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## ABSTRACT

### **Migration and the Wage Curve: A Structural Approach to Measure the Wage and Employment Effects of Migration<sup>\*</sup>**

Based on a wage curve approach we examine the labor market effects of migration in Germany. The wage curve relies on the assumption that wages respond to a change in the unemployment rate, albeit imperfectly. This allows one to derive the wage and employment effects of migration simultaneously in a general equilibrium framework. For the empirical analysis we employ the IABS, a two percent sample of the German labor force. We find that the elasticity of the wage curve is particularly high for young workers and workers with a university degree, while it is low for older workers and workers with a vocational degree. The wage and employment effects of migration are moderate: a 1 percent increase in the German labor force through immigration increases the aggregate unemployment rate by less than 0.1 percentage points and reduces average wages by less 0.1 percent. While native workers benefit from increased wages and lower unemployment, foreign workers are adversely affected.

JEL Classification: F22, J31, J61

Keywords: migration, wage curve, labor demand, panel data

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# 1 Introduction

High and increasing immigration rates in the US and Europe have fanned fears that migrants reduce wages and harm employment opportunities of the native labor force. Concerns that immigration increases unemployment are particularly widespread in the continental European countries, where unemployment is high and persisting. In this paper we apply an aggregate wage curve approach to analyze the labor market effects of immigration. The wage curve relies on the assumption that wages respond to changes in the unemployment rate, albeit imperfectly. This allows us to consider institutional and other labor market rigidities, which are particularly relevant in the European context. In contrast to the overwhelming majority of the empirical literature, which addresses the impact of migration on wages and (un-)employment separately, we analyze the wage and employment effects of migration simultaneously in a general equilibrium framework.

Following the seminal contributions of Borjas (2003) and Ottaviano and Peri (2006), we employ a nested production function which assumes that migrant and native workers within the same experience and education group are imperfect substitutes. We also consider the imperfect adjustment of capital stocks. Since it is likely that the bargaining power of workers and employers varies in the different segments of the labor market, we allow the wage curve to differ across education and experience groups.

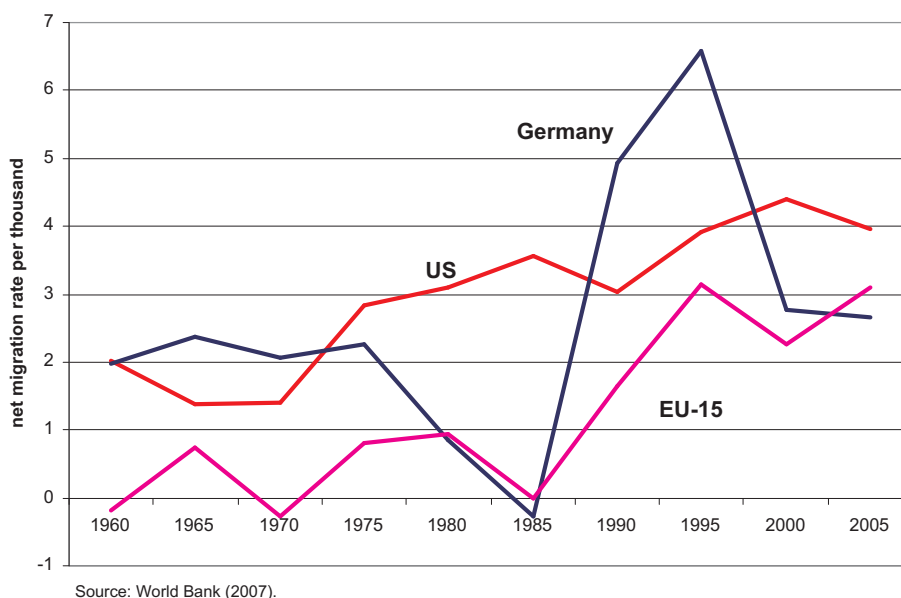


Figure 1: Net migration rate per thousand, 1960-2005

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). Three main groups have contributed to this immigration surge: foreigners from Central and Eastern Europe and the former Yugoslavia, ethnic Germans (so-called "Spätaussiedler"), and East Germans. 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).

Our empirical analysis is based on a 2 percent sample of the German labor force (IABS) which is derived from social security records. The IABS provides detailed information on education and experience of employed and unemployed individuals in the labor force. This data set allows us to identify the elasticities of the wage curve for education and experience groups and to estimate the elasticities of substitution between different types of labor in Western Germany in the period from 1980 to 2004.

We find an average elasticity of the wage curve of -0.12 at the national level, which is slightly higher than the elasticities found in regional level studies in other OECD countries (see Blanchflower and Oswald, 1994a; Card, 1995; Nijkamp and Poot, 2005), but substantially higher than that found at the regional level in Germany. However, the elasticities of the wage curves fluctuate considerably across skill groups and experience groups. Labor market flexibility is particularly high for highly educated workers and workers with little work experience.

At the given skill structure of the foreign workforce, a 1 percent increase in labor supply through the immigration of foreigners increases the unemployment rate by less than 0.1 percentage points in the short run, while it remains stable in the long run. Average wages decline by less than 0.1 percent. While native workers tend to benefit from higher wages and lower unemployment risks, wages of the foreign labor force decline by about 0.5 percent and the unemployment rate increases by about 0.3 percentage points in the short run and by 0.1 percentage points in the long run. Interestingly enough, for the labor supply shock during the period 1980-2004, we find that immigration reduces unemployment in the short run. This can be traced back to the fact that wages do not completely adjust to labor demand changes. The employment gains in a segment with relatively low wage flexibility can therefore more than compensate for losses in labor market segments with higher wage flexibility. However, this effect disappears in our simulations

when wages have adjusted to their long-run levels.

The remainder of the paper is organized as follows: Section 2 reviews the empirical literature on the wage and employment 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 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

Despite a large number of careful studies, the empirical literature has produced mixed evidence regarding the wage and employment effects of migration. The overwhelming share of this literature uses the variance of foreigner shares across regions for the identification of the wage and employment effects of migration. Although the findings of this literature vary from study to study, both the wage and the employment effects of migration seem to cluster around zero (see the surveys and meta-studies by Friedberg and Hunt, 1995; Longhi, Nijkamp, and Poot, 2005, 2006). This spatial correlation approach may yield spurious results if migrants are not randomly distributed across locations. Moreover, the adjustment of other labor or capital flows may equilibrate the migration effects across regions. This literature therefore either relies on natural experiments (e.g. Card, 1990; Carrington and DeLima, 1996; Hunt, 1992) or uses instrumental variable estimators to correct for the endogeneity of locational choices of migrants (e.g. DeNew and Zimmermann, 1994; Haisken-DeNew and Zimmermann, 1995; Mühleisen and Zimmermann, 1994; Ottaviano and Peri, 2005a,b; Pischke and Velling, 1997). It nevertheless remains controversial whether the wage and employment effects of migration can be properly identified by spatial correlations between migration shares and labor market outcomes.<sup>1</sup>

The spatial correlation approach has been challenged in an influential paper by Borjas (2003) which exploits the variance of the foreigner share across education and experience groups at the national level to identify the wage effects of migration. Under the assumption that the education and experience characteristics of the migrant workforce are exogenous, this allows an unbiased estimation of the labor market effects of migration. Borjas (2003) measures the elasticities between wages and labor supply shocks in the different education and experience cells of the US labor market and finds an

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<sup>1</sup>See Card (2001), Borjas, Freeman, and Katz (1997) and Borjas (2003) for controversial arguments and evidence.

elasticity of between -0.3 and -0.4, which implies that a 10 percent increase of the labor force through migration reduces wages by 3 to 4 percent. Aydemir and Borjas (2007) obtain the same elasticities for Canada and Mexico. Based on a similar approach Bonin (2005) however finds that an immigration of 10 percent reduces wages by less than 1 percent in Germany.

Ottaviano and Peri (2006) however find in a national-level framework results which are comparable to those of the spatial-correlation studies. Employing the same dataset as Borjas (2003) they find that immigration has increased native wages on average in the US, while wages of foreigners tend to decline substantially. Two aspects set their approach apart from the Borjas (2003) study: first, they provide evidence that native and foreign workers within the same education and experience cell of the labor market are imperfect substitutes, while Borjas (2003) assumes perfect substitutability.<sup>2</sup> Second, they consider the adjustment of capital stocks, while Borjas (2003) treats the physical capital stock as fixed – in line with the overwhelming majority of the literature.<sup>3</sup> Ottaviano and Peri (2006) find that a one percent increase of the labor force through immigration increases native wages by 0.06 percent under the assumption of a fixed capital stock and by 0.16 percent under the assumption of complete capital stock adjustment, while the wages of the foreign-born workforce decline by about 2.1 percent in the short run and by about 1.8 percent in the long run.

Borjas (2003) and Ottaviano and Peri (2006) focus on wages and rely implicitly on the assumption that labor markets clear. The application of this approach is particularly questionable in the case of economies that are characterized by wage rigidities and involuntary unemployment. There exists a large literature which analyzes the effects of migration on employment opportunities of natives (see Bonin, 2005; Borjas, Grogger, and Hanson, 2006; Hatzius, 1994; Mühleisen and Zimmermann, 1994; Pischke and Velling, 1997; Longhi, Nijkamp, and Poot, 2006, for a meta-analysis). This literature treats the wage and employment effects of migration separately, however, ignoring the interactions between wage rigidities and the employment effects of migration.<sup>4</sup>

This is the aspect in which the present paper contributes to the state of

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<sup>2</sup>Aydemir and Borjas (2007), however, could not replicate these results. They found that native and foreign workers are perfect substitutes in the US and Canadian labor markets, confirming earlier results by Jaeger (1996) for the US.

<sup>3</sup>Aydemir and Borjas (2007) relax this assumption by applying a similar approach to Ottaviano and Peri (2006) for the adjustment of the capital stock.

<sup>4</sup>The Borjas, Grogger, and Hanson (2006) paper, which considers the impact of wages on the decision to participate in labor markets and in criminal activities, may be regarded as an exception in this context, although it still assumes that wages are perfectly flexible.

the literature. We address the labor market effects of migration in a framework where wages and employment are simultaneously determined. Following the wage curve literature (Blanchflower and Oswald, 1994a, 1995), we assume that an equilibrium relationship exists between the wage level and the unemployment rate. This sets the wage curve apart from the Phillips (1958) curve, which relates the growth rate of wages to the unemployment rate and considers this relationship as a disequilibrium phenomenon.<sup>5</sup>

We estimate the wage curve at the national level. This distinguishes our approach from the traditional wage curve literature, which uses the variance across regions for the identification of the wage curve. The macroeconomic relationship between the wage and the unemployment rate is sometimes labeled as a 'wage setting curve' (Blanchard, 2003) or 'aggregate wage curve' (Blanchflower and Oswald, 2005). Starting with Sargan (1964), there exist a number of studies that empirically examine the relation between the wage and unemployment rate at the national level (see e.g. Guichard and Laffargue, 2000, for a recent contribution). Card (1995) presents empirical evidence for the US that a wage curve exists at the national level that displays similar elasticities to those found by Blanchflower and Oswald (1994a) at the regional level.

In our view it is appropriate to estimate the wage curve at the national level if centralized wage setting plays – as in Germany – an important role. In this case regions do not form independent labor market units. Consequently, regional level studies may understate the elasticity between wages and unemployment. Interestingly enough, we find an elasticity of the wage curve at the national level which is substantially larger than that found in a recent regional level study for Germany employing a similar data set (Baltagi, Blien, and Wolf, 2007).

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. Both papers highlight the importance of wage rigidities for an assessment of the labor market effects of migration. However, the empirical framework of these papers follows the standard approach of the existing literature in estimating separate employment equations, while we apply a structural approach that determines employment and wages simultaneously in a general equilibrium framework.

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<sup>5</sup>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 curve is rather stable over time.



### 3 Theoretical background

The model builds on Boeri and Brücker (2005) and Levine (1999) in deriving the wage and employment effects of migration from a wage curve. While these papers focus on the aggregate effects of migration, we group the labor force by education, experience, and nationality here. Similar to Borjas (2003) and Ottaviano and Peri (2006) we follow Card and Lemieux (2001) in employing a nested CES production function for this purpose.

The wage curve can be based on different theoretical foundations (see Blanchflower and Oswald, 1994a; Layard, Nickell, and Jackman, 1991, for a discussion). In our context, two modeling traditions are particularly important. First, the wage curve can be derived from bargaining models (see e.g. Lindbeck, 1993; Layard and Nickell, 1986), which assume that trade unions are concerned about both their employed and unemployed members. Consider the case where 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. Both parties are aware of this. Consequently, the negotiated wage is lower when unemployment is higher and vice versa.

Second, in a completely non-unionized environment, the wage 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 the remuneration of workers if the unemployment rate is increasing since they can achieve the same level of productivity at a lower wage.

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

firm-specific human capital.

Therefore we do not derive the wage curve from a specific wage bargaining or efficiency wage model here. We instead assume that a wage-fixing mechanism exists, which responds to the unemployment rate, albeit imperfectly. Following Card (1995), we allow the wage curve to vary for different groups of the labor force. Once wages are fixed, profit-maximizing firms hire workers until the marginal product of labor equals the wage rate. This approach allows us to derive the employment and wage response to an exogenous labor supply shock in a general equilibrium framework. The elasticities of the production function and of the wage curve determine a system of simultaneous equations that can be solved analytically.

### 3.1 A structural approach to immigration and unemployment

Suppose that the aggregate output of an economy is produced with different types of labor and physical capital. 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.

We distinguish labor inputs by education, experience, and nationality. 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 partners 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 which 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 of education  $i$ , experience  $j$  and national origin  $k$ , respectively.

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 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 which captures the marginal immigration shock to the economy,  $\phi$  a vector of functions which 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 here that the capital stock may adjust to a labor supply shock through migration, i.e., that  $\frac{dK}{dM} \geq 0$ .

Equation (4) has an economic interpretation. Consider two extreme cases: first, assume that labor markets are completely flexible, which requires that  $\phi'_{ijk} \rightarrow -\infty \quad \forall \phi_{ijk}$ . 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 (e.g. Wong, 1995, pp. 628-632).

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.

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

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

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

### 3.2 Outline of the empirical framework

For the empirical analysis we have to impose more structure on the economy. We follow Borjas (2003) and Ottaviano and Peri (2006) in assuming that the production function can be approximated by nested CES technologies. The aggregate workforce is decomposed in  $i = 1 \dots 4$  education groups,  $j = 1 \dots 8$  experience groups, and  $k = 1, 2$  nationality groups, which gives together with physical capital 65 production factors. Although the nested CES function imposes some restrictions on the elasticities of substitution, it has the advantage that it is parsimonious in the parameters. 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.

Supposing that the aggregate production function in equation (1) can be represented by standard Cobb-Douglas technologies yields

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

where  $Y_t$  denotes aggregate output,  $A_t$  total factor productivity,  $L_t$  the aggregate labor input,  $K_t$  physical capital,  $\alpha$  the income share of labor, and  $t$  the time index. Assuming a constant elasticity of substitution across education groups gives for the composite labor input

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

where  $L_{it}$  is an aggregate measure for the employed workforce with education  $i$ ,  $\theta_{it}$  a skill-specific productivity level and  $\delta > 0$  a constant parameter which determines the elasticity of substitution between labor of different education levels. We assume 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.

Analogously, each labor input  $L_{it}$  is defined as

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

where  $L_{ijt}$  denotes an aggregate measure for employed workers of skill group  $i$  and experience group  $j$ ,  $\theta_{ijt}$  a productivity parameter, and  $\rho > 0$  a parameter which determines the elasticity of substitution of labor with similar education but different experience.

Finally, the employment within each education and experience cell is given by an aggregation of native and foreign workers with similar education and experience, i.e., by

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

where  $L_{ijkt}$  denotes workers of skill group  $i$ , experience group  $j$ , and national origin  $k$ ,  $\theta_{ijk}$  a productivity parameter, and  $\sigma_i$  a parameter which determines the elasticity of substitution between native and foreign workers.

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 education and experience group are closer substitutes than those across education and experience groups, which implies that  $\sigma_i > \rho$ , and that workers within the same skill group are closer substitutes than those across skill groups, which implies that  $\rho > \delta$ .

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 of skill  $i$ , education  $j$ , and national origin

$k$  as

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

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

The interest rate is a function of the capital-output ratio, i.e.,  $r = \frac{1-\alpha}{\kappa}$ . 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). For an explicit solution of the employment response, see the Appendix.

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

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

where  $s_{qmnt}$ ,  $s_{inmt}$ ,  $s_{ijmt}$ ,  $s_{ijt}$  and  $s_{it}$  denote the share of the wages paid to workers in the respective labor market cells in the total wage bill.<sup>6</sup> The terms in brackets include the response of employment to migration as determined by equation (4) as well as the response of the capital-output ratio to migration.

Note that the assumption that the wage rate equals the marginal product of labor results in a similar equation for the factor demand to the equations

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<sup>6</sup>Thus,  $s_{ijk} = \frac{w_{ijk}L_{ijk}}{\sum_q \sum_n \sum_m w_{qmnt}L_{qmnt}}$ ,  $s_{ijt} = \frac{\sum_m w_{ijmt}L_{ijmt}}{\sum_q \sum_n \sum_m w_{qmnt}L_{qmnt}}$ , and  $s_{it} = \frac{\sum_n \sum_m w_{inmt}L_{inmt}}{\sum_q \sum_n \sum_m w_{qmnt}L_{qmnt}}$ .

found in the existing literature. Thus we can compare our findings regarding the wage effects of a marginal employment shock inter alia with those of Borjas (2003) and Ottaviano and Peri (2006).

## 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 covering the period 1975-2004. The IABS provides information on socio-economic and job characteristics at the individual level. Supplementary information on benefit recipients is added to the sample. The IABS is stratified according to nationality and therefore representative for the native and foreign working population.

Being of an administrative nature, the IABS provides longitudinal information on the employment and unemployment history of employees. Each employment and unemployment spell contains a starting and an ending date and provides accurate information on the timing of transitions between unemployment and employment. Reported wages are used to calculate social security contributions of the employers and are highly reliable. Hence the dataset is especially suitable for performing analyses taking wages into account.

Nevertheless the IABS has also some limitations in the context of our analysis: the main shortcoming is that we can identify foreigners only on the basis of citizenship. There is no information on the year when immigrants entered the country. This has several implications. First, 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 still 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 parents living for at least eight years in Germany to decide up to the age of 23 which nationality to adopt. This has substantially increased the naturalization of German-born individuals whose parents have a migrant background. Our dataset may therefore suffer from a structural break.

To mitigate the possible effects of naturalizations, we have classified all individuals as foreigners who are reported as foreign citizen in their first available spell. This does not allow us to control for individuals who are 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 labor market integration, and these measures are reported in the benefit recipient file added to our dataset. This allows us to identify the overwhelming share of ethnic Germans who have entered the German labor force since 1980. 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, Eastern Germany is not covered by the IABS before 1992. We can therefore only identify migrants from Eastern Germany if they appear the first time in the dataset after 1992 and if their first spell indicates that they reside in Eastern Germany. A large number of East-West migrants moved to Western Germany before appearing as employed or unemployed in the dataset, e.g., as students (Burda and Hunt, 2001; Hunt, 2006). Moreover, a large part of the East-West migrants in Germany cannot be identified since more than one-third of the two million migrants from Eastern Germany moved to Western Germany immediately after the fall of the Berlin wall, i.e., before German reunification in October 1990 (Bundesamt, 2006).

The dataset thus captures only part of this immigration surge. Moreover, those individuals who can be identified as East Germans have different education and experience characteristics than those individuals from Eastern Germany who we cannot identify. We thus classify East Germans here as natives. Treating East-West migrants as natives is appropriate in our view since individuals from Eastern Germany share the same language and cultural background with individuals who have grown up in Western Germany. Not surprisingly, the labor market performance of East-West migrants is similar or even slightly better than that of West Germans if we control for education and experience (Brücker and Trübswetter, 2007).

There are moreover other features of the dataset that may affect our analysis. First, the employment history of individuals is interrupted if job-seekers are not eligible for unemployment benefits, unemployment assistance, or maintenance allowance. This implies that individuals are considered to be out of the labor force and are therefore not covered in the sample although they might be looking for a job. 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 biased downwards (Wagner and Jahn, 2004).

Second, 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.

Third, 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 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 data set (Büttner and Rässler, 2007). The regression is run separately for each year and according to nationality for Western German employees. In addition we included the following variables: age, age squared, six educational groups, industry codes, four variables for the occupational status, and ten occupational variables, classifying the actual position held by the worker.

Fourth, the dataset reports gross daily wages and does not provide information on the hours worked. We therefore exclude part-time employees, marginal employees, trainees, interns and home-workers from the sample since the wage information is not accurate 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. These workers are likely to hold a "mini job". Their income is exempted from the social security contributions up to threshold which is adjusted on a sporadic basis (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.

Fifth, we restrict our analysis to full-time employees 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 early retirement behavior between German and immigrant men (Bonin, Raffelhüschen, and Walliser, 2000).

We focus in our analysis on Western Germany, since Eastern Germany is not included in the IABS before 1992. Note that the foreigner share in Eastern Germany is almost negligible. German reunification also requires excluding Western Berlin, since mobility between Eastern and Western Berlin has been high since the fall of the wall. Furthermore, local employment offices in Berlin were pooled, which prevents us from clearly distinguishing between unemployed workers in Western and Eastern Berlin since reunification.

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, a high school degree ("Abitur") with a vocational training degree, and a university degree. The group with a university degree also covers individuals with a degree from a university of applied sciences ("Fachhochschule"). 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 (Table 1).

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Table 1 about here

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The information on education is provided by the employers in the IABS. 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 education information is used for extrapolation. This procedure also allows us to correct inconsistent education information on individuals over time. After applying this imputation procedure, we had to drop only 1.5 percent of the individuals because of missing or inconsistent information on education.

Education and work experience acquired in foreign countries may not have the same value in the labor market as education and experience acquired in Germany. Moreover, certain characteristics of foreigners, such as their command of the German language, may prevent them from fully transferring acquired human capital to the German labor market. However, correcting for the acquired education and experience levels of foreigners by variables which are related to their labor market performance in Germany 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.

## 4.2 Immigration trends and descriptive evidence

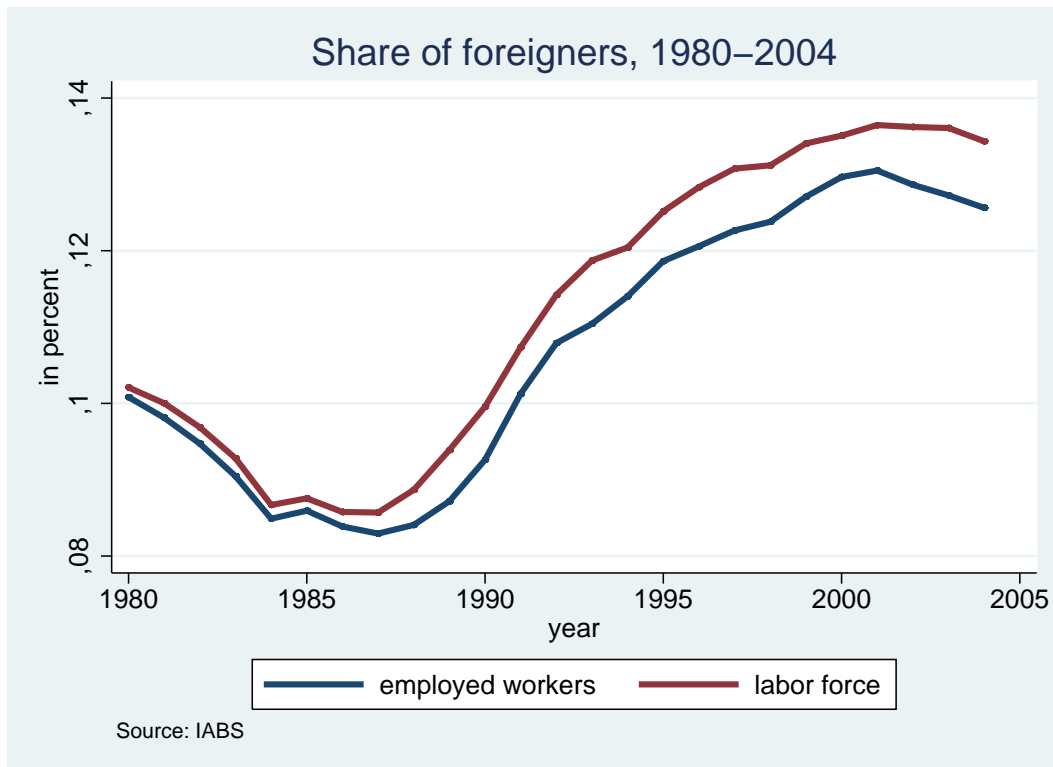


Figure 2: Share of foreign labor force and workers

Figure 2 displays the share of foreigners – including ethnic Germans – in the labor force and the share of foreigners among 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 in Germany. 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 to Germany. Note that the ethnic Germans who contributed substantially to the increasing labor supply in the 1990s are treated here as foreigners. Since the beginning of the 2000s the foreigner share is stagnating as a consequence of the slowdown of economic growth and tightening of immigration conditions. 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 (Figure 2).

The foreign labor force increased dramatically during the period 1984 to 1993 as a consequence of the fall of the Berlin wall and the transition in Central and Eastern Europe. We therefore simulate the effects of this particular labor supply shock separately.

Table A1 presents the share of the foreign workforce by education and experience classes. The foreign workforce is heavily concentrated in the group of no vocational training. The foreigner share is moreover increasing in this low-skilled segment of the labor market from 31 percent in 1980 to 48 percent in 2004. In the other educational groups, the foreigner share varies between 5 percent and 9 percent. In the high-skilled segment of the labor market, the foreigner share fell from 7.5 percent in 1980 to 5.5 percent in the 1990s and recovered slightly later, achieving a share of 6.5 percent in the early 2000s. Altogether, the foreign workforce is more than proportionally represented in the low-skilled segment of the labor market.

Tables A2 and A3 display the wage levels for natives and foreign workers by education and experience groups. We report gross wages on a daily basis. A consistent consumer price index for the observation period is not available. We therefore employed the GDP deflator for the deflation of wages.

Wage levels increase with education levels and with experience in all education groups. The wage levels of foreign workers are in all education groups below those of their counterparts in the native labor force. While these differences are fairly small in the education groups of no vocational degree, they amount to about ten percent in the other education groups (see Tables A2 and A3).

## 5 Estimation

### 5.1 Wage curves

A large empirical literature estimates wage curves using the variance of wages and unemployment rates across regions and branches (see Blanchflower and Oswald, 1994a, 1995; Card, 1995). Based on this approach Baltagi and Blien (1998) have estimated the elasticity of the wage curve at about -0.07 for Western Germany, which matches the average elasticity of about -0.08 found in several OECD countries (see Nijkamp and Poot, 2005). However, in a recent study for Germany, Baltagi, Blien, and Wolf (2007) estimate the long-run elasticity between the wage and the unemployment rate at between -0.02

and -0.03 employing a dynamic fixed effects model.

Based on the model outlined in Section 3, we deviate here from the standard approach by using the variance of wages and unemployment rates over time and across education and experience groups for the identification of the wage curve instead of the variance across regions. Note that our dataset contains 25 time-series observations that can be used for identification. Moreover, we specify the model in dynamic form following Blanchard and Katz (1997), Blanchflower and Oswald (2005) and Bell, Nickell, and Quintini (2002) for the US and Baltagi, Blien, and Wolf (2007) for Germany. This allows to disentangle the short and long-run wage and employment effects of migration if labor markets do not respond instantaneously to labor supply shocks.

More specifically, we estimate the elasticity of the wage with respect to the unemployment rate by experience and education groups as

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

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.

The model is estimated separately for each education and experience cell. In each regression we have pooled two experience groups together in order to achieve more stable results. We have not distinguished between natives and foreigners, assuming that the wage-setting mechanism provides equal wages in each education-experience cell.

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Table 2 about here

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The estimation results are displayed in Table 2. We have in all regressions 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 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.

The first regressions provide estimates of the wage 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 -0.03 and a long-run elasticity of about -0.12. This is slightly higher than the average elasticity of -0.08 found by the regional-level wage curve literature in other OECD countries, but much higher than the elasticity of -0.03 estimated by Baltagi, Blien, and Wolf (2007) at the regional level in Germany.

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 -0.14, and in the high-skilled segment of individuals with a university degree a long-run elasticity of -0.16. 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 -0.63. For workers without a vocational degree the elasticities are particularly high. They decline monotonously 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.

The fixed effects specifications reported in Table 2 are subject to the Nickell (1981) bias of order  $1/T$ .  $T = 23$  in our sample. Monte Carlo simulations suggest that the coefficients for the unemployment rate are slightly overstated in samples of this time dimension. We have also employed the Arellano and Bond (1991) GMM estimator for obtaining unbiased and consistent results. The GMM estimates yield slightly lower results than the standard fixed effects model, but are generally in line with the previous findings (see Table A4). The overall elasticity is, at -0.8, lower than our findings, but the elasticities for the individual education groups are comparable with the IV-estimation results. Since the Sargan test statistics indicate that the GMM model suffers from overidentification, we use the standard IV-fixed effects estimation results for the simulation of the migration effects.

Altogether, our empirical findings support the hypothesis that wages respond to an increase in the unemployment rate, and, hence, to labor supply shocks.

## 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.

The OECD data on capital stocks indeed demonstrate that the capital-output ratio has increased only slightly from about 3.0 to 3.15 in Germany during the four decades since 1960. Moreover, the fluctuations around the long-run ratio of 3.1 are relatively low. Even German reunification did not result in a visible break in the time series.

We employ two specifications for analyzing the impact of the labor supply on the capital-output ratio. First, to analyze whether a change in the labor supply affects the steady-state level of the capital-output ratio, we estimate

$$\ln \kappa_t = \beta_0 + \beta_1 \ln \kappa_{t-1} + \beta_2 \ln N_t + \beta_3 \tau_t + \varepsilon_t, \quad (13)$$

and, second, to analyze the short-term deviation of  $\kappa$  from its long-term growth path

$$\ln \kappa_t = \gamma_0 + \gamma_1 \ln \kappa_{t-1} + \gamma_2 \Delta \ln N_t + \gamma_3 \tau_t + \epsilon_t, \quad (14)$$

where  $\kappa_t$  denotes, as above, the capital-output ratio,  $N_t$  the total labor force,  $\tau_t$  a deterministic time trend which captures the balanced growth path trajectory of  $\ln(\kappa_t)$ , and  $\varepsilon_t$  and  $\epsilon_t$ , disturbances which are assumed to be white noise. We have moreover added a dummy variable that controls for a possible structural break after German reunification.

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Table 3 about here

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The results are displayed in Table 3. The coefficient on  $\ln(N_t)$  is positive and insignificant in the first equation, suggesting that the labor supply does not affect the capital-output ratio on the balanced growth path. In the second equation, the coefficient on the difference in the labor force is negative but not significant from zero.

Thus, we find no significant evidence that a change in labor supply has a short-run impact on the capital-output ratio. In the simulations on the migration impact, we assume that the capital-output ratio remains constant in the long run, while we use the small negative coefficient on the first difference of the log labor force from the second regression for the simulations of the short-run impact.

### 5.3 Elasticity of substitution between natives and foreigners

The model outlined in Section 3 relies on the assumption that firms hire workers until the marginal product of workers equals the wage rate. This allows us to identify the parameters of the production function analogously to Borjas (2003) and Ottaviano and Peri (2006) by the elasticities of relative labor demand.

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

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

For identifying the ratio  $\theta_{ijh}/\theta_{ijf}$ , we employ dummy variables for each education-experience cell. Conditional on these controls, we 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  $\sigma_i$ :

$$\ln(w_{ijht}/w_{ijft}) = D_{ij} - \frac{1}{\sigma_i} \ln(L_{ijht}/L_{ijft}) + \nu_{ijt}, \quad (15)$$

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 4 about here

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The results are reported in Table 4. We ran the regressions separately for the total period 1980-2004 and for the subperiod 1984 to 1993, when Germany experienced a particular labor supply shock. In the total period, 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. However, the estimated coefficients for  $1/\sigma_i$  are, at between 0.05 and 0.07, relatively small. This indicates that the elasticity of substitution between native and foreign workers lies between 15 and 20, which is relatively high. Moreover, the elasticity of substitution is not significantly different from zero in the weighted regression for high-skilled



workers, suggesting that natives and foreigners are perfect substitutes in the high-skilled segment of the labor market. For the subperiod 1984-1993, we obtain very similar results, although the estimated coefficients are slightly larger and the standard errors slightly higher.

These results contrast with the relatively low elasticities found by Ottaviano and Peri (2006) for the US, but do not support the finding that natives and migrants are perfect substitutes (Aydemir and Borjas, 2007). The estimates by D'Amuri, Ottaviano, and Peri (2008) for Germany are, at between 0.04-0.06, very close to ours. Similarly, Felbermayr, Geis, and Kohler (2008) estimate this elasticity based on another dataset at between 0.07 and 0.1.

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 coefficient is equal for all  $\sigma_i$ .

## 5.4 Elasticity of substitution between experience groups

In the next step we estimate the elasticity of substitution between experience groups. We first calculate the productivity weighted labor composite  $L_{ijt}$ . The estimates for the productivity parameters of native and foreign workers can be derived from the estimated fixed effects as

$$\hat{\theta}_{ijh} = \frac{\exp(\hat{D}_{ij})}{1 + \exp(\hat{D}_{ij})}, \quad \hat{\theta}_{ijf} = \frac{1}{1 + \exp(\hat{D}_{ij})},$$

where we have used the restriction that the productivity terms add up to one. We can then employ the estimates for  $\hat{\theta}_{ijh}$  and  $\hat{\theta}_{ijf}$  and of  $\hat{\sigma}_i$  to calculate  $\hat{L}_{ijt}$  as

$$\hat{L}_{ijt} = \left[ \hat{\theta}_{ijh} L_{ijht}^{(\hat{\sigma}_i - 1)/\hat{\sigma}_i} + \hat{\theta}_{ijf} L_{ijft}^{(\hat{\sigma}_i - 1)/\hat{\sigma}_i} \right]^{\hat{\sigma}_i / (\hat{\sigma}_i - 1)}.$$

From the production function we receive the wage for the labor composite  $L_{ijt}$

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

We identify the elasticity of substitution  $\rho$  by estimating

$$\ln w_{ijt} = D_t + D_{it} + D_{ij} - \frac{1}{\rho} \ln \hat{L}_{ijt} + v_{ijt}, \quad (16)$$

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. This allows us to consistently estimate the parameter  $-\frac{1}{\rho}$  by 2SLS, where we use the number of native workers in each experience-education group as an instrument.

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Table 5 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>7</sup> Interestingly enough, Felbermayr, Geis, and Kohler (2008) obtain similar elasticities for Germany as we do, 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 however very similar results. In the subperiod 1984 - 1993 we estimate a coefficient 0.064, which corresponds to an elasticity of substitution in the vicinity of 16 (see Table 5).

## 5.5 Elasticity of substitution between education groups

Analogously to the previous section we use the estimated fixed effects  $\hat{D}_{ij}$  to calculate the efficiency parameters  $\theta_{ij}$  as

$$\hat{\theta}_{ij} = \frac{\exp(\hat{D}_{ij})}{\sum_j \exp(\hat{D}_{ij})},$$

which in turn allows to compute the estimated value of the productivity weighted labor composite  $L_{it}$  as

$$\hat{L}_{it} = \left[ \sum_{j=1}^8 \hat{\theta}_{ij} \hat{L}_{ijt}^{(\hat{\rho}-1)/\hat{\rho}_i} \right]^{\hat{\rho}/(\hat{\rho}-1)}.$$

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<sup>7</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.

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

$$\ln w_{it} = D_t + D_i + \lambda_i \tau_i - \frac{1}{\delta} \ln \hat{L}_{it} + \vartheta_{it}. \quad (17)$$

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  $\theta_{it}$ .  $\vartheta_{it}$  is assumed to be a zero-mean random disturbance. To estimate the parameter  $-\frac{1}{\delta}$  consistently, we again employ the 2SLS estimator and use the number of foreign workers within each education group as an instrument for  $\ln \hat{L}_{it}$ .

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Table 6 about here

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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 (see Table 6). This elasticity is larger than 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. In the subperiod 1984-1993 we find an elasticity of substitution of about 3, which is similar to the findings in the US literature (Table 6).

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 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 curve and by assuming that the capital-output ratio remains constant.

We simulate the following 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 order to analyze the sensitivity of our findings, we simulate a counterfactual scenario under the assumption that labor markets are perfectly flexible, i.e., that  $\eta_{ij} \rightarrow -\infty \forall ij$ . This scenario allows us to compare our findings with those reported in the standard literature (e.g. Borjas, 2003; Ottaviano and Peri, 2006).

In the next step we simulate the wage and employment effects of immigration for the total sample period, i.e., from 1980 to 2004. We consider the actual changes in each cell of the labor market here. Finally, we simulate the labor market effects of the labor supply shock during the ten-year period 1984 - 1993, which covers the fall of the Berlin wall.

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 education levels.

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Table 7 about here

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A one percent immigration of workers with the same education and experience characteristics as the existing foreign workforce reduces average wages by less than 0.1 percent and increases the average unemployment rate by less than 0.1 percent in the short run, while the long-run impact is neutral. Particularly negatively affected are workers with no vocational training degree and a high school degree, where the shares of the foreign workforce are relatively high. The native workforce benefits slightly on average both from increasing wages and from declining unemployment. However, native workers lose slightly in the segments with no vocational degree and a high school

degree. In contrast, wages of foreign workers tend to decline by about 0.6 percent, while the unemployment rate increases by 0.3 percentage points in the short run and 0.1 percentage points in the long run (Table 7).

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Table 8 about here

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In Table 8 we have simulated the potential wage impact of one percent immigration under the counterfactual assumption of perfect labor markets. We find slightly higher wage effects than in the previous scenario, but the overall pattern is the same: average wages of the total labor force decrease slightly in the short run while immigration is neutral in the long run. While wages of native workers tend to increase slightly, those of foreign workers tend to decline by 0.6 percent in the short run. The pattern of our findings is similar to that in the findings of Ottaviano and Peri (2006) for the US, but both the wage losses of the foreign workforce and the wage gains of the native workforce are much smaller in our case since the elasticity of substitution between native and foreign workers is higher in Germany.

The real labor supply shock during the 1980 - 2004 period changed the structure of the foreign workforce: while the number of workers without a vocational degree declined substantially, the labor supply of foreigners increased substantially in the other education groups of the labor market. Particularly affected was the rather small group with a high school degree, but the groups with a vocational degree and a university degree faced a substantial labor supply shock as well during this period. Average wages declined by about 0.1 percent in the short run and remained stable in the long run. Interestingly enough, the unemployment rate decreased in the short run, but increased slightly in the long run. This counterintuitive finding can be traced back to the fact that the change in the composition of the foreign workforce reduced the unemployment rate in the labor market segment without a vocational degree. The positive employment effects there overcompensated for the increasing unemployment in the other segments of the labor market. However, in the long run, wages adjust such that the employment gains in the low-skilled segment of the labor market are mitigated.

The wage impact of migration on the native labor force is almost neutral, but natives tend to benefit by a slightly decreasing unemployment rate in the short run. The foreign labor force experiences a substantial wage loss of about 1.2 percent in the short run and 1 percent in the long run. The unemployment rate declines in the short run by about 0.3 percentage points, but increases in the long-run by 0.4 percentage points. Note that the

unemployment rate of foreign workers without a vocational degree declines substantially by 4.1 percentage points in the short run, but that this decline shrinks to 0.9 percentage points when wages have adjusted 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 (Table 8).

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Table 9 about here

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Finally, we simulated the effects of the immigration shock during the 1984-1993 period, when the foreign workforce increases by about 40 percent. This labor supply shock means that average wages decline by almost 0.2 percent, while the average unemployment rate increases by 0.4 percentage points in the short run. Nevertheless, the wage impact of migration is neutral in the long run, while the unemployment rate increases by less than 0.2 percentage points. Interestingly enough, the native workforce tends to gain both in terms of higher wages and lower unemployment. In the long run, native wages increase by more than 0.2 percent, while the unemployment rate declines by more than 0.1 percentage points. In contrast, wages of the foreign labor force decline by almost 3 per cent. The unemployment rate of the foreign workforce increases by 2.6 percentage points in the short run and by 1.4 percentage points in the long run. Particularly affected are the groups with a high school degree and a vocational degree (Table 9).

## 7 Conclusions

In this paper we presented a general equilibrium framework that allows us to analyze the wage and employment effects of migration simultaneously. We modeled wage rigidities in form of a wage 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 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, 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 simulation of the actual immigration impact demonstrates that the shift in the skill structure of the foreign labor force can reduce the total unemployment rate if wage rigidities exist. A decreasing labor supply in the low-skilled segment of the labor market and an increasing labor supply in the segments with a higher skill level can reduce the overall unemployment rate if wages do not completely adjust to labor demand changes. Indeed, we find that immigration during the 1980 - 2004 period has reduced total unemployment in the short run, while this effect disappears in the long run when wages have adjusted.

Moreover, our empirical analysis has produced further intriguing results. Compared to the findings from the US studies, the elasticity of substitution between natives and foreigners is relatively high in Germany. This implies that the labor market effects of migration are relatively similar for natives and migrants within the same education and experience cells. However, native and foreign workers remain imperfect substitutes.

The elasticity of substitution across education groups is about twice as high in Germany as in the US, and the elasticity of substitution across experience groups is substantially larger. As a consequence, the effects of migration are more evenly distributed across the education and experience groups of the labor market in Germany than in the US.

Finally, we found 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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## A Appendix

The general solution for the marginal employment response is given by equation (4), 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

$$\frac{\partial \mathbf{w}}{\partial \mathbf{L}} = \begin{bmatrix} \frac{\partial w_{111}}{\partial L_{111}} & \dots & \frac{\partial w_{111}}{\partial L_{ijk}} & \dots & \frac{\partial w_{111}}{\partial L_{482}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial w_{ijk}}{\partial L_{111}} & \dots & \frac{\partial w_{ijk}}{\partial L_{ijk}} & \dots & \frac{\partial w_{ijk}}{\partial L_{482}} \\ \vdots & & \vdots & & \vdots \\ \frac{\partial w_{482}}{\partial L_{111}} & \dots & \frac{\partial w_{482}}{\partial L_{ijk}} & \dots & \frac{\partial w_{482}}{\partial L_{482}} \end{bmatrix}. \quad (\text{A.1})$$

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

$$\frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{L}} = \begin{bmatrix} \frac{\partial f_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial L_{111}} & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & \frac{\partial f_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial L_{ijk}} & 0 & \vdots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & \cdots & \frac{\partial f_{482}}{\partial u_{482}} \frac{\partial u_{482}}{\partial L_{482}} \end{bmatrix}. \quad (\text{A.2})$$

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

$$\frac{\partial \mathbf{f}}{\partial \mathbf{u}} \frac{\partial \mathbf{u}}{\partial \mathbf{N}} \frac{d\mathbf{N}}{dM} = \begin{bmatrix} \frac{\partial f_{111}}{\partial u_{111}} \frac{\partial u_{111}}{\partial N_{111}} \frac{dN_{111}}{dM} \\ \vdots \\ \frac{\partial f_{ijk}}{\partial u_{ijk}} \frac{\partial u_{ijk}}{\partial N_{ijk}} \frac{dN_{ijk}}{dM} \\ \vdots \\ \frac{\partial f_{482}}{\partial u_{482}} \frac{\partial u_{482}}{\partial N_{482}} \frac{dN_{482}}{dM} \end{bmatrix} \quad (\text{A.3})$$

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

$$\frac{\partial \mathbf{w}}{\partial \kappa} \frac{d\kappa}{dM} = \begin{bmatrix} \frac{\partial w_{111}}{\partial \kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{\partial w_{ijk}}{\partial \kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{\partial w_{482}}{\partial \kappa} \frac{d\kappa}{dM} \end{bmatrix} = \begin{bmatrix} \frac{1-\alpha}{\alpha} \frac{w_{111}}{\kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{1-\alpha}{\alpha} \frac{w_{ijk}}{\kappa} \frac{d\kappa}{dM} \\ \vdots \\ \frac{1-\alpha}{\alpha} \frac{w_{482}}{\kappa} \frac{d\kappa}{dM} \end{bmatrix}. \quad (\text{A.4})$$

Substituting (A.1) to (A.4) for the individual terms in equation (4) yields the explicit solution for the employment response which we have used for our simulation of the employment response to migration.

Table 1: Description of dataset (Western Germany, 1980 - 2004)

	1980 - 2004		1984 - 1993	
	observations	percent	observations	percent
all spells	11,770,638	100.0	4,460,817	100.0
minus part time workers / trainees	2,698,193	22.9	825,012	18.5
minus age (below 15 and above 60)	163,940	1.4	56,239	1.3
minus missing nationality	1,044	0.0	216	0.0
minus missing education	176,876	1.5	66,763	1.5
minus wages below social security contribution threshold	81,716	0.7	15,033	0.3
total	8,648,869	73.5	3,497,554	78.4

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

Table 2: **The wage curve: IV-estimation results**

education degree	$\ln w_{ij,t-1}$		short-run		$\ln u_{ijt}$		long-run		$R^2$	
	coeff.	se	coeff.	se	coeff.	se	coeff.	se		
all experience groups										
all	0.731	(0.023)	***	-0.032	(0.005)	***	-0.119	(0.019)	***	0.85
no vocational	0.691	(0.051)	***	-0.044	(0.006)	***	-0.142	(0.031)	***	0.94
vocational	0.523	(0.052)	***	-0.047	(0.006)	***	-0.098	(0.015)	***	0.96
high school	0.466	(0.064)	***	-0.067	(0.017)	***	-0.125	(0.030)	***	0.83
university	0.366	(0.064)	***	-0.100	(0.017)	***	-0.157	(0.023)	***	0.86
experience group 1 and 2										
no vocational	0.916	(0.117)	***	-0.053	(0.013)	***	-0.626	(0.953)		0.81
vocational	0.799	(0.086)	***	-0.048	(0.008)	***	-0.237	(0.124)	*	0.98
high school	0.830	(0.114)	***	-0.065	(0.017)	***	-0.380	(0.311)		0.97
university	0.625	(0.109)	***	-0.118	(0.021)	***	-0.313	(0.104)	***	0.88
experience group 3 and 4										
no vocational	0.370	(0.116)	***	-0.080	(0.015)	***	-0.127	(0.028)	***	0.96
vocational	0.293	(0.114)	***	-0.073	(0.013)	***	-0.103	(0.020)	***	0.95
high school	0.358	(0.136)	***	-0.075	(0.026)	***	-0.117	(0.037)	***	0.94
university	0.473	(0.101)	***	-0.115	(0.037)	***	-0.217	(0.069)	***	0.90
experience group 5 and 6										
no vocational	0.419	(0.118)	***	-0.065	(0.015)	***	-0.111	(0.023)	***	0.96
vocational	0.401	(0.127)	***	-0.057	(0.017)	***	-0.095	(0.023)	***	0.87
high school	0.455	(0.152)	***	-0.088	(0.038)	**	-0.162	(0.056)	***	0.62
university	0.294	(0.138)	**	-0.092	(0.035)	***	-0.131	(0.041)	***	0.82
experience group 7 and 8										
no vocational	0.406	(0.125)	***	-0.059	(0.014)	***	-0.099	(0.018)	***	0.98
vocational	0.179	(0.150)		-0.064	(0.016)	***	-0.078	(0.016)	***	0.96
high school	0.358	(0.149)	**	-0.068	(0.054)		-0.106	(0.076)		0.43
university	0.300	(0.253)		-0.058	(0.063)		-0.083	(0.065)		0.86

*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.



Table 3: **Impact of labor supply shocks on the capital-output ratio**

dependent variable: $\ln \kappa_t$	model (1)		model (2)	
$\ln \kappa_{t-1}$	0.850	***	0.742	***
	(0.126)		(0.095)	
$\ln N_t$	0.035			
	(0.042)			
$\Delta \ln N_t$			-0.076	
			(0.070)	
adjusted R <sup>2</sup>	0.611		0.615	
Durbin-Watson statistics	1.468		1.388	

*Notes:* White-heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Each regression includes a constant and a deterministic time trend.

Table 4: **Partial elasticity of native - foreign wages,  $1/\sigma_i$**

	1980 - 2004				1984 - 1993			
	all workers		weighted		all workers		weighted	
	$1/\sigma_i$		$1/\sigma_i$		$1/\sigma_i$		$1/\sigma_i$	
all	0.060	***	0.053	***	0.073	***	0.056	***
	(0.006)		(0.003)		(0.016)		(0.007)	
no vocational	0.084	***	0.070	***	0.076	***	0.058	***
	(0.009)		(0.008)		(0.013)		(0.013)	
vocational	0.048	***	0.051	***	0.050	***	0.054	***
	(0.004)		(0.004)		(0.007)		(0.008)	
high school	0.046	***	0.050	***	0.076		0.131	***
	(0.016)		(0.014)		(0.048)		(0.034)	
university	0.071	***	0.011		0.113	*	0.022	
	(0.023)		(0.023)		(0.069)		(0.063)	
observations	800		800		320		320	
<i>F</i> -test	16.92		9.30		4.14		5.64	
<i>p</i> -value	0%		5%		39%		23%	

*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 in specification 2 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 5: **Partial wage elasticity across education-experience cells,  $1/\rho$**

	1980-2004		1984-1993	
	CES-weighted labor composite (using estimated $\sigma_i$ )	sum native and foreign labor force ( $\sigma_i \rightarrow \infty$ )	CES-weighted labor composite (using estimated $\sigma_i$ )	sum native and foreign labor force ( $\sigma_i \rightarrow \infty$ )
$\ln L_{ijt}$	0.031 *** (0.006)	0.031 *** (0.006)	0.064 *** (0.016)	0.063 *** (0.016)
observations	800	800	320	320

*Notes:* White heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Dependent variable is  $\ln w_{ijt}$ , i.e. the log daily wage in each education-experience cell. The equation is estimated by 2SLS using the log of employed foreign-born workers in the respective education-experience group as an instrument for the variable  $\ln L_{ijt}$ . All regressions include education by experience fixed effects and education by year fixed effects and time fixed effects.

Table 6: **Partial wage elasticity across education cells,  $1/\delta$**

	1980-2004		1984-1993	
	CES-weighted labor composite (using estimated $\rho$ )	sum native and foreign labor force ( $\rho \rightarrow \infty$ )	CES-weighted labor composite (using estimated $\rho$ )	sum native and foreign labor force ( $\rho \rightarrow \infty$ )
$\ln L_{it}$	0.153 ** (0.076)	0.147 ** (0.072)	0.306 (0.213)	0.296 (0.201)
observations	100	100	40	40

*Notes:* White heteroscedasticity robust standard errors in parentheses. \*\*\*, \*\*, \* denote the 1%-, 5%-, and 10%-significance levels. Dependent variable is  $\ln w_{it}$ , i.e. the log wage in each education cell. The equation is estimated by 2SLS using the log of employed foreign-born workers in the respective education group as an instrument for the variable  $\ln L_{it}$ . All regressions include fixed time effects, education group fixed effects and education-specific time trends.

Table 7: Simulation of migration effects on wages and unemployment

education degree	short-run results		long-run results	
	wages	unemployment rate	wages	unemployment rate
<i>wages: change in % at an immigration of 1%</i>				
<i>unemployment rate: change in %-points</i>				
<i>total labor force</i>				
all	-0.04	0.05	-0.00	0.01
no vocational	-0.16	0.10	-0.13	0.02
vocational	0.00	0.02	0.05	0.01
high school	-0.14	0.24	-0.11	0.17
university	-0.05	0.03	-0.01	0.01
<i>native labor force</i>				
all	0.02	-0.00	0.06	-0.01
no vocational	-0.04	0.02	-0.00	0.00
vocational	0.04	-0.01	0.08	-0.02
high school	-0.06	0.03	-0.02	0.01
university	-0.04	0.01	0.00	-0.00
<i>foreign labor force</i>				
all	-0.58	0.32	-0.55	0.12
no vocational	-0.53	0.31	-0.52	0.05
vocational	-0.69	0.31	-0.65	0.18
high school	-1.53	1.32	-1.54	0.71
university	-0.21	0.09	-0.17	0.05

*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 separately. 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 8: **Simulation of migration effects: clearing labor markets**

	all		natives		foreigners	
education degree	short-run results	long-run results	short-run results	long-run results	short-run results	long-run results
<i>wages: change in % at an immigration of 1%</i>						
all	-0.04	-0.00	0.02	0.06	-0.60	-0.56
no vocational	-0.17	-0.13	-0.04	-0.00	-0.56	-0.52
vocational	0.01	0.05	0.04	0.08	-0.70	-0.66
high school	-0.16	-0.12	-0.07	-0.03	-1.65	-1.61
university	-0.05	-0.01	-0.04	0.00	-0.21	-0.17

*Notes:* Both simulations assume labor markets are perfectly flexible, i.e. that  $\eta \rightarrow -\infty$ . The short-run simulations consider the impact of immigration on the capital-output ratio, the long-run simulations assume a constant capital-output ratio. The effects have been calculated for natives and foreigners at each education-experience level separately. 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 9: Simulation of migration effects, 1980-2004 and 1983-1993

education degree	1980 - 2004				1984 - 1993			
	short-run results		long-run results		short-run results		long-run results	
	wage	unempl. rate	wages	unempl. rate	wages	unempl. rate	wages	unempl. rate
<i>wages: change in %, unemployment rate: change in %-points</i>								
<i>total labor force</i>								
all	-0.12	-0.03	0.00	0.09	-0.18	0.41	0.00	0.17
no vocational	1.52	-1.16	1.75	-0.29	-0.52	0.71	-0.45	0.17
vocational	-0.38	0.24	-0.29	0.16	-0.06	0.27	0.15	0.13
high school	-4.34	3.86	-4.45	2.77	-1.13	1.63	-1.08	1.06
university	-1.38	0.47	-1.29	0.32	-0.19	0.28	0.02	0.16
<i>native labor force</i>								
all	-0.01	-0.04	0.10	0.00	0.06	-0.02	0.24	-0.11
no vocational	1.09	-0.48	1.30	-0.13	-0.20	0.26	-0.11	0.03
vocational	-0.08	0.04	0.02	0.00	0.14	-0.10	0.35	-0.16
high school	-2.66	1.59	-2.73	0.97	-0.17	0.19	-0.05	0.05
university	-1.23	0.38	-1.15	0.23	-0.10	0.04	0.11	-0.05
<i>foreign labor force</i>								
all	-1.17	-0.27	-0.97	0.38	-2.93	2.63	-2.89	1.44
no vocational	2.80	-4.11	3.13	-0.86	-1.58	2.05	-1.59	0.69
vocational	-6.34	1.06	-6.30	0.57	-4.24	2.77	-4.14	1.78
high school	-32.01	4.21	-32.86	2.10	-17.56	8.78	-18.63	5.49
university	-3.23	0.37	-3.15	0.21	-1.59	0.83	-1.39	0.42

*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 and then aggregated.

Table A1: Share of foreigners by education and experience

education	experience	1980	1984	1985	1990	1993	1995	2000	2004
no vocational	0-5	0.183	0.175	0.159	0.256	0.402	0.350	0.192	0.143
	6-10	0.278	0.187	0.199	0.227	0.360	0.413	0.334	0.213
	11-15	0.380	0.288	0.268	0.300	0.370	0.394	0.461	0.398
	16-20	0.459	0.352	0.340	0.345	0.397	0.421	0.418	0.470
	21-25	0.345	0.403	0.409	0.373	0.424	0.433	0.429	0.432
	26-30	0.228	0.262	0.293	0.410	0.418	0.435	0.444	0.422
	31-35	0.176	0.186	0.197	0.291	0.393	0.428	0.438	0.450
	36-40	0.081	0.118	0.128	0.183	0.226	0.258	0.388	0.450
	all	0.242	0.224	0.229	0.280	0.349	0.376	0.402	0.397
vocational	0-5	0.030	0.026	0.027	0.049	0.093	0.121	0.094	0.062
	6-10	0.043	0.034	0.034	0.048	0.066	0.083	0.137	0.102
	11-15	0.074	0.052	0.052	0.064	0.077	0.081	0.105	0.150
	16-20	0.090	0.078	0.074	0.079	0.093	0.094	0.096	0.109
	21-25	0.057	0.078	0.085	0.088	0.094	0.102	0.106	0.105
	26-30	0.049	0.047	0.052	0.088	0.102	0.102	0.112	0.109
	31-35	0.037	0.044	0.045	0.054	0.074	0.092	0.110	0.114
	36-40	0.021	0.029	0.032	0.045	0.051	0.054	0.084	0.110
	all	0.051	0.048	0.049	0.063	0.079	0.087	0.105	0.111
high school	0-5	0.039	0.019	0.021	0.020	0.033	0.051	0.064	0.049
	6-10	0.083	0.043	0.034	0.036	0.035	0.038	0.069	0.072
	11-15	0.117	0.097	0.087	0.056	0.056	0.050	0.055	0.077
	16-20	0.075	0.113	0.127	0.111	0.087	0.077	0.071	0.066
	21-25	0.084	0.088	0.084	0.150	0.144	0.126	0.090	0.080
	26-30	0.064	0.074	0.082	0.082	0.120	0.157	0.145	0.108
	31-35	0.030	0.061	0.065	0.074	0.085	0.096	0.164	0.144
	36-40	0.019	0.031	0.036	0.076	0.073	0.075	0.091	0.133
	all	0.065	0.059	0.057	0.057	0.062	0.065	0.078	0.080
university	0-5	0.060	0.034	0.031	0.045	0.049	0.055	0.092	0.113
	6-10	0.084	0.052	0.046	0.040	0.049	0.046	0.044	0.081
	11-15	0.087	0.080	0.072	0.057	0.052	0.050	0.048	0.054
	16-20	0.078	0.081	0.083	0.087	0.073	0.067	0.057	0.056
	21-25	0.059	0.077	0.078	0.083	0.099	0.096	0.071	0.060
	26-30	0.050	0.053	0.054	0.076	0.074	0.085	0.098	0.076
	31-35	0.048	0.047	0.045	0.056	0.075	0.077	0.081	0.102
	36-40	0.025	0.028	0.049	0.042	0.045	0.050	0.047	0.063
	all	0.071	0.062	0.059	0.061	0.063	0.063	0.062	0.070

*Notes:* Individuals included in the sample are between 15 and 60 years old and are either employed or unemployed on September 30 of the respective year.

Table A2: Daily wages of native workers by education and experience  
(constant 2000 Euros)

education	experience	1980	1984	1985	1990	1993	1995	2000	2004
no vocational	0-5	41	39	41	44	46	45	43	45
	6-10	55	54	54	57	59	60	57	58
	11-15	60	61	62	64	67	68	73	69
	16-20	62	62	64	68	70	70	76	78
	21-25	64	65	65	67	71	72	75	80
	26-30	64	66	67	69	70	71	78	77
	31-35	64	65	67	70	72	71	76	80
	36-40	63	65	66	70	71	72	77	76
	all	60	61	62	65	68	69	71	72
vocational	0-5	49	48	49	53	56	56	58	59
	6-10	63	61	62	65	66	66	68	67
	11-15	72	72	72	74	76	76	79	78
	16-20	79	79	80	81	81	82	86	86
	21-25	81	84	85	86	86	86	89	90
	26-30	81	85	87	90	89	89	93	93
	31-35	81	84	87	92	93	93	96	96
	36-40	80	85	86	91	93	94	100	98
	all	73	74	75	78	81	81	86	87
high school	0-5	58	57	57	61	64	65	68	68
	6-10	78	75	75	78	82	81	85	85
	11-15	92	93	94	93	95	95	104	102
	16-20	105	103	104	104	104	104	112	114
	21-25	112	114	114	109	109	109	114	115
	26-30	112	119	120	118	114	112	119	119
	31-35	117	127	126	120	123	120	125	121
	36-40	111	127	131	128	122	119	130	120
	all	90	89	88	87	90	91	101	103
university	0-5	87	92	92	94	96	93	105	95
	6-10	110	119	118	121	125	122	141	138
	11-15	129	141	144	137	144	144	160	168
	16-20	139	160	159	156	154	153	175	180
	21-25	143	166	166	166	168	166	181	186
	26-30	143	171	173	170	174	175	195	188
	31-35	139	171	170	177	179	177	204	199
	36-40	127	154	164	169	171	171	207	187
	all	123	140	141	140	144	144	164	168

*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.

Table A3: Daily wages of foreign workers by education and experience  
(constant 2000 Euros)

education	experience	1980	1984	1985	1990	1993	1995	2000	2004
no vocational degree	0-5	47	47	47	50	46	46	44	43
	6-10	58	56	57	59	56	55	55	53
	11-15	61	61	63	64	61	60	62	62
	16-20	65	63	64	66	63	64	65	66
	21-25	67	66	68	67	65	65	68	70
	26-30	67	67	68	71	67	66	68	70
	31-35	65	65	67	72	71	71	70	71
	36-40	64	64	65	70	70	70	74	74
	all	63	62	64	67	64	64	66	68
vocational degree	0-5	54	51	52	55	55	57	59	57
	6-10	63	61	62	65	62	63	67	67
	11-15	70	68	68	70	68	68	71	75
	16-20	74	73	75	73	70	71	74	75
	21-25	75	76	77	78	73	73	76	78
	26-30	74	76	77	81	78	77	76	78
	31-35	72	73	75	81	80	80	80	78
	36-40	71	73	75	77	79	80	84	82
	all	70	70	72	74	71	71	74	76
high school with vocational degree	0-5	63	64	62	65	61	56	65	65
	6-10	75	74	79	79	74	73	81	78
	11-15	78	78	76	92	82	81	87	90
	16-20	103	96	96	86	86	78	89	89
	21-25	92	103	108	97	78	85	86	88
	26-30	97	82	86	103	100	93	86	91
	31-35	102	99	141	90	93	85	101	85
	36-40	106	127	91	114	85	86	95	113
	all	84	86	89	89	81	79	85	87
university degree	0-5	97	107	119	109	102	105	115	107
	6-10	114	127	135	124	140	132	135	141
	11-15	141	140	190	150	143	144	151	147
	16-20	135	157	172	153	152	157	149	164
	21-25	132	162	173	166	165	163	155	153
	26-30	138	149	167	175	162	189	151	173
	31-35	159	151	158	166	172	165	177	166
	36-40	134	191	147	149	185	151	175	212
	all	126	144	164	150	150	151	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.



Table A4: **The wage curve: GMM-estimation results\***

education level	$\ln w_{ij,t-1}$		$\ln u_{ijt}$			Wald- $\chi^2(3)$ -stat.	obs.
			short-run	long-run			
<b>1980 - 2004</b>							
all <sup>1</sup>	0.626 (0.004)	***	-0.028 (0.001)	***	-0.076 (0.002)	***	143786 736
no vocational <sup>2</sup>	0.658 (0.228)	***	-0.030 (0.016)	*	-0.087 (0.073)		38 184
vocational <sup>3</sup>	0.775 (0.082)	***	-0.035 (0.009)	***	-0.155 (0.070)	**	181 184
high school <sup>4</sup>	0.653 (0.195)	***	-0.044 (0.007)	***	-0.127 (0.075)	*	60 184
university <sup>5</sup>	0.652 (0.196)	***	-0.028 (0.033)	***	-0.082 (0.066)		39 184
<b>1984 - 1993</b>							
all <sup>6</sup>	0.452 (0.006)	***	-0.041 (0.000)	***	-0.075 (0.001)	***	21655 320
no vocational <sup>7</sup>	0.461 (0.104)	***	-0.043 (0.006)	***	-0.080 (0.024)	***	524 80
vocational <sup>8</sup>	0.732 (0.054)	***	-0.043 (0.007)	***	-0.162 (0.049)	***	363 80
high school <sup>9</sup>	-0.937 (0.778)		-0.055 (0.006)	***	0.028 (0.011)	**	127 80
university <sup>10</sup>	0.444 (0.034)	***	-0.032 (0.019)	*	-0.057 (0.037)		363 80

*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 31.8\*\*\*. The Arellano-Bond  $z$ -statistics rejects the H0 of AR(1) at -4.3\*\*\*, and of AR(2) at 0.6. <sup>2</sup> Sargan- $\chi^2(155)$ -test statistics: 6.4\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -1.1, AR(2) 0.4. <sup>3</sup> Sargan- $\chi^2(155)$ -test statistics: 6.7\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.2\*\*, AR(2) -2.1\*\*. <sup>4</sup> Sargan- $\chi^2(155)$ -test statistics: 6.3\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.0\*\*, AR(2) -0.09. <sup>5</sup> Sargan- $\chi^2(155)$ -test statistics: 7.7\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.2\*\*, AR(2) 0.8. <sup>6</sup> Sargan- $\chi^1(75)$ -test statistics: 31.8\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -3.0\*\*\*, AR(2) 0.1. <sup>7</sup> Sargan- $\chi^2(64)$ -test statistics: 7.6\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -0.9, AR(2) -1.2. <sup>8</sup> Sargan- $\chi^2(64)$ -test statistics: 7.6\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) -2.2\*\*, AR(2) -2.1\*\*. <sup>9</sup> Sargan- $\chi^2(65)$ -test statistics 2.0\*\*\*. Arellano-Bond  $z$ -statistics: AR(1) 1.3, AR(2) -0.4. <sup>10</sup> Sargan- $\chi^2(65)$ -test statistics 7.7\*\*\*. Arellano-Bond  $z$ -statistics AR(1) -2.2\*\*, AR(2) 0.2. GMM two-step standard errors are biased.