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Abstract

We investigate the labor market effects of immigration in Denmark, Germany and the UK, three countries which are characterized by considerable differences in labor market institutions and welfare states. Institutions such as collective bargaining, minimum wages, employment protection and unemployment benefits affect the way in which wages respond to labor supply shocks, and, hence, the labor market effects of immigration. We employ a wage-setting approach which assumes that wages decline with the unemployment rate, albeit imperfectly. We find that wage flexibility is substantially higher in the UK compared to Germany and, in particular, Denmark. As a consequence, immigration has a much larger effect on the unemployment rate in Germany and Denmark, while the wage effects are larger in the UK. Moreover, the elasticity of substitution between natives and foreign workers is high in the UK and particularly low in Germany. Thus, the preexisting foreign labor force suffers more from further immigration in Germany than in the UK.

Keywords: immigration, unemployment, wages, labor markets, panel data, comparative studies.

JEL code: F22, J31, J61.

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1 Introduction

Concerns that immigrants take jobs away from natives and reduce their wages are widespread in most European countries. The current financial and economic crisis has further fueled these fears and raised sentiments against immigration. However, the overwhelming share of the empirical literature finds only moderate wage and employment effects of immigration, if at all (see for example the meta-studies by Longhi *et al.*, 2005, 2006, 2008). In this paper we take a fresh look at the effects of immigration on employment and wages using a theoretical and empirical framework which considers imperfect labor markets. Such labor markets are characterized by the presence of labor market institutions, that is systems of laws, bargaining rules, unemployment benefits and labor market programs, that shape the behavior of workers and employers. These institutions differ considerably across countries. We therefore apply a cross-country approach to analyze whether, and to what extent, the labor market effects of immigration vary between countries depending on their institutional settings.

Based on a theoretical framework which assumes that wages adjust only imperfectly to labor supply shocks, we use micro data from Denmark, Germany and the UK to estimate the wage and employment effects of immigration in those countries. All three countries have seen a substantial influx of migrants during the last two decades. From 1990 to 2010, cumulative net migration amounted to 8.6% of the population in Germany, 4.3% in Denmark and 4.1% in the UK (World Bank, 2011). While migration to Germany surged following the fall of the Iron Curtain, net migration to Denmark and the UK has also accelerated substantially since the turn of the century, partly as a consequence of the European Union's Eastern enlargement.

The institutions of the labor market and the welfare state of these three countries are characterized by different institutional settings, as Table 1 illustrates. The so-called Danish 'flexicurity' system features relatively weak employment protection and a high rate of hirings and firings, but high transfers to unemployment households (Anderson and Svarer, 2007). Moreover, Denmark is characterized by industry- and company-level collective bargaining, with extremely high coverage of collective bargaining agreements and union membership density. Competition in national product markets as well as exposure to international competition is high, suggesting that rents at the firm level are rather low. Finally, taxes are high and progressive in Denmark, which in turn affects wage-setting for different groups in the labor market in different ways (Lockwood *et al.*, 2000).

Germany is the archetypal example of a "continental" European welfare state, where employment protection is strict and welfare benefits are relatively high. The level of employment protection is significantly higher than in Denmark and the UK, while unemployment benefits are below those in Denmark, but above those of the UK. Germany features industry-level bargaining with an intermediate coverage of collective bargaining agreements and a relatively low union membership density. National product market

Table 1: Institutional indicators for Denmark, Germany and the UK, 2008

	Denmark	Germany	UK
Principal bargaining level[a]	industry	industry	firm
Collective bargaining coverage in %[b]	82	63	35
Union density in %[c]	68	19	27
Legal minimum wage	no	no	yes
Net income of unemployed household as % of average employed net income[d]			
Single, no children	83	59	55
Married, one earner, two children	88	80	77
Net personal marginal tax rate %[e]			
67% of average earnings	42.56	50.53	31.00
100% of average earnings	49.43	56.78	31.00
167% of average earnings	62.96	44.38	41.00
Strictness of employment protection (index)[f]	1.50	2.12	0.75
Product market regulation (index)[g]	1.06	1.33	0.84
Import penetration (in % of GDP)[h]	54	44	31
Export propensity (in % of GDP)[i]	50	46	29
Net migration 1990–2010 as % of population[j]	4.3	8.6	4.2

[a] See Venn (2009) for a classification.

[b] Collective bargaining coverage corresponds to wage and salary earners covered by collective wage contracts divided by all wage and salary earners. Source: OECD (2011).

[c] Union density corresponds to the ratio of wage and salary earners that are trade union members divided by all wage and salary earners. Source: OECD (2011).

[d] Measured at 67% of average earnings level. The ratio of the net income of unemployed to employed households considers all types of benefits made available to non-wage earners compared to wage earners as well as all taxes for different household types. Source: OECD (2011).

[e] Principal earner, single household, no child, 2010. Source: OECD (2011).

[f] See Venn (2009) for the calculation of the employment protection indicator.

[g] Product market regulation index measures the level by which policies inhibit competition. Source: OECD (2011).

[h] The import penetration rate is measured as the ratio of imports to GDP. Source: OECD (2011).

[i] The export propensity rate is measured as the ratio of exports to GDP. Source: OECD (2011).

[j] Source: World Bank (2011).

competition is more strongly regulated than in Denmark or the UK, but exposure to international competition is, for a country of this size, high.

Finally, the United Kingdom is characterized by weak employment protection and, relative to the other two countries, low unemployment benefits. The UK typically has firm-level bargaining, low coverage of collective bargaining agreements and an intermediate level of union membership. In contrast to the other two countries, a legal minimum wage exists in the UK. While national product market competition is strong, exposure to international competition is weak compared to the other two countries.

All these institutional dimensions — the level and effectiveness of collective wage bargaining, the system of unemployment benefits, the system of taxes, the level of employment protection and the regulation of product markets — affect the wage-setting mechanism, the reservation wage and the scope for bargaining, which in turn have an impact on the responsiveness of wages to labor supply shocks. A comparative analysis of these three countries therefore promises new insights into the impact of immigration.

Our theoretical framework derives the wage and employment effects of immigration from a wage-setting approach (e.g. Layard and Nickell, 1986; Layard *et al.*, 2005). This approach rests on the empirically supported assumption that wages respond to changes in the unemployment rate, albeit imperfectly. The elasticity between wages and unemployment depends on the wage-setting mechanism, other labor market institutions which affect the reservation wage and the value of the outside option, and competition in product markets which determines *inter alia* the scope for wage bargaining or efficiency wages. Thus, the elasticity between wages and unemployment reflects the different institutional features which characterize the three countries we investigate. In our empirical application of this approach we assume that the elasticity of this wage-setting curve varies across different types of workers. Once wages are fixed, firms adjust their employment in a way which maximizes their profits. Under this right-to-manage assumption we can derive the labor demand of firms in the same way as other papers in the literature which use a production function approach (e.g. Grossman, 1982; Borjas, 2003; Ottaviano and Peri, 2012), although our approach uses a monopolistically competition framework (Dixit and Stiglitz, 1977).

In the empirical application we use a nested CES framework which distinguishes labor by education, experience and national origin. Having estimated the elasticities of the wage-setting curves and the elasticities of substitution between different types of labor, we can solve for the wage and employment effects of immigration simultaneously and simulate the labor market effects of immigration for different groups. We use rich micro data sets for this analysis, which are derived from social security records from Denmark and Germany and household survey data from the UK.

Our paper draws on a large literature which has investigated the labor market effects of immigration. Three aspects distinguish our contribution from that literature. First,

we derive the wage and employment effects of immigration simultaneously from an equilibrium framework with imperfect labor markets. In contrast, the overwhelming share of the literature which uses structural models rests either explicitly or implicitly on the assumption that labor markets clear. Starting with the seminal contribution by Grossman (1982), a number of papers derive the wage effects of immigration from a production function framework, see *inter alia* the recent contributions by Borjas (2003), Aydemir and Borjas (2007), D'Amuri *et al.* (2010), Ottaviano and Peri (2012) and Manacorda *et al.* (2012). While these papers differ in many aspects — for example whether they assume that natives and foreigners are perfect or imperfect substitutes in the labor market or whether capital stocks adjust to labor supply shocks — they all derive the wage effects of immigration from a framework which relies on the assumption that labor markets clear. Not surprisingly, this approach was originally developed in the US, a country characterized by flexible labor markets.[1]

Another strand of the literature relies on partial correlations between wages and (un)employment rates on the one hand and the migration share in certain regions, industries, or education and experience groups on the other hand (see for example the contributions by Altonji and Card (1991); Borjas *et al.* (1996); Pischke and Velling (1997); Dustmann *et al.* (2005) and Friedberg and Hunt (1995) for a review). This partial correlation approach does not necessarily rely on the assumption that labor markets clear, but it does not consider the interaction between wages and employment and the cross-effects of labor supply shifts in different segments of the labor market.

However, there are some studies which are more closely related to our theoretical approach. Brücker and Jahn (2011) and Felbermayr *et al.* (2010) apply a wage-setting framework to analyze the labor market effects of immigration. The literature analyzing the effects of immigration on the shape of the Phillips curve (Bentolila *et al.*, 2008; Binyamini and Razin, 2008; Engler, 2009) also addresses the relationship between wage rigidities and immigration. However, this literature focuses on the inflation-unemployment tradeoff from an aggregate perspective, while we analyze the long-run relationships between immigration and unemployment in different segments of the labor market.

Our second contribution is that, as a consequence of the assumption that labor markets do not clear, we employ a novel identification strategy for the estimation of the elasticities of substitution between different types of labor compared to large parts of the literature. The existing literature usually estimates the elasticities of substitution by treating wages as the endogenous and labor as the exogenous variable (e.g. Katz and Murphy, 1992; Card and Lemieux, 2001; Borjas, 2003; Ottaviano and Peri, 2012; Manacorda *et al.*, 2012). This identification strategy relies on the assumption that wages adjust perfectly to exogenous labor supply changes. In contrast, based on our wage-setting framework, we assume that

[1] Some of the papers above also supplement their analysis by employment regressions in order to address the effects of immigration on unemployment. However, the theoretical framework of this literature is clearly derived from a perfect competition framework with clearing labor markets.

firms determine their labor demand when wages are fixed. Consequently, we treat labor demand as the endogenous and wages as the exogenous variable. However, because of the potential endogeneity of the wage variable we employ an instrumental variable strategy which uses instruments related to the reservation wage, such as the number of children in the household and the income of the unemployed.

Third, there are few papers which address the effects of immigration from a comparative perspective. Aydemir and Borjas (2007) analyze the wage effects of immigration in Canada, Mexico and the US, employing a production function framework and using disaggregated micro data. However, this paper derives the wage effects of migration from a standard production function framework assuming perfect competition and clearing labor markets. Angrist and Kugler (2003) estimate the employment effects of immigration for a sample of Western Europe countries by applying a reduced-form regression approach and using aggregate employment data. While this approach allows one to consider institutional variables directly, it relies on a partial correlation framework which does not take the interaction between wages and employment and the cross-effects of labor supply changes into account. Docquier *et al.* (2011) simulate the wage effects of immigration and emigration for 21 OECD countries based on a novel data set which covers the skill structure of migrants, but they use the parameters estimated in the literature and apply a standard production function framework which, again, relies on the assumption of clearing labor markets.

The remainder of the paper is organized as follows. Section 2 outlines our theoretical framework. Section 3 briefly describes the data we use.[2] Section 4 presents the empirical model, the identification strategy and the estimation results for the elasticities of the wage-setting curves and the parameters of the production function. Section 5 simulates the employment and wage impact of immigration in Denmark, Germany and the UK. Finally, Section 6 concludes.

2 Theoretical framework

2.1 Wage-setting theories

Building on Boeri and Brücker (2005), Brücker and Jahn (2011) and Levine (1999) we apply a wage-setting framework to analyze the wage and employment effects of immigration. Our model replaces the conventional labor supply curve with a wage-setting function. This wage-setting function relies on the simple assumption that wages decline with the unemployment rate, albeit imperfectly. This relationship is empirically widely supported, both at the macro level (e.g. Layard and Nickell, 1986; Layard *et al.*, 2005) and at the regional level (Blanchflower and Oswald 1994; 2005). Theoretically, the assumption of a

[2] A detailed description is provided separately in Appendix B.

wage-setting function can be derived from right-to-manage models of collective bargaining (Nickell and Andrews, 1983) and efficiency wage theories derived from turnover cost (Salop, 1979) or shirking (Shapiro and Stiglitz, 1984) models. These models have in common the idea that the slope of the wage-setting curve depends on both the mark-up of the wage over the outside option of workers, and on the value of the outside option.

We do not present an explicit collective bargaining or efficiency wage model here, since different types of models may be relevant in our context. Instead, we think of the elasticity of the wage-setting curve as the composite effect of wage-setting mechanisms and other labor market institutions which affect the elasticity of the wage with respect to labor supply changes. We expect that the slope of the wage-setting curve will vary across the three countries in our analysis for a number of reasons.

First, the three countries have different types of collective bargaining institutions. Calmfors and Driffill (1988) have argued for a hump-shaped relationship between the degree of centralization in collective bargaining arrangements and the mark-up of wages.[3] The UK is the classic example of decentralized collective bargaining at the firm level and has a low level of coordination of unions, while in Germany the coverage of industry-level bargaining is still high, although the share of firms which are not covered by industry-level contracts has increased. In Denmark, collective bargaining was traditionally carried out at the industry level, but increasingly wage contracts are settled at the company level. However, both in Germany and Denmark the level of informal coordination of unions is rather high (Boeri and van Ours, 2008; Venn, 2009). Thus, while the higher degree of decentralization in the UK suggests that wages respond more elastically to changes in the unemployment rate, the higher level of coordination of unions in Denmark and Germany may help to internalize the social costs of unemployment, so that, in practice, differences with the UK may not be that great.

Second, Germany has a relatively high level of employment protection, compared to the UK and Denmark. Insider-outsider models of collective bargaining (Lindbeck and Snower, 1987, 2001) would therefore predict that the slope of the wage-setting curve is flatter in Germany compared to the UK and Denmark.

Third, transfers to unemployed households are high in Denmark, significantly lower in Germany and lowest in the UK. Both collective bargaining and efficiency wage models predict that this would result, *ceteris paribus*, in a flatter wage-setting curve in Denmark and Germany compared to the UK.

Fourth, high and progressive taxes may affect the responsiveness of wages for different groups of workers in different ways. Lockwood *et al.* (2000) find evidence that progressive taxes increase wages for high and medium skilled workers, while wages of less skilled workers remain unaffected. Consequently, it is reasonable to expect that the wage responsiveness to labor supply shocks declines with the skill level of workers in countries with

[3]Others have argued that the relationship is monotonic (Di Tella and MacCulloch, 2005).

very progressive tax systems such as Denmark.

Fifth, product markets are much more regulated in Germany compared to the UK and Denmark. This would reduce the scope for collective bargaining in the latter countries and, hence, increase the responsiveness of wages to changes in the unemployment rate. However, the high exposure to international competition, particularly in the manufacturing sector in Germany, might reduce the potential impact of product market regulation in that country.

Thus, the slope of the wage-setting curve is likely to vary between the three countries considered in our study as the complexity of the institutional differences allows no unambiguous predictions. It remains therefore an empirical question whether and to what extent the elasticity of the wage-setting curves will differ.

Finally, following a suggestion by Card (1995), we do not assume that the slope of the wage-setting curve is uniform for all types of workers. The slope of the wage-setting curve is likely to vary with the bargaining power and the human capital characteristics of workers. We therefore allow the elasticity of the wage-setting curve to differ by skill levels in our empirical analysis.

2.2 A wage-setting model of migration

Consider an economy where output is produced with different types of labor and capital. Let $\overline{N}_\ell$ be the pre-migration labor force in each cell of the labor market, where the subscript $\ell = 1, \ldots, n$ denotes the type of labor. The post-migration labor force is then given by

$$N_\ell = \overline{N}_\ell + \gamma_\ell M, \qquad \sum_{\ell=1}^{n} \gamma_\ell = 1, \tag{1}$$

where M is the total stock of migrants γ_ℓ is the share of workers of type ℓ in the total immigrant inflow.

Firms produce varieties of a differentiated good under monopolistic competition. Production involves some fixed setup costs, but thereafter each firm produces output with constant returns to scale. Hence, production of a representative firm i is given by

$$Y^i = F(\mathbf{L}^i, K^i), \tag{2}$$

where Y^i denotes a variety of the output good, $\mathbf{L}^i$ the vector of labor inputs, K^i is physical capital. Firms do not necessarily employ the entire labor force, i.e. $L_\ell \leq N_\ell$. The production technology $F(\cdot)$ is increasing, concave, twice continuously differentiable in all inputs and homogeneous of degree one.

Wages and the demand for labor are determined sequentially. In the first stage wages are determined, and in the second stage, given the agreed wages, firms set prices and hire

workers up to a level where profits are maximized. Suppose that each firm faces a constant elasticity of demand $\eta > 1$. Profit maximization implies that the wage rate equals

$$w_\ell^i = \nu^{-1} P^i Y_{L_\ell}^i \quad \forall\ \ell,$$

where the mark-up, ν, is $(1 - 1/\eta)^{-1}$, P^i is the product price of variety i of the output good, and $Y_{L_\ell}^i$ is the marginal product of labor of type ℓ.

Assuming that firms are identical, we can move to the level of the aggregate economy by writing $w_\ell^i = w_\ell$, $Y_{L_\ell}^i = Y_{L_\ell}$, and $P^i = P = 1$, where we have normalized the price level to one. The real wage is then given by

$$w_\ell = \nu^{-1} Y_{L_\ell}, \quad \forall\ \ell. \tag{3}$$

In the first stage of the decision process, firms and employees set wages as a function of unemployment, which enables us to write the aggregate wage-setting equation as

$$w_\ell = f_\ell(u_\ell), \qquad f_\ell' < 0, \quad \forall\ \ell, \tag{4}$$

where f_ℓ is a function that captures the response of the wage to the unemployment rate $u_\ell = 1 - L_\ell/N_\ell$. The rationale behind equation (4) is that a higher unemployment rate weakens the outside options of workers and, hence, reduces their wages, as outlined in Section 2.1.

The wage-setting relation in equation (4) and the relationship between the real wage and marginal product of labor in equation (3) allow us to solve for the employment response to a change in foreign labor supply. This requires solving a system of equations which is determined by the wage-setting curves and the production function for each type of labor. This system has to satisfy, in each cell of the labor market, the implicit function

$$\Omega_\ell(\mathbf{L}, M) \equiv \nu^{-1} Y_{L_\ell}(\mathbf{L}, K(\mathbf{N}(M))) - f_\ell(u_\ell(L_\ell, N_\ell(M))) = 0, \quad \forall\ \ell. \tag{5}$$

Note that equation (5) implies that the capital stock may adjust to labor supply shocks, i.e., that $\partial K/\partial \mathbf{N} \geq 0$. Differentiating this system implicitly with respect to a marginal labor supply shock through immigration yields, for the change in employment

$$\frac{d\mathbf{L}}{dM} = \left(\frac{\partial \nu^{-1} \mathbf{Y_L}}{\partial \mathbf{L}} - \frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} \right)^{-1} \times \left(\frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} - \frac{\partial \nu^{-1} \mathbf{Y_L}}{\partial K} \frac{\partial K}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} \right), \tag{6}$$

where $\mathbf{Y_L}$ denotes a vector of the marginal products of labor in each cell as in equation (3), $\mathbf{f}$ the vector of wage-setting functions that determines the wage response to the unemployment rate as outlined in equation (4), and $\mathbf{u}$ is the vector of unemployment rates.

Having solved for the equilibrium employment response, it is straightforward to use

the relation in equation (3) to derive the wage effects of migration:

$$\frac{d\mathbf{w}}{dM} = \frac{\partial \nu^{-1} \mathbf{Y_L}}{\partial \mathbf{L}} \frac{d\mathbf{L}}{dM} + \frac{\partial \nu^{-1} \mathbf{Y_L}}{\partial K} \frac{\partial K}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM}. \tag{7}$$

It is clear that the employment response to migration in equation (6) increases with (i) the absolute value of the elasticity of the wage with respect to the unemployment rate, (ii) the adjustment of the capital stock to the labor supply shock and (iii) the elasticity between the marginal product of labor and the capital stock. The response declines with the absolute value of the elasticity between the marginal product of labor and employment.[4] In contrast, wages decline with the absolute elasticity of the wage-setting curve.

This simple model establishes the general framework for our analysis. In the empirical specification of the model we distinguish labor by education, work experience and national origin. The wage-setting curves are estimated separately for the different skill groups in the labor force, while the labor demand functions for the different types of labor are estimated by using a nested CES production function.

3 Description of the data

We use three micro data sets in our empirical analysis: the Integrated Database for Labor Market Research (IDA) in Denmark, the Integrated Employment Biographies (IEB) in Germany and the Quarterly Labour Force Survey (LFS) for the UK. The IDA and the IEB are administrative data derived from social security records, while the LFS is based on quarterly household surveys. The IDA covers the entire working-age population, while the IEB is a 5 percent sample of employees and benefit recipients in Germany. The LFS is a survey of approximately 60,000 households living at private addresses in the UK.[5] Although smaller than the German and Danish samples, the LFS is the largest UK data source available to researchers which provides information on wages and employment spells for natives and immigrants.[6] Because of its smaller size, there may be concerns that UK estimates suffer from attenuation bias as a result of measurement error in the proportion of foreigners in a labour market cell. Aydemir and Borjas (2011) argue that this attenuation bias may explain the small (often insignificant) coefficient estimates in wage effect of migration papers. However, our estimate of the size of the likely bias (see Aydemir and Borjas Eq. 8) is under 2%, largely because the cell sizes we use are still relatively large.

The sample periods vary slightly across the three countries. We use the 1990-2006

[4]Note that the derivative of the unemployment rate with respect to employment is positive, while it is negative with respect to the labor force.

[5]The sampling rate is 0.16% of GB households (Office for National Statistics, 2011).

[6]The LFS has been used recently to estimate wage effects of immigration in the UK by Dustmann *et al.* (2008) and Manacorda *et al.* (2012).

period in Denmark[7], the 1992–2008 period in Germany,[8] and the 1993–2009 period in the UK.[9]

We harmonize the definitions and categories in the three data sets as far as possible, although some differences remain. The most important difference is that the Danish IDA and the UK LFS allow us to identify immigrants by country of birth, while the German IEB distinguishes natives and foreigners by citizenship. We therefore use further information from the IEB to get as close as possible to the internationally comparable concept of foreign-born. First, we classify all individuals as foreigners who are reported as foreign citizens in their first available spell. This prevents naturalizations from being recorded as a declining foreigner share in our sample. Second, we define ethnic Germans — so-called *Spätaussiedler* — as foreigners. In the IEB ethnic Germans are coded as German citizens. However, we are able to identify this group by their participation in active labor market programs especially designed for ethnic Germans (such as language courses and other integration programs). This enables us to identify the overwhelming share of this non-trivial immigrant influx of about 3.1 million persons since the fall of the Iron Curtain. The main remaining difference between the measure of migrants in the German data and the foreign-born measure is that we are not able to exclude second- and third-generation immigrants who did not acquire German citizenship before entering the labor force.[10]

We classify native and foreign workers by education and work experience. In our view it is most suitable to distinguish three education groups in European labor markets: low skilled workers, skilled workers and workers with a university degree. Since educational systems differ across our three countries, we have used country-specific classifications. Statistics Denmark provides information on the highest attained education. Low skilled workers are defined as those who left school without any further education, medium skilled workers have a vocational training or a short academic education and high skilled workers hold at least a master degree. In Germany we classify workers by educational degrees: low skilled workers have no vocational degree, medium skilled workers a vocational training degree and high skilled workers a university degree. In the UK, low skilled workers are defined as those who left school at 17 or younger, medium skilled workers are those who left school between 18 and 20, and high-skilled individuals left education at 21 years or older.[11]

We distinguish four groups of work experience: 5 years or less, 6 to 10 years, 11 to 19 years, 21 years or more. This ensures that we have sufficient observations in each cell of

[7]The 2006–2008 waves of the IDA data set were not yet available when we started our empirical investigation.

[8]Note that starting in 1992 enables us to cover the unified Germany throughout our empirical analysis.

[9]The UK LFS does not provide wage information until the last quarter of 1992.

[10]As a robustness check, we have also produced data sets for Denmark and the UK which identify foreigners by citizenship. The results do not differ greatly, and we therefore restrict the analysis presented here to the more common concept of foreign-born.

[11]These three groups capture the three basic levels of educational qualification in the UK, namely GCSE, A-level and university degree.

the labor market in all three data sets.

We consider male and female workers throughout our analysis. Since the German data set does not contain information on hourly wages and hourly wages for part-time workers with few hours are known to be of bad quality, we consider full-time employees in all three data sets. Unemployed individuals are identified in the Danish and the German data set as recipients of unemployment benefits and allowances, while the UK LFS relies on the self-reported ILO definition of unemployment. Wages are deflated by the CPI.

A detailed description of the three data sets and the definitions of the variables are presented in Appendix B.

Table 2 presents some descriptive information of the data. The skill structure of employment reveals some interesting differences between the three countries. In Denmark, the immigrant workforce is concentrated in both the low and high education groups relative to natives. In Germany, immigrants are over-represented in the group with low education, but under-represented in the medium and high skilled groups. Finally, in the UK, immigrant workers have higher shares in the medium and high education groups.

In all three countries we observe that immigrants are disproportionately affected by unemployment. In Denmark the unemployment rates of immigrants at the end of the sample period exceed those of natives by a factor between 2 and 3 depending on the education group; in Germany by a factor of 1.4 and 1.8, in the groups of medium and high skilled workers, respectively, while unemployment of immigrants is below that of natives in the less skilled group. In the UK, differences in unemployment rates between immigrants and natives vary by a factor of between 1.3 and 1.8.

Not surprisingly, wages of immigrant workers are lower than those of native workers. In Denmark, the wages of low, medium and high-skill immigrants are, respectively, 1.5%, 6.5% and 9.3% below those of equivalent natives at the end of the sample period. In Germany, wage levels of immigrants are about 8% below those of natives in all education groups at the end of the sample period. In the UK, wage differentials between native and immigrant workers are 9.2% for low, 17.6% for medium, and 9.9% for high skilled employees at the end of the sample period.

4 Empirical specification and estimation

4.1 Wage-setting equations

The first step of our empirical analysis is the estimation of the wage-setting equations. As outlined in Section 2, we expect the wage-setting curves to vary across different groups in the labor market. For the estimation we use the variance in the data across education ($q = 1, 2, 3$) and experience groups ($j = 1, 2, 3, 4$) as defined in Section 3, but impose the

Table 2: Employment, unemployment, and wages by education, end of sample period

	Education group[a] in % of total employment			Unemployment rate[b] by education group in %			Wages[c] by education group		
	Low	Med	High	Low	Med	High	Low	Med	High
					Denmark				
Natives	27.54	64.58	7.88	5.43	2.39	2.88	151.87	176.75	237.87
Immigrants	44.15	46.89	8.96	15.44	8.54	7.22	149.59	165.17	215.65
					Germany				
Natives	6.15	78.57	15.28	38.49	12.51	4.86	73.20	85.87	144.60
Immigrants	27.23	62.94	9.83	30.33	18.08	8.86	67.32	78.86	133.68
					UK				
Natives	55.30	20.79	23.91	12.40	8.50	4.82	10.00	11.88	15.73
Immigrants	23.02	29.33	47.65	18.27	11.57	8.29	9.15	9.79	14.26

[a] In Denmark, low education is defined as no vocational training, medium education as vocational training or short academic education, and high education as a master degree or above. In Germany, low education is defined as no vocational training, medium education as vocational training, and high education by a university degree. In the UK, education levels are defined by age left school: low < 18, medium: 18-21, high: ≥ 21.

[b] The unemployment rate is defined here as the ratio of all unemployed persons to the sum of full-time employed and all unemployed persons. Note that part-time workers who are not covered by our definition of employed workers are disproportionately represented in the low skilled segment of the labor market.

[c] In Denmark, wages are defined as hourly wages in Danish Crowns (2000 constant prices), in Germany as daily wages in Euros (2005 constant prices), and in UK as hourly wages in British Pounds (2005 constant prices).

restriction that the slope parameter of the wage-setting curve is uniform across experience groups. This increases the efficiency of estimation without imposing a too demanding restriction on the parameter of interest.

More specifically, we estimate the following wage-setting equation separately for each country:[12]

$$\ln w_{qjt} = \beta_q \ln u_{qjt} + \lambda_{qj}\tau_{qjt} + \eta'\mathbf{x}_t + \epsilon_{qjt}, \tag{8}$$

where u_{qjt} denotes the unemployment rate in education-experience cell (q, j), τ_{qjt} is an education-experience specific deterministic time trend, and $\mathbf{x}_t$ is a vector of control variables. As controls we use in all three countries the log of real GDP, the log CPI, the log oil price index and the log export performance index.[13] We thus capture both domestic and external shocks in output, demand, supply and prices. In the UK we furthermore employ a dummy variable for the minimum wage. The error term ϵ_{qjt} is specified as a one-way error component model with a fixed effect for each education-experience cell (q, j).

The specification of equation (8) is similar to that used in the wage-setting and wage curve literature, but it differs in that it allows the elasticity between wages and the unemployment rate to vary across education groups. This enables us to capture different degrees of wage flexibility in different skill segments of the labor market.

[12] Country subscripts are omitted to clarify the notation

[13] see Appendix B for a definition of variables

Unobserved shocks may affect wages and the unemployment rate simultaneously. Moreover, unemployment might itself be a function of wages. In order to address this potential endogeneity problem, we estimate equation (8) by 2SLS. We consider two types of instruments. Our first instrument draws on the regional wage curve literature (e.g. Bartik, 1991; Blanchard and Katz, 1992; Blanchflower and Oswald, 1994) and uses an industry composition variable that measures how much of the deviation in employment growth from average employment growth in an education-experience cell can be explained by the concentration of workers in the respective cell in fast- or slow-growing industries (see Annex B.3 for the calculation of the variable). This variable captures how much of the change in employment can be attributed to a shift in sectoral structure, triggered by exogenous factors such as technological change.

Our second instrument captures shifts in labor demand triggered by exogenous shocks in product markets. We use an export demand index for this purpose, which is constructed as the log of GDP per capita at constant prices and exchange rates of all OECD countries weighted by their average share in exports of the respective country during the sample period (see Annex B.3). This variable can be considered as exogenous if the economic activity of the trading partners is not affected by the wage level in the country of interest.

Table 3 presents the regression results for Denmark, Germany and the UK. All regressions have the expected negative sign for the coefficient on the unemployment rate and are highly significant in most cells of the labor market in all three countries. The only exception is the regression for low skilled workers in the UK, where the coefficient is only significant at the 10%-level. Moreover, our test results support our instrumentation strategy. The Hansen-J-statistics do not reject the null of no overidentification in all three countries. High values of the Cragg-Donald Wald F-statistics reject the hypothesis that the instruments are weak and suggest that estimation bias is small. This is also confirmed by the first stage regression results. Finally, the Kleibergen Paap rk LM-statistics rejects the null of underidentification at the 1% level in all three countries.

The pooled regression results (across all three skill groups combined) indicate that the elasticity of the wage-setting curve is relatively high in the United Kingdom (-0.12), followed by Germany (-0.10) and Denmark (-0.06). The pooled results confirm by and large the estimates in the regional wage curve literature, which usually find an elasticity of about -0.1 (Bell *et al.*, 2002; Blanchflower and Oswald, 1994; 2005). The absolute value of the elasticity of the wage-setting curve is largest in the UK, i.e. in that country where wages are set at the firm level, where union density is low, where employment protection is weak and the replacement rate is low compared to the other countries. This confirms our *a priori* expectations. It is also striking that the elasticity of the wage-setting curve is much larger in Germany compared to Denmark. Although both countries are characterized by industry-level bargaining, this can be traced back to a much higher union density and a higher net replacement rate for unemployed workers in Denmark, which in turn raises the value of the outside option for Danish workers compared to German ones.

Table 3: IV-estimates of the wage-setting curve

Education level	Coeff.	SE	R^2	Obs.
		Denmark[a]		
All	-0.064^{***}	(0.010)	0.72	180
Low	-0.080^{***}	(0.014)	0.70	60
Medium	-0.075^{***}	(0.019)	0.88	60
High	-0.044^{***}	(0.015)	0.57	60
		Germany[b]		
All	-0.099^{***}	(0.023)	0.65	180
Low	-0.064^{**}	(0.031)	0.75	60
Medium	-0.104^{***}	(0.028)	0.59	60
High	-0.158^{***}	(0.043)	0.70	60
		UK[c]		
All	-0.121^{***}	(0.021)	0.92	180
Low	-0.060^{*}	(0.031)	0.98	60
Medium	-0.084^{***}	(0.020)	0.94	60
High	-0.221^{***}	(0.053)	0.76	60

Standard errors are clustered at the education-experience level.– ***, **, * denote the 1%-, 5%-, 10%-significance levels, respectively.– Dependent variable is the log wage in each education-experience class.– Macroeconomic controls are the log GDP per capita, the log CPI, the log oil price index, the log export performance index and a deterministic time trend in each regression. The regression for the UK includes also a dummy variable for the minimum wage.– IVs are the lagged log export demand variable and the lagged industry-mix variable.

[a] The p-value of the Hansen-J-statistic is 0.64, the Cragg-Donald Wald F-statistic for weak instruments is 25.10 and the Kleibergen-Paap rk LM test statistic for underidentification is 26.98^{***} in the pooled Danish regression.

[b] The p-value of the Hansen-J-statistic is 0.85, the Cragg-Donald Wald F-statistic for weak instruments is 25.49 and the Kleibergen-Paap rk LM test statistic for underidentification is 41.15^{***} in the pooled German regression.

[c] The p-value of the Hansen-J-statistic is 0.91, the Cragg-Donald Wald F-statistic for weak instruments is 55.06 and the Kleibergen-Paap rk LM test statistic for underidentification is 35.67^{***} in the pooled UK regression.

The estimation results by skill groups reveal interesting insights as well. In Germany and the UK, the absolute value of the elasticity of the wage-setting curve is monotonically increasing with the skill level, suggesting that wage-flexibility is highest in the labor market segment of workers with a college or university degree. This might reflect the fact that the union density is lower there and collective wage contracts are less effective in this segment. In contrast, we find that the elasticity of the wage-setting curve is lowest in the high-skilled segment in Denmark. This can be explained by two institutional features. First, in contrast to Germany and the UK, union density is not declining and collective wage agreements are still effective in the high-skilled segment of the Danish labor market. Second, high and progressives taxes result in higher wage requests and a lower wage responsiveness for high and medium skilled workers in Denmark (Lockwood *et al.*, 2000).

4.2 Labor demand equations

For the estimation of the labor demand equation, we have to impose some structure on the aggregate production function of the economy. In the same way as Borjas (2003), Brücker and Jahn (2011) and Ottaviano and Peri (2012) we follow Card and Lemieux (2001) and use a nested CES production function. More specifically, we employ a four-level production function which groups the workforce into $q = 1, \ldots, 3$ education groups, $j = 1, \ldots, 4$ work experience groups, and $k = 1, 2$ (native, foreign) nationality groups. Although the nested CES function imposes some restrictions on the elasticities of substitution, it has the advantage that it is parsimonious in parameters.

Suppose that aggregate production in equation (2) can be represented by a standard Cobb-Douglas production function:

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha}, \tag{9}$$

where Y_t denotes aggregate output, A_t is an exogenous parameter which captures total factor productivity, L_t is aggregate labor input, K_t is physical capital, α is the production elasticity of labor, and t is a time index.

The aggregate labor input, L_t, can be built up from L_{qjkt}, the number of workers of education q, experience j and national origin k in the following way:

$$L_{qjt} = \left[\sum_{k=1}^{2} \theta_{qjk} L_{qjkt}^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)} \qquad \sum_{k=1}^{2} \theta_{qjk} = 1, \tag{10}$$

$$L_{qt} = \left[\sum_{j=1}^{4} \theta_{qj} L_{qjt}^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)} \qquad \sum_{j=1}^{4} \theta_{qj} = 1, \tag{11}$$

$$L_{t} = \left[\sum_{q=1}^{3} \theta_{qt} L_{qt}^{(\delta-1)/\delta} \right]^{\delta/(\delta-1)} \qquad \sum_{q=1}^{3} \theta_{qt} = 1. \tag{12}$$

Thus, L_{qt} is a labor composite that aggregates all workers with education q and L_{qjt} aggregates native and migrant workers of education q and experience j. The technology parameters θ_{qt}, θ_{qj}, and θ_{qjk} determine the productivity levels of the respective factor. We allow the productivity parameter θ_{qt} to vary over time since skill-biased technological progress might affect the productivity of various types of labor in different ways (Katz and Murphy, 1992). The other production parameters are assumed to be constant over time.

Finally, $\delta > 0$, $\rho > 0$, and $\sigma > 0$ are constant parameters measuring the elasticity of substitution between labor of different educational levels, between workers with similar education but different work experience, and between native and migrant workers with similar education and experience levels. Our *a priori* expectation is that workers within each experience group are closer substitutes than those across skill groups, which implies that $\rho > \delta$.

Whether foreign and native workers in each education and experience group are imperfect substitutes is controversial in the literature (Borjas *et al.*, 2008; Ottaviano and Peri, 2012). We will therefore investigate whether native and foreign workers are imperfect substitutes.

Based on equation (3) we can write the real wage rate as the marginal product of labor divided by the mark-up factor. Using the nested CES production function we thus write the log wage of a worker with skill q, experience j and national origin k as

$$\begin{aligned} \ln w_{qjkt} &= \ln\left(\nu^{-1}\alpha A_t^{1/\alpha}\right) + \frac{1}{\delta}\ln L_t + \ln\theta_{qt} - \left(\frac{1}{\delta}-\frac{1}{\rho}\right)\ln L_{qt} \\ &+ \ln\theta_{qj} - \left(\frac{1}{\rho}-\frac{1}{\sigma}\right)\ln L_{qjt} + \ln\theta_{qjk} - \frac{1}{\sigma}\ln L_{qjkt} + \frac{1-\alpha}{\alpha}\ln\kappa_t, \end{aligned} \tag{13}$$

where $\kappa_t \equiv K_t/Y_t$ denotes the capital-output ratio.

From equation (13) we can derive the labor demand functions. Our identification strategy differs from that traditionally used in the literature. As noted, the literature relies on the assumption of perfect competition and clearing labor markets, and, hence, treats employment as the exogenous and wages as the endogenous variable (Card and Lemieux, 2001; Borjas, 2003; Ottaviano and Peri, 2012). In contrast, it follows from our wage-setting framework that labor demand is endogenously determined once wages are fixed. Employment is therefore the dependent variable, and the wage is the independent variable.

Let us start with the identification of the elasticity of substitution between native and foreign workers. Based on equation (13) we can express the relative demand for native and foreign workers with education q and experience j as

$$\ln\left(L_{qj1t}/L_{qj2t}\right) = \sigma\ln\left(\theta_{qj1}/\theta_{qj2}\right) - \sigma\ln\left(w_{qj1t}/w_{qj2t}\right),$$

where the index $k = 1, 2$ denotes natives and foreigners respectively. We estimate this equation as

$$\ln\left(L_{qj1t}/L_{qj2t}\right) = D_{qj} - \sigma \ln\left(w_{qj1t}/w_{qj2t}\right) + \varepsilon_{qjt}, \tag{14}$$

where D_{qj} denotes a vector of dummy variables for each education-experience cell and ε_{qjt} a zero-mean disturbance term. Notice that by using the ratio of the wage equations for natives and foreigners, the education and experience levels of the nested production function disappear, such that we do not have to use control variables in estimating the elasticity of substitution between natives and foreigners.

Following the approach of Ottaviano and Peri (2012) the dummy variables in each education-experience cell capture the log of the relative labor productivity of natives and foreigners times the elasticity of substitution. This implies that the relative productivity of natives and immigrants varies across education and experience groups but is constant over time.[14]

Estimating equation (14) by OLS can generate inconsistent results if unobserved idiosyncratic shocks affect both the relative labor demands and relative wages of natives and foreigners. To address this issue we estimate equation (14) with instrumental variables.

Because of the potential endogeneity of the wage variable we employ an instrumental variable strategy which uses instruments related to the reservation wage, such as the number of children in the household and the income of the unemployed. We would not expect the same determinants of the reservation wage across the three countries because of the different institutional settings, and so we allow the set of instruments to vary across countries.

As instruments for the relative wage we use the ratio of the average number of children in each education-experience group in Denmark and Germany.[15] This instrument is expected to be closely correlated with the reservation wage and, hence, the actual wage, but not with labor demand. As additional instruments we use the average tax burden in Denmark and the government ideology index in Germany. The former instrument is again expected to affect the reservation wage without being correlated with labor demand. The latter instrument is calculated as the share of left- and right-wing parties in the government weighted by their seats in parliament (Bjørnskov, 2008).[16] This instrument captures government policies and legislation that can affect reservation wages through different channels, such as progressive taxation, generosity of welfare benefits, and so on. Note that

[14] Borjas *et al.* (2008) suggest also including interaction dummies of the education-experience-specific fixed effects with linear time trends, which would absorb a large part of the identifying variation. However, there is no empirical evidence that the relative labor productivity of foreigners has changed systematically over time at a given level of education and work experience.

[15] The average number of children in each cell is taken from the GSOEP as there is no information on children in the German data set. Our argument is that in Germany children aged between 8 and 16 are usually not covered by the child care system. However, as there are two empty cells for the number of children aged between 8-16 for high skilled foreigners we use the number of children below 16 for the estimates of the elasticity of substitution between natives and foreigners.

[16] We are grateful to Christian Bjørnskov who provided the ideology indices.

foreigners' access to welfare benefits is a core issue in the policy debate, which in turn affects relative reservation wages for foreigners and natives. Finally, in the UK we use the minimum wage in British Pounds for adult workers as an instrument, which should affect wages of natives and foreigners in different ways. The first stage regressions results show indeed that this instrument is closely correlated with ratio of native and foreign wages. Other instruments for the UK did not have much explanatory power in the first stage regressions, and so we present the results for the fully identified model here.

Table 4: 2SLS estimates of the elasticity of substitution between natives and foreigners

	Denmark[a]		**Germany**[b]		**UK**[c]	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
σ	-11.099^{***}	(2.044)	-6.046^{***}	(1.473)	-12.556^{***}	(3.201)
Hansen J-statistics (p-value)	0.27		0.33		–	
Kleibergen-Paap LM statistics	19.39^{***}		31.24^{***}		11.87^{***}	
Cragg-Donald Wald F statistics	15.29		15.76		10.81	

[a] IVs are the log ratio of the average number of children aged 17 or below and its first lag, and the log ratio of the tax burden and its first lag.
[b] IVs are the ratio of the average number of children aged 16 or below and ideology index.
[c] IV is the minimum wage of adult workers in British Pounds.

Table 4 presents the 2SLS estimates of equation (14). In all three countries we have the expected signs for the elasticity of substitution. We find that the elasticity of substitution between natives and foreigners is relatively high in the UK (-12.6) and in Denmark (-11.1), but low in Germany (-6.0). We have tested whether σ differs across education groups in each country, and we cannot reject the null hypothesis that all coefficients σ_q are identical across education groups. Consequently, we use the pooled elasticity for further analysis and in our simulations.

Our estimates are about one third higher than those of Manacorda *et al.* (2012) for the UK, who estimate an elasticity of -7.8. In Germany, our estimates are quite similar to that estimated by Brücker and Jahn (2011) (-7.0) and Felbermayr *et al.* (2010) (-7.4), but much lower than the estimates by D'Amuri *et al.* (2010) (-21.7).[17] For Denmark, comparable estimates do not exist, to the best of our knowledge.

The finding that natives and immigrants are imperfect substitutes in the labor market has important consequences for the wage and employment effects of immigration. The lower the elasticity of substitution between natives and immigrants the more are the adverse labor market effects of immigration concentrated in the foreigner cells of the labor market. We thus expect that foreigners are particularly affected in Germany, while the effects are much more dispersed across the native and foreigner cells in the UK and Denmark.

In the next step we estimate the elasticity of substitution between experience groups.

[17] Note that this last paper uses another estimation and instrumentation strategy.

Using equation (13) we can estimate the demand for the labor composite L_{qjt} as

$$\ln L_{qjt} = D_t + D_{qt} + D_{qj} - \rho \ln w_{qjt} + \upsilon_{qjt}, \tag{15}$$

where the D_t fixed effects control for the variance of

$$\rho \ln \left(\nu^{-1} \alpha A_t^{1/\alpha} \kappa_t^{(1-\alpha)/\alpha} \right) + \frac{\rho}{\delta} \ln L_t,$$

the D_{qt} fixed effects control for the variation in

$$\rho \ln \theta_{qt} - \left(\frac{\rho}{\delta} - 1 \right) \ln L_{qt},$$

and the D_{qj} fixed effects control for the variance in $\rho \ln \theta_{qj}$ (the productivity term times the elasticity of substitution), which is assumed to be constant over time. υ_{qjt} denotes the zero-mean disturbance.

The labor composite is then calculated as

$$\hat{L}_{qjt} = \left[\hat{\theta}_{qj1} L_{qj1t}^{(\hat{\sigma}-1)/\hat{\sigma}} + \hat{\theta}_{qj2} L_{qj2t}^{(\hat{\sigma}-1)/\hat{\sigma}} \right]^{\hat{\sigma}/(\hat{\sigma}-1)}$$

where we use our estimates of the education-experience-specific fixed effects from equation (14) to calculate the productivity parameters for native and foreign workers as

$$\hat{\theta}_{qj1} = \frac{\exp(\hat{D}_{qj}/\hat{\sigma})}{1 + \exp(\hat{D}_{qj}/\hat{\sigma})}$$

and

$$\hat{\theta}_{qj2} = \frac{1}{1 + \exp(\hat{D}_{qj}/\hat{\sigma})}.$$

We estimate equation (15) by 2SLS since the wage might be again endogenous. As instruments we use the tax burden in Denmark, the number of dependent children aged 8–16 and the average level of unemployment benefits in each education-experience cell in Germany, and the number of dependent children aged below 16 years and of the median household income of the unemployed in the UK. We expect that unemployment benefits and allowances and the median household income of the unemployed are valid instruments since they affect the reservation wage but not labor demand. The rationale for using dependent children and the tax burden as instruments is the same as that in used previous regressions.[18]

The regression diagnostics in Table 5 do not reject the null hypothesis of no overidentification and reject the null hypothesis of underidentification in all three countries. However, we can reject the hypothesis of weak instruments only in case of Germany, such

[18]The median household income of the unemployed is taken from the BHPS. The definition of the age groups vary across countries due to different systems of schooling and child care.

Table 5: 2SLS estimates of the elasticity of substitution across education-experience groups

	Denmark[a]		**Germany**[b]		**UK**[c]	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
ρ	-4.488^{*}	(2.649)	-3.209^{***}	(0.671)	-3.288^{**}	(1.392)
Hansen J-statistics (p-value)	0.83		0.47		0.96	
Kleibergen-Paap LM statistics	7.20^{*}		48.87^{***}		12.71^{***}	
Cragg-Donald Wald F statistics	2.89		16.92		4.37	

[a] IVs are the log of the tax burden and its first and second lag.
[b] IVs are the average number of dependent children aged 8–16 and the log of unemployment benefits and its first and second lag.
[c] IVs are the log of the first and second lag of the average number of dependent children aged 15 or below and the first and second lag of the median household income of the unemployed.

that the results have to be interpreted with some caution. The results indicate that the elasticity of substitution across experience cells is highest in Denmark (−4.5), followed by the UK (−3.3) and Germany (−3.2). The results for Germany are identical to those found by D'Amuri *et al.* (2010) (−3.2), but below the estimates by Brücker and Jahn (2011) (−8.6) and Felbermayr *et al.* (2010) (−13.0). The difference with the estimates by Brücker and Jahn (2011) might be traced back to the fact that they estimate the elasticity of substitution for eight experience groups, while we estimate it for four, which should reduce the elasticity of substitution. Overall, our results for all three countries are consistent with those found using the standard identification strategy in the international literature (see e.g. Katz and Murphy, 1992, Card and Lemieux, 2001, Borjas, 2003, Ottaviano and Peri, 2012).

Finally, the elasticity of substitution between education groups is estimated analogously as

$$\ln \hat{L}_{qt} = D_t + D_q + \beta_q \tau_{qt} - \delta \ln w_{qt} + \xi_{qt}, \tag{16}$$

where the time-specific fixed effects D_t control for the variance of

$$\delta \ln \left(\nu^{-1} \alpha A_t^{1/\alpha} \kappa_t^{(1-\alpha)/\alpha} \right) + \ln L_t$$

and other macroeconomic fluctuations. The education-specific fixed effects D_q and the education-specific deterministic time trend τ_{qt} control for the variance in the term $\delta \ln \theta_{qt}$, which captures the variance in the skill-specific productivity parameter which is driven, *inter alia*, by skill-biased technological progress (see Katz and Murphy, 1992 for a similar specification). ξ_{qt} denotes a zero-mean random disturbance.

The labor composite $\hat{L}_{qt}$ is computed as

$$\hat{L}_{qt} = \left[\sum_{j=1}^{4} \hat{\theta}_{qj} \hat{L}_{qjt}^{(\hat{\rho}-1)/\hat{\rho}} \right]^{\hat{\rho}/(\hat{\rho}-1)}$$

where the estimated efficiency parameters $\hat{\theta}_{qj}$ are derived from the fixed-effects estimates as

$$\hat{\theta}_{qj} = \frac{\exp(\hat{D}_{qj}/\hat{\rho})}{\sum_j \exp(\hat{D}_{qj}/\hat{\rho})}$$

.

We estimate equation (16) again by 2SLS using the number of dependent children in Denmark, the number of dependent children aged 8–16 and an income satisfaction variable in Germany, and the number of dependent children aged ≤ 15 and the median household income of the unemployed in the UK as instruments.[19]

Table 6: 2SLS estimates of the elasticity of substitution between education groups

	Denmark[a]		**Germany**[b]		**UK**[c]	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
δ	-3.207^{***}	(0.887)	-2.977^{*}	(1.662)	-0.858^{**}	(0.215)
Hansen J-statistics (p-value)	0.14		0.64		0.56	
Kleibergen-Paap LM statistics	7.06^{**}		8.00^{**}		5.51^{*}	
Cragg-Donald Wald F statistics	3.62		2.74		6.63	

[a] IVs are the average number of children aged 17 or below and its first lag.
[b] IVs are the average number of children aged 8–16 and a income satisfaction variable in Germany.
[c] IVs are the average number of children aged 15 or below and the median household income of the unemployed in the UK.

The regression diagnostics presented in Table 6 do not reject the null hypothesis of no overidentification and reject the null hypothesis of underidentification in all three countries. However, the F statistic suggests we may have weak instruments. The estimated elasticity of substitution between education groups is again largest in Denmark (-3.2) followed by Germany (-3.0). The UK is an outlier with an estimated elasticity of (-0.84), suggesting that education groups are not close substitutes. Our results for Germany are very close to those found by Brücker and Jahn (2011) (-2.9) based on a similar identification strategy and match also those of D'Amuri *et al.* (2010) (-2.9).

In summary, we find that — as predicted by our nested CES-production function — the elasticity of substitution between natives and foreigners is larger than the elasticity of substitution between experience groups, and that the elasticity of substitution between experience groups is larger than that between education groups. Overall, our strategy to derive the elasticities of substitution from labor demand equations rather than from wage equations yield slightly lower elasticities of substitution compared to the traditional literature, but are not far away from their findings.

[19] The income satisfaction variable is taken from the GSOEP household survey and the median household income of unemployed for the UK is taken from the BHPS. Both instruments should be closely correlated with the wage but not with labor demand.

5 Simulating the impact of immigration

To calculate the wage effects of a labor supply shock due to immigration, we first compute the employment effects. The general solution for the employment effects is given in equation (6), and an explicit solution for our case with 24 types of labor and a nested CES production function is provided in Appendix A.

In the second step, we differentiate the wage equation (13) with respect to the employment changes in all cells of the labor market and with respect to a change in the capital-output ratio triggered by immigration. This gives us the wage response to immigration:

$$\begin{aligned}\frac{dw_{qjkt}}{w_{qjkt}} &= \frac{1}{\delta}\sum_z\sum_x\sum_m\left(s_{zxmt}\frac{dL_{zxmt}}{L_{zxmt}}\right) \\ &- \left(\frac{1}{\delta}-\frac{1}{\rho}\right)\frac{1}{s_{qt}}\sum_x\sum_m\left(s_{qxmt}\frac{dL_{qxmt}}{L_{qxmt}}\right) \\ &- \left(\frac{1}{\rho}-\frac{1}{\sigma_q}\right)\frac{1}{s_{qjt}}\sum_m\left(s_{qjmt}\frac{dL_{qjmt}}{L_{qjmt}}\right) \\ &- \frac{1}{\sigma_q}\left(\frac{dL_{qjkt}}{L_{qjkt}}\right)+\frac{1-\alpha}{\alpha}\frac{d\kappa_t}{\kappa_t}\ ,\end{aligned} \tag{17}$$

where $z = 1,\ldots,3$ indexes education, $x = 1,\ldots,4$ work experience, $m = 1,2$ national origin, and s denotes the share of wages paid to workers in the respective labor market cell in the total wage bill:

$$\begin{aligned}s_{qjkt} &= \frac{w_{qjkt}L_{qjkt}}{\sum_z\sum_x\sum_m w_{zxmt}L_{zxmt}}, \\ s_{qjt} &= \frac{\sum_m w_{qjmt}L_{qjmt}}{\sum_z\sum_x\sum_m w_{zxmt}L_{zxmt}}, \\ s_{qt} &= \frac{\sum_x\sum_m w_{qxmt}L_{qxmt}}{\sum_z\sum_x\sum_m w_{zxmt}L_{zxmt}}.\end{aligned}$$

In this section we simulate the case of a one percent labor supply shock through immigration at the education-experience structure of the immigrant labor force at the end of the sample periods. Our simulations are based on the elasticities of the wage-setting curves in the different segments of the labor market, and the elasticities of substitution between natives and foreigners, experience and education groups. For the simulation of the labor supply shock we use the education and experience structure of the foreign labor force at the end of the sample period in each country.

We simulate both a short- and a long-run scenario. In the simulations of the short-run impact of immigration we assume that the capital stock remains fixed. In the long-

run simulations we assume that the capital stock adjusts completely to an aggregate labor supply shock, such that the capital-output ratio is fixed. The latter assumption is empirically supported by the Kaldor facts on economic growth and can be explained, *inter alia*, by international capital mobility (see Ottaviano and Peri, 2012, for a discussion). Note that empirical estimates suggest that the capital stock adjusts rather fast to labor supply changes.

The parameters for the wage-setting curves are taken from our estimates of equation (8) and the estimates of σ, ρ, and δ from equations (14) – (16). Following the literature, we set α to 0.67 (e.g. Cahuc and Zylberberg, 2001). Having calculated the employment effects of immigration, we use equation (13) for the calculation of the wage effect. The shares of education and education-experience groups in the total wage bill are taken from our data sets. Note that the mark-up factor is a constant that cancels out when we calculate changes of wage and (un-)employment levels.

Table 7 presents the simulation results for Denmark, Germany, and the UK. We have calculated the average effects for the total labor force, the native labor force, and the foreign labor force by educational levels. For the calculation of the average effects, we weight the wage changes by the income share in each cell, and the changes in the unemployment rate by the share in the labor force in each cell.

The aggregate results indicate that a one percent immigration reduces wages in the UK by 0.29%, but only by 0.15% in Denmark and by 0.16% in Germany in the short-term. However, the Kaldor facts and the empirical findings by Ottaviano and Peri (2012) and others suggest that capital stocks adjust fast to labor supply shocks, if not immediately. Not surprisingly, the aggregate wage effects of immigration disappear completely after capital stock adjustment in all three countries.

For the unemployment rate, the opposite picture emerges. We find that a one percent labor supply shock through immigration increases the unemployment rate in the short term by 0.35 percentage points in Germany, by 0.20 percentage points in Denmark, but only by 0.11 percentage points in the UK. In the first place, this result can be traced back to the different elasticities of the wage-setting curves in our three countries. Differences in the labor supply shocks across education, experience and national origin cells of the labor market play also a role. The skill level of the immigrant workforce is particularly low in Germany, such that the labor supply shock affects labor market cells with low wage flexibility and high unemployment. In contrast, immigrants are relatively skilled in the UK, such that immigration involves large wage and low unemployment effects there. In the long-term, after the adjustment of capital stocks, we find that the unemployment rate increases by 0.17 percentage points in Germany and by 0.13 percentage points in Denmark, while it declines slightly by 0.10 percentage points in the UK. Note that migration can involve changes in the unemployment rate even after the adjustment of capital stocks if the composition of the workforce, and, hence, the unemployment risks of the labor force

Table 7: Simulated wage and employment effects of an immigration of 1% of the labor force

	Denmark				**Germany**				**UK**			
	Short-run[b]		Long-run[b]		Short-run		Long-run		Short-run		Long-run	
	Wage change[c]	U-rate change[d]	Wage change	U-rate change	Wage change	U-rate change	Wage change	U-rate change	Wage change	U-rate change	Wage change	U-rate change
						Natives and foreigners						
All education groups	−0.15	0.20	0.00	0.12	−0.16	0.35	0.00	0.17	−0.29	0.11	0.00	−0.10
Low[e]	−0.10	0.31	0.05	0.20	−0.45	1.41	−0.35	1.10	0.11	−0.09	0.32	−0.35
Medium[e]	−0.17	0.12	−0.02	0.07	−0.12	0.18	0.04	0.01	−0.21	0.38	0.07	0.16
High[e]	−0.27	0.40	−0.12	0.30	−0.13	0.08	0.07	−0.01	−0.84	0.28	−0.40	0.18
						Natives						
All education groups	−0.09	0.06	0.06	0.00	−0.06	0.10	0.10	−0.09	−0.16	−0.02	0.11	−0.22
Low	−0.06	0.07	0.08	−0.03	−0.14	0.44	0.44	−0.13	0.14	−0.18	0.35	−0.43
Medium	−0.11	0.04	0.05	−0.01	−0.05	0.06	0.06	−0.12	−0.10	0.22	0.19	0.01
High	−0.16	0.22	−0.01	0.13	−0.06	0.03	0.03	−0.06	−0.65	0.18	−0.24	0.10
						Foreigners						
All education groups	−1.69	2.38	−1.55	2.18	−1.41	2.99	−1.28	2.72	−1.16	0.93	−0.84	0.68
Low	−1.52	2.62	−1.40	2.38	−1.27	3.94	−1.17	3.64	−0.42	1.29	−0.28	0.90
Medium	−1.74	2.03	−1.60	1.87	−1.47	2.27	−1.32	2.03	−0.80	1.16	−0.57	0.85
High	−1.75	2.92	−1.63	2.72	−1.68	1.28	−1.49	1.14	−1.53	0.59	−1.14	0.45

[a] In all three countries we have simulated the effects of an immigration of 1% of the labor force at the education and experience structure of the immigrant labor force at the end of the sample period.

[b] The short-term simulations assume that the capital stock remains fixed, the long-run simulations that the capital-output ratio remains constant, i.e. that the capital stock adjusts completely to the aggregate labor supply change.

[c] Aggregate wage figures are calculated by weighting the wage change of each group by its share in the total wage bill. Wage change expressed as a % change.

[d] Aggregate unemployment figures are obtained by weighting each cell with its share in the labor force. Unemployment rate change expressed as a %-point change.

[e] Low education category refers to individuals without vocational training, the medium education category to workers with vocational training or similar skills, and the high education category to workers with a university degree.

changes. While immigrants increase the labor supply in segments with less wage flexibility and higher unemployment in Denmark and Germany, the reverse is true for the UK.

In all three countries we observe that native workers benefit both in terms of higher wages and lower unemployment risks from immigration, at least in the long-term. This is caused by the limited elasticity of substitution between native and foreign workers in each education-experience cell of the labor market and by differences in the skill and experience composition of the native and immigrant workforce. The results are particularly large in the UK case, where native wages increase by 0.11% and the unemployment risk of natives declines by 0.22 percentage points.

Earlier migrants are the main losers from further immigration. Their wages decline by 1.7% in Denmark, 1.4% in Germany and 1.2% in the UK, while their unemployment rates increase by 2.5 percentage points in Denmark, 3.0 percentage points in Germany and 0.9 percentage points in the UK in the short-term. The long-term effects are only slightly smaller. The differences across the three countries can be explained both by the different elasticities of substitution between natives and foreigners and by the different elasticities of the wage-setting curves. In particular, there are less pronounced effects in the UK since the elasticity of substitution between natives and foreigners is much higher there compared to the other two countries. Altogether, we can conclude that the existing foreign workforce suffers from immigration, while the native workforce tends to benefit.

Finally, we find different effects in different education groups across the three countries considered here. In Germany we find particularly large wage and unemployment effects in the less-skilled segment of the labor market, while the high-skilled are more affected in the UK, and, to a lesser extent, in Denmark. These differences between the three countries are caused by the different skill structure of the foreign workforce, and, hence, the different skill structure of the simulated labor supply shocks.

6 Conclusions

The great majority of existing studies on the wage effects of migration rely on the assumption of clearing labor markets. Therefore, they do not consider the role of labor market institutions and policies in shaping the impact of migration. Nor do they allow a role for unemployment. Because institutions and policies differ significantly between countries, in this paper we take a comparative perspective in a setting with imperfect labor markets. We apply an estimation and instrumentation strategy which does not rely on the assumption of clearing labor markets, and we derive the wage and unemployment effects simultaneously from a coherent framework which considers wage rigidities.

Our findings suggest that labor market institutions do play an important role in determining the wage and employment effects of immigration. In the UK, where labor markets

are characterized (both in the literature and according to our estimates) by a high level of wage flexibility we find the highest elasticity between wages and unemployment, followed by Germany and Denmark. Interestingly, we find that wage flexibility is particularly low in Denmark. This can be explained by a higher union density, a higher coverage of collective bargaining and higher unemployment benefits compared to the other countries, although employment protection is weak and the level of centralized collective bargaining is similar to that of Germany. Another intriguing finding is that the elasticity between wages and unemployment tends to increase monotonically with the skill level of workers in Germany and the UK, while it tends to decline in Denmark. While the former result can be explained by a lower union density and coverage of collective bargaining in the high skilled segments of the labor markets in Germany and the UK, the latter finding might be caused by the progressive tax system and the high level of union density and collective bargaining coverage for high skilled workers in Denmark.

As a consequence of the varying degrees of wage flexibility we find considerable differences in the effects of immigration on wages and employment in the three countries. Our estimates indicate that the impact of immigration on unemployment is particularly low in the UK in the short-term. However, the wage effects are about twice as high compared to Germany and Denmark, where the flexibility of labor markets, measured in terms of the elasticity of the wage-setting curve, is lower. Conversely, the short-term effects of immigration on unemployment exceed that of the UK by a factor of three in Germany and by a factor of two in Denmark. In the long term, under the empirically supported assumption that capital stocks adjust to labor supply shocks, immigration does not affect wages. However, since immigration affects the composition of the workforce, unemployment tends to increase slightly in Germany and Denmark and to decline in the UK. The latter finding can be traced back to the fact that immigration increases labor supply in the flexible segments of the labor market (i.e. the high-skilled segment) and creates additional labor demand in the less flexible segments in the UK. Due to the higher wage flexibility and the relatively skilled immigrant labor force the overall effects of immigration are therefore much more favorable in the UK compared to Germany and Denmark.

An important factor which affects our results is the labor market assimilation of immigrants, measured in terms of the elasticity of substitution between native and foreign workers. Again, the labor market assimilation of immigrants might be affected by institutions. As well as labor market and immigration policies which affect assimilation (such as language tuition or housing), job turnover may be a crucial factor in determining how quickly immigrants integrate into the labor market. Note that job turnover rates are much higher in the United Kingdom and Denmark compared to Germany (Bassanini and Marianna, 2009). This is supported by our findings: while the elasticity of substitution between immigrants and natives is relatively high in the United Kingdom and Denmark, it is particularly low in Germany. This elasticity is crucial in determining the wage and employment effects of further immigration. The impact on the immigrant workforce is rel-

atively modest in the UK, where the elasticity of substitution is high, while the opposite is true for Germany, where the elasticity is particularly low. Although we find that the pre-existing immigrant workforce is the main loser from immigration, the magnitude of these effects differs significantly across countries. This suggests that labor market institutions which affect job turnover play an important role in the distribution of the effects of immigration across different groups in the labor market.

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A Technical Annex: Explicit solution for the employment response

The general solution for the marginal employment response to an increase in labor supply through immigration is given in equation (6). The model in Section 2.2 distinguishes $3 \times 4 \times 2 = 24$ types of labor. Using the notation from the nested production function we write the vector as $\mathbf{x} = [x_{111}, x_{112}, x_{121}, \ldots, x_{211}, \ldots, x_{ijk}, \ldots, x_{342}]$, where $\mathbf{x} \in \{\mathbf{L}, \mathbf{N}, \mathbf{Y_L}, \mathbf{u}, \mathbf{f}\}$. The subscript 111 therefore indexes the first, 112 the second, 121 the third, and 342 the $24th$ element of each vector.

Thus, we can write the partial derivative of wages with respect to employment as

$$\frac{\partial \nu^{-1} \mathbf{Y_L}}{\partial \mathbf{L}} = \nu^{-1} \begin{bmatrix} \frac{\partial Y_{L111}}{\partial L_{111}} & \cdots & \frac{\partial Y_{L111}}{\partial L_{ijk}} & \cdots & \frac{\partial Y_{L111}}{\partial L_{342}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial Y_{Lijk}}{\partial L_{111}} & \cdots & \frac{\partial Y_{Lijk}}{\partial L_{ijk}} & \cdots & \frac{\partial Y_{Lijk}}{\partial L_{342}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial Y_{L342}}{\partial L_{111}} & \cdots & \frac{\partial Y_{L342}}{\partial L_{ijk}} & \cdots & \frac{\partial Y_{L342}}{\partial L_{342}} \end{bmatrix}. \tag{A.1}$$

Due to the nested structure of the production function we have four types of partial derivatives in equation (A.1):

$$\begin{aligned}
\frac{\partial \nu^{-1} Y_{Lqjk}}{\partial L_{qjk}} &= \frac{w_{qjk}}{L_{qjk}} \left[s_{qjk} \left\{ \frac{1}{\delta} + I^* - \frac{1}{s_q} \left(\frac{1}{\delta} - \frac{1}{\rho} \right) - \frac{1}{s_{qj}} \left(\frac{1}{\rho} - \frac{1}{\sigma_q} \right) \right\} - \frac{1}{\sigma_q} \right], \\
\frac{\partial \nu^{-1} Y_{Lqjk}}{\partial L_{ijk'}} &= \frac{w_{qjk}}{L_{ijk}} \left[s_{qjk'} \left\{ \frac{1}{\delta} + I^* - \frac{1}{s_q} \left(\frac{1}{\delta} - \frac{1}{\rho} \right) - \frac{1}{s_{qj}} \left(\frac{1}{\rho} - \frac{1}{\sigma_q} \right) \right\} \right], \\
\frac{\partial \nu^{-1} Y_{Lqjk}}{\partial L_{ij'm}} &= \frac{w_{qjk}}{L_{qj'm}} \left[s_{qj'm} \left\{ \frac{1}{\delta} + I^* - \frac{1}{s_q} \left(\frac{1}{\delta} - \frac{1}{\rho} \right) \right\} \right], \\
\frac{\partial \nu^{-1} Y_{Lqjk}}{\partial L_{q'nm}} &= \frac{w_{qjk}}{L_{q'nm}} \left[s_{q'xm} \left\{ \frac{1}{\delta} + I^* \right\} \right],
\end{aligned}$$

where $k \neq k'$, $j \neq j'$ and $q \neq q'$, and s_{qjk}, s_{qj} and s_q denote the share of wages paid to workers in the respective cell of the labor market in the total wage bill. The index function I^* is

$$I^* = \begin{cases} \alpha - 1 & \text{in the short run} \\ 0 & \text{in the long run,} \end{cases}$$

which follows from the production function if physical capital is fixed in the short run, i.e., if $K = \overline{K}$, and if the capital-output ratio is constant in the long-run, i.e, if $\kappa = \overline{\kappa}$.

Using the wage-setting equation in (3) we can write

$$\frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} = \begin{bmatrix} \frac{\partial \phi_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial L_{111}} & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & & & \vdots \\ 0 & & \frac{\partial \phi_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial L_{ijk}} & & 0 \\ \vdots & & & \ddots & \vdots \\ 0 & \cdots & 0 & \cdots & \frac{\partial \phi_{342}}{\partial u_{342}} \frac{\partial u_{342}}{\partial L_{342}} \end{bmatrix}, \tag{A.2}$$

and

$$\frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} = \begin{bmatrix} \frac{\partial \phi_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial N_{111}} \frac{dN_{111}}{dM} \\ \vdots \\ \frac{\partial \phi_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial N_{ijk}} \frac{dN_{ijk}}{dM} \\ \vdots \\ \frac{\partial \phi_{342}}{\partial u_{342}} \frac{\partial u_{342}}{\partial N_{342}} \frac{dN_{342}}{dM} \end{bmatrix}. \tag{A.3}$$

Substituting the matrices (A.1), (A.2), and (A.3) into equation (6) yields the marginal employment response to immigration for the two cases of a fixed capital stock or a constant capital output ratio.

B Data Annex (not for publication)

B.1 Labor market and immigration data

The labor market and immigration data which we use for our empirical analysis are taken from three data sets: the Integrated Database for Labor Market Research (IDA) in Denmark, the Integrated Employment Biographies (IEB) database in Germany, and the UK Quarterly Labour Force Survey (UK LFS).

The IDA is compiled from a variety of sources such as the population register, the labor force and unemployment registers and administrative tax data (Statistics Denmark, 2007). It covers the entire population including all employed and unemployed persons. Immigrants can be identified both by their country of birth and citizenship. We use the 1990–2006 period for our analysis.

The IEB is a 5% random sample of all employees registered with the social security system, and of all unemployment benefit recipients in Germany. Self-employed individuals and civil servants who are not obliged to pay social security contributions (*Beamte*) are not included in the data set. As with the IDA, the IEB is compiled from a variety of administrative data sources which comprise, *inter alia* information on employment histories provided by the German pension system and on unemployed benefit recipients provided by the Federal Employment Services (Dorner *et al.*, 2010). Due to the German *jus sanguis* tradition, the data set identifies foreigners only by citizenship. Since 1992 is the first year where the data covers the unified Germany, we use the 1992–2008 period for our analysis.

Administrative data on earnings in the UK are not available to researchers. The largest survey which contains information on migration status is the UK Labour Force Survey,[20] a quarterly random sample of 60,000 households. Each quarter of the LFS sample is made up of five waves, each of approximately 12,000 households. Each wave is interviewed in five successive quarters. As a result, there is an 80% overlap in the samples for successive quarters. The UK LFS contains information on wages, qualification, occupational status, unemployment, the country of birth of foreigners as well as information on citizenship. Wage information is not available before 1993, so we use the 1993–2009 period in our analysis. Building on these data sources, we used the following classifications and definitions for our empirical analysis (see Table 8 for an overview).

1. *Definition of foreigners*: In Denmark foreigners are restricted to first generation immigrants. A first generation immigrant is defined as an individual who was born outside Denmark, and who has foreign-born parents or parents with foreign citizenship. If information on one of the parents is missing but the other parent fulfills the

[20] The Annual Survey of Hours and Earnings (ASHE) provides a larger sample size, but no information on nationality or country of birth.

Table 8: Labor Market and Immigration data

	Denmark	**Germany**	**UK**
Data source	Integrated Database for Labor Market Research (IDA)	Integrated Employment Biographies data set (IEB)	UK Quarterly Labour Force Survey
Data characteristics	Administrative register data	Administrative register data	Household survey data
Sample size	All employees and benefit recipients	5% sample of all wage and salary employees and benefit recipients	60,000 private households
Sample period	1990 – 2006	1992 – 2009	1993 Q1 – 2009 Q4
Sample coverage	Full-time employees and unemployed benefit recipients aged 16-60	Full-time employees and unemployed benefit recipients aged 18-60	Full-time employees and self-reported unemployed aged 16-60
Definition of immigrants	Foreign born as classified by Statistics Denmark	Foreign citizens corrected for naturalization and ethnic German immigrants	Foreign born (self-reported)
Definition of full-time work	Weekly working time $\geq$ 30 hours	Reported by employers (reference is usual working time in the establishment)	Weekly working time $\geq$ 30 hours
Definition of unemployment	Recipients of unemployment benefits and allowances	Recipients of unemployment benefits and unemployment assistance. Since 2005 recipients of unemployment benefits (UB I) and allowances (UB II).	Self-reported according to ILO definition
Definition of wages	Hourly wage deflated by CPI (2000 prices)	Daily wage deflated by CPI (2005 prices); daily wages above social security contribution ceiling are imputed	Hourly wage deflated by CPI (2005 prices)
Education classifications			
Low	No vocational training	No vocational training degree	Left education before the age of 18
Medium	Vocational training or short academic education	Vocational training degree	Left education 18–21
High	Master degree or above	University degree	Left education $\geq$ 21
Work experience classifications	0-5, 6-10, 11-20, $\geq$ 20 years	0-5, 6-10, 11-20, $\geq$ 20 years	0-5, 6-10, 11-20, $\geq$ 20 years

criteria, the individual is also defined as an immigrant. If there is no information on either of the parents then the individual is defined as a first generation immigrant if he or she is born outside Denmark.

The German data set provides no information on when immigrants entered the country or their country of birth. Due to the *jus sanguinis* tradition of German law, naturalization rates have been traditionally low, but increased slightly after the reform of the immigration act in 1999. To mitigate the possible effects of naturalization, we have classified all individuals as foreigners who are reported as foreign citizens in their first available spell. This prevents naturalization from being displayed as a declining foreigner share in our sample.

Moreover, since German law regards ethnic German immigrants (*Spätaussiedler*) as German citizens, the number of immigrants is likely to be underreported in the IEB. Using information from the benefit recipient file we are able to identify the majority of the ethnic German immigrants by their participation in language courses and other integration measures especially designed for this group. In our sample, the cumulative inflow of ethnic Germans accounts for more than 3 percent of the German labor force.

In the UK LFS individuals report whether they are born outside the UK. The same is true for citizenship.

Even after correcting for naturalization and the immigration of ethnic Germans, the definition of foreigners in the German data still differs from that in the Danish and the UK data sets, since second and third generation immigrants appear as foreign citizens in the German data set. As a robustness check, we have created also data sets where foreigners are defined by citizenship in Denmark and in the UK. It turns out that our results are qualitatively robust to the different definition of the foreign workforce.

2. *Definition of the employed and unemployed labor force*: In Denmark and the UK we consider males and females aged between 16 and 60; in Germany we restricted our sample to the labor force aged between 18 and 60 (see below). All samples consists of wage and salary full-time employees and unemployed persons. We exclude part-time workers, since the German IEB data set provides only wage information on a daily basis and hourly wages for part-time workers with few hours are usually known as of bad quality in Denmark. Full-time employment is defined by 30 working hours or more in Denmark and the UK. In Germany, employers are obliged to report workers as full time if the contracted agreed working time equals the usual working time in the establishment.

   Self-employed persons are excluded, since we have no information on the self-employed in the German data set and no comparable income information of self-employed are available in Denmark and the UK. We include employees in the public sector, with

the exception of workers who do not pay social security contributions ('Beamte' and marginal employed workers) in Germany.

The definition of unemployment varies slightly across the data sets. While the UK LFS employs the ILO definition, the register data in Denmark classifies the recipients of unemployment benefits and unemployment allowances as unemployed. In Germany, the recipients of insurance-based unemployment benefits I and the recipients of the mean-tested unemployment benefits II (until 2004 unemployment assistance) are defined as unemployed. The 2004 reform of the social security system in Germany involves an unavoidably structural break in 2005, which increased the number of unemployed particularly among the younger cohorts as they became eligible for unemployment benefits II without any prior employment experience. In order to alleviate that problem we have excluded persons aged below 18 in the German sample.

3. *Definition of wages*: In Germany, the wage information in the IEB is used to calculate social security contributions and is therefore highly reliable. The daily income is measured in Euro and is right-censored since gross wages can only be observed up to the social security contribution ceiling. About 8,7 percent of the employment spells in the final data set are right-censored. This may affect the estimation of the wage-setting curve in the high-skilled segments of the labor market. We have therefore imputed wages above the social security contribution ceiling using a heteroscedastic single imputation approach specifically developed for the IEB data set Büttner and Rässler (2008). In Denmark the gross hourly wage is measured in DKK. In the UK information on earnings is only available in interview wave 5 (up to 1996) and in waves 1 and 5 from 1997 onwards. We use reported gross hourly pay which is either directly reported or calculated as gross weekly pay in the main job divided by usual weekly hours worked in the main job.

4. *Classification of education groups*: In all three countries we distinguish three education groups: high, medium and low. This sets our paper apart from the approach of Katz and Murphy (1992), Card and Lemieux (2001) and Card and Schleifer (2009) which distinguish only two education classes (tertiary and secondary) as well as from the approach of Borjas (2003) and Ottaviano and Peri (2012), which employ four groups (college, college drop-outs, high-school and high-school-drop outs). In our view a distinction of education levels in university degrees, vocational training degrees and skilled workers with equivalent qualification levels, and workers without a vocational training degree or equivalent degrees is more suitable for the conditions in European labor markets.

   In Denmark low skilled workers are defined as those who left school without any further education, medium skilled workers have a vocational training or a short academic education and high skilled workers hold at least a master degree. In the

German and UK data set information on the qualification of the foreign workforce is often missing.

In Germany, we imputed the missing information on education by employing a procedure especially developed for the data set by (Fitzenberger *et al.*, 2006), which allows inconsistent education information to be corrected over time as well. After applying this imputation procedure, we had to drop 3.8 percent of the individuals due to missing or inconsistent information on education.

In the UK information on qualification levels of foreigners display either high missing rates or a large share of the foreign workforce is placed in the "other qualifications" category, even though these workers may have a rather high level of education (see the evidence provided by Saleheen and Shadforth 2006). We therefore followed the procedure applied by Manacorda *et al.* (2012) and used the information on age left school to classify education groups. This enables us to circumvent the problem of missing information on the highest qualification degree.

We define a low level of education if an individual leaves school at an age of 17 or below, a medium level of education if an individual leaves school at an age between 18 and 20, and a high level of education if they leave school at an age of 21 or more. These three groups capture the three basic levels of educational qualification in the UK, namely GCSE, A-level and university degree. Other studies have tended to define "low-skilled" as those who leave school before the age of 16, but, since the 1970s, the majority of school-children in the UK were required to stay at school until they were 16 (the exception was for those born late in the academic year). For UK born workers, we can compare the highest educational qualification across these three groups. 23% of the low-skilled sample report having no qualifications, compared to 2% of the middle-skilled sample and 0.35% of the high-skilled sample.

5. *Classification of experience groups*: In all three data sets we distinguish four groups of work experience: 0 to 5 years, 6 to 10 years, 11 to 20 years, and more than 20 years. This assures that we have sufficient observations in each group in all three data sets.

B.2 Control variables

The estimates of the wage-setting curves and of the elasticities of substitution consider a number of variables which control for macroeconomic shocks and other influences at the aggregate level. The estimates of the wage-setting curves control for real GDP measured at purchasing power parities and constant prices as controls for economic growth, the consumer price index and/or the crude oil price index as controls for price changes, and a number of trade variables as controls for external demand and supply. In estimating the elasticities of substitution we use time fixed effects to control for macroeconomic shocks

and other aggregate effects. As a robustness check, we have also used the real PPP GDP growth and the change in the CPI as macro controls in some specifications. Definitions of the variables and data sources are displayed in Table 9.

B.3 Instrumental variables

As outlined in Section 4, we use an industry mix variable and an export demand index as instrumental variables in the wage-setting equations. The industry mix variables measures how much of the deviation in employment growth in an education-experience cell from the average employment growth can be explained by the concentration of workers in the respective cell in fast- or slow-growing industries. This variable simply measures how much of the change in employment can be attributed to an exogenous shift of the sectoral structure, for example due to technological change (Bartik, 1991). It is calculated as

$$indumix_{qj} = \sum_{h=1}^{n} g_{ht} \frac{L_{qjh,t-1}}{L_{qj,t-1}} - g_t,$$

where g_{ht} is the employment growth rate in industry h in year t, $L_{qjh,t-1}$ is the employment of education-experience group qj in industry h in year $t-1$, $L_{qj,t-1}$ is the aggregate employment of education-experience group qj in year $t-1$, and g_t the average overall employment growth rate in year t. The summation is over all two digit, non-agricultural, private-sector industries in the UK and Denmark and over all manufacturing industries in Germany.

The export demand variable should capture the size of external demand and is calculated as the GDP of all trading partners in the OECD at constant prices weighted by their average share in exports of the respective country during the sample period (in constant USD in DK and the UK, in constant national currency at PPP in DE).

In the labor demand equations we use the following instruments as approximations for the reservation wage: first, the average number of dependent children in each cell of the labor market. The definition of the age groups vary across countries due to different systems of schooling and child care. Second the ratio of the average income of unemployed households to that of employed households in each cell of the labor market. Third, the mean average tax burden. Fourth, an income satisfaction index. Finally, the minimum wage in the UK.

Definitions of the variables and the data sources are presented in the bottom panel of Table 9.

Table 9: Control and instrumental variables

Variable	Definition	Sources
Control variables		
Real GDP	GDP in USD, current prices	OECD STAT database
CPI	Consumer price index, 2005 = 100	OECD STAT database
Oil price	Crude oil import price in USD (index)	OECD STAT database
Export performance index	Growth rate of exports minus growth rate of imports, goods and services, current prices, current exchange rates	OECD STAT database
Minimum Wage	Dummy variable for minimum wage in UK	Own calculation
Instrumental variables		
Industry mix	Deviation of employment growth in each education-experience cell from average employment growth (summation across all non-agricultural private sector industries in DK and UK, across all manufacturing industries in DE)	Own calculations based on IDA (DK), IEB (DE) and LFS (UK)
Export demand	GDP per capita of OECD trading partners at constant prices (USD in UK and DK, national currency at PPP in DE) weighted by average export share of trading partner during sample period	Own calculations based on OECD STAT database
Average number of dependent children	Average number of dependent children for different age groups	Own calculations based on IDA (DK), GSOEP (DE) and LFS (UK)
Median household income of unemployed	Median average household income of unemployed individuals (UK)	Own calculations based on BHPS (UK)
Mean unemployment benefits	Mean daily unemployment benefits (DE)	Own calculations based on IEB (DE)
Tax burden	Mean of the total amount of tax payed over all jobs a person held during the year (only for employed DK)	Own calculations based on IDA (DK)
Minimum wage	Minimum wage in the UK (GBP)	Low Pay Commission
Ideology index	Share of left- and right-wing parties in government weighted by their seats in parliament	(Bjørnskov, 2008)
Income satisfaction	Mean satisfaction with household income measured on a Likert scale ranging from 0 (totally unsatisfied) to 10 (totally satisfied).	GSOEP