matching, Labor Unions, Skill-heterogeneity

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1 Introduction

In recent years, the number of immigrants 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 in the number of immigrants, 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 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 paper 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). Even if there are, up to now, no completely reliable numbers concerning the qualification of 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 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 distribution of workers is exogenously given, the skill requirements of firms adjust endogenously. Thus, the paper 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.

In most European countries wages are determined by collective bargaining agreements between firms and labor unions, with the average coverage rate of collective bargaining being slightly above 60% (Eurofound, 2015). Therefore, labor unions are an important institution in the wage negotiations in the European Union. Low-skilled immigrants offer firms the option to use a cheaper production possibility. As they are not covered by collective bargaining, due to their marginal position in the labor force, the lack of a social network etc., low-skilled immigration has an effect on the power of labor unions and may deteriorate their position in the labor market.

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 the paper is as follows. Section 2 gives a brief discussion of related literature. Section 3 describes the outline of the model and its components in more detail, before the equilibrium is derived in Section 4. Section 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 6 calibrates the model to German data and measures quantitatively the effects of these two scenarios. Finally, Section 7 summarizes the results and concludes.

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 very 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. (2014) provide first contributions to analyze the labor market effects of immigration. Their focus is on the effect 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 and that most of the wage rates are determined collectively in most European countries.

Even if the behavior of labor unions has already been widely discussed (for an overview see Booth, 1995; Boeri et al., 2001; Addison & Schnabel, 2003), little attention was paid on modeling unionized labor markets in the framework of search and matching until recent years. Delacroix (2006) gives a first contribution of collective wage bargaining in the matching framework. He introduces a multisectorial model with a varying degree of union coverage and monopolistic competition in the goods market and analyzes how unions react due to changes in the unemployment insurance. Based on this framework, Ebell & Haefke (2006) investigate the effect of product market deregulation on the formation of labor unions by endogenizing the choice of the bargaining institution. Krusell & Rudanko (2012) study the intertemporal effect of unions' commitment to future wages, while Bauer & Lingens (2013) analyze the efficiency in search models with large firms and collectively bargained wages. In another recent contribution, Baudy & Cords (2016) examine the general equilibrium effects of deregulating temporary agency employment in a unionized, frictional 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.[1] This paper 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.[2] Davidson et al. (2008) extend this framework to two countries that differ in the technologies firms produce with. In comparison to this paper, 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.

[1] 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.

[2] 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.

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 paper is the first theoretical work that combines labor unions, immigration, educational mismatch among natives and endogenous, skill specific technology choices all together in a search and matching framework. Thus, the paper is able to reveal how immigration affects the technological orientation of the host country and, in addition, how the position of labor unions in the economy is altered.

3 Outline of the Model

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 $I_L = I$.[3] 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

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

[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.

vacancy, it has to make a decision concerning its technology choice. The firm‘s 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. Firms that use the advanced technology can only produce with high-skilled workers. If a job is filled, high-skilled workers produce y_H units of output, with $y_H > y_L$. 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 paper, the focus is on a CSM, meaning that high-skilled workers take any job that is offered to them.[6] 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 EU-LFS for high-skilled German natives that are aged 15-64, it can be shown that 9.8 % are overqualified.

[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.

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

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

$$M = M(v, u). \tag{1}$$

As in Albrecht & Vroman (2002) and Dolado et al. (2009), for example, 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.[7] 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 $(1 - \gamma)m(\theta)$.

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

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

firm's expected profit is

$$r\Pi_{NL}^{F} = y_L - w_{NL} + \delta(\Pi_L^V - \Pi_{NL}^F) \quad (2)$$

$$r\Pi_{IL}^{F} = y_L - w_{IL} + \delta(\Pi_L^V - \Pi_{IL}^F) \quad (3)$$

$$r\Pi_{OH}^{F} = y_L - w_{OH} + \delta(\Pi_L^V - \Pi_{OH}^F). \quad (4)$$

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. (2) and (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}, respectively.[8] 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 (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

$$r\Pi_{H}^{F} = y_H - w_H + \delta(\Pi_H^V - \Pi_H^F). \quad (5)$$

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.[9]

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

$$r\Pi_L^V = -c_L + m(\theta)\Big[\gamma\big[\varepsilon(\Pi_{IL}^F - \Pi_L^V) + (1-\varepsilon)(\Pi_{NL}^F - \Pi_L^V)\big] + (1-\gamma)(\Pi_{OH}^F - \Pi_L^V)\Big], \quad (6)$$

[8]Even if immigrants and low-skilled natives produce the same output, their wages are different. Section 4.1 shows that the reason is the difference in the costs of searching for a job.

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

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 $\Pi_{OH}^F - \Pi_L^V$.

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

$$r\Pi_H^V = -c_H + m(\theta)(1-\gamma)(\Pi_H^F - \Pi_H^V), \tag{7}$$

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 firm with high skill requirements 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.

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

$$r\Psi_{NL}^E = w_{NL} + \delta(\Psi_{NL}^U - \Psi_{NL}^E) \tag{8}$$

$$r\Psi_{IL}^E = w_{IL} + \delta(\Psi_{IL}^U - \Psi_{IL}^E). \tag{9}$$

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

$$r\Psi_{OH}^{E} = w_{OH} + \delta(\Psi_{H}^{U} - \Psi_{OH}^{E}) \tag{10}$$

$$r\Psi_{H}^{E} = w_{H} + \delta(\Psi_{H}^{U} - \Psi_{H}^{E}). \tag{11}$$

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

$$r\Psi_{NL}^{U} = z_L + \theta m(\theta)\phi(\Psi_{NL}^{E} - \Psi_{NL}^{U}) \tag{12}$$

$$r\Psi_{IL}^{U} = z_L - h_I + \theta m(\theta)\phi(\Psi_{IL}^{E} - \Psi_{IL}^{U}) \tag{13}$$

$$r\Psi_{H}^{U} = z_H + \theta m(\theta)\Big[(1-\phi)(\Psi_{H}^{E} - \Psi_{H}^{U}) + \phi(\Psi_{OH}^{E} - \Psi_{H}^{U})\Big], \tag{14}$$

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., 2014; 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. (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 vacancies for low-skilled workers $\theta m(\theta)\phi$, and high-skilled workers $\theta m(\theta)(1-\phi)$, respectively.

3.4 Labor Unions

It is assumed that most of native workers are members of a labor union. This is in line with the observed situation in the European Union. In Western Germany, for example, 56 % of the employees work in firms that are covered by collective wage bargaining, see (Brücker et al., 2012). While most natives are organized in labor unions, immigrants are not covered by collective bargaining. The reason is that immigrants do have a marginal position in the labor force and are badly organized, for example, due to existing language barriers and the lack of a social network. Thus, immigrants bargain individually with the firm. Furthermore, high-skilled workers that are occupied in a job with low-skill requirements also have to bargain individually. A reason is that the union is threatened by those types of workers, since they are perfect substitutes for its clients, and, therefore, does not represent them.

Since there are one-worker firms, industry wide unions determine the wage rate for native workers, that are properly matched according to their skill level, by maximizing the rent of its members. It is further assumed that each skill type is represented by a separate labor union. The rent of a union member equals the difference between the expected value of being employed and the outside option, the value of being unemployed. Hence, the rent of a high-skilled union member is $\Psi_H^E - \Psi_H^U$, while the rent of a low-skilled union member is $\Psi_{NL}^E - \Psi_{NL}^U$. Multiplying the rent of a union member with the number of workers employed in the industry, the objective functions of the unions representing high- and low-skilled natives, respectively, are given by

$$U_H = [1-p-(1-\gamma)u](1-\sigma)[\Psi_H^E - \Psi_H^U] \tag{15}$$

$$U_{NL} = [p-\gamma u(1-\varepsilon)][\Psi_{NL}^E - \Psi_{NL}^U], \tag{16}$$

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.

3.5 Employer Associations

Firms that offer only one job are rather weak when they negotiate with labor unions that are representing several workers. Hence, it makes sense that firms also organize themselves in employer associations to increase their power in the wage negotiations.[10] In Western Germany, about 30 percent of firms engage in industry-wide multi-firm agreements. In addition, more than 40 percent of those firms, that are not part of the industry-wide multi-firm agreements, comply with the negotiated wage level (Ellguth & Kohaut, 2014).

Firms organize themselves in employer associations to determine the wage rates for each skill group separately. Low-tech firms that fill their job with an immigrant or a high-skilled worker are not part of the employer association but bargain over the wage rate with the worker individually. The objective functions of the employer associations are similar to that of labor unions, since they maximize the rent of the firm. In addition, as the employer associations bargain for all firms in the industry, the objective functions are given by

$$\Omega_H = [1 - p - (1-\gamma)u](1-\sigma)[\Pi_H^F - \Pi_H^V] \tag{17}$$

$$\Omega_{NL} = [p - \gamma u(1-\varepsilon)][\Pi_{NL}^F - \Pi_L^V]. \tag{18}$$

Note, that the number of workers that are represented by the labor unions equal the number of firms that are represented by the employer associations. This necessarily has to be the case since there are one worker firms, implying that the number of firms equals the number of workers.

[10]The employer association density is in almost all European countries much higher than the labor union density, see Eurofound (2015, Table A1).

4 Solution of the Model

4.1 Wage Determination

Following Masui (2013), the wages for low-skilled natives are determined via bargaining between a labor union and an employer association. The collective bargaining problem is formally described by maximization of the Nash product

$$\max_{w_{NL}} \left\{ U_{NL} - \bar{U}_{NL} \right\}^{\beta} \cdot \left\{ \Omega_{NL} - \bar{\Omega}_{NL} \right\}^{1-\beta}, \tag{19}$$

where $\beta \in (0,1)$ represents the bargaining power of the labor union. Further, $\bar{U}_{NL}$ and $\bar{\Omega}_{NL}$ are the thread points of the labor union and the employer association, respectively, i.e. the utility of both bargaining parties in case that negotiations are not successful. However, the thread points can be ignored in the following since the utility of both parties in case of unsuccessful negotiations equals zero. Inserting the objective functions (16) and (18) yields

$$\max_{w_{NL}} \left\{ [p - \gamma u(1-\varepsilon)][\Psi^{E}_{NL} - \Psi^{U}_{NL}] \right\}^{\beta} \cdot \left\{ [p - \gamma u(1-\varepsilon)][\Pi^{F}_{NL} - \Pi^{V}_{L}] \right\}^{1-\beta}. \tag{20}$$

Maximizing the Nash product gives

$$w_{NL} = z_L + (y_L - z_L) \cdot \Gamma_L(\theta), \tag{21}$$

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 the labor union that represents low-skilled natives, see Cahuc et al. (2014).

The wage rate for high-skilled workers is also determined via bargaining between a labor union and an employer association. The wage is given by

$$w_H = z_H + (y_H - z_H) \cdot \Gamma_H(\theta) - (1-\beta) \frac{\theta m(\theta)\beta\phi(y_H - y_L)}{r + \delta + \theta m(\theta)\beta}, \tag{22}$$

with $\Gamma_H(\theta) = \beta \frac{r+\delta+\theta m(\theta)}{r+\delta+\theta m(\theta)\beta}$ denoting the effective bargaining power of the labor union that represents 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 mismatch.

As discussed in Section 3.4, the wage rate for immigrants is determined by individual bargaining. Thus, the bargaining problem is formally described by maximization of the Nash product

$$\max_{w_{IL}} \left\{\Psi^E_{IL} - \Psi^U_{IL}\right\}^{\beta} \cdot \left\{\Pi^F_{IL} - \Pi^V_{L}\right\}^{1-\beta}. \tag{23}$$

Maximization yields

$$w_{IL} = z_L - h_I + [y_L - (z_L - h_I)] \cdot \Gamma_L(\theta). \tag{24}$$

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

$$w_{OH} = z_H + (y_L - z_H) \cdot \Gamma_H(\theta) + (1-\beta)\frac{\theta m(\theta)\beta(1-\phi)(y_H - y_L)}{r + \delta + \theta m(\theta)\beta}. \tag{25}$$

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 A.1 provides detailed calculations about the derivation of the wage rates.

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.

$$\Pi^V_H = \Pi^V_L = 0. \tag{26}$$

Further, the present value functions of a filled job, eqs. (2) to (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

$$\frac{c_H(r+\delta)}{m(\theta)} = (1-\beta)(1-\gamma)\frac{(y_H - z_H)(r+\delta) + \phi\theta m(\theta)\beta(y_H - y_L)}{r+\delta+\theta m(\theta)\beta}, \tag{27}$$

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

$$\begin{aligned}\frac{c_L(r+\delta)}{m(\theta)} =& \frac{\gamma(r+\delta)(1-\beta)}{r+\delta+\phi\theta m(\theta)\beta}\Big[\varepsilon[y_L - (z_L - h_I)] + (1-\varepsilon)(y_L - z_L)\Big] \\ &+ (1-\beta)\frac{(1-\gamma)(r+\delta)}{r+\delta+\theta m(\theta)\beta}\Big[(y_L - z_H) - \theta m(\theta)\beta(1-\phi)(y_H - y_L)\Big].\end{aligned} \tag{28}$$

Appendix A.2 gives 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

$$\phi\theta m(\theta)\gamma\varepsilon u = \delta(I - \gamma u\varepsilon). \tag{29}$$

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 $I - \gamma u\varepsilon$ is destroyed at rate δ. The equilibrium in- and outflow of low-skilled natives can be summarized as

$$\phi\theta m(\theta)\gamma(1-\varepsilon)u = \delta[p - \gamma u(1-\varepsilon)]. \tag{30}$$

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 $p - \gamma u(1-\varepsilon)$ 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

$$\phi\theta m(\theta)(1-\gamma)u = \delta[1 - p - (1-\gamma)u)]\sigma. \tag{31}$$

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 $[1-p-(1-\gamma)u]\sigma$ is destroyed with rate δ. The equilibrium in- and outflow of high-skilled natives at a high-tech firm can be summarized as

$$(1-\phi)\theta m(\theta)(1-\gamma)u = \delta[1-p-(1-\gamma)u](1-\sigma). \tag{32}$$

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 $[1-p-(1-\gamma)u](1-\sigma)$ is destroyed with rate δ.

The flow eqs. (29) - (32) can be used to solve for the two endogenous variables u and ϕ, which yields[11]

$$u = \frac{\delta(1-p)}{(1-\gamma)[\delta+\theta m(\theta)]} \tag{33}$$

$$\phi = \frac{(p+I)(1-\gamma)(\theta m(\theta)+\delta)-\gamma(1-p)\delta}{\theta m(\theta)\gamma(1-p)}. \tag{34}$$

It can easily be shown that the ceteris paribus changes of ϕ are[12]

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

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

$$u_{IL} = \delta\frac{I}{\delta+\phi\theta m(\theta)}, \qquad u_{NL} = \delta\frac{p}{\delta+\phi\theta m(\theta)} \qquad \text{and} \qquad u_H = \delta\frac{1-p}{\delta+\theta m(\theta)}. \tag{35}$$

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 $\varepsilon = \frac{I}{p+I}$.

[11] Appendix 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.

[12] $\frac{\partial\phi}{\partial\theta} > 0$ 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.

The interest of this paper 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

$$(y_L - z_H)(r + \delta) > \theta m(\theta)\beta(1 - \phi)(y_H - y_L). \tag{36}$$

Appendix A.4 provides detailed explanations.

Finally, the four endogenous variables u, θ, γ and ϕ can be determined using the labor demand conditions, eqs. (27) and (28), and the expressions for the unemployment rate and the fraction of vacancies that require a low-skill level, eqs. (33) and (34).

5 General Equilibrium Analysis

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 taken into account 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 identical, i.e. $h_I = 0$. This implies that the wage rates of low-skilled natives and immigrants are identical, meaning that there are no differences between those two types of workers. Considering job creation of low-skilled jobs, eq. (28), it becomes obvious 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 ($h_N = h_I$), it can be shown that an influx of low-skilled immigrants I*

(i) Promotes the behavior of 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 workers.

Formal proofs are provided in Appendix A.5.

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 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. On the other hand, there is a countervailing effect since low-skilled natives face a higher competition due to the new arrivals. As the first effect dominates the latter one, more low-skilled natives exit the unemployment pool. A smaller unemployment rate raises the scope of bargaining of the labor union that represents 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. (14). On the other hand, the availability of more low-tech vacancies increases the overall job offer arrival rate. As the former effect dominates, the corresponding union and the overqualified workers reduce their wage claims. This leads to a concomitant decrease in high-skilled workers' unemployment rate.

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 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) Reduces the behavior of 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 workers.

Formal proofs are provided in Appendix A.6.

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 of the union that represents low-skilled natives. Thus, the unions' wage claims decline, which leads to a lower wage rate of low-skilled natives.

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, the union, that represents high-skilled natives, and the workers that are employed in a low-tech firm 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.

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 immigration affects the position of labor unions in the economy, and 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, the overall welfare of natives is

$$\begin{aligned} W =& \big[1-p-(1-\gamma)u\big](1-\sigma)y_H + \big[p-\gamma u(1-\varepsilon)+I-\gamma u\varepsilon+[1-p-(1-\gamma)u]\sigma\big]y_L \\ &+(1-\gamma)uz_H+\gamma u(1-\varepsilon)z_L - v\phi c_L - v(1-\phi)c_H - (I-\gamma u\varepsilon)w_{IL}. \end{aligned} \tag{37}$$

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

$$W_1 = W - (1-\gamma)uz_H - \gamma u(1-\varepsilon)z_L. \tag{38}$$

The calibration uses the following Cobb-Douglas matching function

$$M = \xi \cdot u^{\alpha} v^{1-\alpha}, \tag{39}$$

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 1 lists eight parameters that are taken from available empirical literature. First, the elasticity of the

Table 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. (2014)
I	Share of low-skilled immigrants	0.1215	Battisti et al. (2014)

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), 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. (2014) 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.

The remaining six parameters of the model are chosen such that the model reflects seven calibration targets obtained from German data, see Table 2. Table 3 shows the six parameters that are obtained by exactly reproducing the number of moments with the model for Germany.[13]

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

Table 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. (2014)	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.

Table 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.

6.1 Increase in Low-skilled Immigration

This Section analyzes the effects of a low-skilled immigration influx by increasing the share of immigrants in the labor force by one percentage point, i.e. an increase from 12.15% to 13.15% of the labor force. Table 4 provides the results for two different versions of the model.

Table 4: The Effects of an Increase in Immigration (Changes in Percentage Points)

Variable	(1) $h_I = h_N$ $c_H = c_L$	(2) $h_I > h_N$ $c_H > c_L$
Overall		
θ	0.00	0.96
γ	0.09	-0.02
ϕ	0.74	1.34
u	0.07	-0.06
Low-skilled Natives		
w_{NL}	0.05	0.08
u_{NL}	-0.07	-0.08
Low-skilled Immigrants		
w_{IL}	0.05	0.16
u_{IL}	0.14	0.03
High-skilled Natives		
w_H	-0.17	-0.37
w_{OH}	-0.17	-0.37
u_H	-0.00	-0.01
Unions		
Ω_H	-1.47	-2.68
Ω_L	-0.56	-1.20
Welfare		
W	-0.01	-0.10
W_1	0.02	-0.06

Column (1) shows the results for the simplified version that was analyzed qualitatively in Section 5.1. In addition to the results that have been shown analytically, the qualitative analysis contains results about the utility level of the labor union, which declines due to low-skilled immigration. This might be puzzling at first sight, especially for the union that represents low-skilled natives, since low-skilled workers gain in terms of both, employment and wages. However, these increases are overcompensated by an increase in the value of being unemployed, which in total leads to a decrease in the utility function of the labor union, see eq. (16). Finally, it is worth noting that the effect on overall income to natives is not clear since the change in the two welfare measures have different signs.

Column (2) shows the effects for the full version of the model, with $h_I > h_N$ and $c_H > c_L$. In comparison to the simplified version, immigration also has a direct effect via job creation, see eq. (28), since it is cheaper for firms to hire immigrants due to their higher search costs. Hence, 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. In both specifications it is a priori unclear, if the demand or the supply effect is dominant. However, it is shown analytically that the demand effect is the dominant one in the basic model. In the full model, the demand effect is even strengthened by the effect that is active through job creation.[14] Thus, the unemployment rate of low-skilled natives decreases, while the unions' 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 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, the union reduces their wage claims for high-skilled workers, while the unemployment rate of high-skilled workers decreases.

Further, Table 4 reveals that almost all effects coincide for both specifications of the model, whereas the only qualitative difference is that in Column (2) overall unemployment does not increase, but slightly decreases and that the fraction of unemployed that are low skilled (γ) decreases. The driving force for the decrease in overall unemployment is the much smaller increase in the unemployment rate of low-skilled immigrants. The argument is the same as above: due to enhanced low-tech vacancy posting, the demand effect is strengthened. Even if it can not fully serve the inflow of immigrants in the pool of unemployed, the increase in immigrants' unemployment rate is much smaller than in

[14]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.

specification (1).

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. The shift in the production towards cheaper, simpler products goes along with a decrease in welfare. Thus, the welfare of natives shrinks due to the change in the technological orientation of the economy. Overall, it can be noted that the utility of the labor unions decrease. However, it is worth noting that even if the utility of the labor unions decrease, the economy-wide coverage rate of collective bargaining increase since the rate of native low-skilled and high-skilled employment increases. The decrease in the unions' utility is only possible, since these are the product out of the employment rate and the individuals workers' rent. The reduction in the individuals workers' rent overcompensates the increase in the employment rates and, thereby, leads to a decline of the unions' utility. However, even if the utility of the labor unions decrease, they gain of importance in the economy.

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 illustrates the results for the full model. The qualitative results are exactly the same as for the simplified version of the model analyzed in Section 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, 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,

Table 5: The Effects of a Decrease in Search Costs of Immigrants (Changes in Percentage Points)

Variable	Change
Overall	
θ	-1.19
γ	0.16
ϕ	-0.96
u	0.11
Low-skilled Natives	
w_{NL}	-0.08
u_{NL}	0.08
Low-skilled Immigrants	
w_{IL}	0.45
u_{IL}	0.01
High-skilled Natives	
w_H	0.25
w_{OH}	0.25
u_H	0.02
Unions	
Ω_H	1.90
Ω_L	1.16
Welfare	
W	0.04
W_1	-0.00

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 the union that represents 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, it is less painful for them to be unemployed and the union, that represents high-skilled natives, increases their wage claims leading to higher unemployment.

Overall, it is evident that firms invest more in the advanced technology. Thus, policies that simplify the participation of immigrants in the labor market are a suitable policy to cushion or even reverse the unfavorable shift towards a low-tech economy. As expected, the shift towards the production of high-tech goods benefits the overall welfare of natives. In contrast to the case of an influx of low-skilled immigration, where the position of unions is strengthened in the economy, a decrease in the search costs of low-skilled immigrants erodes the position of labor unions in the economy due the decline in the coverage rate of collective bargaining. Even if the position of the labor unions erodes, their utility increases since the increase in individuals workers' rent overcompensates the decline in coverage rates. It should further be noted that the wage inequality between low-skilled natives and high-skilled natives rises.

7 Summary and Conclusion

This paper develops a theoretical model to study the general equilibrium effects of low-skilled immigration on wages, the employment structure and especially the technology choice of firms in a unionized host country. 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. Bargaining of native workers, that are properly matched according to their skill level, takes place between firms, which are represented by employer associations, and labor unions as in most European countries wages are determined by collective bargaining.

While there already exist contributions that study one or more issues of immigration, labor unions, overqualification and endogenous technology choices, this paper 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, the position of labor unions in the economy 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 economy changes and leads to the formation of a low-tech production industry in the host country. 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 their immigrant counterpart is unfounded. Next, the quantitative analysis shows that even if low-skilled immigration leads to an increase in the coverage of collectively bargained wages for high-skilled workers in the economy, it leads to a reduction of their wage rate and, thereby, to a decline in the utility of the union that represents high-skilled natives. On the other hand, the utility of the labor union that represents low-skilled natives also declines, even if low-skilled natives gain due to immigration. The reason is that the increase in collectively bargained wages and their employment level are overcompensated by the increase in the expected utility of an unemployed low-skilled worker.

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 paper 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 invest in a basic education 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.

A Appendix

A.1 Wage Determination

The wage rate for high-skilled workers is determined by bargaining between a labor union and an employer association.[15] Taking into account, that the thread points of both parties are equal to zero, since the utility of both parties in case of unsuccessful negotiations equals zero, the maximization of the generalized Nash-bargaining problem can be written as

$$\max_{w_H} \Big\{ U_H \Big\}^{\beta} \cdot \Big\{ \Omega_H \Big\}^{1-\beta}. \tag{40}$$

Inserting the objective functions (15) and (17), the bargaining problem is

$$\max_{w_H} \Big\{ \big[1-p-(1-\gamma)u\big](1-\sigma)[\Psi_H^E - \Psi_H^U] \Big\}^{\beta} \cdot \Big\{ \big[1-p-(1-\gamma)u\big](1-\sigma)[\Pi_H^F - \Pi_H^V] \Big\}^{1-\beta}. \tag{41}$$

Maximization of the Nash product delivers the sharing rule

$$\beta[\Pi_H^F - \Pi_H^V] = (1-\beta)[\Psi_H^E - \Psi_H^U]. \tag{42}$$

Using the present value functions, eqs. (5) and (11), together with the free entry condition $\Pi_H^V = 0$, the rents of firms and workers can be substituted by

$$\Psi_H^E - \Psi_H^U = \frac{w_H - r\Psi_H^U}{r+\delta} \qquad \text{and} \qquad \Pi_H^F - \Pi_H^V = \frac{y_H - w_H}{r+\delta}. \tag{43}$$

Rearrangement leads to

$$w_H = \beta y_H + (1-\beta) r \Psi_H^U. \tag{44}$$

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

[15]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.

high-skilled workers, eq. (14). To substitute for the rent of a high-skilled worker that is employed in a high-tech firm, the sharing rule, eq. (42), gives

$$\Psi_H^E - \Psi_H^U = \beta \cdot S, \tag{45}$$

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. (43), it turns out that

$$\Psi_H^E - \Psi_H^U = \beta\Big(\frac{y_H - r\Psi_H^U}{r+\delta}\Big). \tag{46}$$

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

$$\Psi_{OH}^E - \Psi_H^U = \beta\Big(\frac{y_L - r\Psi_H^U}{r+\delta}\Big). \tag{47}$$

Substituting eqs. (46) and (47) in eq. (14), the expected value of being unemployed for a high-skilled worker is

$$r\Psi_H^U = \frac{z_H(r+\delta) + \theta m(\theta)\beta\Big[(1-\phi)y_H + \phi y_L\Big]}{r+\delta+\theta m(\theta)\beta}. \tag{48}$$

Finally, insertion of eq. (48) in eq. (44) and some rearrangement leads to the wage rate given in eq. (22)

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

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

A.2 Derivation of Equilibrium Labor Demand

Using the firm's value functions (5) and (7) and the free-entry condition $\Pi_H^V = 0$, job creation of high-tech jobs can be stated as

$$\frac{c_H}{m(\theta)(1-\gamma)} = \frac{y_H - w_H}{r+\delta}. \tag{49}$$

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. (22), 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 (2) to (4), (6) and the free-entry condition $\Pi_L^V = 0$, job creation of low-tech jobs can be stated as

$$\frac{c_L}{m(\theta)} = \gamma\Big[\varepsilon\frac{y_L - w_{IL}}{r+\delta} + (1-\varepsilon)\frac{y_L - w_{NL}}{r+\delta}\Big] + (1-\gamma)\frac{y_L - w_{OH}}{r+\delta}. \tag{50}$$

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. (21), (24) and (25), equilibrium labor demand for low-tech jobs is

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

A.3 Derivation of σ

Solving the flow for overqualified high-skilled workers that end up in low-tech jobs, eq. (31), for σ gives

$$\sigma = \frac{\phi\theta m(\theta)(1-\gamma)u}{\delta\big[1-p-(1-\gamma)u\big]}. \tag{51}$$

The unemployment rate u can be replaced by using eq. (33). 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.

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.[16] Using eq. (5), the profit of a high-tech firm that hires a high-skilled native is

$$\Pi_H^F = \frac{y_H - w_H}{r + \delta}. \tag{52}$$

Insertion of eq. (22) to substitute w_H and simplification gives

$$\Pi_H^F = \frac{1-\beta}{r + \delta + \theta m(\theta)\beta}(y_H - z_H), \tag{53}$$

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

$$\Pi_{OH}^F = \frac{1-\beta}{\beta}[\Psi_{OH}^E - \Psi_H^U] > 0 = \Pi_L^V. \tag{54}$$

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

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

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

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

A.5 Comparative Statics for Changing I

As discussed in Section 5.1, it is assumed that $c_H = c_L = c$ and $h_I = 0$. This leads the LHS of eqs. (27) and (28) to be identical. Equalizing eqs. (27) and (28) and some rearrangement gives

$$\frac{\gamma(r+\delta)}{r+\delta+\phi\theta m(\theta)\beta}(y_L - z_L) = (1-\gamma)(y_H - y_L). \tag{55}$$

To derive the changes in ϕ, γ, θ and u, eqs. (27), (33), (34) and (55) are used. Taking the total derivative of eq. (34) and solving for $d\phi/dI$ gives

$$\frac{d\phi}{dI} = \frac{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}D_2 - \frac{d\gamma}{dI}C_1 + D_1}{\theta m(\theta)\gamma(1-p)}, \tag{56}$$

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 $D_2 \equiv (p+I)(1-\gamma) - \phi\gamma(1-p)$.[17] Next, take the total derivative of eq. (27), rearrange and collect terms to obtain

$$\begin{aligned} A_1\frac{d\gamma}{dI} =& (1-\gamma)\theta m(\theta)\beta(y_H - y_L)\frac{d\phi}{dI} + \frac{d\theta}{dI}\frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)} \\ &- \frac{d\theta}{dI}\frac{\frac{\partial\theta m(\theta)}{\partial\theta}m(\theta)\beta\Big[c(r+\delta) - (1-\beta)m(\theta)(1-\gamma)\phi(y_H - y_L)\Big]}{m(\theta)^2(1-\beta)}, \end{aligned} \tag{57}$$

with $A_1 \equiv (y_H - z_H)(r+\delta) + \phi\theta m(\theta)\beta(y_H - y_L)$. The total derivative of eq. (55) is given by

$$\frac{d\gamma}{dI}\Big[D_3 + (y_H - y_L)\big[r+\delta+\phi\theta m(\theta)\beta\big]\Big] = (1-\gamma)(y_H - y_L)\beta\Big[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\Big], \tag{58}$$

where $D_3 \equiv (r+\delta)(y_L - z_L)$. Substitution of $d\phi/dI$ by eq. (56) and some rearrangement leads to

$$\frac{d\gamma}{dI} = \frac{C_3\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + C_4}{A_2}, \tag{59}$$

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. (59), $d\gamma/dI$ can be substituted in eq. (56) and, thus,

$$\frac{d\phi}{dI} = \frac{1}{\theta m(\theta)\gamma(1-p)}\left\{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}\left[D_2 - \frac{C_1C_3}{A_2}\right] + D_1 - \frac{C_1C_4}{A_2}\right\}. \tag{60}$$

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

Finally, eqs. (59) and (60) are inserted into eq. (57) 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

$$\frac{d\theta}{dI} = -\frac{C_4(r+\delta)(z_H - z_L)}{A_2 B}, \tag{61}$$

with

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

It can be easily seen that the numerator in eq. (61) 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. (61) would be negative implying a positive relationship between overall labor market tightness and low-skilled immigration. The term is positive if it holds that

$$\frac{c(r+\delta)}{m(\theta)(1-\beta)} - \frac{(1-\gamma)^2(p+I)(y_H - y_L)}{\gamma(1-p)} > 0. \tag{62}$$

Replacing the first fraction by eq. (27) gives

$$\frac{(y_H - z_H)(r+\delta)}{r+\delta+\theta m(\theta)\beta} + (y_H - y_L)\left[\frac{\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)}\right] > 0. \tag{63}$$

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. (63). 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

$$\frac{r+\delta+\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)} > 0. \tag{64}$$

Now, two cases can be distinguished in order to show that eq. (64) 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. (64) 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

$$\frac{d\theta}{dI} > 0. \tag{65}$$

In order to derive the change in γ, $d\theta/dI$ has to be inserted in eq. (59). Expanding the second fraction to the same denominator and some rearrangement leads to

$$\frac{d\gamma}{dI} = \frac{C_4}{A_2 B}\left[B - \frac{C_3}{A_2}\frac{\partial\theta m(\theta)}{\partial\theta}(r+\delta)(z_H - z_L)\right] > 0. \tag{66}$$

To examine how the fraction of low-tech vacancies changes due to an increase in immigration, eq. (66) has to be inserted in eq. (56). Simplification yields

$$\frac{d\phi}{dI} = \frac{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}D_2 + \frac{D_1}{A_2}(y_H - y_L)[r+\delta+\phi\theta m(\theta)\beta] + \frac{D_1 D_3 B_1}{A_2 B} - \frac{C_1 C_3 C_4}{A_2^2 B}(r+\delta)(y_L - z_H)}{\theta m(\theta)\gamma(1-p)}, \tag{67}$$

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

$$\frac{d\phi}{dI} > 0. \tag{68}$$

To examine the change in overall unemployment, total derivation of eq. (33) gives

$$\frac{du}{dI} = \frac{u}{(1-\gamma)\big[\delta+\theta m(\theta)\big]}\left[\big[\delta+\theta m(\theta)\big]\frac{d\gamma}{dI} - (1-\gamma)\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}\right]. \tag{69}$$

Substituting $\frac{d\gamma}{dI}$ and $\frac{d\theta}{dI}$ by eqs. (59) and (61) yields

$$\frac{du}{dI} = u\,\frac{\frac{\delta+\theta m(\theta)}{A_2}C_3\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \frac{C_4}{A_2 B}\Big[B\big[\delta+\theta m(\theta)\big] + (1-\gamma)\frac{\partial\theta m(\theta)}{\partial\theta}(r+\delta)(z_H - z_L)\Big]}{(1-\gamma)\big[\delta+\theta m(\theta)\big]}. \tag{70}$$

For the whole expression to be positive, it has to be shown that the term in big corner brackets is negative. By inserting the expression for B and some rearrangement, it turns out that the expression is negative if

$$B_2 + (1-\gamma)\frac{\partial\theta m(\theta)}{\partial\theta}(r+\delta)\Big[(z_H - z_L) - (y_H - z_H)\beta\frac{\delta+\theta m(\theta)}{r+\delta+\theta m(\theta)\beta}\Big] < 0, \tag{71}$$

with

$$\begin{aligned} B_2 \equiv & \frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)} - \frac{C_3}{A_2}\frac{\partial\theta m(\theta)}{\partial\theta}\left[A_1 + (1-\gamma)\beta(y_H - y_L)\frac{C_1}{\gamma(1-p)}\right] \\ & - \frac{\partial\theta m(\theta)}{\partial\theta}\left[\beta(1-\gamma)\frac{\phi\theta m(\theta)\beta(y_H - y_L)}{r+\delta+\theta m(\theta)\beta} - C_3\right]. \end{aligned}$$

The second term in eq. (71) is negative, if the term in corner brackets is negative. As the difference between the output of a high-tech job and net unemployment benefits of a high-skilled worker is much larger than simply the difference in net unemployment benefits of high- and low-skilled individuals, this condition is fulfilled if $\beta\frac{\delta+\theta m(\theta)}{r+\delta+\theta m(\theta)\beta}$ is not very small, which is only the case if β is close to zero. Thus, plausible parameter values for the bargaining power of the union ensures that the condition is fulfilled. What is left is to show that B_2 is negative as well. The first term is obviously negative. After some computational steps, it can be shown that the second and third term are negative if the following condition holds:

$$\frac{r+\delta+\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta}\phi\theta m(\theta)\beta(y_H - y_L) - \frac{(1-\gamma)(p+I)}{\gamma(1-p)}(r+\delta)(z_H - z_L) > 0. \tag{72}$$

It has already been verified that $\frac{r+\delta+\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)} > 0$. Thus, it is enough to show that $\theta m(\theta)\beta\phi(y_H - y_L) \geq (r+\delta)(z_H - z_L)$. This inequality holds for plausible parameter values. Thus, the overall unemployment rate increases in immigration:

$$\frac{du}{dI} > 0. \tag{73}$$

The changes in the unemployment rates of the different types of workers can be analyzed forming the total differential of eq. (35)

$$\frac{du_{NL}}{dI} = -\frac{u_{NL}}{\delta + \phi\theta m(\theta)}\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] < 0 \tag{74}$$

$$\frac{du_H}{dI} = -\frac{u_H}{\delta + \theta m(\theta)}\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} < 0. \tag{75}$$

It is easy to see that the unemployment rate of low- and high-skilled natives 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 u_{IL} 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 overall unemployment rate increases, and the unemployment rates of low- and high-skilled natives decrease, the unemployment rate of low-skilled immigrants necessarily has to increase. Thus, the increase even exaggerates the decrease in the unemployment rates of all natives.

Finally, the change in the four wage rates have to be determined. Taking the total differential of eqs. (22) and (25), the wage rates of high-skilled workers are identical and given by

$$\frac{dw_H}{dI} = \frac{dw_{OH}}{dI} = \beta\frac{(1-\beta)\left[\frac{r+\delta}{r+\delta+\theta m(\theta)\beta}\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}\left[y_H - z_H - \phi(y_H - y_L)\right] - \theta m(\theta)(y_H - y_L)\frac{d\phi}{dI}\right]}{r + \delta + \theta m(\theta)\beta}. \tag{76}$$

Since the sign is not clear, the change in labor market tightness, eq. (61), and the change in the fraction of vacancies that are opened for low-skilled workers, eq. (67), have to be inserted. Rearrangement yields to

$$
\begin{aligned}
\frac{dw_H}{dI} = \beta\frac{1-\beta}{r+\delta+\theta m(\theta)\beta}\Bigg[& -\frac{y_H-y_L}{\gamma(1-p)}\frac{D_1D_3}{A_2B}B_3 - \frac{r+\delta}{r+\delta+\theta m(\theta)\beta}\frac{\partial\theta m(\theta)}{\partial\theta}\phi(y_H-y_L)\frac{d\theta}{dI} \\
& - \frac{y_H-y_L}{\gamma(1-p)}\left(\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI}D_2 + \frac{D_1}{A_2}(y_H-y_L)[r+\delta+\phi\theta m(\theta)\beta] - \frac{C_1C_3C_4}{A_2^2B}(r+\delta)(y_L-z_H)\right) \\
& + \frac{\partial\theta m(\theta)}{\partial\theta}\frac{C_4}{A_2B}(r+\delta)\Bigg\{\frac{r+\delta}{r+\delta+\theta m(\theta)\beta}(y_H-z_H)(y_L-z_H) \\
& + (y_L-z_L)(y_H-y_L)\left(\frac{\phi\theta m(\theta)\beta}{r+\delta+\theta m(\theta)\beta} - \frac{(1-\gamma)(p+I)}{\gamma(1-p)}\right)\Bigg\}\Bigg],
\end{aligned}
\tag{77}
$$

with

$$
B_3 \equiv \frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)} - \frac{C_3A_1}{A_2}\frac{\partial\theta m(\theta)}{\partial\theta} < 0.
$$

In eq. (77), 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,

$$
\frac{dw_H}{dI} < 0 \quad \text{and} \quad \frac{dw_{OH}}{dI} < 0. \tag{78}
$$

What is left is to analyze how the wage rates of low-skilled workers change in immigration. Taking the total derivative of eqs. (21) and (24), the change in the wage rates for low-skilled natives and immigrants can be expressed as follows:

$$
\frac{dw_{NL}}{dI} = \beta\frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2}(y_L-z_L)\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] > 0 \tag{79}
$$

$$
\frac{dw_{IL}}{dI} = \beta\frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2}(y_L-z_{IL})\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] > 0. \tag{80}
$$

As the overall labor market tightness and the fraction of low-tech vacancies increase in immigration, it can be directly seen that the wage rates of all low-skilled workers increase due to an influx of low-skilled immigration.

A.6 Comparative Statics for Changing h_I

As discussed in Section 5.2, it is taken into account that $c_H = c_L = c$. This leads the LHS of eqs. (27) and (28) to be identical. Equalizing eqs. (27) and (28) and some rearrangement gives

$$\frac{\gamma(r+\delta)}{r+\delta+\phi\theta m(\theta)\beta}\Big[\varepsilon[y_L-(z_L-h_I)]+(1-\varepsilon)(y_L-z_L)\Big]=(1-\gamma)(y_H-y_L). \tag{81}$$

To derive the changes in ϕ, γ and θ, eqs. (27), (34) and (81) are used. Total differentiation of eq. (34) and some rearrangement gives

$$\frac{d\phi}{dh_I}=\frac{1}{\theta m(\theta)\gamma(1-p)}\left[\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}D_2-\frac{d\gamma}{dh_I}C_1\right]. \tag{82}$$

The total derivative of eq. (27) is similar to the previous case and given by

$$\begin{aligned}A_1\frac{d\gamma}{dh_I}=&(1-\gamma)\theta m(\theta)\beta(y_H-y_L)\frac{d\phi}{dh_I}+\frac{d\theta}{dh_I}\frac{c(r+\delta)\big[r+\delta+\theta m(\theta)\beta\big]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)}\\&-\frac{d\theta}{dh_I}\frac{\frac{\partial\theta m(\theta)}{\partial\theta}m(\theta)\beta\Big[c(r+\delta)-(1-\beta)m(\theta)(1-\gamma)\phi(y_H-y_L)\Big]}{m(\theta)^2(1-\beta)}.\end{aligned} \tag{83}$$

In a next step, the total differential of eq. (81) is computed, which gives

$$\frac{d\gamma}{dh_I}\left[D_4+(y_H-y_L)\big[r+\delta+\phi\theta m(\theta)\beta\big]\right]+\varepsilon\gamma(r+\delta)=(1-\gamma)(y_H-y_L)\beta\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}+\theta m(\theta)\frac{d\phi}{dh_I}\right], \tag{84}$$

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. (82) and rearrangement gives

$$\frac{d\gamma}{dh_I}=\frac{C_3\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}-\varepsilon\gamma(r+\delta)}{A_3}, \tag{85}$$

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. (85), in eq. (82) leads to

$$\frac{d\phi}{dh_I}=\frac{1}{\theta m(\theta)\gamma(1-p)}\left\{\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dh_I}\left[D_2-\frac{C_1C_3}{A_3}\right]+\frac{C_1}{A_3}\varepsilon\gamma(r+\delta)\right\}. \tag{86}$$

Using eqs. (85) and (86) in eq. (83) it is possible to derive a single equation that only depends on the change in overall labor market tightness:

$$\frac{d\theta}{dh_I}=-\frac{\varepsilon\gamma(r+\delta)}{A_3B_4}\left[A_1+(1-\gamma)(y_H-y_L)\beta\frac{C_1}{\gamma(1-p)}\right]>0, \tag{87}$$

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. (87) has to be inserted in eq. (85). This gives

$$\frac{d\gamma}{dh_I} = -\frac{B_5}{A_3 B_4}\varepsilon\gamma(r+\delta) < 0, \tag{88}$$

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. (82) it is easy to verify that

$$\frac{d\phi}{dh_I} > 0. \tag{89}$$

Total differentiation of the overall unemployment rate and the unemployment rates of each type of worker gives their changes as

$$\frac{du}{dh_I} = \frac{u}{(1-\gamma)\big[\delta+\theta m(\theta)\big]}\left[\big[\delta+\theta m(\theta)\big]\frac{d\gamma}{dh_I} - (1-\gamma)\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dh_I}\right] < 0 \tag{90}$$

$$\frac{du_{NL}}{dh_I} = -\frac{u_{NL}}{\delta+\phi\theta m(\theta)}\left[\phi\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dh_I} + \theta m(\theta)\frac{d\phi}{dh_I}\right] < 0 \tag{91}$$

$$\frac{du_H}{dh_I} = -\frac{u_H}{\delta+\theta m(\theta)}\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dh_I} < 0 \tag{92}$$

$$\frac{du_{IL}}{dh_I} = -\frac{u_{IL}}{\delta+\phi\theta m(\theta)}\left[\phi\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dh_I} + \theta m(\theta)\frac{d\phi}{dh_I}\right] < 0. \tag{93}$$

Next, to analyze the change in the wage rates of high-skilled workers, the total differentials are given by

$$\frac{dw_H}{dh_I} = \frac{dw_{OH}}{dh_I} = \beta\frac{(1-\beta)\left[\frac{r+\delta}{r+\delta+\theta m(\theta)\beta}\frac{\partial \theta m(\theta)}{\partial \theta}\frac{d\theta}{dh_I}\Big[y_H - z_H - \phi(y_H-y_L)\Big] - \theta m(\theta)(y_H-y_L)\frac{d\phi}{dh_I}\right]}{r+\delta+\theta m(\theta)\beta}. \tag{94}$$

Substitution of eq. (86) and eq. (87) leads to

$$\begin{aligned}\frac{dw_H}{dh_I} &= -\beta\frac{1-\beta}{r+\delta+\theta m(\theta)\beta}\frac{\varepsilon\gamma(r+\delta)}{A_3B_4}\left[\frac{\partial\theta m(\theta)}{\partial\theta}\frac{D_5D_6}{1-\gamma}\right.\\ &\quad\left.+\frac{y_H-y_L}{\gamma(1-p)}C_1\left(\frac{c(r+\delta)\left[r+\delta+\theta m(\theta)\beta\right]\frac{\partial m(\theta)}{\partial\theta}}{m(\theta)^2(1-\beta)}-\frac{\partial\theta m(\theta)}{\partial\theta}\beta D_6\right)\right],\end{aligned} \tag{95}$$

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

$$\frac{dw_H}{dh_I} < 0 \quad \text{and} \quad \frac{dw_{OH}}{dh_I} < 0. \tag{96}$$

Finally, the change in the wage rate for low-skilled natives is given by

$$\frac{dw_{NL}}{dh_I} = \beta\frac{(r+\delta)(1-\beta)}{\left[r+\delta+\theta m(\theta)\beta\phi\right]^2}(y_L - z_L)\left[\phi\frac{\partial\theta m(\theta)}{\partial\theta}\frac{d\theta}{dI} + \theta m(\theta)\frac{d\phi}{dI}\right] > 0. \tag{97}$$

As the overall labor market tightness and the fraction of low-tech vacancies increase in immigration, it can be directly seen that the wage rate of all low-skilled natives increase due to an influx of low-skilled immigration.

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