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## Migration and wage-setting: reassessing the labor market effects of migration

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## **Working Papers**

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### **Migration and Wage-Setting: Reassessing the Labor Market Effects of Migration**

**by Herbert Brücker and Elke J. Jahn**

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This paper employs a wage-setting approach to analyze the labor market effects of immigration into Germany. The wage-setting framework relies on the assumption that wages tend to decline with the unemployment rate, albeit imperfectly. This enables us to consider labor market rigidities, which are particularly relevant in Europe. We find that the elasticity of the wage-setting curve is particularly high for young and well-educated workers. The labor market effects of immigration are moderate: a 1 percent increase in the German labor force through immigration increases the unemployment rate by less than 0.1 percentage points and reduces wages by 0.1 percent.

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# Migration and Wage-Setting: Reassessing the Labor Market Effects of Migration

Herbert Brücker\* and Elke J. Jahn<sup>‡</sup>

This version: January 2009

## Abstract

This paper employs a wage-setting approach to analyze the labor market effects of immigration into Germany. The wage-setting framework relies on the assumption that wages tend to decline with the unemployment rate, albeit imperfectly. This enables us to consider labor market rigidities, which are particularly relevant in Europe. We find that the elasticity of the wage-setting curve is particularly high for young and well-educated workers. The labor market effects of immigration are moderate: a 1 percent increase in the German labor force through immigration increases the unemployment rate by less than 0.1 percentage points and reduces wages by 0.1 percent.

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# 1 Introduction

High and increasing immigration rates in the US and Europe have fanned fears that migrants reduce wages and limit employment opportunities of the native labor force. Concerns that immigration increases unemployment are particularly widespread in the continental European countries, where unemployment is persistently high. In this paper we apply a wage-setting approach along the lines proposed by Layard, Nickell, and Jackman (2005) to analyze the labor market effects of immigration. This framework relies on the assumption that wages tend to decline with the unemployment rate at given price expectations, albeit imperfectly. This enables us to consider institutional and other labor market rigidities which are particularly relevant in the European context.

The wage-setting framework we use here addresses the wage and employment effects of immigration in a joint framework which considers the cross effects of supply changes in the different segments of the labor market. For this purpose, we estimate wage-setting curves for different groups in the labor market. This distinguishes our approach from the existing empirical literature, which tempts to identify the employment impact of immigration from spatial or national correlations between (un-)employment and immigration rates.

Our approach replaces conventional labor supply curves by a bundle of wage-setting functions, but relies on standard assumptions about labor demand. This enables us to derive the labor demand from a production function approach. Following Borjas (2003), Ottaviano and Peri (2006) and others we identify the immigration effects at the national level. Aggregate technologies are approximated by a nested CES production function, which groups the labor force by education, work experience and national origin. Following the theoretical and empirical literature on economic growth, we consider moreover that physical capital adjusts at least partially to labor supply shocks. The estimated elasticities of the wage-setting curves, the elasticity between the capital-output-ratio and labor supply changes, and the parameters of the production function enable us to derive a unique solution to a system of equations which determines the employment and wage effects of immigration simultaneously.

We apply this framework empirically to Germany, which is the third most popular destination for migrants in the world after the US and Russia (Freeman, 2006). With the fall of the Berlin wall, the net immigration rate climbed in Western Germany from about zero at the beginning of the 1980s to about 6 per thousand at the beginning of the 1990s, compared to 3 per thousand in the fifteen member states of the then European Union (EU-

15) and 4 per thousand in the US (World Bank, 2007). However, since the beginning of this millennium, the net immigration rate has dropped to less than 3 per thousand in the course of Germany's economic downturn (Figure 1).

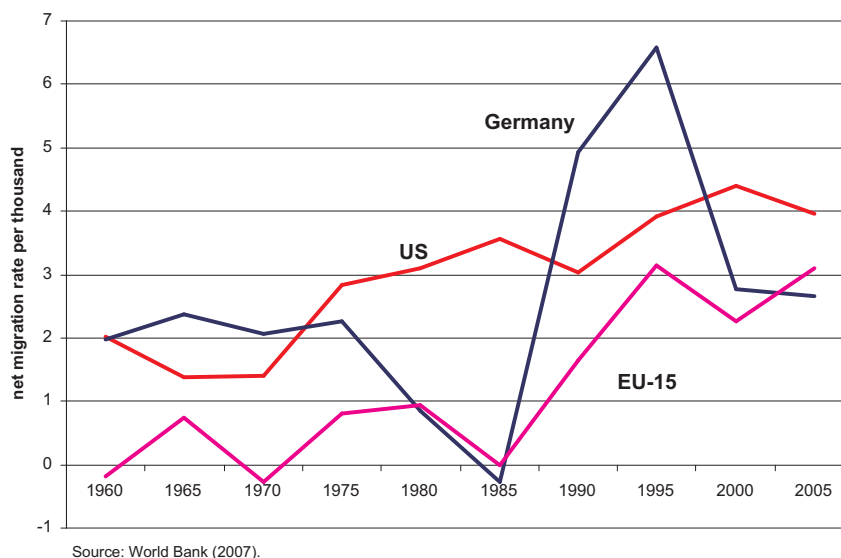


Figure 1: Net migration rate per thousand, 1960-2005

Our empirical analysis is based on a two percent random sample drawn from German social security records (IABS) for the period from 1980 to 2004. The IAB provides accurate information on wages and on employment histories of individuals and is therefore especially suitable for identifying the elasticities of the wage-setting curves and the elasticities of substitution between different types of labor.

We find that the elasticities of the wage-setting curves fluctuate considerably across skill groups and experience groups. The elasticity between wages and unemployment is particularly large for workers with little work experience, and well above the average for highly educated workers. We provide moreover evidence that natives and immigrants are imperfect substitutes in the labor market. Our simulation results suggest that the aggregate impact of immigration on employment opportunities and wages is modest. Immigration can both reduce and increase employment opportunities of natives and foreigners, depending on the flexibility of the labor market segments which absorb immigrants.

The remainder of the paper is organized as follows: Section 2 compares our approach to the existing empirical literature on the employment and

wage effects of immigration. Section 3 outlines the model. Section 4 describes the dataset. Section 5 presents the identification strategy and the estimation results for the elasticities of the wage-setting curves, the capital stock adjustment, and the elasticities of the production function. Section 6 simulates the employment and wage impact of immigration on the German labor market. Finally, Section 7 concludes.

## 2 Review of the literature

The empirical framework we apply here has differences and similarities to the existing literature on the labor market impact of immigration. The main feature of our approach is that we address the employment and wage effects of migration in a joint framework which considers the cross-effects of labor supply shifts. Moreover, we consider varying degrees of wage flexibility in different segments of the labor market. This sets our approach apart from the existing empirical literature which derives the employment effects of immigration from simple correlations between employment and immigration rates (see Longhi, Nijkamp, and Poot, 2006, 2008, for a survey and meta-analysis).

Most existing studies relate the (un-)employment rate of natives or foreigners to the immigrant share and use the variance of the immigrant share across areas or industries for the identification of the employment impact (Angrist and Kugler, 2003; Borjas, Freeman, and Katz, 1997; Card, 2001; Dustmann, Fabbri, and Preston, 2005; Friedberg, 2001; Pischke and Velling, 1997; Winter-Ebmer and Zimmermann, 1999). While some of these studies define local labor markets only in terms of geographical areas or industries, others define it both in terms of geography and education (e.g. Borjas, Freeman, and Katz, 1997; Card, 2001). Both approaches deliver only aggregate employment effects because they do not consider different education and experience groups at all or average out the skill specific impact of immigration. For a general equilibrium analysis of the labor market effects we need however the disaggregated employment response to labor supply shifts since the elasticities of substitution or complementarity differ across the segments of the labor market.

Another part of the empirical literature tempts to identify the elasticities of substitution in different segments of the labor market by regressing the employment rates of different education or age groups against the immigration share (Ottaviano and Peri, 2006, 2008). This approach captures however only the partial equilibrium effects of immigration and ignores cross-effects resulting from labor supply shifts in other segments of the labor market.

The spatial correlation approach applied by most empirical studies yields

moreover spurious results if migrants are not randomly distributed across local labor markets or if other factors equilibrate conditions across geographical areas (Borjas, Freeman, and Katz, 1997; Borjas, 2003). Some recent studies exploit therefore the variance of the immigrant share across education and experience groups at the national level for the identification of the employment impact of migration on the native or foreign workforce (Aydemir and Borjas, 2007; Bonin, 2005; D'Amuri, Ottaviano, and Peri, 2008). Again, this approach averages out the employment effects of immigration and does not deliver the employment response to immigration in different segments of the labor market required for a general equilibrium analysis.

While the wage-setting framework applied here deviates from the standard procedure to identify the employment impact of immigration, it allows to derive the labor demand from a conventional production function approach. The production function approach has been pioneered in the migration context by Grossman (1982) and Borjas (1987) and experienced recently a renaissance in a number of studies which follow Borjas (2003) in identifying the wage impact of immigration at the national level (Aydemir and Borjas, 2007; Ottaviano and Peri, 2006; Manacorda, Manning, and Wadsworth, 2006). We follow here this well established tradition and derive the labor demand from a nested CES production function which groups the labor force by education, experience and national origin.

The question whether natives and immigrants are perfect or imperfect substitutes at given education levels is subject of some controversy in the literature. While the Borjas (2003) study assumes perfect substitutability, Ottaviano and Peri (2006) find that natives and immigrants are imperfect substitutes in the labor market. This has important consequences for the labor market effects of immigration: While the results of Borjas (2003) indicate that both natives and foreign workers suffer from further immigration, Ottaviano and Peri (2006) find that native workers tend to benefit.<sup>1</sup> In our empirical application we impose no a priori restriction on the substitutability of natives and immigrants in the labor market.

Altogether, this paper deviates from most of the empirical literature in deriving the wage and employment effects of immigration simultaneously in a wage-setting framework, while it follows the standard approach to identify

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<sup>1</sup>Recently, Borjas, Grogger, and Hanson (2008) argue that the findings of Ottaviano and Peri (2006) are the result of a misclassification of skill groups, while Ottaviano and Peri (2008) present evidence that natives and immigrants are imperfect substitutes based on a similar skill classification but a different identification strategy. However, the reclassification of skill groups involves that the elasticity of substitution between native and immigrant labor has increased substantially in the Ottaviano and Peri (2008) study compared to the findings in Ottaviano and Peri (2006).



the labor demand from the elasticities of a nested production function. Three recent studies which are close to our approach are worthwhile to mention: Bentolila, Dolado, and Jimeno (2007) examine the effects of immigration in a Phillips curve framework. This paper addresses the question of whether immigration has changed the slope of the Phillips curve in Spain, while we assume – based on the existing empirical evidence – that the slope of the wage-setting curve is rather stable over time. D’Amuri, Ottaviano, and Peri (2008) and Felbermayr, Geis, and Kohler (2008) recently applied the Ottaviano and Peri (2006) approach to the analysis of the labor market impact of immigration in Germany. Like the present paper, both highlight the importance of wage rigidities for an assessment of the labor market effects of immigration. Although D’Amuri, Ottaviano, and Peri (2008) acknowledge that the employment effects of immigration have to be addressed in a general equilibrium framework, they follow the standard procedure to derive the employment impact of immigration from a simple correlation between employment and immigration rates. The Felbermayr, Geis, and Kohler (2008) paper is based similar to ours on a wage-setting approach, but it does not derive an empirical framework which allows the wage-setting curves to vary across the different segments of the labor market. Moreover, they employ for their empirical analysis the German Socioeconomic Panel (GSOEP), i.e. a data set with a small sample size compared to the IABS used here.

### 3 Theoretical background

The model we present builds on Boeri and Brücker (2005) and Levine (1999) in deriving the wage and employment effects of immigration from a wage-setting framework. While these papers focus on the effects of immigration in a setting with one or two types of labor, ours derives a general solution which can be applied empirically to a labor market which distinguishes many types of labor.

The wage-setting framework explains unemployment by the interaction between price- and wage-setting (Layard, Nickell, and Jackman, 2005). Under the simplifying assumptions of perfect competition on output markets and perfect foresight, product prices equal marginal costs, which in turn determine factor demand. The real wage rate is assumed to be a declining function of the unemployment rate and may deviate from market-clearing levels.

One can base the assumption of the wage-setting framework that wages are a declining function of the unemployment rate on different theoretical foundations (see Blanchard, 2007; Blanchflower and Oswald, 1994, 2005; La-

yard, Nickell, and Jackman, 2005, for a discussion). In our context, two modeling traditions are particularly important. First, a wage-setting curve can be derived from bargaining models (see e.g. Lindbeck, 1993; Layard and Nickell, 1986). Wages are fixed in a bilateral bargaining monopoly between trade unions and employer federations. Once wages are fixed, firms hire workers until the marginal product of labor equals the wage rate. If unions are concerned about both their employed and unemployed members, the negotiated wage is lower when unemployment is higher and vice versa.

Second, in a completely non-unionized environment, the wage-setting curve can be explained by efficiency wage considerations (Shapiro and Stiglitz, 1984), where the productivity of workers is linked to the wage level. Unemployment works here as disciplining device since it determines the difficulties in finding a new job. As a result, firms will reduce workers' pay if the unemployment rate is increasing since they can achieve the same level of productivity at a lower wage.

Both approaches replace the conventional labor supply curve with a wage-setting function, and rely on standard assumptions about labor demand (Blanchflower and Oswald, 1995; Layard and Nickell, 1986). However, different conclusions regarding the shape of the wage-setting curve emerge from these different theoretical foundations: on the one hand, the bargaining model predicts a flatter wage-setting curve in labor market segments with a higher share of unionized workers. The share of unionized workers is exceptionally high among workers with a vocational training degree in Germany, i.e., workers with a medium skill level. On the other hand, the efficiency wage model expects a flatter wage-setting curve for workers with a higher level of firm-specific human capital, since this drives a wedge between productivity at the current employer and the outside opportunity wages, thereby allowing employers to smooth wages over the business cycle (Card, 1995). Thus, it is likely that the wage-setting curve is flatter for high-skilled workers since they tend to acquire greater levels of firm-specific human capital.

In our empirical application of the wage-setting framework we do not rely on a specific wage bargaining or efficiency wage model. Instead we take up a suggestion by Card (1995) and allow the relationship between wages and the unemployment rate to vary for different groups in the labor force. This enables us to determine the wage-setting curve empirically without imposing a priori restrictions on its shape from theoretical considerations of one kind or another.

### 3.1 A structural model of immigration and unemployment

Suppose that the aggregate output of an economy is produced with different types of labor and physical capital. We distinguish labor by education, work experience, and national origin. In general form, we can write the aggregate production function as

$$Y = F(\mathbf{L}, K), \quad (1)$$

where  $Y$  denotes aggregate output,  $\mathbf{L}$  a vector of different types of labor inputs, and  $K$  the capital stock. We assume that the production function  $F(\cdot)$  exhibits constant returns to scale and positive and diminishing marginal products with respect to each input, and satisfies the Inada (1963)-conditions. For the sake of convenience, we have skipped time subscripts.

Wages and the demand for labor are determined sequentially. In the first stage, wages are fixed. The elasticity of the wage with respect to the unemployment rate may differ in each cell of the labor market depending on the bargaining power of the parties in the wage negotiations or the level of specific human capital. In the second stage, profit-maximizing firms hire workers until the marginal product of labor equals the wage rate.

Writing the wage in each cell of the labor market as a function of the respective unemployment rate gives

$$w_{ijk} = \phi_{ijk}(u_{ijk}), \quad \phi'_{ijk} < 0, \quad (2)$$

where  $w_{ijk}$  is the wage of a worker with education  $i$ , experience  $j$  and national origin  $k$ ,  $\phi_{ijk}$  is a function that captures the response of the wage to the unemployment rate. The unemployment rate  $u_{ijk}$  is defined as

$$u_{ijk} = 1 - \frac{L_{ijk}}{N_{ijk}},$$

where  $L_{ijk}$  and  $N_{ijk}$  denote the employed workforce and the labor force, respectively, of education  $i$ , experience  $j$ , and national origin  $k$ .

The condition that the wage rate in equation (2) equals the marginal product of labor allows us to solve for the employment response to a change in labor supply. Note that the marginal product of labor in a specific education, experience, and national origin cell of the labor market is affected by the employment changes in all other cells of the labor market. Solving for the employment response thus requires solving a system of equations for all other cells of the labor market, which is determined by the wage-setting curves and the production function. This system has to satisfy in each cell of the labor

market the implicit function

$$\Phi_{ijk} = w_{ijk}(\mathbf{L}, K) - \phi_{ijk}(u_{ijk}) = 0, \quad \forall ijk. \quad (3)$$

Differentiating this system implicitly with respect to a marginal migration shock yields for the change in employment

$$\frac{d\mathbf{L}}{dM} = \left( \frac{\partial \mathbf{w}}{\partial \mathbf{L}} - \frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} \right)^{-1} \times \left( \frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} - \frac{\partial \mathbf{w}}{\partial K} \frac{dK}{dM} \right), \quad (4)$$

where  $dM$  is a scalar that captures the marginal immigration shock to the economy,  $\phi$  a vector of functions that determine as above the wage response to the unemployment rate, and  $\mathbf{N}$  a vector of the labor force in each cell of the labor market. We assume that the capital stock may adjust to a labor supply shock through migration, i.e., that  $\frac{dK}{dM} \geq 0$ .

Finally, having solved for the employment response, it is straightforward to derive the wage effects of migration:

$$\frac{d\mathbf{w}}{dM} = \frac{\partial \mathbf{w}}{\partial \mathbf{L}} \frac{d\mathbf{L}}{dM} + \frac{\partial \mathbf{w}}{\partial K} \frac{dK}{dM}. \quad (5)$$

Consider three cases: first, assume that labor markets are completely flexible, which requires that  $\phi'_{ijk} \rightarrow -\infty \forall \phi_{ijk}$ . In this case, equation (4) simplifies to

$$\frac{d\mathbf{L}}{dM} \rightarrow \frac{d\mathbf{N}}{dM},$$

i.e., the marginal employment response equals the marginal increase in the labor force in each cell of the labor market. This case corresponds to the textbook example of the impact of migration in an economy with clearing labor markets and an inelastic supply of native labor.

Second, assume that labor markets are completely inflexible, i.e., that  $\phi'_{ijk} \rightarrow 0 \forall ijk$ . In this case, equation (4) yields

$$\frac{d\mathbf{L}}{dM} \rightarrow \left( \frac{\partial \mathbf{w}}{\partial \mathbf{L}} \right)^{-1} \times \left( -\frac{\partial \mathbf{w}}{\partial K} \frac{dK}{dM} \right),$$

which equals zero if the capital stock does not adjust to the labor supply shock. This case corresponds to the famous Harris and Todaro (1970) model.

Third, in the empirically relevant case, i.e., when  $0 > \phi'_{ijk} > -\infty$ , employment adjusts partially to a labor supply shock through immigration, depending on the elasticities of the wage-setting curve and the elasticities of substitution as determined by the production function.

For an illustration of the difference of our general equilibrium framework to the partial correlation approach widely applied in the literature it may be convenient to distinguish only two types of labor indexed by 1 and 2. If the capital stock is fixed, the employment response in equation (4) yields

$$\begin{aligned}\frac{dL_1}{dM} &= \frac{1}{a} \left[ \left( \frac{\partial w_2}{\partial L_2} - \frac{\partial \phi_2}{\partial u_2} \frac{\partial u_2}{\partial L_2} \right) \frac{\partial \phi_1}{\partial u_1} \frac{\partial u_1}{\partial N_1} \frac{dN_1}{dM} - \frac{\partial w_1}{\partial L_2} \frac{\partial \phi_2}{\partial u_2} \frac{\partial u_2}{\partial N_2} \frac{dN_2}{dM} \right], \\ \frac{dL_2}{dM} &= \frac{1}{a} \left[ \left( \frac{\partial w_1}{\partial L_1} - \frac{\partial \phi_1}{\partial u_1} \frac{\partial u_1}{\partial L_1} \right) \frac{\partial \phi_2}{\partial u_2} \frac{\partial u_2}{\partial N_2} \frac{dN_2}{dM} - \frac{\partial w_2}{\partial L_1} \frac{\partial \phi_1}{\partial u_1} \frac{\partial u_1}{\partial N_1} \frac{dN_1}{dM} \right],\end{aligned}$$

where  $a = \left( \frac{\partial w_1}{\partial L_1} - \frac{\partial \phi_1}{\partial u_1} \frac{\partial u_1}{\partial L_1} \right) \left( \frac{\partial w_2}{\partial L_2} - \frac{\partial \phi_2}{\partial u_2} \frac{\partial u_2}{\partial L_2} \right) - \frac{\partial w_1}{\partial L_2} \frac{\partial w_2}{\partial L_1} > 0$ . The partial correlation approach tends to understate the employment impact of immigration if the two labor types are  $q$ -complements in the sense of Hamermesh (1993), while it tends to overstate it when they are  $q$ -substitutes.

### 3.2 Outline of the empirical framework

For the empirical analysis, we have to impose more structure on the economy. Similar to Borjas (2003) and Ottaviano and Peri (2006), we follow Card and Lemieux (2001) in using a nested CES production function for this purpose. More specifically, we employ a four-level CES technology which groups the workforce in  $i = 1..4$  education groups,  $j = 1..8$  experience groups, and  $k = 1, 2$  nationality groups, which gives together with physical capital 65 production factors.<sup>2</sup> Although the nested CES function imposes some restrictions on the elasticities of substitution, it has the advantage that it is parsimonious in the parameters.<sup>3</sup>

Suppose that aggregate production in equation (1) can be represented by a standard Cobb-Douglas production function:

$$Y_t = A_t L_t^\alpha K_t^{1-\alpha}, \quad (6)$$

where  $Y_t$  denotes aggregate output,  $A_t$  an exogenous parameter which captures total factor productivity,  $L_t$  the aggregate labor input,  $K_t$  physical

<sup>2</sup>Our four-level framework resembles the specification proposed by Ottaviano and Peri (2006). D'Amuri, Ottaviano, and Peri (2008) have recently applied a five-level framework for Germany which distinguishes different vintages of immigrants in a further nest of the production function. They find however for the inverse of the elasticity of substitution between old and new arrivals values which are not statistically different from zero suggesting that old and new arrivals are perfect substitutes.

<sup>3</sup>Note that a general specification of the production technologies, such as the translog function, would require estimating 2,016 different parameters of the production function in our case.

capital,  $\alpha$  the income share of labor, and  $t$  the time index.

Grouping the labor force by education, experience and national origin yields for the other nests of the production function

$$L_t = \left[ \sum_{i=1}^4 \theta_{it} L_{it}^{(\delta-1)/\delta} \right]^{\delta/(\delta-1)}, \quad \sum_{i=1}^4 \theta_{it} = 1, \quad (7)$$

$$L_{it} = \left[ \sum_{j=1}^8 \theta_{ij} L_{ijt}^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)}, \quad \sum_{j=1}^8 \theta_{ij} = 1, \quad (8)$$

$$L_{ijt} = \left[ \sum_{k=1}^2 \theta_{ijk} L_{ijk}^{(\sigma_i-1)/\sigma_i} \right]^{\sigma_i/(\sigma_i-1)}, \quad \sum_{k=1}^2 \theta_{ijk} = 1, \quad (9)$$

where  $L_{it}$  denotes a labor composite which aggregates all workers with education  $i$ ,  $L_{ijt}$  a labor composite which aggregates native and migrant workers of education  $i$  and experience  $j$ , and  $L_{ijk}$  the number of employed workers of education  $i$ , experience  $j$  and national origin  $k$ . The technology parameters  $\theta_{it}$ ,  $\theta_{ij}$  and  $\theta_{ijk}$  determine the productivity levels of the respective factor. We allow the productivity parameter  $\theta_{it}$  to vary over time since skill-biased technological progress might affect the productivity of various types of labor in different ways. More specifically, we adopt the assumption by Katz and Murphy (1992) that the shift in the technology parameters can be approximated by a linear time trend.

Finally,  $\delta > 0$ ,  $\rho > 0$  and  $\sigma_i > 0$  are constant parameters measuring the elasticity of substitution between labor of different education levels, between labor of similar education but different work experience, and between native and migrant workers of similar education and experience levels. We allow  $\sigma_i$  to differ across education groups, assuming that the elasticity of substitution between native and foreign workers varies across education groups given that the importance of language, culture, and other factors may differ by education. 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 the subject of some controversy in the literature. We simply assume that  $\sigma_i \geq 0$ , i.e., we do not base our empirical analysis on an a priori assumption as to whether foreign and native workers are perfect substitutes or not.

Assuming that the wage rate equals the marginal product of labor, and choosing output as the numeraire good, we can derive from the production function the log wage of a worker with skill  $i$ , education  $j$ , and national origin

$k$  as

$$\begin{aligned} \ln w_{ijkt} &= \ln(\alpha A_t^{1/\alpha}) + \frac{1}{\delta} \ln L_t + \ln \theta_{it} - \left( \frac{1}{\delta} - \frac{1}{\rho} \right) \ln L_{it} \\ &+ \ln \theta_{ij} - \left( \frac{1}{\rho} - \frac{1}{\sigma_i} \right) \ln L_{ijt} + \ln \theta_{ijk} - \frac{1}{\sigma_i} \ln L_{ijkt} + \frac{1-\alpha}{\alpha} \ln \kappa_t, \end{aligned} \quad (10)$$

where  $\kappa$  denotes the capital-output ratio.

The interest rate is a function of the capital-output ratio,  $r = \frac{1-\alpha}{\kappa}$ . Thus, the complete adjustment of the capital stock to an aggregate labor supply shock requires that the capital-output ratio remains constant. Note that a constant capital-output ratio is predicted by neoclassical growth models and one of the stylized facts about economic growth (Kaldor, 1961). Following Ottaviano and Peri (2006) we assume that  $\frac{d\kappa}{dM} \leq 0$ , which is examined below.

The derivatives of equation (10) are used for finding the partial derivatives of the wage with respect to the labor supply changes in equation (4). These partial derivatives determine together with the elasticities of the wage-setting curves the employment and wage response to a labor supply shock. We assume that the elasticities of the wage-setting curves vary by education and work experience reflecting differences in the bargaining power and productivity of different groups in the labor market. However, we impose the restriction of a uniform wage-setting curve in each education-experience cell since centralized wage-setting makes it rather unlikely that different wages are agreed for native and foreign workers at given levels of education and work experience.<sup>4</sup>

Finally, having solved for the employment response we can express the wage effect of migration in equation (5) as

$$\begin{aligned} \frac{dw_{ijkt}}{w_{ijkt}} &= \frac{1}{\delta} \sum_q \sum_n \sum_m \left( s_{qnmt} \frac{dL_{qnmt}}{L_{qnmt}} \right)_{immigration} \\ &- \left( \frac{1}{\delta} - \frac{1}{\rho} \right) \frac{1}{s_{it}} \sum_n \sum_m s_{inmt} \left( \frac{dL_{inmt}}{L_{inmt}} \right)_{immigration} \\ &- \left( \frac{1}{\rho} - \frac{1}{\sigma_i} \right) \frac{1}{s_{ijt}} \sum_m \left( s_{ijmt} \frac{dL_{ijmt}}{L_{ijmt}} \right)_{immigration} \\ &- \frac{1}{\sigma_i} \left( \frac{dL_{ijkt}}{L_{ijkt}} \right)_{immigration} + \frac{(1-\alpha)}{\alpha} \left( \frac{d\kappa_t}{\kappa_t} \right)_{immigration}, \end{aligned} \quad (11)$$

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<sup>4</sup>The explicit solution for the employment response is derived in a separate Appendix which is available upon request from the authors.

where  $s_{qnm t}$ ,  $s_{inm t}$ ,  $s_{ijm t}$ ,  $s_{ijt}$  and  $s_{it}$  denote the share of the wages paid to workers in the respective labor market cells in the total wage bill.<sup>5</sup> The change of the labor supply in each cell of the labor market as denoted by the terms in brackets in equation (11) refers to the employment changes as determined by equation (4). Finally, as before, the term  $d\kappa_t$  refers to the change in the capital-output ratio triggered by immigration.

## 4 Data

### 4.1 Description of the dataset

In our empirical analysis we use the IAB Sample (IABS), a two percent random sample of all German employees registered with the social security system in the period 1975-2004. In addition to socio-economic and job characteristics the IABS provides information on benefit recipients at the individual level.<sup>6</sup>

The IABS is stratified according to nationality and therefore representative for the native and foreign working population. The dataset is especially suitable for performing analyses taking wages into account since the wage information is used to calculate social security contributions and is therefore highly reliable.<sup>7</sup>

Nevertheless the IABS has also some minor limitations in the context of our analysis: the main shortcoming is that we can identify foreigners only on the basis of citizenship. Some further limitations arise from the wage and qualification information provided by the dataset. This has several implications:

First, there is no information on the year when immigrants entered the country. Due to the *jus sanguinis* tradition of the German law, naturalization rates have been traditionally very low, such that second and third generation migrants often have foreign citizenship and are therefore recorded as foreign workers in our sample. On August 1, 1999, a new immigration act came into effect that allows German-born children of foreign-born par-

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<sup>5</sup>Thus,  $s_{ijkt} = \frac{w_{ijkt}L_{ijkt}}{\sum_q \sum_n \sum_m w_{qnm t}L_{qnm t}}$ ,  $s_{ijt} = \frac{\sum_m w_{ijm t}L_{ijm t}}{\sum_q \sum_n \sum_m w_{qnm t}L_{qnm t}}$ , and  $s_{it} = \frac{\sum_n \sum_m w_{inm t}L_{inm t}}{\sum_q \sum_n \sum_m w_{qnm t}L_{qnm t}}$ .

<sup>6</sup>From administrative data sources of the Federal Employment Agency, we know that about 90 percent of the registered unemployed are eligible for benefits. Therefore, the unemployment rate is only slightly downward biased (Wagner and Jahn, 2004).

<sup>7</sup>In our sample the average size of the foreigner cells is well above 1,000 observations. Therefore, it is not likely that our results suffer from 'attenuation bias' (Aydemir and Borjas, 2006)



ents living in Germany for at least eight years to decide up to the age of 23 which nationality to adopt. This has slightly increased the naturalization of German-born individuals whose parents possess a migrant background. To mitigate the possible effects of naturalizations, we have classified all individuals as foreigners who are reported as foreign citizens in their first available spell. This does not allow us to control for individuals who were naturalized before entering the sample, but avoids naturalizations from being displayed in our sample as a declining foreigner share.

Second, ethnic Germans – so-called "Spätaussiedler" – are reported in the dataset as Germans, since the concept of citizenship does not allow us to distinguish between home and foreign-born German citizens. However, special benefits have been offered to ethnic Germans, such as language courses and other integration subsidies that should facilitate their labor market integration. These measures are reported in the benefit recipient file added to our dataset. This allows us to identify the majority of ethnic Germans who have entered the German labor force since 1980. In our sample, the cumulative inflow of ethnic Germans achieves 3.2 percent of the labor force in Western Germany. Since ethnic Germans' labor market performance and language command resembles that of other foreigners (see e.g. Bauer and Zimmermann, 1997; Zimmermann, 1999), we have classified ethnic Germans as members of the foreign labor force.

Third, the IABS covers only a part of the immigration surge from Eastern Germany. The IABS included Eastern Germany for the first time in 1992. A large part of the East-West migrants in Germany moved immediately after the fall of the Berlin wall. This implies that more than one-third of the 2 million migrants who have moved from Eastern to Western Germany since 1989 are not covered by the dataset (Bundesamt, 2006). In addition, a large number of East-West migrants moved to Western Germany before appearing as employed or unemployed in the IABS, e.g., as students (Burda and Hunt, 2001; Hunt, 2006). The IABS thus not only understates the actual level of East-West migration, it also distorts the skill distribution, since most of the highly educated migrants move from Eastern to Western Germany before their first employment spell (Brücker and Trübswetter, 2007).

For this reason, we decided to classify migrants from East Germany as natives here and focus our analysis on Western Germany. Western Germany accounts for more than four-fifth of the German labor force and the foreigner share is negligible in Eastern Germany. Focussing our analysis only on the unified Germany after 1992 would exclude the main immigration shock during 1987-1991. <sup>8</sup> German reunification also requires excluding Western Berlin,

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<sup>8</sup>Including Eastern Germany from 1992 on does not change significantly the estimated

since mobility between Eastern and Western Berlin has been high since the fall of the Berlin wall.

Fourth, the dataset reports gross daily wages and does not provide information on hours worked. We therefore exclude part-time employees, trainees, interns, and at-home workers from the sample since the wage information is not comparable for these groups. For the same reason we exclude workers with wages below the social security contribution threshold although they are coded as full-time workers.<sup>9</sup>

Fifth, we restrict our analysis to individuals between the ages of 15 and 60. The reasons are that the statutory retirement age for females is the age of 60, for males the age of 65. In addition, there is some empirical evidence of differences in the early retirement behavior between German and immigrant men (Bonin, Raffelhüschen, and Walliser, 2000).

Sixth, our data are right-censored since gross wages can only be observed up to the social security contribution ceiling. About three percent of the employment spells are censored. This may affect the estimation of the wage-setting curves, particularly 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 IABS dataset (Büttner and Rässler, 2008).

Seventh, self-employed workers and civil servants do not contribute to the social security system and are therefore not covered by our sample. To the best of our knowledge, there is no indication that foreign workers are disproportionately self-employed compared to native workers. In the case of civil servants, it seems plausible to assume that due to legal restrictions, immigrants do not substitute natives.

Eighth, the information on education is provided by the employers. This means that information on education levels is missing for about 17 percent of the individuals. Foreigners are disproportionately affected by missing information on education levels. We therefore imputed the missing information on education by employing the procedure developed by Fitzenberger, Osikominu, and Völter (2005) for an earlier version of the IABS. In a first step, spells with valid and invalid educational information are identified by classifying the reliability of employers' reporting behavior. In subsequent steps, only valid educational information is used for extrapolation. This

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parameters of the model.

<sup>9</sup>These workers are likely to hold a 'mini-job'. Mini-jobs are attractive to workers because only the employer, not the employee, has to pay social security contributions if total earnings are below a legally defined threshold (400 Euros per month in 2007). There is no indication that this creates a source of bias in the empirical analysis since foreigners are proportionally represented in the respective groups.

procedure also allows us to correct inconsistent educational information on individuals over time. After applying this imputation procedure, we had to drop only 1.6 percent of the individuals because of missing or inconsistent information on education.

Finally, education and work experience acquired in foreign countries may not have the same value in the labor market as education and experience obtained in Germany. Moreover, certain characteristics of foreigners, such as their command of the German language, may prevent them from fully transferring their human capital to the German labor market. However, correcting for the education and experience levels of foreigners by variables related to their current labor market performance involves an endogeneity problem. It may moreover bias our estimates of the elasticity of substitution between native and foreign workers. We therefore employ the same rules for the classification of education and experience groups for foreign and native workers.

Following the model outlined in Section 3, we group the labor force by education and potential work experience. A sensible classification following the characteristics of the German labor market requires us to distinguish four education groups: no vocational degree, vocational degree, high school degree ('Abitur') with vocational degree, and university degree. At first glance, one might consider aggregating the groups "vocational degree" and "high school degree with vocational degree", but in Germany these are separate labor markets. Despite its small size, we therefore decided to treat the group with high school degree separately.

Furthermore, we distinguish eight potential work experience classes following the standard approach by Borjas (2003) in subtracting the typical number of years spent in the educational system from the age of the worker, and splitting the experience in intervals of five years. At the beginning of the sample period, we have only a few observations in some education experience classes. Therefore, we exclude the 1975-1979 period and confine our analysis to individuals who were employed or unemployed on September 30 during the period from 1980 to 2004.

## 4.2 Immigration trends and descriptive evidence

Figure 2 displays the share of foreigners in the labor force and the share of foreigners in the employed workforce. During the 1980s, we observe a sharp decline, which is a consequence of tightening migration restrictions after the first and second oil price shock. Between the mid 1980s and the mid 1990s the foreign share in the labor force of Western Germany increased by 5 percentage points compared to 4 percentage points during the total sample

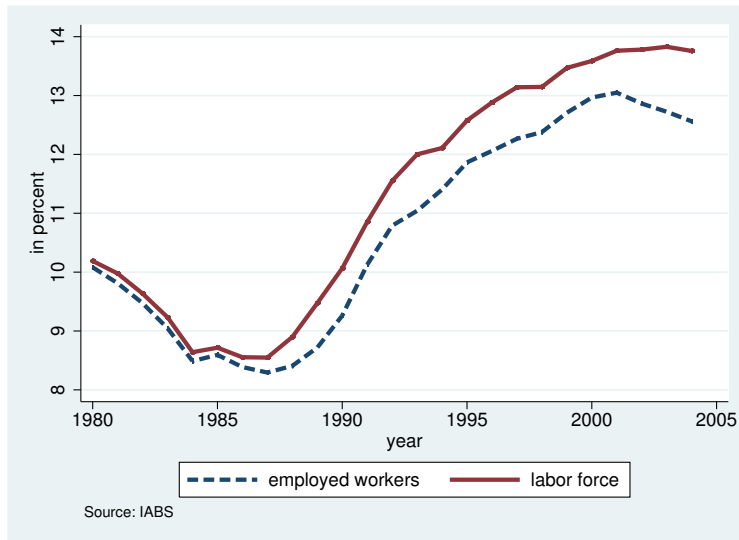


Figure 2: Share of foreign labor force and workers

period. The sharp increase in the foreigner share during the 1990s is a result of the fall of the Berlin wall and the civil wars in the former Yugoslavia, which triggered large migration flows into Germany. Note that the ethnic Germans who contributed substantially to the increasing labor supply in the 1990s are treated as foreigners. Since the beginning of the 2000s, the foreigner share has plateaued as a consequence of the slowdown in economic growth and tighter restrictions on immigration. Moreover, foreigners tend to be more than proportionally affected by unemployment, such that their share in the employed workforce declined relative to their share in the labor force during the 1990s.

The foreign workforce is heavily concentrated in the group with no vocational training. Its share has increased there from 24 percent in 1980 to 39 percent in 2004, and the share of foreign workers in the group with a vocational degree from 5 percent to 11 percent during the same period of time. In the high-skilled segments of the labor market the foreigner share has been roughly stable (Figure 3).

Table A1 displays the gross daily wages in 2000 prices. Wage levels increase with educational levels and with experience in all education groups. The wage levels of foreign workers are in all education groups below those of the native labor force. While these differences are fairly small in the education groups with no vocational degree, they are as high as 20 percent in the other education groups.

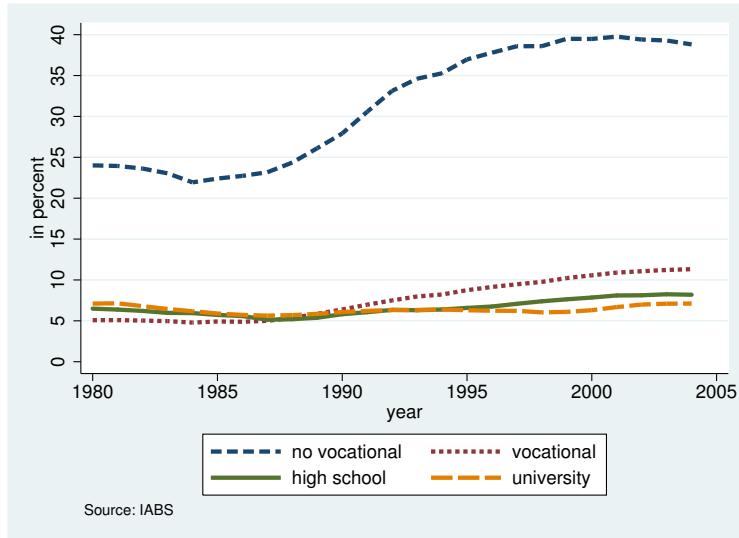


Figure 3: Share of foreigners by education

## 5 Estimation

### 5.1 Wage curves

The first step in the empirical application of the model outlined in Section 3 is to estimate the elasticities of the wage-setting curve. Following Baltagi, Blien, and Wolf (2007), Bell, Nickell, and Quintini (2002) and Blanchflower and Oswald (2005) we estimate the model in dynamic form, which allows to disentangle short-run and the long-run wage and employment effects of migration if labor markets do not adjust instantaneously to labor supply shocks. We estimate the elasticity of the wage-setting curve for each education and experience group separately which yields

$$\ln w_{ijt} = \beta_{ij} \ln w_{ij,t-1} + \eta_{ij} \ln u_{ijt} + \gamma_{ij} \tau_{ijt} + e_{ijt}, \quad (12)$$

where  $\eta$  denotes the elasticity between the wage and the unemployment rate and  $\tau$  a deterministic time trend. We consider a linear and a squared trend here. The error term  $e_{ijt}$  is specified as a one-way error component model with fixed effects for each education-experience group. Since unemployment might be endogenous, we follow Blanchflower and Oswald (2005) and Baltagi, Blien, and Wolf (2007) and instrument the unemployment rate with the first, second, and third lag of the unemployment rate. In each regression we have pooled two experience groups together to achieve more stable results.

Table 1 about here

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The estimation results are displayed in Table 1. All regressions have the expected negative sign for the coefficient on the unemployment rate. The autoregressive parameter on the lagged wage is well below 1, supporting a wage-setting curve rather than a Phillips curve. Moreover, in most regressions, the short-run and the long-run elasticities between the wage and the unemployment rate are highly significant. We obtain only insignificant results in the group of workers with a high school degree and university degree and the most extensive work experience, suggesting that the responsiveness of wages to the unemployment rate is close to zero in this segment of the labor market.<sup>10</sup>

The first regressions provide estimates of the wage-setting curve for all groups and for each education group separately. In the regression where all education-experience groups are pooled, we find a short-run elasticity of about -0.08 and a long-run elasticity of about -0.15. The national-level estimates presented here are somewhat higher than the average elasticity of -0.1 found by the regional-level wage curve literature in other OECD countries (see Blanchflower and Oswald, 1994, 2005; Nijkamp and Poot, 2005), but much higher than the elasticity of -0.03 estimated by Baltagi, Blien, and Wolf (2007) at the regional level in Germany. This is not surprising, since the regional level estimates control for all macroeconomic influences which are particularly relevant in economies such as Germany where centralized wage-setting plays an important role.

Interestingly enough, the long-run elasticities are high at both ends of the skill spectrum: in the labor market segment without a vocational degree, we find a long-run elasticity of about -0.17, and in the high-skilled segment of individuals with a university degree a long-run elasticity of -0.19. The elasticity is particularly low in the segment with a vocational training degree, i.e., the labor market segment with a high share of unionized workers.

Even more intriguing is our finding of extremely high elasticities in segments with low work experience. Here we obtain long-run elasticities of between -0.24 and -0.37. They decline monotonically with increasing work experience in all cells of our sample and are particularly low in the labor segment with work experience of more than 30 years.

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<sup>10</sup>As a robustness check we have estimated equation (12) also by GMM since our results might be subject to the Nickell (1981) bias. We expect however a moderate bias since  $T = 23$  in our sample. The overall elasticity of the GMM estimates is somewhat below the IV-estimation results, but the elasticities for the individual education groups are comparable. The GMM estimation results are available from the authors upon request.

## 5.2 Capital adjustment

The impact of migration on aggregate wages depends largely on the adjustment of the capital stock. The Kaldor (1961) stylized facts on economic growth suggest that the capital-output ratio remains constant over time, indicating that capital stocks adjust to changes in labor supply.

For the calculation of the capital-output ratio we employ the net fixed capital stock series provided by the OECD.<sup>11</sup> These data indeed demonstrate that the capital-output ratio has increased only slightly from about 3.0 to 3.15 in Western Germany during the four decades since 1960. Moreover, the fluctuations around the long-run ratio of 3.1 are relatively small.

The unit root tests indicate that the capital-output ratio and the labor force follow different stochastic processes over time. We can reject the hypothesis of a unit root for the capital-output ratio at the 1 percent level if we include only a constant, and at the 5 percent level if we include a constant and a deterministic time trend. Thus, the capital output ratio seems to be stationary. In contrast, the unit root test results suggest that the labor force is a non-stationary variable which is integrated of first order. The levels of the capital-output ratio and the labor force hence cannot form a long-run equilibrium relationship. This may be interpreted as support for the Kaldor (1961) facts.

For analyzing the short-run effects of labor supply shocks on the capital-output ratio we estimate the following model:

$$\ln \kappa_t = \beta_0 + \sum_{s=1}^{s=Z} \gamma_s \ln \kappa_{t-s} + \beta_1 \Delta \ln N_t + \beta_2 \ln \tau_t + \varepsilon_t, \quad (13)$$

where  $\kappa_t$  denotes, as above, the capital-output ratio,  $N_t$  the total labor force,  $\tau_t$  a deterministic time trend,  $\varepsilon_t$  disturbances which are assumed to be white noise, and  $s = 1, \dots, Z$  an index for the autoregressive terms considered by the model.

The number of autoregressive terms is determined by the Breusch-Godfrey test for serial correlation. The test results suggest a second-order autoregressive specification. We have moreover added a dummy variable that controls for a structural break after German reunification, which is present in our data according to the Chow-breakpoint test.

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<sup>11</sup>German unification involves a break in the time series on capital stocks. Since the OECD reports only data on the unified Germany from 1991 on, we use the share of Western Germany in the gross fixed assets provided by the Statistical Offices of the Federal States for the calculation of the share of Western Germany in Germany's total capital stock. This does not involve any visible break in the time series.

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Table 2 about here

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The results are displayed in Table 2. In the simple OLS specification we find a coefficient on  $\Delta \ln(N_t)$  in the vicinity of about -0.7. A change of the capital-output ratio of this size would be expected if the labor share in national income is 0.7 and if physical capital remains fixed in the short run. The sum of the coefficients for the autoregressive terms suggest that adjustment is fairly fast, i.e., that two-thirds of the labor supply shock disappears within one year.

The simple OLS regression suffers, however, from the endogeneity of labor supply shocks. We therefore instrumented the labor force variable with the first and second lag of the population in Western Germany. In this case the impact of labor supply shocks becomes insignificant and shrinks to -0.2. Although we cannot exclude that the actual impact of short-run labor supply shocks on the capital-output ratio is zero, we use this value for the short-run simulations, while we assume that labor supply shocks have no impact in the long run.<sup>12</sup>

### 5.3 Elasticities of substitution

The empirical estimation of the elasticities of the production function is straightforward as Card and Lemieux (2001), Borjas (2003) and Ottaviano and Peri (2006) have shown. Let us start with the identification of the elasticity of substitution between native and foreign workers. The relative demand of native and foreign workers of education  $i$  and experience  $j$  can be expressed as

$$\ln(w_{ijht}/w_{ijft}) = \ln(\theta_{ijh}/\theta_{ijf}) - \frac{1}{\sigma_i} \ln(L_{ijht}/L_{ijft}).$$

To identify the ratio  $\theta_{ijh}/\theta_{ijf}$ , we employ dummy variables for each education-experience cell following Ottaviano and Peri (2006, 2008). This implies that relative productivity of natives and immigrants varies across education and experience groups, but is constant over time. Note that technology shifts in the productivity of education (or experience) groups are absorbed by the higher levels of the production function.<sup>13</sup> Conditional on these controls, we

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<sup>12</sup>Using a short-run parameter of zero for the change in the capital-output ratio would reduce the wage and (un-)employment effects of immigration in our simulations only slightly.

<sup>13</sup>Borjas, Grogger, and Hanson (2008) suggest to include furthermore interaction dummies of the education-experience specific fixed effects with linear time trends. While this



assume that changes in the relative employment of natives and foreigners in each education-experience cell are due to random shocks in the labor supply. We thus estimate the following regression to identify  $\sigma_i$ :

$$\ln(w_{ijht}/w_{ijft}) = D_{ij} - \frac{1}{\sigma_i} \ln(L_{ijht}/L_{ijft}) + \nu_{ijt}, \quad (14)$$

where the error term  $\nu_{ijt}$  is a zero-mean random disturbance. In total we have  $i \times j \times t = 800$  observations. We estimate the equations by OLS and weighted OLS using total employment in each cell as a weight.

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Table 3 about here

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The results are reported in Table 3. The coefficient for  $\sigma_i$  is significantly different from zero in all regressions except for the groups of workers with a university degree, providing support for the hypothesis that native and foreign workers are imperfect substitutes in the first three education groups. For the further analysis, we use the education-specific estimates of the parameter  $\sigma_i$  since the  $F$ -test rejects the null hypothesis that the coefficients are of equal size.

The estimated coefficients for  $1/\sigma_i$  of between 0.05 and 0.07 suggest that the elasticity of substitution between native and foreign workers lies between 15 and 20. This is substantially larger than the estimate by Ottaviano and Peri (2006) for the US, but remarkably close to their revised estimate which employs a different classification of education groups compared to the first study (Ottaviano and Peri, 2008). The estimates by D'Amuri, Ottaviano, and Peri (2008) for Germany are, at between 0.04-0.06, also very close to ours. Similarly, Felbermayr, Geis, and Köhler (2008) estimate this elasticity based on another dataset at between 0.07 and 0.1. In contrast, Borjas, Grogger, and Hanson (2008) find no evidence that immigrants and natives are imperfect substitutes for the US, but the large number of dummy variables considered in their specification may have absorbed the variance needed for the identification of the parameter  $1/\sigma$  (Ottaviano and Peri, 2008).

In the next step we estimate the elasticity of substitution between experience groups. From the production function we obtain the wage for the labor

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would absorb a large part of the identifying variation, we cannot see a theoretical argument why the elasticities of substitution between natives and foreigners should change systematically over time.

composite  $L_{ijt}$

$$\ln w_{ijt} = \ln \left( \alpha A_t^{1/\alpha} \kappa_t^{\frac{1-\alpha}{\alpha}} \right) + \frac{1}{\delta} \ln L_t + \ln \theta_{it} - \left( \frac{1}{\delta} - \frac{1}{\rho} \right) \ln L_{it} + \ln \theta_{ij} - \frac{1}{\rho} \ln L_{ijt},$$

which we can rewrite for the estimation of the parameter  $1/\rho$  as

$$\ln w_{ijt} = D_t + D_{it} + D_{ij} - \frac{1}{\rho} \ln \hat{L}_{ijt} + v_{ijt}, \quad (15)$$

where the time-specific fixed effects  $D_t$  control for the variance of  $\ln \left( \alpha A_t^{1/\alpha} \kappa_t^{\frac{1-\alpha}{\alpha}} \right) + \frac{1}{\delta} \ln L_t$ , and the time by education-specific fixed effects  $D_{it}$  for the variation in  $\ln \theta_{it} - \left( \frac{1}{\delta} - \frac{1}{\rho} \right) \ln L_{it}$  and the education-experience group fixed effects  $D_{ij}$  for the productivity term  $\ln \theta_{ij}$ , which is assumed to be constant over time. The labor composite  $\hat{L}_{ijt}$  is calculated as  $\hat{L}_{ijt} = \left[ \hat{\theta}_{ijh} L_{ijht}^{(\hat{\sigma}_i-1)/\hat{\sigma}_i} + \hat{\theta}_{ijf} L_{ijft}^{(\hat{\sigma}_i-1)/\hat{\sigma}_i} \right]^{\hat{\sigma}_i/(\hat{\sigma}_i-1)}$ , where the productivity parameters of native and foreign workers can be derived from the estimated fixed effects as  $\hat{\theta}_{ijh} = \frac{\exp(\hat{D}_{ij})}{1+\exp(\hat{D}_{ij})}$  and  $\hat{\theta}_{ijf} = \frac{1}{1+\exp(\hat{D}_{ij})}$ .

Equation (15) allows us to consistently estimate the parameter  $-\frac{1}{\rho}$  by 2SLS, where we use the log of employed native workers in each experience-education group as an instrument.<sup>14</sup>

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Table 4 about here

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We find an elasticity of substitution of about 30 in the regressions that refer to the total period, which is substantially higher than the elasticity of substitution of between 4 and 5, which Borjas (2003), Card and Lemieux (2001) and Ottaviano and Peri (2006) obtain in their studies for the US.<sup>15</sup> Interestingly enough, Felbermayr, Geis, and Kohler (2008) obtain similar elasticities for Germany to ours, although they employ another dataset for their analysis. As a robustness check we have also assumed an infinite elasticity of substitution between native and foreign workers in the calculation of  $L_{ijt}$ , which yields very similar results (see Table 4).

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<sup>14</sup>Considering the log of employed foreign workers as an instrument in addition does not change our results significantly.

<sup>15</sup>In their recent study on Germany, D'Amuri, Ottaviano, and Peri (2008) do not provide estimates for the elasticity of substitution across experience and education groups but use the US estimates.

The elasticity of substitution between education groups is estimated analogously. From the production function we have

$$\ln w_{it} = \ln \left( \alpha A_t^{1/\alpha} \kappa_t^{\frac{1-\alpha}{\alpha}} \right) + \frac{1}{\delta} \ln L_t + \ln \theta_{it} - \frac{1}{\delta} \ln L_{it},$$

which enables us to identify the parameter  $\frac{1}{\delta}$  as

$$\ln w_{it} = D_t + D_i + \lambda_i \tau_i - \frac{1}{\delta} \ln \hat{L}_{it} + \vartheta_{it}. \quad (16)$$

The time-specific fixed effects  $D_t$  control for the variance in  $\ln \left( \alpha A_t^{1/\alpha} \kappa_t^{\frac{1-\alpha}{\alpha}} \right) + \frac{1}{\delta} \ln(L_t)$  and the education-specific fixed effects  $D_i$  and the education-specific deterministic time trend  $\tau_i$  for the variance in the skill-specific efficiency parameter  $\theta_{it}$ . The labor composite  $\hat{L}_{it}$  is computed as  $\hat{L}_{it} = \left[ \sum_{j=1}^8 \hat{\theta}_{ij} \hat{L}_{ijt}^{(\hat{\rho}-1)/\hat{\rho}_i} \right]^{\hat{\rho}/(\hat{\rho}-1)}$ , where the estimated efficiency parameters  $\hat{\theta}_{ij}$  are derived from the fixed-effects estimates as  $\hat{\theta}_{ij} = \frac{\exp(\hat{D}_{ij})}{\sum_j \exp(\hat{D}_{ij})}$ .  $\vartheta_{it}$  is assumed to be a zero-mean random disturbance.

Equation (16) is estimated again by 2SLS using the the log of employed native workers in each experience-education group as an instrument. We receive for  $1/\delta$  an estimated parameter of about 0.15 in the total sample period, which corresponds to an elasticity of substitution between education groups of 6.5. This elasticity is about twice as high as the elasticities found in US studies (e.g. Katz and Murphy, 1992; Ottaviano and Peri, 2006), but again matches the findings by Felbermayr, Geis, and Kohler (2008) for Germany. As a robustness check we apply the assumption that the elasticity  $\rho$  tends to infinity for the calculation of  $L_t$ , which yields a similar elasticity of substitution (Table 4).

Finally, the parameter  $\alpha$  has been calculated from the labor share in national income, which yields an average value of 0.67.

## 6 Simulation results

We now use the estimated parameter values for the simulation of the impact of migration on (un-)employment and wages. In each scenario, we distinguish between the short-run and the long-run effects of migration. For the simulation of the short-run effects we employ the short-run coefficients for the elasticity  $\hat{\eta}_{ij}$  from the wage-setting curve estimates and the (small) negative effect of an increase in the labor force on the capital-output ratio. The long-

run effects are calculated by using the long-run elasticities of the wage-setting curve and by assuming that the capital-output ratio remains constant.

We simulate two scenarios here. First, we simulate the effects of a one percent increase of the labor force through immigration using the average distribution of foreigners across the education-experience cells of the labor market. This implies that the overwhelming majority of the increase takes place in the education group of those with no vocational training, while the increase in the other education groups is modest. This scenario provides an indication as to the marginal effects of immigration at the given structure of the workforce.

In a second scenario we simulate the wage and employment effects of immigration using the actual immigration figures during the sample period, i.e., 1980-2004. We consider the actual changes in each cell of the labor market here.

The employment and wage effects are calculated for native and foreign workers for each education-experience group. For the aggregation, we weighted 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. In the tables, we report the average effects for the total labor force, the native labor force, and the foreign labor force by educational levels.

A one percent immigration of workers with the same education and experience characteristics as the existing foreign workforce reduces average wages by 0.1 percent and increases the average unemployment rate by less than 0.1 percentage points in the short run, while the long run impact is neutral. Particularly negatively affected are workers with no vocational training degree, where the share of the foreign workforce is relatively high. The native workforce is only slightly negatively affected in the short run and benefits from both increasing wages and declining unemployment in the long run. However, native workers lose slightly in the segment with no vocational degree. In contrast, wages of foreign workers tend to decline by about 0.7 percent in the short run and by 0.6 percent in the long run, while the unemployment rate increases by 0.4 percentage points in the short run and by 0.1 percentage points in the long run (Table 5).

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Table 5 about here

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The actual labor supply shock during the 1980-2004 period changed the structure of the foreign workforce. The total workforce increased by 4.1 percent through an increasing number of foreign workers, but the individual

education groups were affected in different ways: The change in the foreign labor supply increased the workforce with an university degree and – to a lesser extent – with a vocational training degree more than proportionally, while it reduced the labor supply in the group without a vocational degree substantially. Particularly affected by the increasing foreign labor supply is the rather small group with a high school degree. Note that the changing skill structure of the foreign workforce reflects an overall trend of increasing educational levels in the German workforce. As a consequence, the foreigner share in the skill group without vocational training has increased albeit the absolute number of foreigners has declined in this segment of the labor market.

Table 5 shows that the 1980-2004 foreign labor supply shock reduces average wages by a mere 0.4 percent in the short run. In the long run, average wages remain stable due to the adjustment of capital stocks. The unemployment rate increases by less than 0.1 percentage points in the short run, and stays almost stable in the long run. Particularly affected are the groups with a high school degree and a university degree, since the immigration shock was large compared to the other groups here.

The wage impact of migration on the native labor force is almost neutral, but natives tend to benefit by increasing wages and a slightly decreasing unemployment rate in the short run. However, the rather small group with a high school degree experiences a substantial, and the group with a university degree a small loss in terms of lower wages and higher unemployment.

The foreign labor force suffers from a substantial wage loss of about 2.3 percent in the short run and 1.8 percent in the long run. The unemployment rate declines in the short run by about 0.1 percentage points, but increases in the long run by 0.25 percentage points. Note that the unemployment rate of foreign workers without a vocational degree declines substantially by 3.3 percentage points in the short run, but this decline shrinks to 1.0 percentage points when wages adjust in the long run. As a consequence, the reduced unemployment of less skilled foreigners is outpaced by higher unemployment in the other education groups in the long run. Altogether, wages of foreign workers are adversely affected by the increasing labor supply, while the impact on unemployment is ambiguous due to the change in the skill composition of the foreign workforce.

## 7 Conclusions

In this paper we presented a general equilibrium framework that allowed us to analyze the wage and employment effects of migration simultaneously.

We modeled wage rigidities in form of a wage-setting curve, which assumes that wages respond imperfectly to an increase in the unemployment rate. In the empirical application of the model we found that the elasticities of the wage-setting curve differ widely for the different segments of the labor market. While the elasticity of the wage with respect to the unemployment rate is relatively high in the segments of the labor market with a university degree and limited work experience, it is particularly low in the labor market segment with a vocational degree and extensive work experience.

At the given structure of the foreign workforce, migration reduces average wages and increases unemployment of the total workforce slightly in the short run, while it is neutral in the long run. More interesting are the structural effects: while native workers tend to benefit, the foreign workforce tends to suffer from lower wages and increasing unemployment, at least in the short run.

The analysis of actual immigration into Germany during the 1980 to 2004 period, which includes the immigration shock surrounding the fall of the Berlin wall, demonstrates that natives have suffered from this immigration episode only in the short run if at all. In the long run they tend to benefit both from higher wages and slightly declining unemployment. The increase of the foreign workforce by about 40 percent during this 25 year period has reduced the unemployment of the foreign workforce in the short run and increased it in the long run by only 0.25 percent. This counter-intuitive finding can be traced back to the fact that migrants entered the flexible segments of the labor market more than proportionally, in particular the segment with low work experience. While this labor supply change has not resulted in higher unemployment of the foreign workforce, it has reduced wages of foreign workers by almost 4 percent in this 25 year period.

Our empirical analysis has produced a number of further intriguing results. We found evidence that native and foreign workers are imperfect substitutes in the labor market. The elasticity of substitution is however much higher than that obtained in the Ottaviano and Peri (2006) study for the US, but is similar to that found recently by Ottaviano and Peri (2008) and D'Amuri, Ottaviano, and Peri (2008).

Finally, our results provide strong evidence that capital stocks adjust to labor supply shocks. We found no negative relationship between labor supply and the capital-output ratio in the long run, and only small and insignificant effects for short-term supply shocks. This supports one of the famous stylized facts on economic growth by Nicholas Kaldor (1961) and the evidence that Ottaviano and Peri (2006) found for the US. This again has important implications for the wage effects of migration: at least in the long run, an increasing labor supply through migration does not reduce the

average wage level in the economy.

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Table 1: **The wage-setting curve: IV-estimation results**

education	$\ln w_{ij,t-1}$			short-run		$\ln u_{ijt}$		long-run		R <sup>2</sup>
	coeff.	se		coeff.	se	coeff.	se			
all experience groups										
all	0.480	(0.029)	***	-0.077	(0.007)	***	-0.148	(0.014)	***	0.88
no vocational	0.649	(0.050)	***	-0.061	(0.007)	***	-0.172	(0.031)	***	0.94
vocational	0.535	(0.052)	***	-0.055	(0.007)	***	-0.119	(0.019)	***	0.96
high school	0.508	(0.064)	***	-0.081	(0.023)	***	-0.164	(0.048)	***	0.82
university	0.356	(0.064)	***	-0.120	(0.019)	***	-0.186	(0.026)	***	0.86
experience group 1 (0 - 5 years) and experience group 2 (6 - 10 years)										
no vocational	0.776	(0.102)	***	-0.059	(0.013)	***	-0.265	(0.142)	*	0.820
vocational	0.778	(0.086)	***	-0.053	(0.009)	***	-0.238	(0.114)	**	0.980
high school	0.807	(0.110)	***	-0.072	(0.018)	***	-0.372	(0.266)		0.970
university	0.531	(0.100)	***	-0.132	(0.020)	***	-0.281	(0.067)	***	0.900
experience group 3 (11 - 15 years) and experience group 4 (16 - 20 years)										
no vocational	0.464	(0.122)	***	-0.104	(0.023)	***	-0.194	(0.057)	***	0.950
vocational	0.303	(0.114)	***	-0.092	(0.017)	***	-0.132	(0.027)	***	0.960
high school	0.405	(0.143)	***	-0.094	(0.050)	*	-0.159	(0.076)	**	0.930
university	0.481	(0.102)	***	-0.138	(0.045)	***	-0.266	(0.088)	***	0.890
experience group 5 (21 - 25 years) and experience group 6 (26 - 30 years)										
no vocational	0.460	(0.111)	***	-0.080	(0.018)	***	-0.149	(0.033)	***	0.960
vocational	0.428	(0.124)	***	-0.067	(0.020)	***	-0.117	(0.030)	***	0.860
high school	0.507	(0.159)	***	-0.122	(0.060)	**	-0.247	(0.110)	**	0.500
university	0.316	(0.133)	**	-0.094	(0.036)	***	-0.137	(0.044)	***	0.820
experience group 7 (31 - 35 years) and experience group 8 (> 35 years)										
no vocational	0.394	(0.115)	***	-0.090	(0.019)	***	-0.148	(0.024)	***	0.980
vocational	0.215	(0.147)		-0.076	(0.019)	***	-0.097	(0.021)	***	0.960
high school	0.412	(0.137)	***	-0.069	(0.069)		-0.117	(0.113)		0.430
university	0.290	(0.238)		-0.081	(0.075)		-0.114	(0.075)		0.850

*Notes:* Dependent variable is  $\ln w_{ijt}$ , i.e. the log wage in each education-experience group. White-heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. The model is estimated by 2SLS. The unemployment rate is instrumented by its first, second and third lag. The model is specified as a one-way error component model with group specific fixed effects and contains a deterministic time trend and a squared deterministic time trend for each experience group. The regressions for each education-experience group are based on 44 observations, the regressions in each education group on 176 observations, and the overall regression on 704 observations. Within R<sup>2</sup> are reported.

Table 2: **Impact of labor supply shocks on the capital-output ratio**

dependent variable: $\ln \kappa_t$	OLS		IV		
$\ln \kappa_{t-1}$	0.745	***	0.911	***	
	(0.165)		(0.275)		
$\ln \kappa_{t-2}$	-0.393	***	-0.500	***	
	(0.153)		(0.211)		
$\Delta \ln N_t$	-0.692	**	-0.205		
	(0.278)		(0.698)		
observations	44		44		
adjusted R <sup>2</sup>	0.66		0.64		
Durbin-Watson statistics	1.54		1.73		
<b>ADF test for unit roots</b>					
	constant		constant and trend		
	<i>t</i> -statistic		<i>t</i> -statistic		lags
$\ln \kappa_t$	-3.89	***	-3.82	***	1
$\ln N_t$	0.13		-2.49		1
$\Delta \ln N_t$	-4.20	***	-4.25	***	0

*Notes:* White-heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Each regression includes a constant and a logarithmic deterministic time trend.– The Log Likelihood statistic of Chow-breakpoint test for the year 1990 is 19.2, which rejects the Null of no statistical break at the 1 percent level. We included therefore a dummy variable which has for all years from 1991 onwards a value of 1 and of 0 otherwise.– The Breusch-Godfrey test rejects the Null of no serial correlation for the first-order autoregressive model, but does not reject the Null for the second-order autoregressive model which is reported here.– The IV-regressions use the first and the second lag of the (log) population as an instrument for the change in the labor force.– The Augmented Dickey Fuller test results for unit-roots applies the MacKinnon (1996) critical values. The lag length has been determined by the Schwarz-information criterion.

Table 3: **Partial elasticity of native - foreign wages,  $1/\sigma_i$**

	all workers		weighted	
	$1/\sigma_i$		$1/\sigma_i$	
all	0.060	***	0.053	***
	(0.006)		(0.003)	
no vocational	0.084	***	0.070	***
	(0.009)		(0.008)	
with vocational	0.048	***	0.051	***
	(0.004)		(0.004)	
high school	0.046	***	0.051	***
	(0.016)		(0.014)	
university	0.072	***	0.012	
	(0.023)		(0.023)	
observations	800		800	
$F$ -test	17.08		9.29	
$p$ -value	0%		5%	

*Notes:* White-heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Dependent variable is  $\ln(w_{ijht}/w_{ijft})$ , i.e. the relative daily wage of native to foreign workers within the same education-experience cell. The explanatory variable is the relative employment of native and foreign workers within the same education-experience cell. All regressions include education-by-experience group fixed effects. Observations are weighted by total employment in the cell. The  $F$ -statistic tests the Null hypothesis that all coefficients  $1/\sigma_i$  are identical across educational groups.

Table 4: **Partial wage elasticities across education-experience cells ( $1/\rho$ ) and education cells ( $1/\delta$ )**

	CES-weighted labor composite using estimated			sum native and foreign labor force using				
	$\sigma_i$		$\rho$	$\sigma_i \rightarrow \infty$		$\rho \rightarrow \infty$		
$\ln w_{ijt} (\ln w_{it})$	0.031	***	0.152	**	0.031	***	0.146	**
	(0.006)		(0.076)		(0.006)		(0.072)	
observations	800		100		800		100	

*Notes:* White heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Dependent variable is  $\ln w_{ijt} (\ln w_{it})$ , i.e. the log daily wage in each education-experience (education) cell. As the partial R-squares of the first-stage regressions indicate that the log of employed native workers is a more appropriate instrument than the log of employed foreign workers, the equations are estimated by 2SLS using the log of employed native workers in the respective education-experience (education) group as an instrument for the variable  $\ln L_{ijt} (\ln L_{it})$ . Including the log of employed foreign workers as an additional instrument does not change significantly our results .

Table 5: Simulation of migration effects on wages and unemployment

education	immigration of 1 %				labor supply shock 1980-2004			
	short-run		long-run		short-run		long-run	
	wage	u-rate	wage	u-rate	wage	u-rate	wage	u-rate
<i>wages: changes in %, unemployment rate: changes in %-points</i>								
<i>total labor force</i>								
all	-0.10	0.07	0.00	0.01	-0.42	0.07	0.00	0.05
no vocational	-0.31	0.19	-0.23	0.03	1.12	-0.83	1.63	-0.31
vocational	-0.04	0.02	0.07	0.00	-0.65	0.29	-0.25	0.13
high school	-0.05	0.08	0.05	0.03	-4.83	3.79	-4.65	2.59
university	-0.07	0.03	0.03	0.01	-1.60	0.62	-1.22	0.37
<i>native labor force</i>								
all	-0.04	0.02	0.07	-0.01	-0.22	0.05	0.19	-0.03
no vocational	-0.13	0.07	-0.03	0.01	0.75	-0.27	1.23	-0.18
vocational	-0.02	0.00	0.09	-0.02	-0.33	0.10	0.07	-0.01
high school	-0.02	0.01	0.08	-0.02	-3.19	1.76	-2.97	0.92
university	-0.02	0.01	0.08	-0.02	-0.67	0.22	-0.28	0.07
<i>foreign labor force</i>								
all	-0.71	0.42	-0.64	0.11	-2.30	-0.09	-1.83	0.25
no vocational	-0.87	0.54	-0.81	0.12	2.23	-3.30	2.83	-0.99
vocational	-0.47	0.20	-0.37	0.10	-6.84	0.88	-6.49	0.39
high school	-0.45	0.51	-0.36	0.23	-32.00	3.14	-32.48	1.18
university	-0.70	0.28	-0.60	0.17	-13.61	1.86	-13.35	1.14

*Notes:* The short-run simulations are based on the short-run semi-elasticities of the wage curve and consider the short-run impact of migration on the capital-output ratio. The long-run results are based on the long-run elasticities of the wage curve and a constant capital-output ratio. The effects have been calculated for natives and foreigners at each education-experience level. Aggregate wage figures are calculated by weighting each cell with the income share, aggregate unemployment figures by weighting each cell with the share in the labor force

Table A1: **Daily wages of native and foreign workers by education and experience**  
(constant 2000 Euros)

education	experience	1980	1990	2000	2004	1980	1990	2000	2004
		native				foreign			
no vocational	0-5	41	44	43	45	47	50	44	43
	6-10	55	57	57	58	58	59	55	53
	11-15	60	64	73	69	61	64	62	62
	16-20	62	68	76	78	65	66	65	66
	21-25	64	67	75	80	67	67	68	70
	26-30	64	69	78	77	67	71	68	70
	31-35	64	70	76	80	65	72	70	71
	36-40	63	70	77	76	64	70	74	74
all	60	65	71	72	63	67	66	68	
vocational	0-5	49	53	58	59	54	55	59	57
	6-10	63	65	68	67	63	65	67	67
	11-15	72	74	79	78	70	70	71	75
	16-20	79	81	86	86	74	73	74	75
	21-25	81	86	89	90	75	78	76	78
	26-30	81	90	93	93	74	81	76	78
	31-35	81	92	96	96	72	81	80	78
	36-40	80	91	100	98	71	77	84	82
all	73	78	86	87	70	74	74	76	
high school	0-5	58	61	68	68	63	65	65	65
	6-10	78	78	85	85	75	79	81	78
	11-15	92	93	104	102	78	92	87	90
	16-20	105	104	112	114	103	86	89	89
	21-25	111	109	114	115	92	97	86	88
	26-30	112	118	119	119	97	103	86	91
	31-35	117	120	125	121	102	90	101	85
	36-40	111	128	130	120	106	114	95	113
all	90	87	101	103	84	89	85	87	
university	0-5	87	94	105	95	97	109	115	107
	6-10	110	121	141	138	114	124	135	141
	11-15	129	137	160	168	141	150	151	147
	16-20	139	156	175	180	135	153	149	164
	21-25	143	166	181	186	132	166	155	153
	26-30	143	170	195	188	138	175	151	173
	31-35	139	177	204	199	159	166	177	166
	36-40	127	169	207	187	134	149	175	212
all	123	140	164	168	126	150	147	151	

*Notes:* Individuals included in the sample are between 15 and 60 years old, receive non-zero income and work at least on September 30 of the respective year. Wages are calculated in real Euro using the GDP deflator (base year: 2000). Wages above the social security ceiling are imputed.



## Appendix (not for publication)

### A Technical Appendix

The general solution for the marginal employment response is given by equation (4) in the main text, i.e. by

$$\frac{d\mathbf{L}}{dM} = \left( \frac{\partial \mathbf{w}}{\partial \mathbf{L}} - \frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} \right)^{-1} \times \left( \frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} - \frac{\partial \mathbf{w}}{\partial \kappa} \frac{d\kappa}{dM} \right),$$

where we have used the definition of  $\kappa$ . Using the nested structure of the production function we can write

$$\begin{aligned} \mathbf{w} &= [w_{111}, w_{112}, w_{121}, \dots, w_{211}, \dots, w_{ijk}, \dots, w_{482}], \\ \mathbf{L} &= [L_{111}, L_{112}, L_{121}, \dots, L_{211}, \dots, L_{ijk}, \dots, L_{482}], \\ \mathbf{N} &= [N_{111}, N_{112}, N_{121}, \dots, N_{211}, \dots, N_{ijk}, \dots, N_{482}], \\ \mathbf{u} &= [u_{111}, u_{112}, u_{121}, \dots, u_{211}, \dots, u_{ijk}, \dots, u_{482}], \\ \phi &= [\phi_{111}, \phi_{112}, \phi_{121}, \dots, \phi_{211}, \dots, \phi_{ijk}, \dots, \phi_{482}]. \end{aligned}$$

The term  $\frac{\partial \mathbf{w}}{\partial \mathbf{L}}$  is the  $64 \times 64$  matrix

$$\frac{\partial \mathbf{w}}{\partial \mathbf{L}} = \begin{bmatrix} \frac{\partial w_{111}}{\partial L_{111}} & \dots & \frac{\partial w_{111}}{\partial L_{ijk}} & \dots & \frac{\partial w_{111}}{\partial L_{482}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial w_{ijk}}{\partial L_{111}} & \dots & \frac{\partial w_{ijk}}{\partial L_{ijk}} & \dots & \frac{\partial w_{ijk}}{\partial L_{482}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial w_{482}}{\partial L_{111}} & \dots & \frac{\partial w_{482}}{\partial L_{ijk}} & \dots & \frac{\partial w_{482}}{\partial L_{482}} \end{bmatrix}. \quad (17)$$

Note that we have from the nested structure of the production function four types of partial derivatives of any wage  $w_{ijk}$ :

$$\begin{aligned} \frac{\partial w_{ijk}}{\partial L_{ijk}} &= \frac{w_{ijk}}{L_{ijk}} \left[ s_{ijk} \left\{ \frac{1}{\delta} - \frac{1}{s_i} \left( \frac{1}{\delta} - \frac{1}{\rho} \right) - \frac{1}{s_{ij}} \left( \frac{1}{\rho} - \frac{1}{\sigma_i} \right) \right\} - \frac{1}{\sigma_i} \right], \\ \frac{\partial w_{ijk}}{\partial L_{ijk'}} &= \frac{w_{ijk}}{L_{ijk'}} \left[ s_{ijk'} \left\{ \frac{1}{\delta} - \frac{1}{s_i} \left( \frac{1}{\delta} - \frac{1}{\rho} \right) - \frac{1}{s_{ij}} \left( \frac{1}{\rho} - \frac{1}{\sigma_i} \right) \right\} \right], \\ \frac{\partial w_{ijk}}{\partial L_{ij'm}} &= \frac{w_{ijk}}{L_{ij'm}} \left[ s_{ij'm} \left\{ \frac{1}{\delta} - \frac{1}{s_i} \left( \frac{1}{\delta} - \frac{1}{\rho} \right) \right\} \right], \\ \frac{\partial w_{ijk}}{\partial L_{i'nm}} &= \frac{w_{ijk}}{L_{i'nm}} \left[ s_{i'nm} \frac{1}{\delta} \right], \end{aligned}$$

where  $\frac{\partial w_{ijk}}{\partial L_{ijk}}$  is the partial derivative of the wage with respect to labor in the same education, experience and nationality cell of the labor market,  $\frac{\partial w_{ijk}}{\partial L_{ijk'}}$  the partial derivative of the wage with respect to labor of the same education and experience, but different nationality,  $\frac{\partial w_{ijk}}{\partial L_{ij'm}}$  the partial derivative of the wage with respect to labor of the same education, but different experience,  $\frac{\partial w_{ijk}}{\partial L_{i'nm}}$  the partial derivative of the wage with respect to labor of different education, and  $s_{ijk}$ ,  $s_{ij}$ ,  $s_i$ , etc. denote the share of wages paid to workers in the respective cells of the labor market in the total wage bill.

The term  $\frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}}$  is given by the  $64 \times 64$  matrix

$$\frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} = \begin{bmatrix} \frac{\partial \phi_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial L_{111}} & \dots & 0 & \dots & 0 \\ \vdots & \ddots & & & \vdots \\ 0 & & \frac{\partial \phi_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial L_{ijk}} & & 0 \\ \vdots & & & \ddots & \vdots \\ 0 & \dots & 0 & \dots & \frac{\partial \phi_{482}}{\partial u_{482}} \frac{\partial u_{482}}{\partial L_{482}} \end{bmatrix}. \quad (18)$$

Finally, we can write the term  $\frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM}$  as the  $1 \times 64$  vector

$$\frac{\partial \phi}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} = \begin{bmatrix} \frac{\partial \phi_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial N_{111}} \frac{dN_{111}}{dM} \\ \vdots \\ \frac{\partial \phi_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial N_{ijk}} \frac{dN_{ijk}}{dM} \\ \vdots \\ \frac{\partial \phi_{482}}{\partial u_{482}} \frac{\partial u_{482}}{\partial N_{482}} \frac{dN_{482}}{dM} \end{bmatrix} \quad (19)$$

and the term  $\frac{\partial \mathbf{w}}{\partial \kappa} \frac{d\kappa}{dM}$  as the  $1 \times 64$  vector

$$\frac{\partial \mathbf{w}}{\partial \kappa} \frac{d\kappa}{dM} = \begin{bmatrix} \frac{\partial w_{111}}{\partial \kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{\partial w_{ijk}}{\partial \kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{\partial w_{482}}{\partial \kappa} \frac{d\kappa}{dM} \end{bmatrix} = \begin{bmatrix} \frac{1-\alpha}{\alpha} \frac{w_{111}}{\kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{1-\alpha}{\alpha} \frac{w_{ijk}}{\kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{1-\alpha}{\alpha} \frac{w_{482}}{\kappa} \frac{d\kappa}{dM} \end{bmatrix}. \quad (20)$$

Substituting (17) to (20) for the individual terms in equation (4) of the main text yields the explicit solution for the employment response which we have used for our simulation of the employment response to migration.

## B Annex Tables

Table B1: **Ethnic German labor force as a percentage of total labor force (Western Germany, 1980 - 2004)**

year	arrivals	stock	year	arrivals	stock	year	arrivals	stock
1980	0.08	0.24	1990	0.59	1.78	2000	0.03	3.23
1981	0.06	0.29	1991	0.41	2.06	2001	0.02	3.23
1982	0.03	0.29	1992	0.32	2.24	2002	0.01	3.20
1983	0.04	0.32	1993	0.39	2.46	2003	0.00	3.21
1984	0.04	0.35	1994	0.26	2.47	2004	0.00	3.20
1985	0.06	0.40	1995	0.30	2.71			
1986	0.06	0.44	1996	0.21	2.84			
1987	0.11	0.53	1997	0.20	3.02			
1988	0.33	0.84	1998	0.11	3.09			
1989	0.56	1.33	1999	0.08	3.21			

*Source:* Authors' calculations based on the IABS.

Table B2: **Description of dataset (Western Germany, 1980 - 2004)**

	observations	percent
all spells	11,769,872	100.0
minus part time workers / trainees	2,543,869	21.6
minus age (below 15 and above 60)	166,262	1.4
minus missing nationality	1,098	0.0
minus missing education	183,070	1.6
minus wages below social security contribution threshold	81,712	0.7
total	8,793,861	74.7

*Source:* Authors' calculations based on the IABS.

Table B3: **Change of foreign labor force by education**

education	change in percent of	
	total labor force	foreign labor force
all	4.14	41
no vocational	-6.13	-26
vocational	6.79	134
high school	38.75	597
university	12.52	176

*Source:* Authors' calculations based on the IABS.

Table B4: **The wage-setting curve: GMM-estimation results\***

education	$\ln w_{ij,t-1}$		$\ln u_{ijt}$		Wald- $\chi^2(3)$ -stat.	obs.		
			short-run	long-run				
all <sup>1</sup>	0.623	***	-0.034	***	-0.090	***	413354	736
	(0.002)		(0.001)		(0.003)			
no vocational <sup>2</sup>	0.606	***	-0.044	**	-0.111		28	184
	(0.228)		(0.019)		(0.080)			
vocational <sup>3</sup>	0.743	***	-0.041	***	-0.161	***	184	184
	(0.086)		(0.010)		(0.059)			
high school <sup>4</sup>	0.644	***	-0.044	***	-0.122	*	46	184
	(0.188)		(0.007)		(0.071)			
university <sup>5</sup>	0.668	***	-0.028		-0.084		39	184
	(0.183)		(0.032)		(0.070)			

*Notes:* The dependent variable is  $\ln w_{ijt}$ . \* Arellano-Bond (1992) two-step estimation. <sup>1</sup> The Sargan- $\chi^2(276)$ -test statistics rejects the H0 of no over-identification with 31.7\*\*\*. The Arellano-Bond  $z$ -statistics rejects the H0 of AR(1) at -3.3\*\*\*, and of AR(2) at 0.7. <sup>2</sup> Sargan- $\chi^2(156)$ -test statistics: 5.9\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -1.2, AR(2) 0.8. <sup>3</sup> Sargan- $\chi^2(155)$ -test statistics: 6.6\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.1\*\*, AR(2) -2.0\*\*. <sup>4</sup> Sargan- $\chi^2(156)$ -test statistics: 6.0\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.0\*\*, AR(2) 0.02. <sup>5</sup> Sargan- $\chi^2(155)$ -test statistics: 7.7\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.2\*\*, AR(2) 0.7. GMM two-step standard errors are biased.